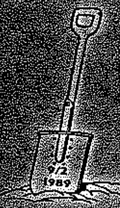
Material gathered in Sweden

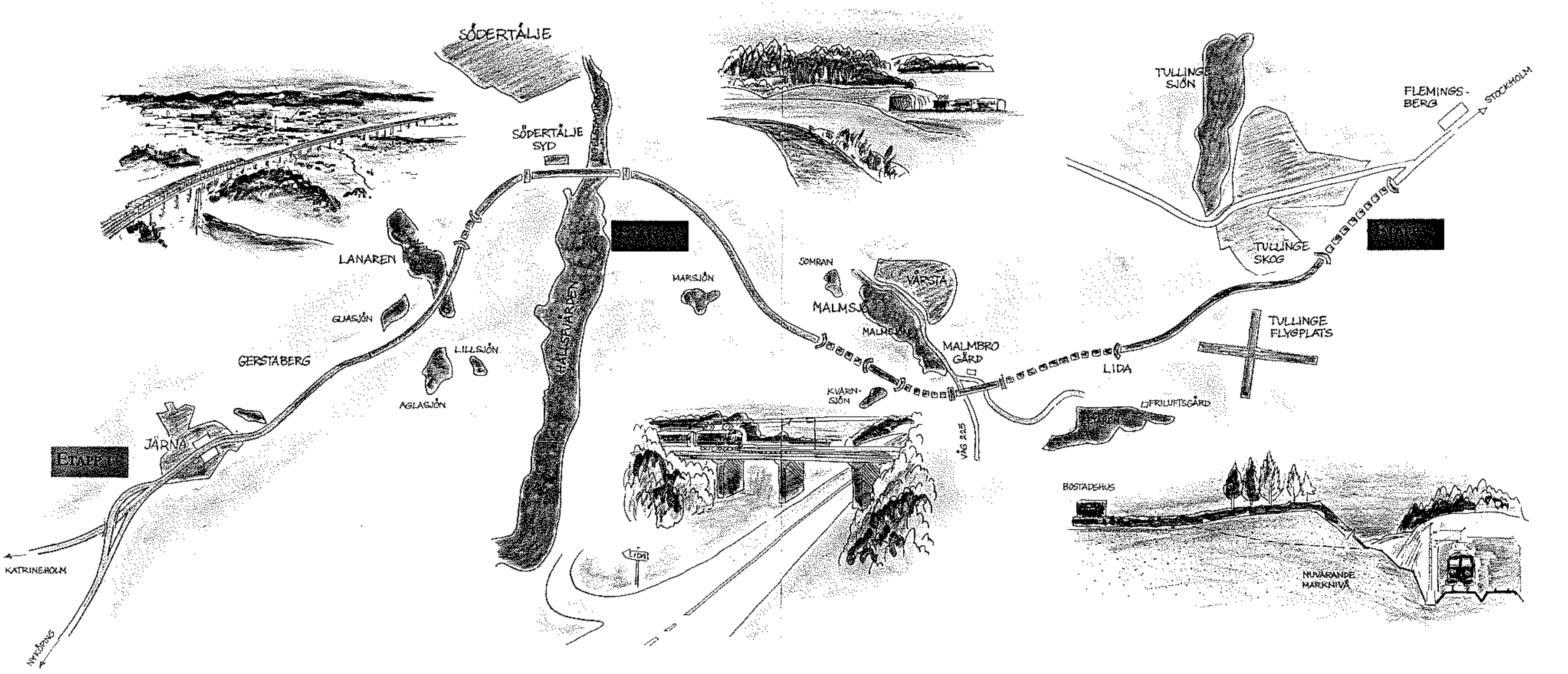
1

New Construction on SJ/BV

BANVERKET
Östra regionen

Projekt Grödingebanan
1989–1995



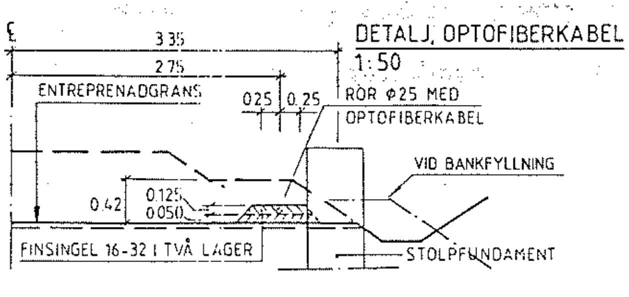


BANVERKET
Östra regionen
Projekt Grödingebanan
Box [illegible], Grödingevägen [illegible] Södertälje
Tel 08-762 [illegible]

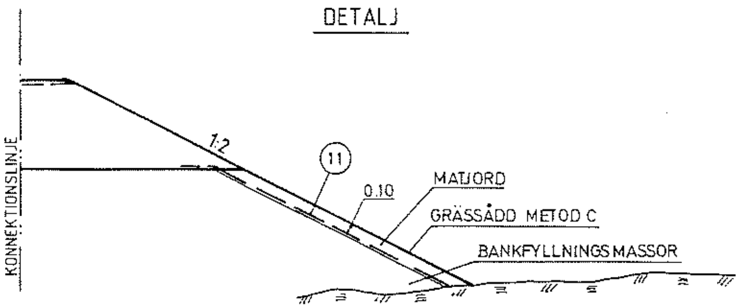
GRÖDINGEBANAN

ELRÄNNA

DETALJ, OPTOFIBERKABEL
1:50

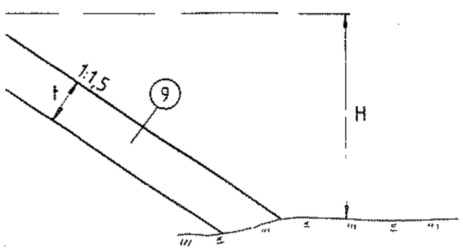


DETALJ



ALT. UTFÖRANDE VID GRÄSBEKLÄDD
SLÄNT ENLIGT RROFIL OCH TVÄRSEKTION

IJE RÖK



SLÄ[illegible]ÄDNA

Slänthöjd H m		
<2	a	0,2
	b	0,3
	t	0,4
2 - 3	a	0,2
	b	0,35
	t	0,4
3 - 4	a	0,2
	b	0,4
	t	0,5
4 - 5	a	0,2
	b	0,5
	t	0,5
5 - 6	a	0,2
	b	0,55
	t	0,5
6 - 7	a	0,2
	b	0,6
	t	0,6
7 - 8	a	0,2
	b	0,7
	t	0,6
8 - 9	a	0,3
	b	0,75
	t	0,6
>9	a	0,3
	b	0,85
	t	0,7

NR	BENÄMNING	MATERIAL	ANM.
1	Räler	UIC 60	Ingår ej
2	Sliprar	Betong	Ingår ej
3	Ballast	Makadam klass I enligt D8.351	Ingår ej
4	Underballast	Material enligt C1.74	
5	Ballast	Makadam klass I enligt D8.351	
6	Undersprängning		
7	Bankfyllning	Sprängsten enligt C1.71	
8	Bankfyllning	Fyllning med jord enligt C1.72	
9	Släntskydd	Friktionsmaterial (även krossmaterial) enligt D2.54 och D2.55	
10	Tätning	Geotextil (Polyfelt TS-550, Fibertex F-4M el likvärdig)	
11	Tätning	Geotextil (Polyfelt, Fibertex bruksklass II el likvärdig)	
12	Tätning	Skärv enligt C3.16, C3.36 och C3.37	
13	Dränering	Dräneringsledning 233/200 typ Upolan DSA el likvärdigt enl SJFT 541.1.14 Bil. 1. Dock kringfyllning enligt fabrikantens anvisningar.	

Anm. Fundament till kontaktledningsstolpar sätts enligt koordinattabell.

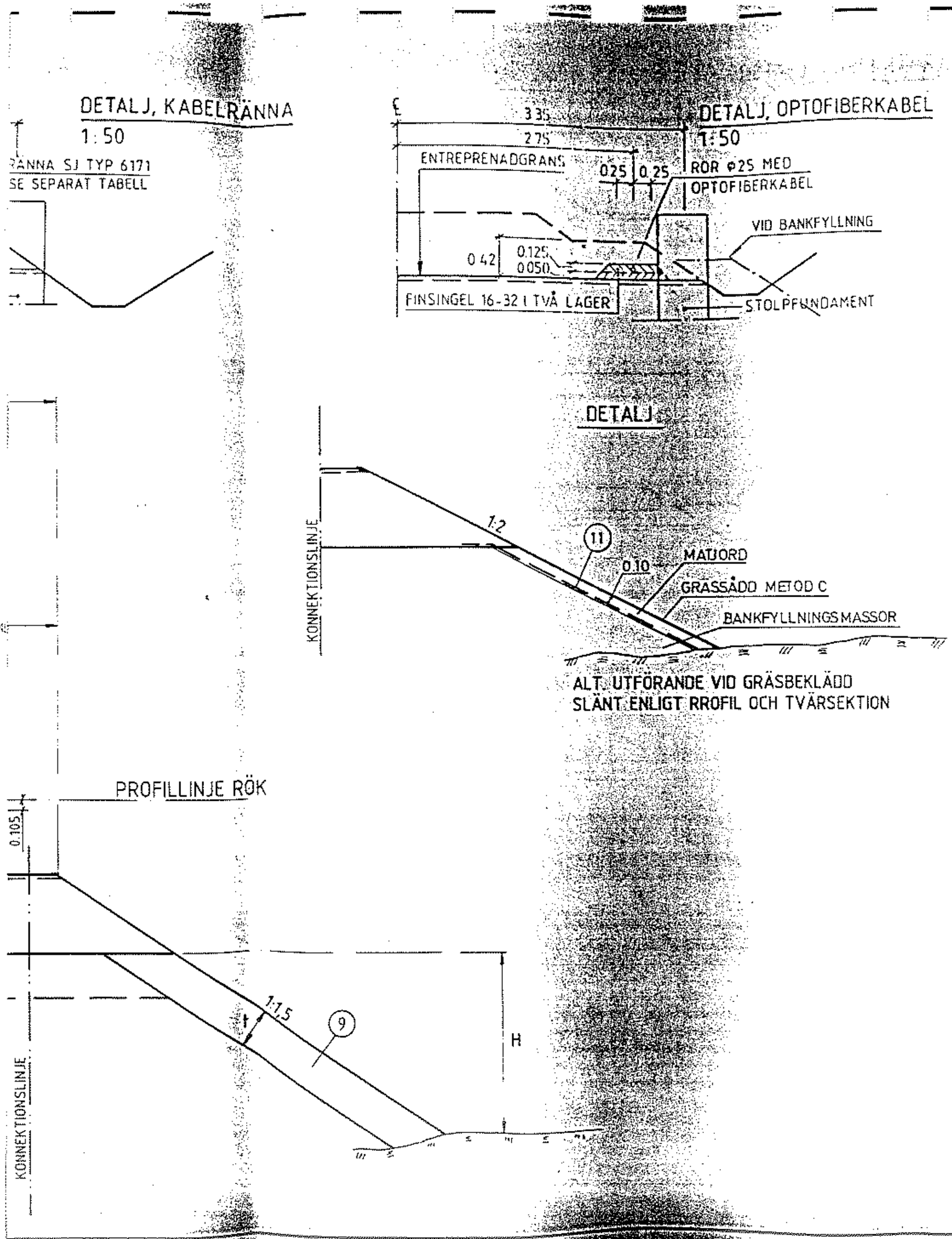
REG	ANT	REGISTRERINGEN AVSER	SIGN	DATUM

UPPRÄTTAD FÖR **BANVERKET ÖSTRA REGIONEN**

KM KJESSLER & MANNERSTRÅLE AB
INGENJÖRER ARKITEKTER EKONOMER
BOX 7124, 171 07 SOLNA Telefon 08-55 30 00

FLEMINGSBERG - JÄRNA
NYTT DUBBELSPÅR
NORMALSEKTION
DUBBELSPÅR
BANK, JORDFYLLNING, RAKSPÅR SKALA 1:50

RITAD KONSTRUERAD | GRANSKAD | UPPDRAG
SOLNA | KOD TYP POS | RITNINGSNUMMER 1-550 677-11



SLÄNTBEKLÄDNAD

Slänthöjd H m		
<2	a	0,2
	b	0,3
	t	0,4
2 - 3	a	0,2
	b	0,35
	t	0,4
3 - 4	a	0,2
	b	0,4
	t	0,5
4 - 5	a	0,2
	b	0,5
	t	0,5
5 - 6	a	0,2
	b	0,55
	t	0,5
6 - 7	a	0,2
	b	0,6
	t	0,6
7 - 8	a	0,2
	b	0,7
	t	0,6
8 - 9	a	0,3
	b	0,75
	t	0,6
>9	a	0,3
	b	0,85
	t	0,7

NR	BENÄMNING	MATERIAL
1	Räler	UIC 60
2	Sliprar	Betong
3	Ballast	Makadam klass I enligt D8.3
4	Underballast	Material enligt C1.74
5	Ballast	Makadam klass I enligt D8.3
6	Undersprängning	
7	Bankfyllning	Sprängsten enligt C1.71
8	Bankfyllning	Fyllning med jord enligt C1
9	Släntskydd	Friktionsmaterial (även kro material) enligt D2.54 och
10	Tätning	Geotextil (Polyfelt TS-550, tex F-4M el likvärdig)
11	Tätning	Geotextil (Polyfelt, Fibert bruksklass II el likvärdig)
12	Tätning	Skärv enligt C3.16, C3.36 o C3.37
13	Dränering	Dräneringsledning 233/200 Upolan DSA el likvärdigt e SJFT 541.1.14 Bil. 1. Dock fyllning enligt fabrikante anvisningar.

Anm. Fundament till kontaktledningsstolpar sätts enligt koordinattabell.

REG | ANT | REGISTRERINGEN AV

UPPRÄTTAD FÖR BANVERKET ÖSTRA RE

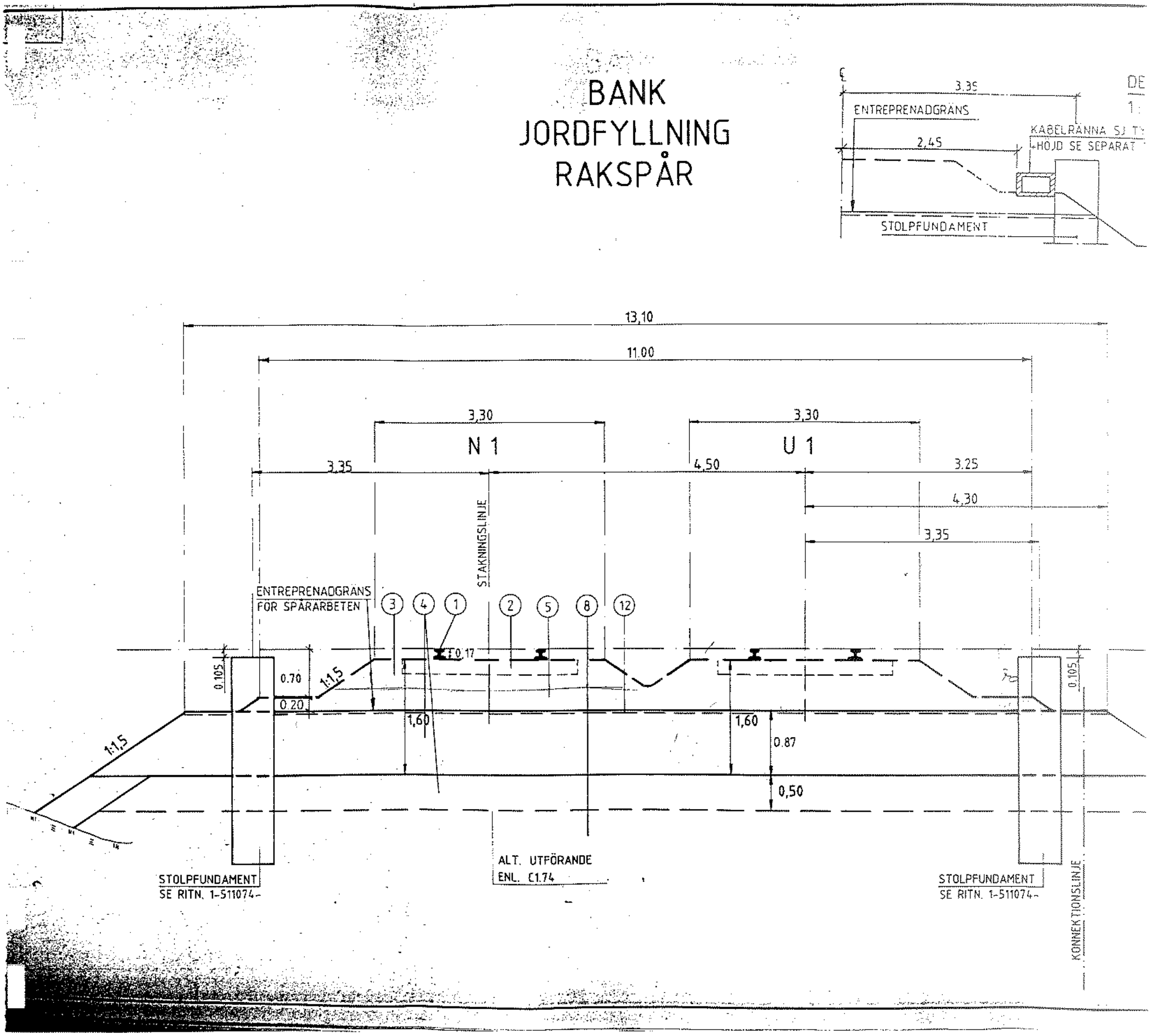
KM KJESSLER & MANNERSTRÅLE AB
INGENJÖRER ARKITEKTER EKONOMER
BOX 7124, 171 07 SOLNA Telefon 08-55 30 00

FLEMINGSBERG
NYTT DUBBELSPÅR
NORMALSEKTI
DUBBELSPÅR
BANK, JORDFYLLNING, RAKSP

RITAD KONSTRUERAD | GRANSKAD | UPPDRAG

SOLNA

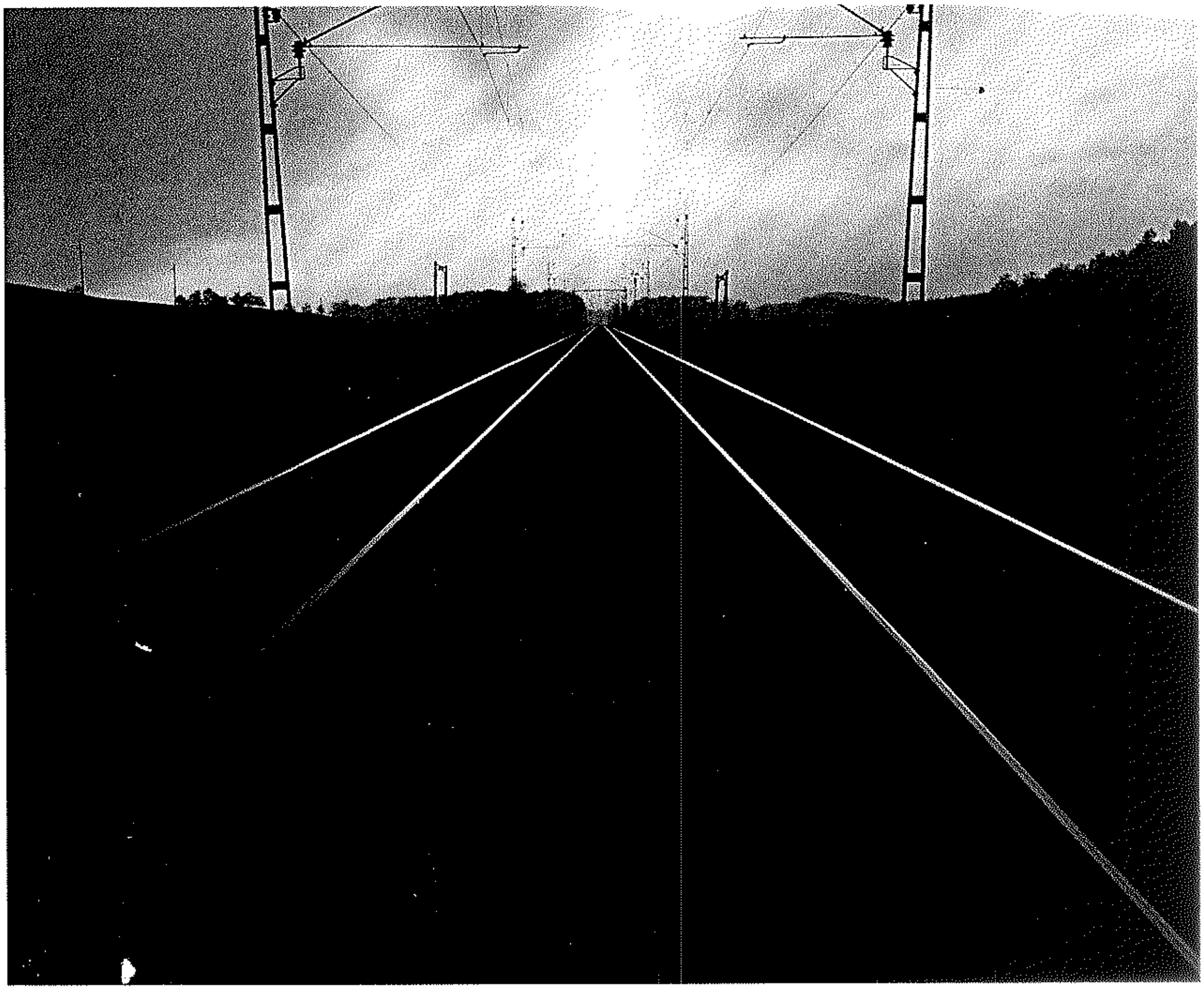
KOD TYP POS



BANK
JORDFYLLNING
RAKSPÅR
3,35
ENTREPRENADGRÄNS
2,45
KABELRÄNNA
HÖJD SE SEPARAT
STOLPFUNDAMENT
13,10
11.00
3,30
3,30
N 1
U 1
3,35
4,50
3,25
4,30
3,35
STAKNINGSLINJE
ENTREPRENADGRÄNS
FÖR SPÅRARBETEN
3
4
1
2
5
8
12
0.17
0.105
0.70
0.20
1:1,5
1:1,5
1,60
1,60
0.87
0,50
0.105
ALT. UTFÖRANDE
ENL. C1.74
STOLPFUNDAMENT
SE RITN. 1-511074-
STOLPFUNDAMENT
SE RITN. 1-511074-
KONNEKTIONSLINJE

BANVERKET
Östra regionen

THE GRÖDINGE LINE



TRACKS FOR THE '90S

SWEDISH NATIONAL RAIL ADMINISTRATION

INFORMATION ABOUT THE GRÖDINGE LINE
CONSTRUCTION PERIOD 1989–1995

By the end of 1994, 30 km of double track will have been added to the Stockholm regional rail network. That is when the Grödinge Line will be opened, Long-distance trains to and from Stockholm will then go by the new section linking Flemingsberg, Södertälje and Järna and leaving the present Södertälje Line with spare capacity for further development of commuter services in the southern region.

The Grödinge Line will accommodate both present and future demand for an improvement of train services. At the new Södertälje Syd station, the intended Svealand Line will be able to join up with the Grödinge Line, offering fast and convenient connections between the Mälaren Valley and the Stockholm region. The Grödinge Line also opens up the possibility of an express shuttle service between Södertälje and Arlanda International Airport.

The Grödinge Line is being constructed for high speeds and heavy axle loads, which calls for large curved radii and slight gradients. Since, however, part of the line goes through areas of outstanding natural interest, its positioning and design have also been influenced by various environmental considerations. Part of the line, for example, goes through tunnels or cuttings.

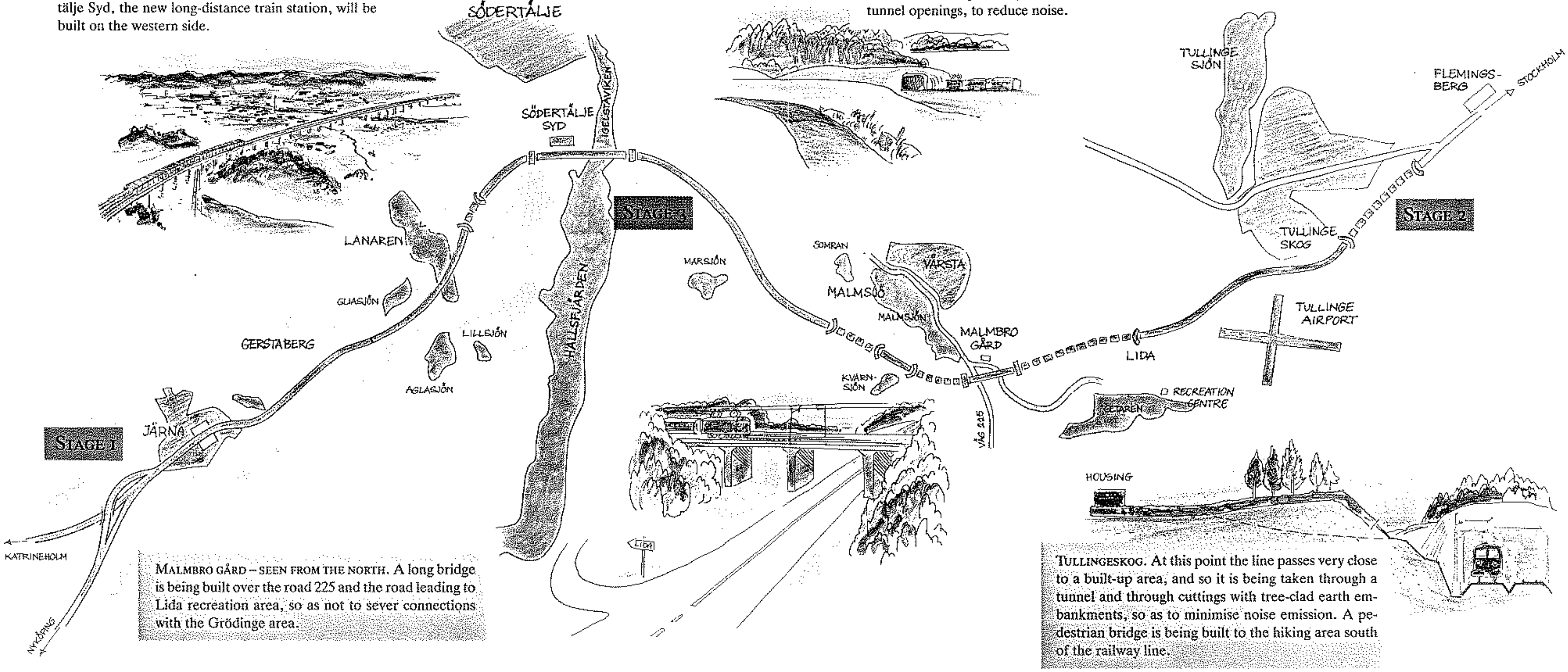
The Grödinge Line is being built in the following three stages:

- STAGE 1. SOUTH JÄRNA–GERSTABERG
- STAGE 2. MALMSJÖ–FLEMINGSBERG
- STAGE 3. GERSTABERG–MALMSJÖ

The course of the line is illustrated below, together with some of the construction details.

IGELSTAVIKEN. One of the longest railway bridges in Europe, 2 km long and with a headroom of about 40 metres, is being built over the shipping lane. Södertälje Syd, the new long-distance train station, will be built on the western side.

LIDA RECREATION AREA. To avoid disruptions of the natural scenery and outdoor recreational activities, about 1,800 m. of the line at this point will be enclosed in a tunnel. Deep cuttings will be constructed at the tunnel openings, to reduce noise.



MALMBRO GÅRD – SEEN FROM THE NORTH. A long bridge is being built over the road 225 and the road leading to Lida recreation area, so as not to sever connections with the Grödinge area.

TULLINGESKOG. At this point the line passes very close to a built-up area, and so it is being taken through a tunnel and through cuttings with tree-clad earth embankments, so as to minimise noise emission. A pedestrian bridge is being built to the hiking area south of the railway line.

The Swedish National Rail Administration is laying the foundations of an efficient rail network. We are responsible for the maintenance of national railways, and at the same time we are planning and constructing new lines, so that Sweden will have a future as well as a present alternative to road traffic. An alternative which is both easier on the environment, safer and more energy-efficient.

Many new projects are being started during the nineties. First of all, we are building those stretches of line to which the national economy gives top priority. In this way, all actual and potential rail passengers will benefit from the new development. Environmental benefits also form part of this calculation. The Mälaren Valley lines, the West Coast line and the HST Malmö and Sundsvall lines are just a few of our projects for the nineties.

If you would like to know more about the Swedish National Rail Administration or the Grödinge Line, we will be delighted to hear from you.

BANVERKET
Östra regionen

THE SWEDISH NATIONAL RAIL ADMINISTRATION
Eastern Region
The Grödinge Line Project
Box 7073, Grödingevägen 70, S-152 07 SÖDERTÄLJE Tel. +46 8 762 39 95

Soil replacement

1. Organic soil
Peat is taken away.

2. Cohesive soil
All cohesive soil is taken away till you reach strong friction soil, moraine.

3. Clay of considerable extent
To-day deep soil stabilization is normal. It consists mostly of lime / cement columns to firm soil. Column diameter 50, 60, 80 cm. Distances 1–2 m.

B Furustam 92-12-15

NORMALSEKTION FÖR BANAN

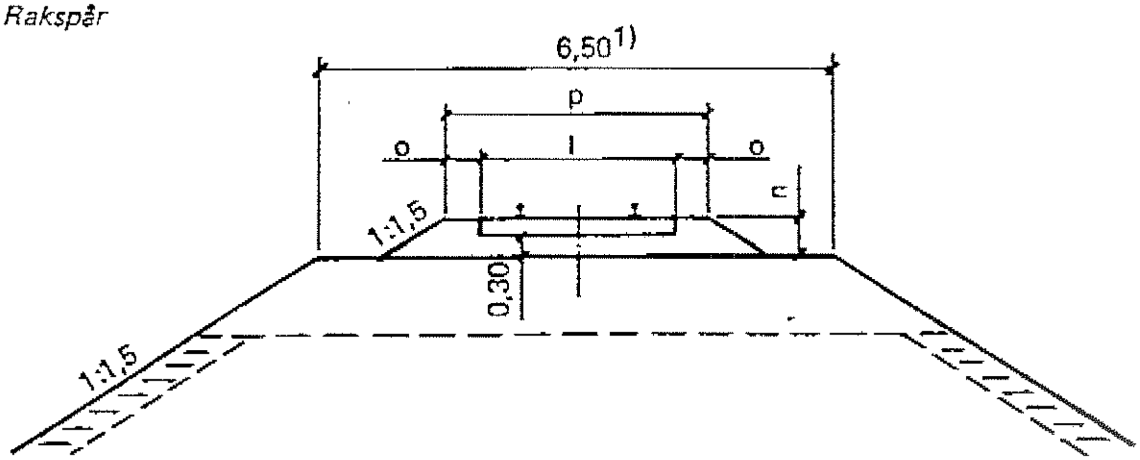
Enkelspår banklass A och B

Bank

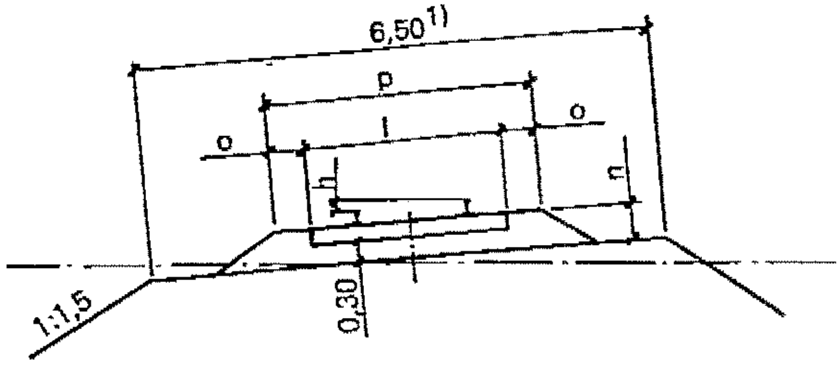
Sektion nr	Sliper		Ballast				
	Material	l (m)	n (m)	o (m) R ≥ 500m	o (m) R < 500m	p (m) R ≥ 500m	p (m) R < 500m
101	Trä	2,60	0,45	0,40	0,55	3,40	3,70
102	Betong	2,50	0,50	0,40	0,55	3,30	3,60

Anm. I kurva med R < 400 m skall ballastskuldrorna överhöjas 0,10 m.

Rakspår



Kurvspår



1) Vid spårupprustning i undantagsfall 6,00 m

NORMALSEKTION FÖR BANAN

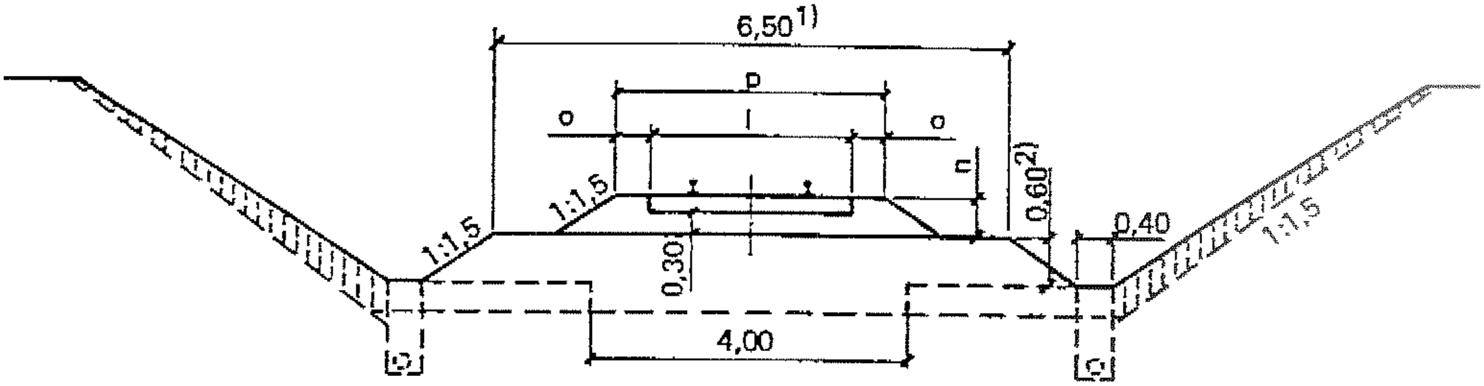
Enkelspår banklass A och B

Jordskärning

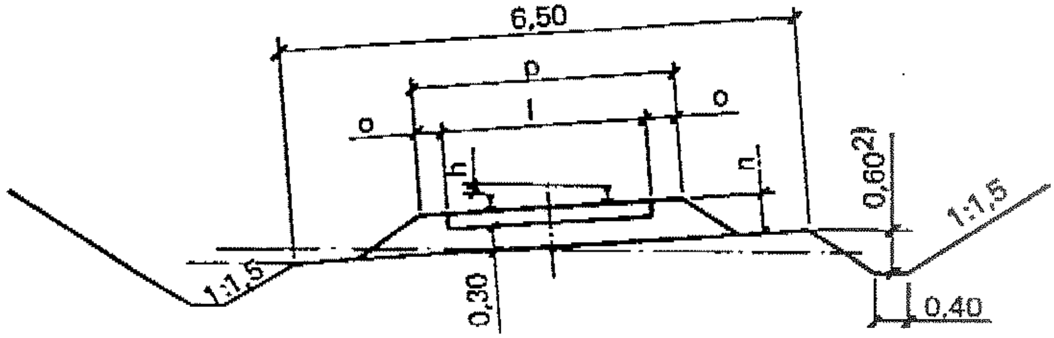
Sektion nr	Sliper		Ballast				
	Material	l (m)	n (m)	o (m)		p (m)	
				R ⩾ 500m	R < 500m	R ⩾ 500m	R < 500m
103	Trä	2,60	0,45	0,40	0,55	3,40	3,70
104	Betong	2,50	0,50	0,40	0,55	3,30	3,60

Anm. I kurva med R < 400 m skall ballastskuldrorna överhöjas 0,10 m

Rakspår



Kurvspår



1) Vid spårupprustning i undantagsfall 6,00 m
2) Djupare diken krävs i vissa fall. Se kap 3.6

NORMALSEKTION FÖR BANAN

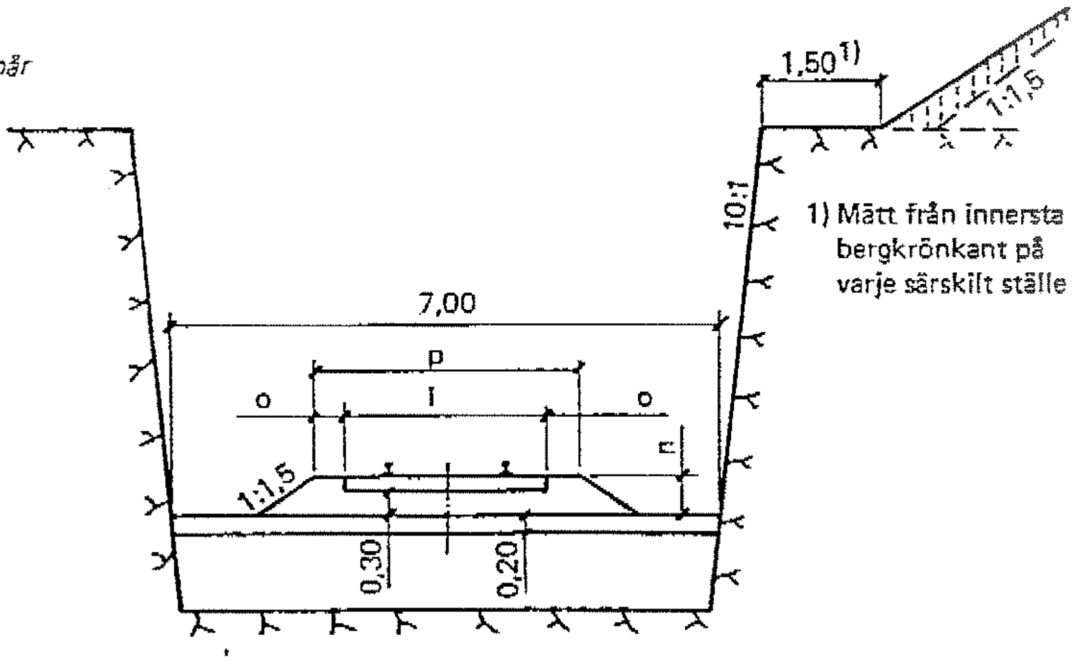
Enkelspår banklass A och B

Bergskärning

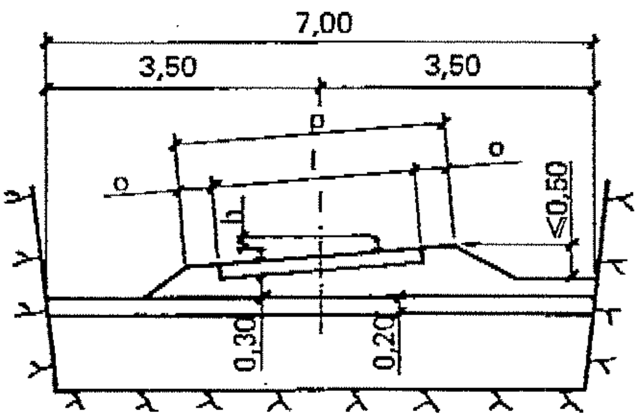
Sektion nr	Sliper		Ballast				
	Material	l (m)	n (m)	o (m) R ≥ 500m	o (m) R < 500m	p (m) R ≥ 500m	p (m) R < 500m
105	Trä	2,60	0,45	0,40	0,55	3,40	3,70
106	Betong	2,50	0,50	0,40	0,55	3,30	3,60

Anm. I kurva med R < 400 m skall ballastskuldrorna överhöjas 0,10 m

Rakspår



Kurvspår



NORMALSEKTION FÖR BANAN

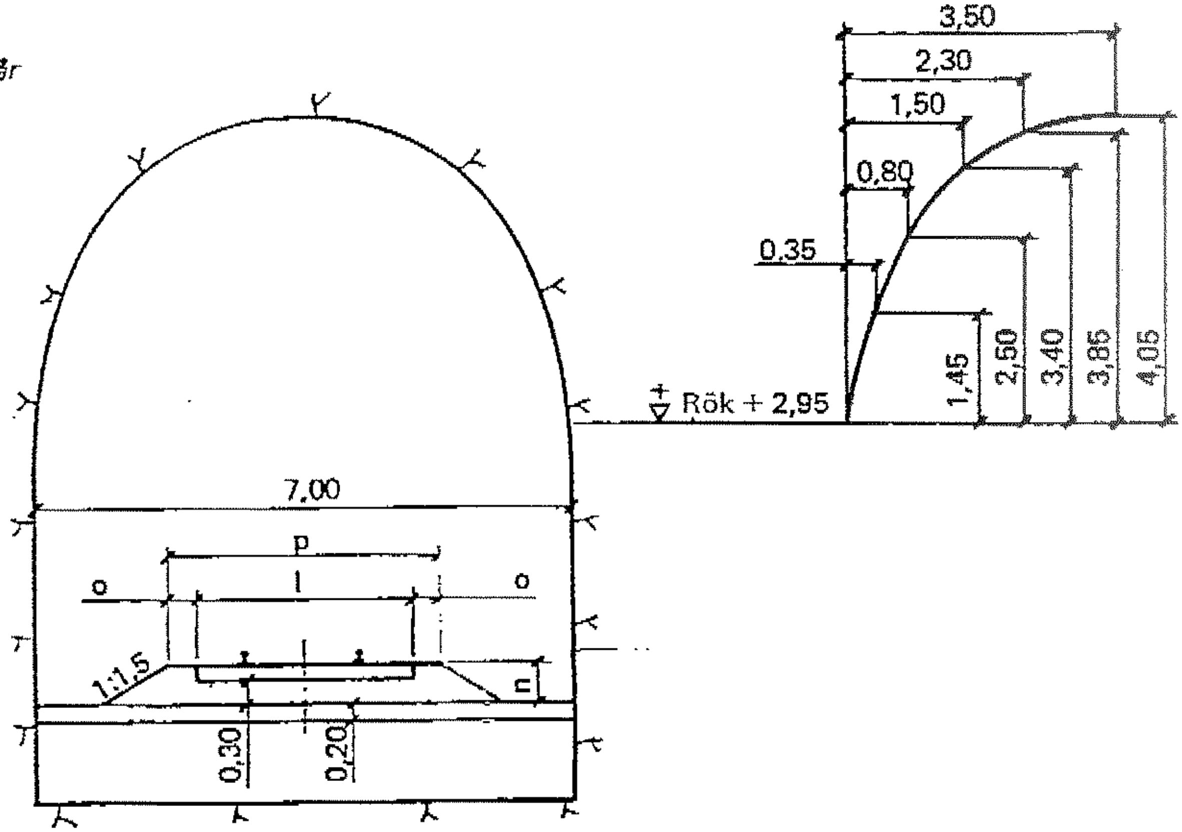
Enkelspår banklass A och B

Bergtunnel

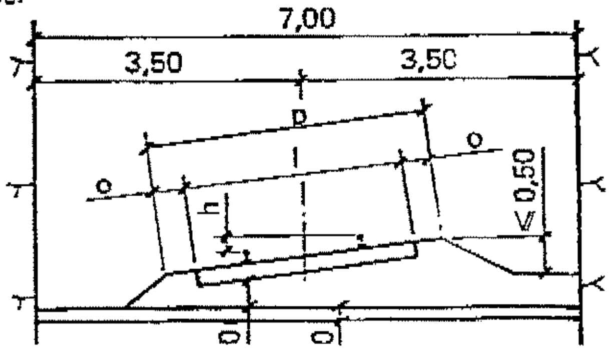
Sektion nr	Sliper		Ballast				
	Material	l (m)	n (m)	o (m) R ≥ 500m	o (m) R < 500m	p (m) R ≥ 500m	p (m) R < 500m
107	Trä	2,60	0,45	0.40	0,55	3,40	3,70
108	Betong	2,50	0,50	0.40	0,55	3,30	3,60

Anm. I kurva med R < 400 m skall ballastskuldrorna överhöjas 0,10 m

Rakspår



Kurvspår



NORMALSEKTION FÖR BANAN

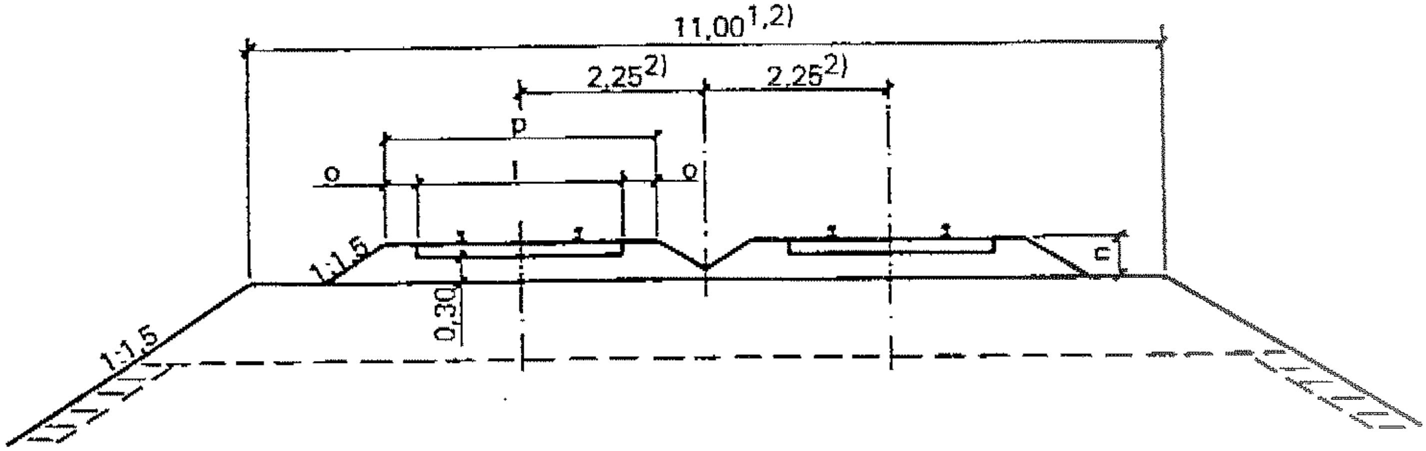
Dubbelspår banklass A och B

Bank

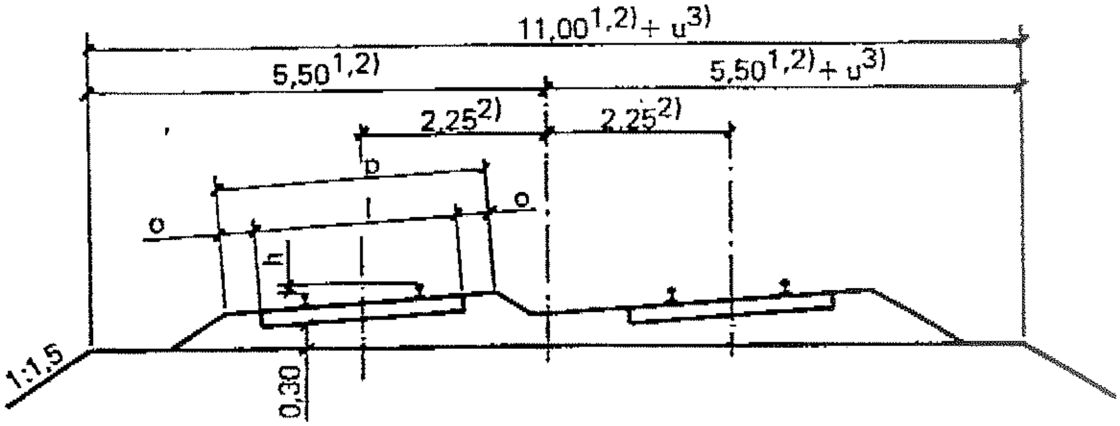
Sektion nr	Sliper		Ballast				
	Material	l (m)	n (m)	o (m) R ⩾ 500m	o (m) R < 500m	p (m) R ⩾ 500m	p (m) R < 500m
121	Trä	2,60	0,45	0,40	0,55	3,40	3,70
122	Betong	2,50	0,50	0,40	0,55	3,30	3,60

Anm. I kurva med R < 400 m skall ballastskuldrorna överhöjas 0,10 m

Rakspår



Kurvspår



1) Vid spårupprustning i undantagsfall 10,50[2)]m resp 5,25[2)]m
2) Anpassas vid spårupprustning till befintligt spåravstånd

3)

Rälsförhöjning h (mm)	Breddning u (m)
0- 49	0

NORMALSEKTION FÖR BANAN

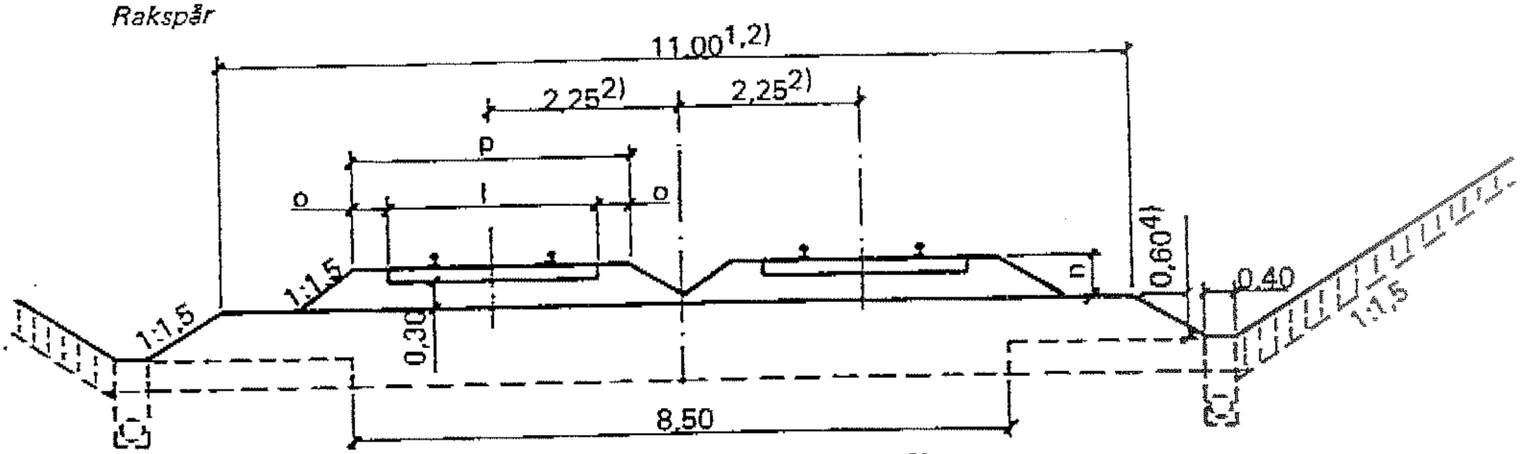
Dubbelspår banklass A och B

Jordskärning

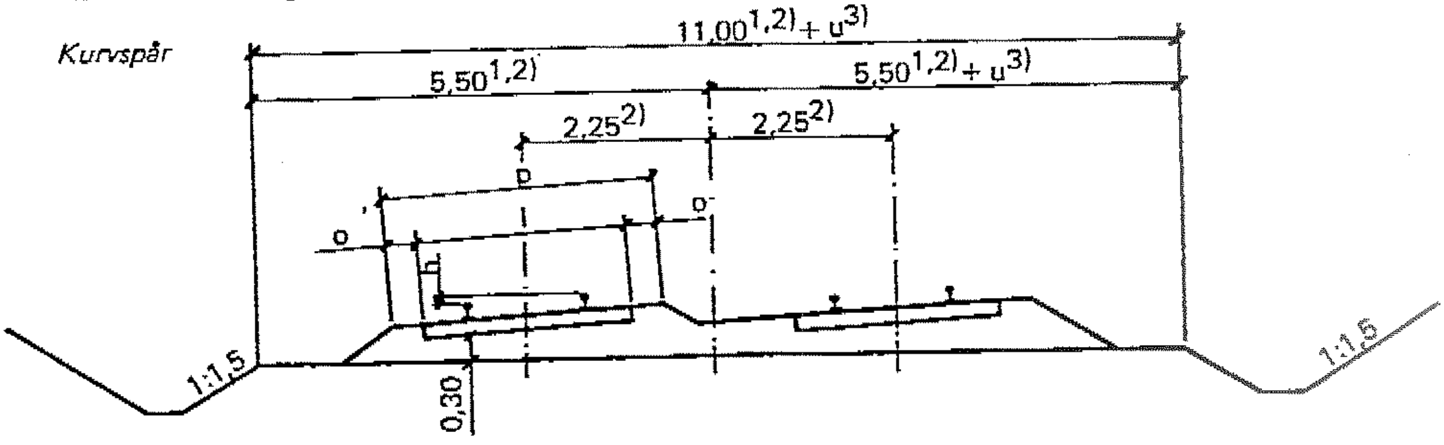
Sektion nr	Sliper		Ballast				
	Material	l (m)	n (m)	o (m) R ≥ 500m	o (m) R < 500m	p (m) R ≥ 500m	p (m) R < 500m
123	Trä	2,60	0,45	0,40	0,55	3,40	3,70
124	Betong	2,50	0,50	0,40	0,55	3,30	3,60

Anm. I kurva med R < 400 m skall ballastskuldrorna överhöjas 0,10 m.

Rakspår



Kurvspår



1) Vid spårupprustning i undantagsfall 10,50[2)] m resp 5,25[2)] m
2) Anpassas vid spårupprustning till befintligt spåravstånd

3)

Rälsförhöjning h (mm)	Breddning u (m)
0- 49	0
50- 99	0,30
100-150	0,50

NORMALSEKTION FÖR BANAN

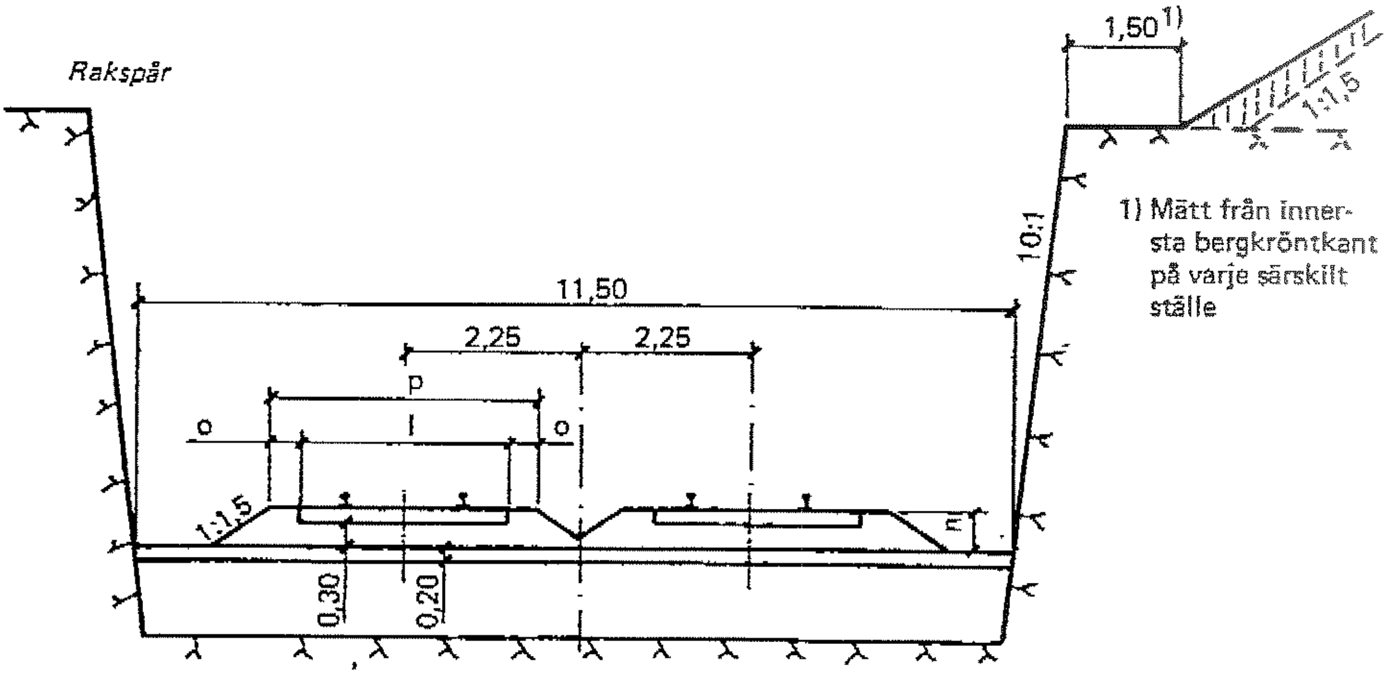
Dubbelspår banklass A och B

Bergskärning

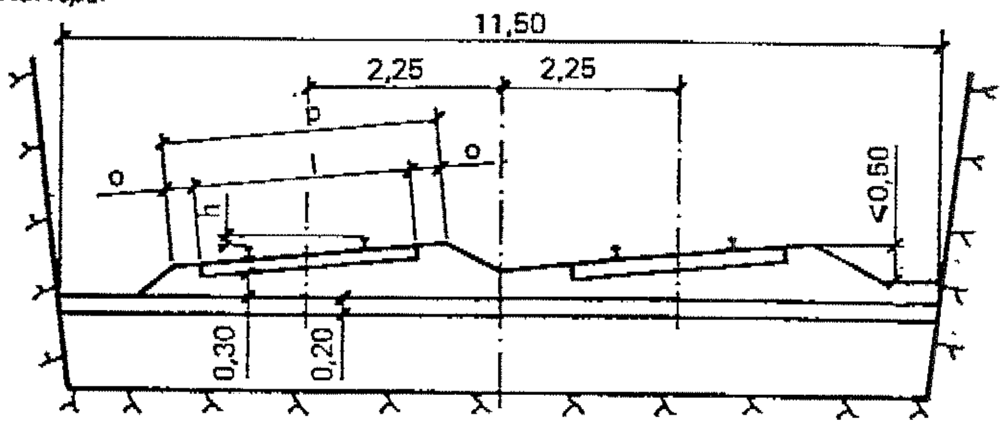
Sektion nr	Sliper		Ballast				
	Material	l (m)	n (m)	o (m) R ≥ 500m	o (m) R < 500m	p (m) R ≥ 500m	p (m) R < 500 m
I25	Trä	2,60	0,45	0,40	0,55	3,40	3,70
I26	Betong	2,50	0,50	0,40	0,55	3,30	3,60

Anm. I kurva med R <400 m skall ballastskuldrorna överhöjas 0,10 m

Rakspår



Kurvspår



NORMALSEKTION FÖR BANAN

Dubbelspår banklass A och B

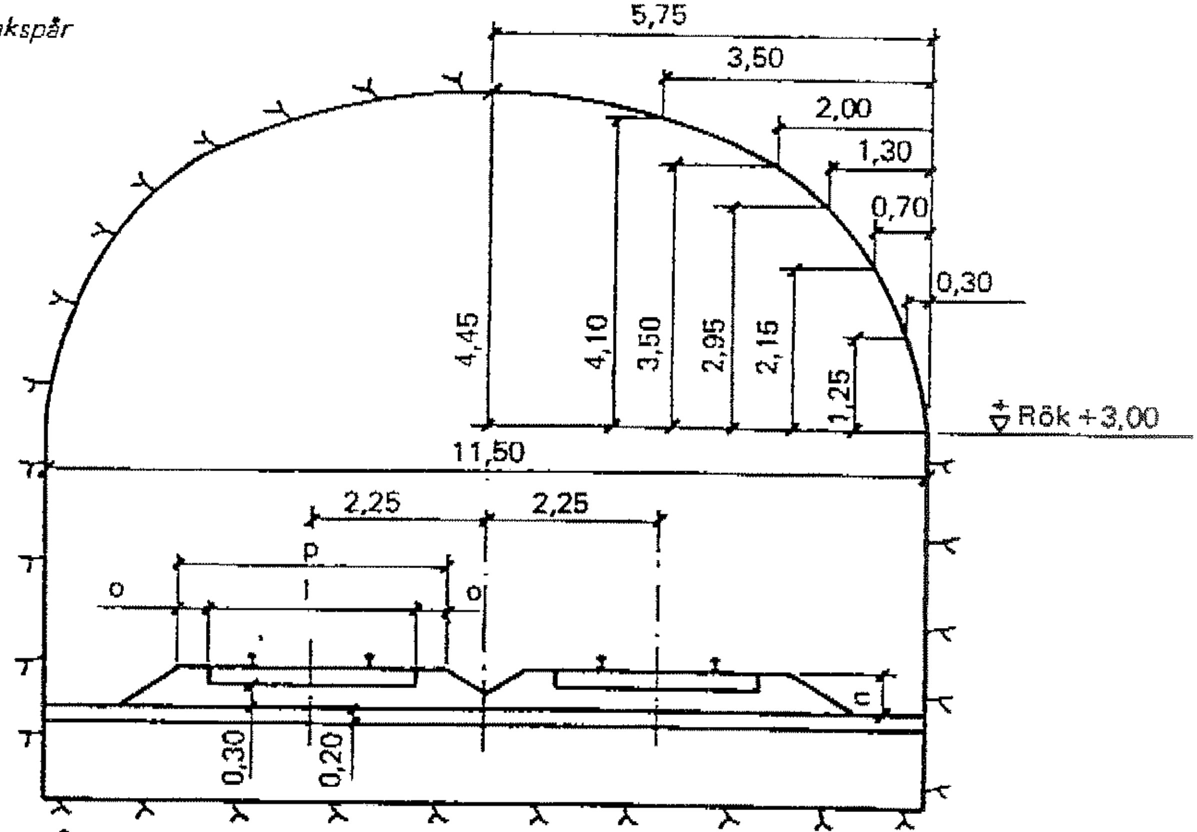
Bergtunnel

Sektion nr	Sliper		Ballast				
	Material	l (m)	n (m)	o (m) R ≥ 500m	o (m) R < 500m	p (m) R ≥ 500m	p (m) R < 500m
127	Trä	2,60	0,45	0,40	0,55	3,40	3,70
128	Betong	2,50	0,50	0,40	0,55	3,30	3,60

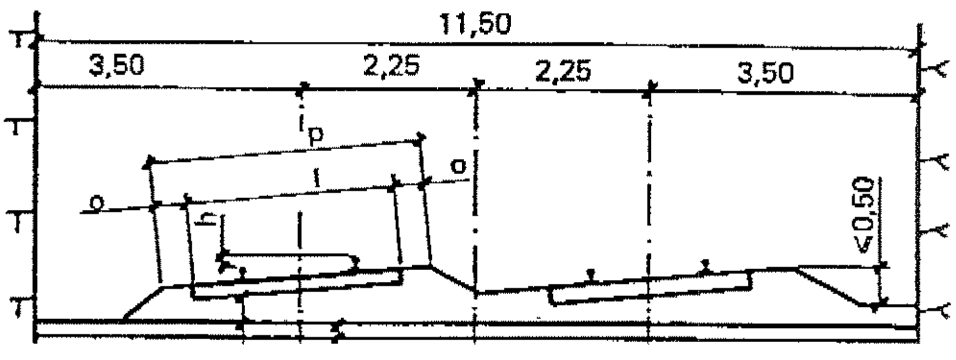
Anm. I kurva med R < 400 m skall ballastskuldrorna överhöjas 0,10 m

Valvmått

Rakspår



Kurvspår



LNG

HUVUDLÄNGDMÄTNING LIGGER I SPÅRMITT U1

VARJE SPÅR HAR DOCK INDIVIDUELL BERÄKNAD LÄNGD-MÄTNING.

LÄNGDMÄTNINGSANGIVELSE

0+0 SEKTION I BASLINJE
(0+0) SEKTION I ÖVRIGT SPÅR MED EGEN LÄNGDMÄTNING.

KONNEKTIONER

SPÅR U1 KM 21+000 = KM 21+000

SPÅR N1 KM (20 999.58)= KM (21+000)

ÖVRIGA SPÅR VID VARJE KM-STOLPE. NY STOLPE PLACERAS VID VARJE KM I SPÅR U1. LÄNGS BEFINTLIG LINJE BIBEHÅLLS NUVARANDE KM-STOLPAR.

BETECKNINGAR

PLANGEOMETRI PLANERAT SPÅR

Lr 300 = LÄNGD ÖVERGÅNGSKURVA
1) LÄNGDMÄTNINGSMARKERING

PLANERAD VÄXEL

1) FSK
2) MKP
3) BKS

BEFINTLIGT SPÅR OCH VÄXEL SOM UTGÅR

BEFINTLIGT SPÅR OCH VÄXEL

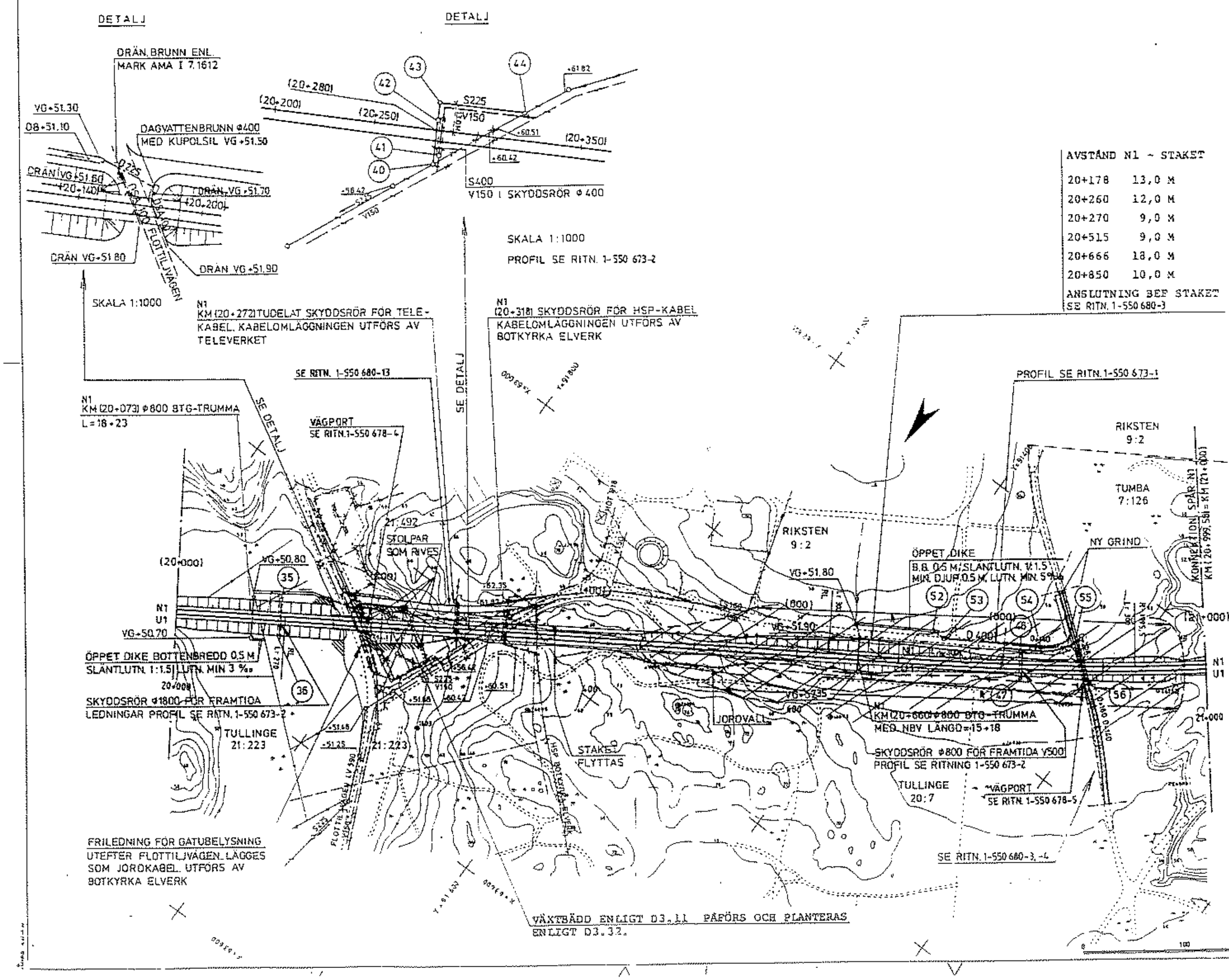
O PLANFIX

+ NIVAFIX

OMRÅDE MED FORNMINNEN

RITNINGSBETECKNINGAR FÖR DIKEN, JORDVALLAR OCH LEDNINGAR SE RITNING 1-550 660-1

REDOVISNING AV DRÄNERING SE PROFILRITNINGAR 1-550 673



AVSTÅND N1 - STAKET	
20+178	13,0 M
20+260	12,0 M
20+270	9,0 M
20+515	9,0 M
20+666	18,0 M
20+850	10,0 M

ANSLUTNING BEF STAKET SE RITN. 1-550 680-3

FÖRFRÅGNINGSUNDERLAG

BANVERKET ÖSTRA REGIONEN

KM KJESSLER & MANNERSTRÅLE AB

FLEMINGSBERG - JÄRNA
NYTT DUBBELSPÅR

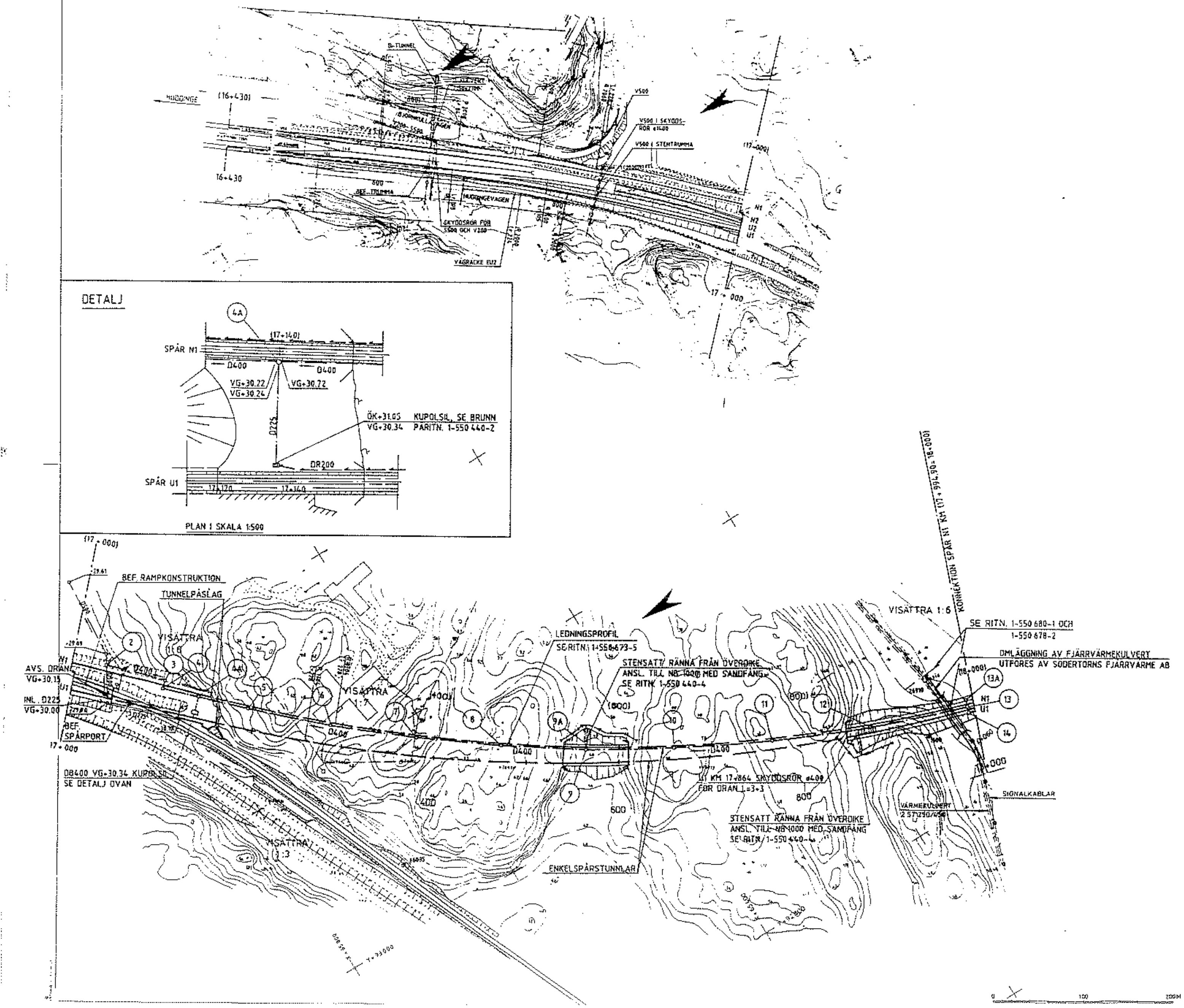
KM 20+000 - 21+000

PLAN

SKALA 1:2000

1989-06-30

1-550 670-4



SYSTEM I PLAN ST 74 I HÖJD RH 00

LÄNGDMÄTNING

HUVUDLÄNGDMÄTNING LIGGER I SPÅRMITT U1

VARJE SPÅR HAR DOCK INDIVIDUELL BERÄKNAD LÄNGDMÄTNING.

LÄNGDMÄTNINGSANGIVELSE

0+0 SEKTION I BASLINJE
(0+0) SEKTION I ÖVRIGT SPÅR MED EGEN LÄNGDMÄTNING.

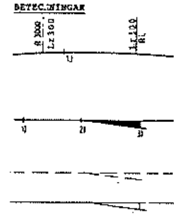
KONNEKTIONER

SPÅR U1 KM 18 + 000 = KM 18 + 000

SPÅR N1 KM (17 + 994.900) = KM (18 + 000)

ÖVRIGA SPÅR VID VARJE KM-STOLPE. NY STOLPE PLACERAS VID VARJE KM I SPÅR U1. LÄNGS BEFINTLIG LINJE BIBEHÅLLS NUVARANDE KM-STOLPAR.

BETECKNINGAR



PLANGEOMETRI PLANERAT SPÅR

Lr 300 = LÄNGD ÖVERGÅNGSKURVA
1) LÄNGDMÄTNINGSMARKERING

PLANERAD VÄXEL

1) FST
2) HKP
3) BKS

BEFINTLIGT SPÅR OCH VÄXEL SOM UTGÅR

BEFINTLIGT SPÅR OCH VÄXEL

O PLANFIX

● NIVAFIX

RITNINGSBETECKNINGAR FÖR DIKEN, JORDVALLAR OCH LEDNINGAR SE RITNING 1-550 440-1

REDOVISNING AV DRÄNERING SE PROFILRITNINGAR 1-550 67.

FÖRFRÅGNINGSUNDERLAG

UPPDRAG FÖR BANVERKET ÖSTRA REGIONEN

KM KJESSLER & MANNERSTRÅLE AB

FLEMINGSBERG - JÄRNA
NYTT DUBBELSPÅR

KM 16+430 - 18+000

PLAN

SKALA 1:2000

1-550 670-1

SYSTEM I PLAN ST 74 i HÖJD RH 00

LÄNGDMÄTNING

HUVUDLÄNGDMÄTNING LIGGER I SPÅRMITT U1

VARJE SPÅR HAR DOCK INDIVIDUELL BERÄKNAD LÄNGDMÄTNING.

LÄNGDMÄTNINGSANGIVELSE

0+0 SEKTION I BASLINJE
(0+0) SEKTION I ÖVRIGT SPÅR MED EGEN LÄNGDMÄTNING.

KONNEKTIONER

SPÅR U1 KM 18+996.432 = KM 19+000

SPÅR N1 KM (18+997.210) = KM (19+000)

ÖVRIGA SPÅR VID VARJE KM-STOLPE. NY STOLPE PLACERAS VID VARJE KM I SPÅR U1. LÄNGS BEFINTLIG LINJE BIBEHÅLLS NUVARANDE KM-STOLPAR.

BETECKNINGAR

PLANGEOMETRI PLANERAT SPÅR

Lr 300 = LÄNGD ÖVERGÅNGSKURVA
1) LÄNGDMÄTNINGSMARKERING

PLANERAD VÄXEL

1) FSK
2) HKP
3) BKS

BEFINTLIGT SPÅR OCH VÄXEL SOM UTGÅR

BEFINTLIGT SPÅR OCH VÄXEL

O PLANFIX

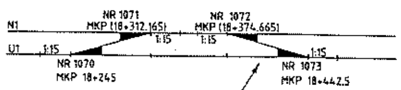
● NIVÅFIX

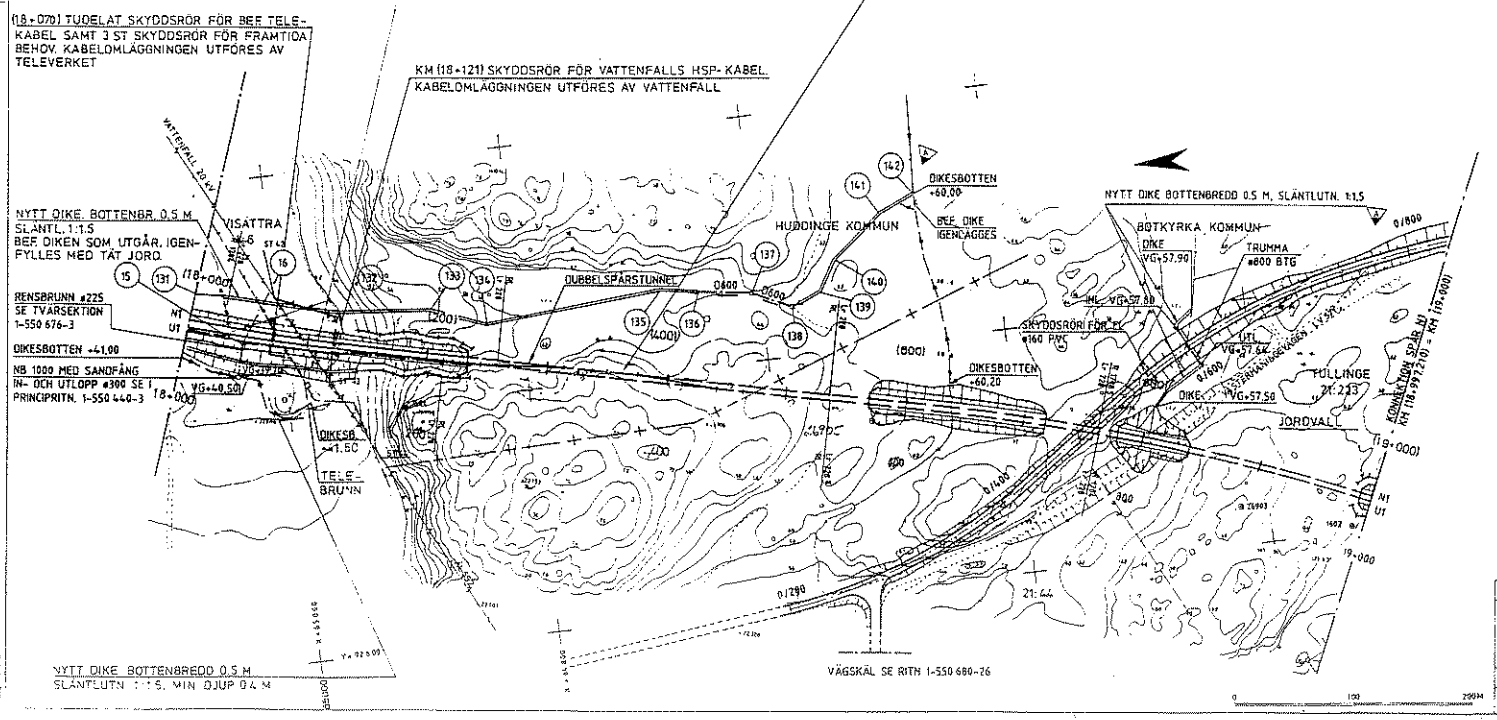
RITNINGSBETECKNINGAR FÖR DIKEN, JORDVALLAR OCH LEDNINGAR SE RITNING 1-550 440-?

REDOVISNING AV DRÄNERING SE PROFILRITNINGAR 1-550 672

VALL UTFÖRS ENLIGT C1.54 OCH D3 I MÄNGDBESKRIVNING

SEKTION HÖGER	HÖJD
18+000	+ 44,85
18+020	+ 45,02
18+040	+ 45,19
18+060	+ 45,36
18+080	+ 45,53
18+100	+ 45,70
18+120	+ 45,87
18+140	+ 46,04





FÖRFRÅGNINGSUNDERLAG

REV	ANT	REGISTRERINGEN AVSER	SIGN	DATUM
A	2	VÄG + DIKE		99-?-??

BANVERKET ÖSTRA REGIONEN

KM KJESSLER & MANNERSTRÅLE AB

FLEMINGSBERG - JÄRNA
NYTT DUBBELSPÅR

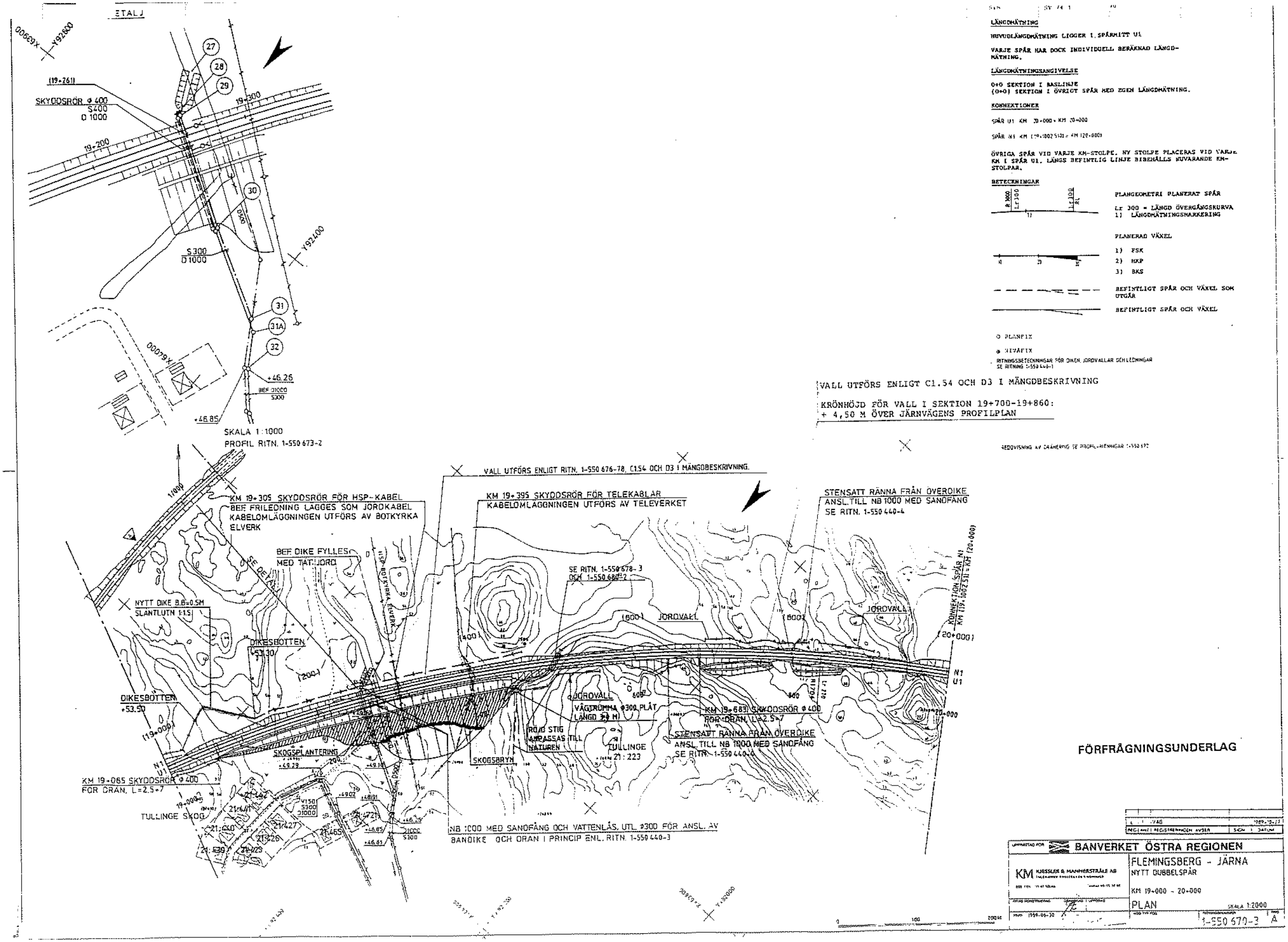
KM 18+000 - 19+000

PLAN

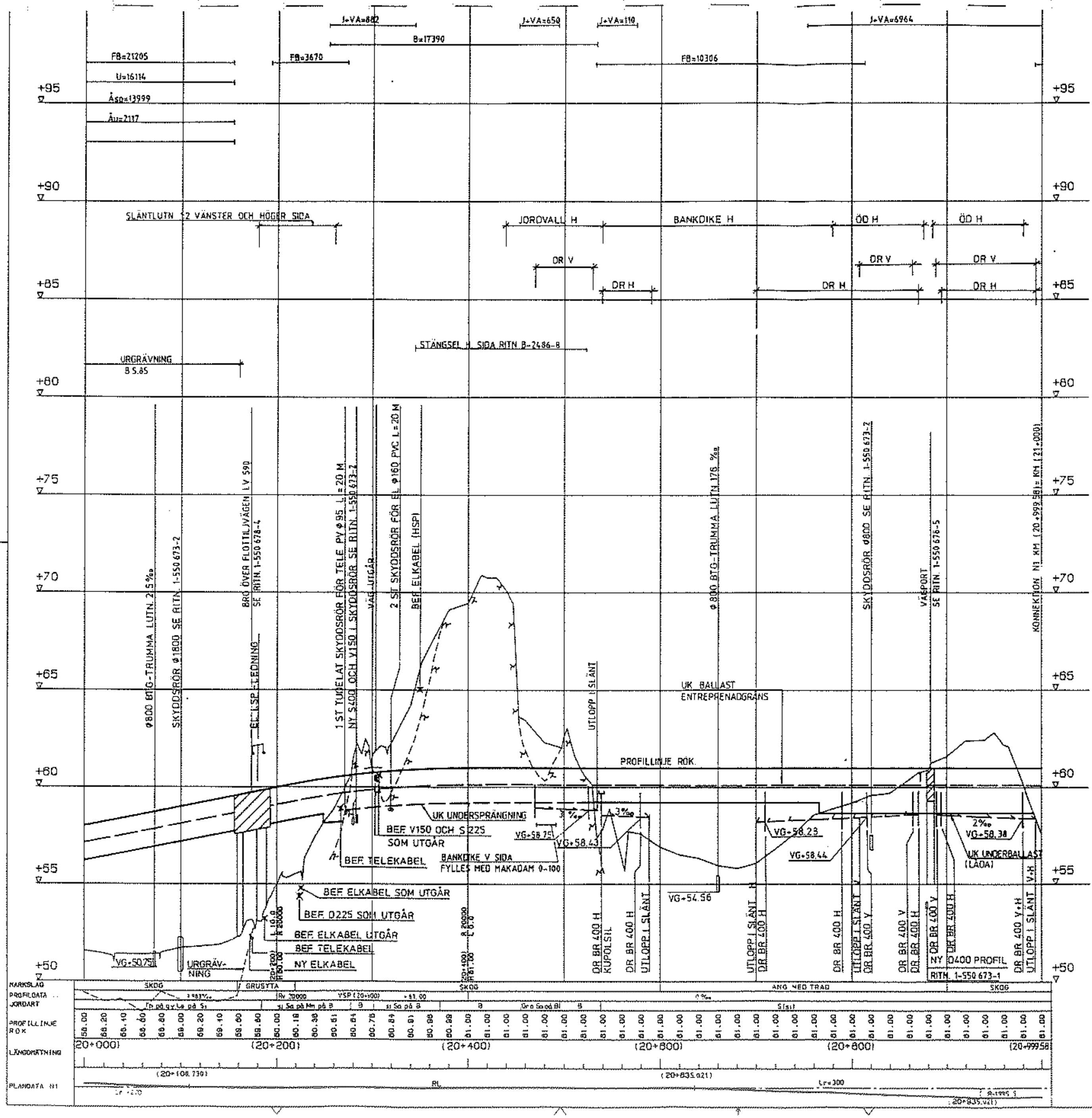
SKALA 1:2000

1999-06-30

1-550 670-2 A



DETALJ
LÄNGDMÄTNING
HUVUDLÄNGDMÄTNING LIGGER I SPÅRMITT U1
VARJE SPÅR HAR DOCK INDIVIDUELL BERÄKNAD LÄNGDMÄTNING.
LÄNGDMÄTNINGSANGIVELSE
0+0 SEKTION I BASLINJE
(0+0) SEKTION I ÖVRIGT SPÅR MED EGEN LÄNGDMÄTNING.
KONNEXTIONER
ÖVRIGA SPÅR VID VARJE KM-STOLPE. NY STOLPE PLACERAS VID VARJE KM I SPÅR U1. LÄNGS BEFINTLIG LINJE BIBEHÅLLS NUVARANDE KM-STOLPAR.
BETECKNINGAR
PLANGEOMETRI PLANERAT SPÅR
Lr 300 = LÄNGD ÖVERGÅNGSKURVA
1) LÄNGDMÄTNINGSMARKERING
PLANERAD VÄXEL
1) FSK
2) MXP
3) BKS
BEFINTLIGT SPÅR OCH VÄXEL SOM UTGÅR
BEFINTLIGT SPÅR OCH VÄXEL
O PLANFIX
NIVÅFIX
VALL UTFÖRS ENLIGT C1.54 OCH D3 I MÄNGDBESKRIVNING
KRÖNHÖJD FÖR VALL I SEKTION 19+700-19+860:
+ 4,50 M ÖVER JÄRNVÄGENS PROFILPLAN
SKYDDSRÖR ⌀ 400
S400
D 1000
S 300
D 1000
SKALA 1:1000
PROFIL RITN. 1-550 673-2
VALL UTFÖRS ENLIGT RITN. 1-550 676-78, C1.54 OCH D3 I MÄNGDBESKRIVNING.
KM 19+305 SKYDDSRÖR FÖR HSP-KABEL
BEF. FRILEDNING LÄGGES SOM JORDKABEL
KABELOMLÄGGNINGEN UTFÖRS AV BOTKYRKA ELVERK
KM 19+395 SKYDDSRÖR FÖR TELEKABLAR
KABELOMLÄGGNINGEN UTFÖRS AV TELEVERKET
STENSATT RÄNNA FRÅN ÖVERDIKE
ANSL. TILL NB 1000 MED SANDFÅNG
SE RITN. 1-550 440-4
BEF. DIKE FYLLES MED TÄT JORD
NYTT DIKE B.B=0.5M
SLÄNTLUTN 1:1.5
DIKESBOTTEN
JORDVALL
DIKESBOTTEN
+53.50
SKOGSPLANTERING
SKOGSBRYN
RÖJD STIG ANPASSAS TILL NATUREN
VÄGTRUMMA ⌀300 PLÅT
TULLINGE 21:223
KM 19+683 SKYDDSRÖR ⌀ 400
FÖR DRÄN. L=2.5+7
STENSATT RÄNNA FRÅN ÖVERDIKE
ANSL. TILL NB 1000 MED SANDFÅNG
KM 19+065 SKYDDSRÖR ⌀ 400
FÖR DRÄN. L=2.5+7
TULLINGE SKOG
NB 1000 MED SANDFÅNG OCH VATTENLÅS, UTL. ⌀300 FÖR ANSL. AV BANDIKE OCH DRÄN I PRINCIP ENL. RITN. 1-550 440-3
N1
U1
(20+000)
20+000
(19+000)
FÖRFRÅGNINGSUNDERLAG
BANVERKET ÖSTRA REGIONEN
KM KJESSLER & MANNERSTRÅLE AB
FLEMINGSBERG - JÄRNA
NYTT DUBBELSPÅR
KM 19+000 - 20+000
PLAN
SKALA 1:2000
1-550 670-3 A



FÖRKLARINGAR

SYSTEM I HÖJD RH 00
HUVUDLÄNGDMÄTNING LIGGER I SPÅRMITT U 1
VARJE SPÅR HAR INDIVIDUELLT BERÄKNAD LÄNGDMÄTNING
RKS PROFILDATA GÄLLER FÖR SPÅR U1

LÄNGDMÄTNINGSANGIVELSE

0 + 0 SEKTION I BASLINJE
(0 + 0) SEKTION I ÖVRIGT SPÅR MED EGEN LÄNGDMÄTNING

KONNEKTIONER

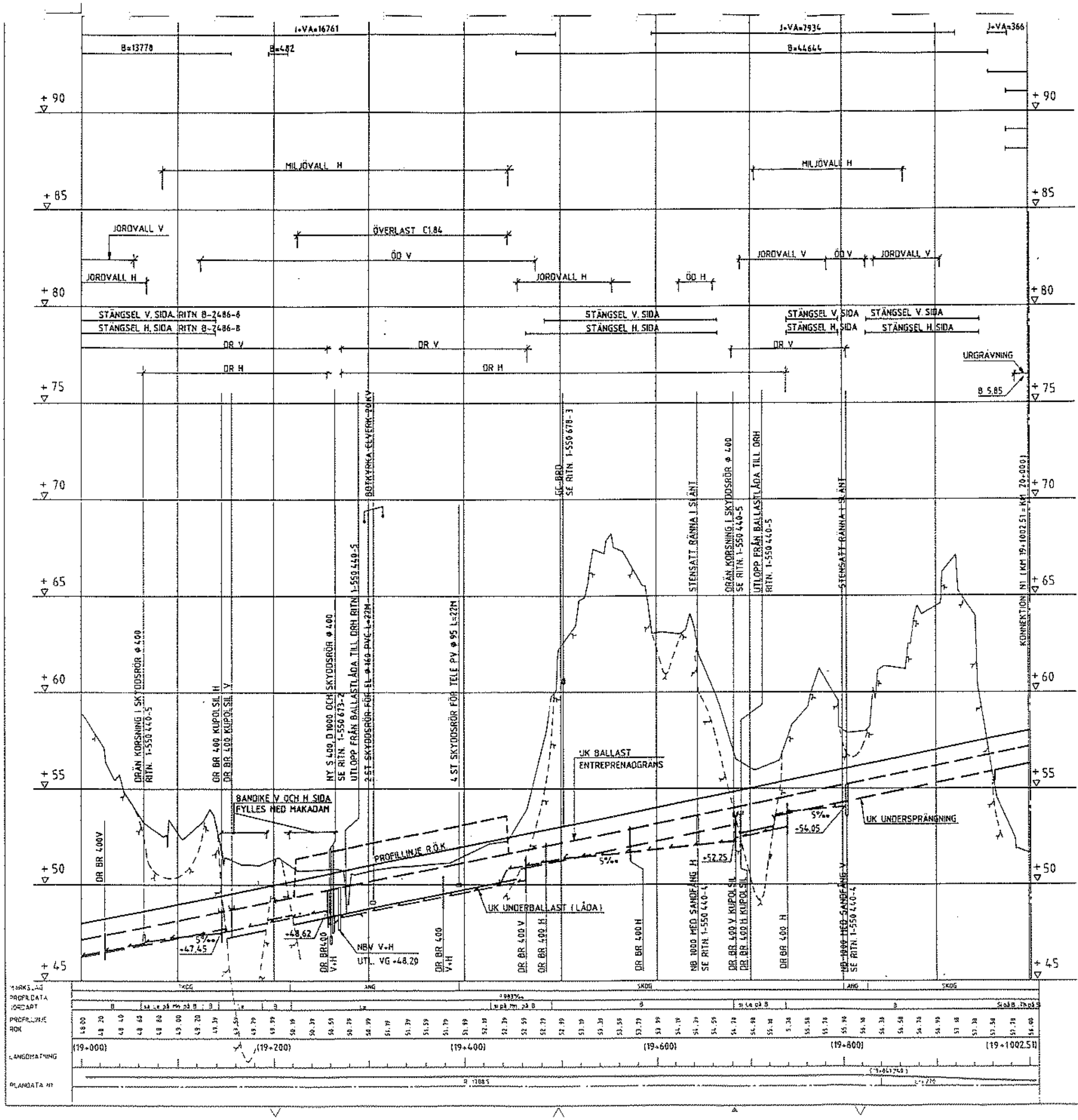
U1 KM 21+000 = KM 21+000

N1 KM (20+999.580) = KM (21+000)

ÖDV = ÖVERDIKE VÄNSTER
DRV = DRÄNERING VÄNSTER
DR.BR 400 V = DRÄNERINGSBRUNN Ø 400 VÄNSTER SIDA

FÖRFRÅGNINGSUNDERLAG

BANVERKET ÖSTRA REGIONEN	
KM KJESSLER & MANNERSTRÅLE AB	FLEMINGSBERG – JÄRNA NYTT DUBBELSPÅR KM (20+000) – KM (20+999.580) N1 H=1:100 L=1:2000
1989-06-30	PROFIL
	1-550 672-6



...RINGAR

SYSTEM I HÖJD RH 00
HUVUDLÄNGDMÄTNING LIGGER I SPÅRMITT U 1
VARJE SPÅR HAR INDIVIDUELLT BERÄKNAD LÄNGDMÄTNING

LÄNGDMÄTNINGSANGIVELSE

0 + 0 SEKTION I BASLINJE
(0 + 0) SEKTION I ÖVRIGT SPÅR MED EGEN LÄNGDMÄTNING

KONNEKTIONER

U1 KM 70+000 = KM 70+000
N1 KM (19+1002.51) = KM (20+000)

ÖDV = ÖVERDIKE VÄNSTER
DRV = DRÄNERING VÄNSTER
DR.BR 400 V = DRÄNERINGSBRUNN Ø 400 VÄNSTER SIDA

FÖRFRÅGNINGSUNDERLAG

REG	ÄNT	REGISTRERINGEN AVSER	SIGN	DATUM

BANVERKET ÖSTRA REGIONEN

KM KJESSLER & MANNERSTRÅLE AB

FLEMINGSBERG - JÄRNA
NYTT DUBBELSPÅR

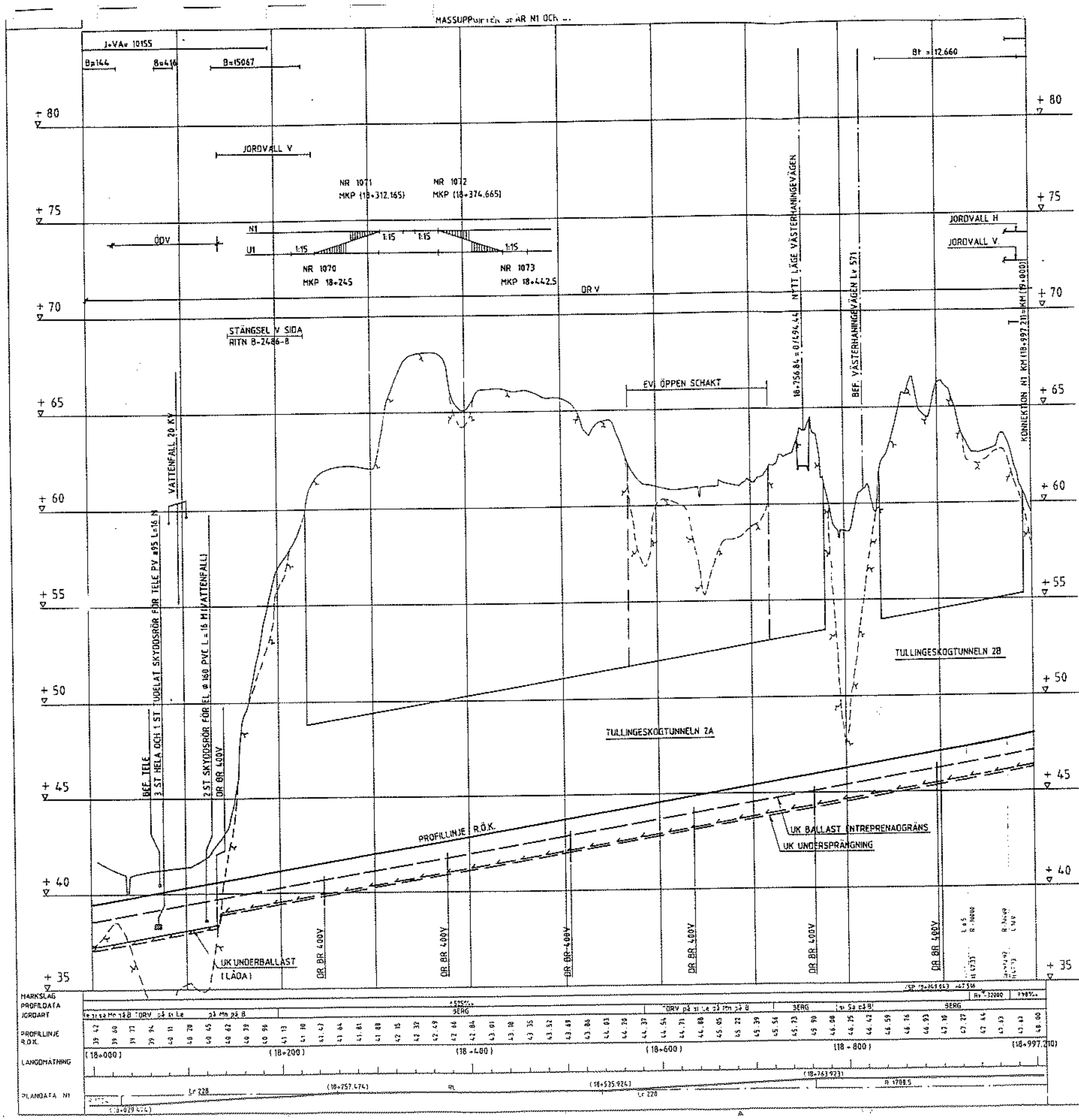
KM (19+000) - (19+1002.510) N1

PROFIL

SKALA H=1:100 L=1:2000

1999-05-30

1-550 672-5



FÖRKLARINGAR

SYSTEM I HÖJD RH 00
HUVUDLÄNGDMÄTNING LIGGER I SPÅRMITT U 1
VARJE SPÅR HAR INDIVIDUELLT BERÄKNAD LÄNGDMÄTNING

LÄNGDMÄTNINGSANGIVELSE

0 + 0 SEKTION I BASLINJE
(0 + 0) SEKTION I ÖVRIGT SPÅR MED EGEN LÄNGDMÄTNING

KONNEKTIONER

N1 KM (18+997.210) = KM (19+000)

U1 KM 18+996.632 = KM 19+000

ÖDV = ÖVERDIKE VÄNSTER
DRV = DRÄNERING VÄNSTER
DR,BR 400 V = DRÄNERINGSBRUNN ø 400 VÄNSTER SIDA

FÖRFRÅGNINGSUNDERLAG

REG	ANT	REGISTRERINGEN AVSER	SIGN	DATUM

BANVERKET ÖSTRA REGIONEN

KM KJESSLER & MANNERSTRÅLE AB

FLEMINGSBERG - JÄRNA
NYTT DUBBELSPÅR

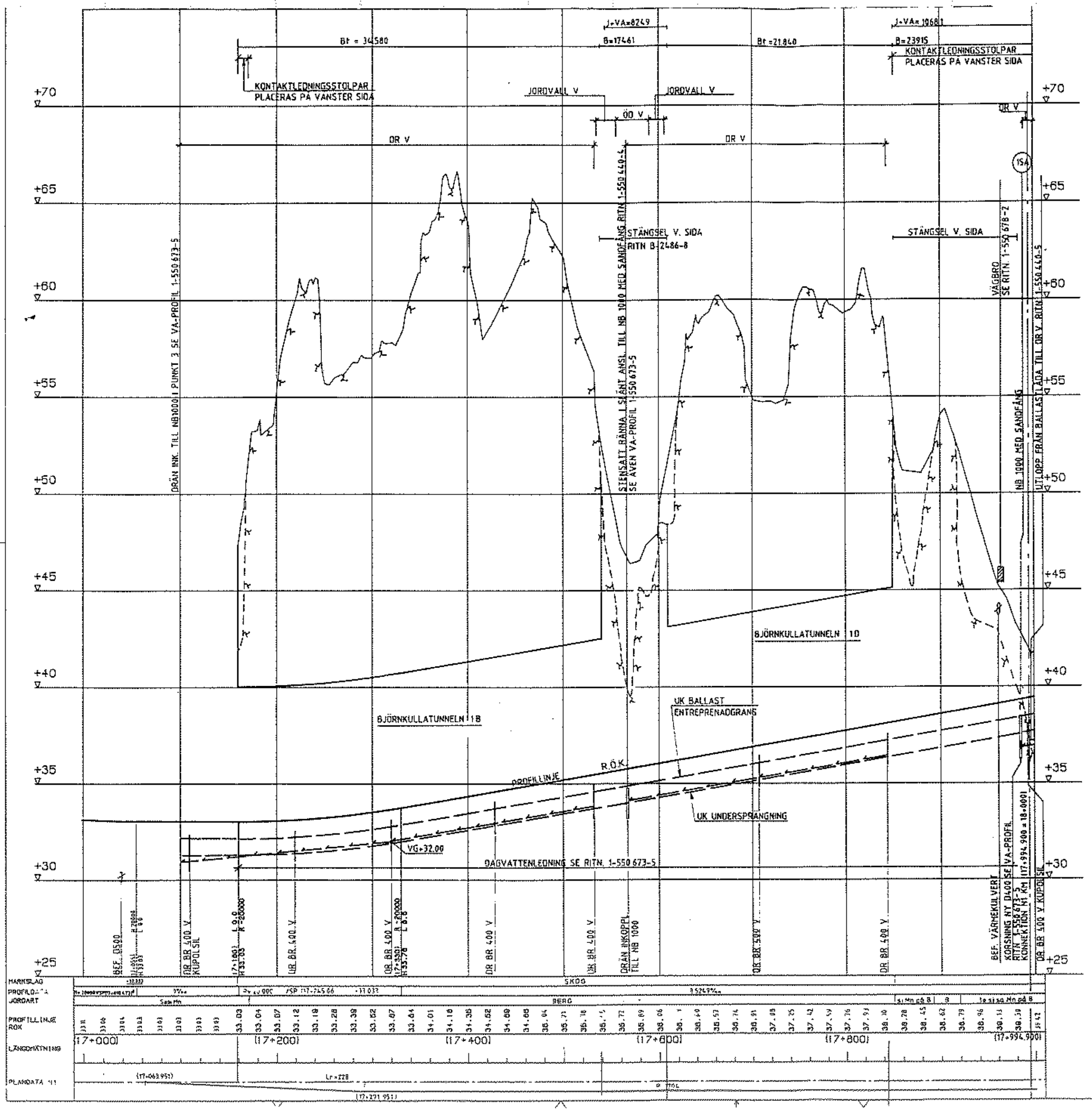
KM (18+000) - KM (18+997.210) N1

PROFIL

SKALA H=1:100 L=1:2000

1999-06-30

1-550 672-4



FÖRKLARINGAR

SYSTEM I HÖJD RH 00
HUVUDLÄNGDMÄTNING LIGGER I SPÅRMITT U 1
VARJE SPÅR HAR INDIVIDUELLT BERÄKNAD LÄNGDMÄTNING

LÄNGDMÄTNINGSANGIVELSE

0 + 0 SEKTION I BASLINJE
(0 + 0) SEKTION I ÖVRIGT SPÅR MED EGEN LÄNGDMÄTNING

KONNEKTIONER

N1 KM (17+994.90) = KM (18+000)

ÖDV = ÖVERDIKE VÄNSTER
DRV = DRÄNERING VÄNSTER
DR.BR 400 V = DRÄNERINGSBRUNN Ø 400 VÄNSTER SIDA

FÖRFRÅGNINGSUNDERLAG

BET	ÄNDRINGEN AVSER	SIGN	DATUM

BANVERKET ÖSTRA REGIONEN

KM KJESSLER & MANNERSTRÅLE AB

FLEMINGSBERG - JÄRNA
NYTT DUBBELSPÅR

KM (17+000)-(KM 17+994.90) N1

PROFIL

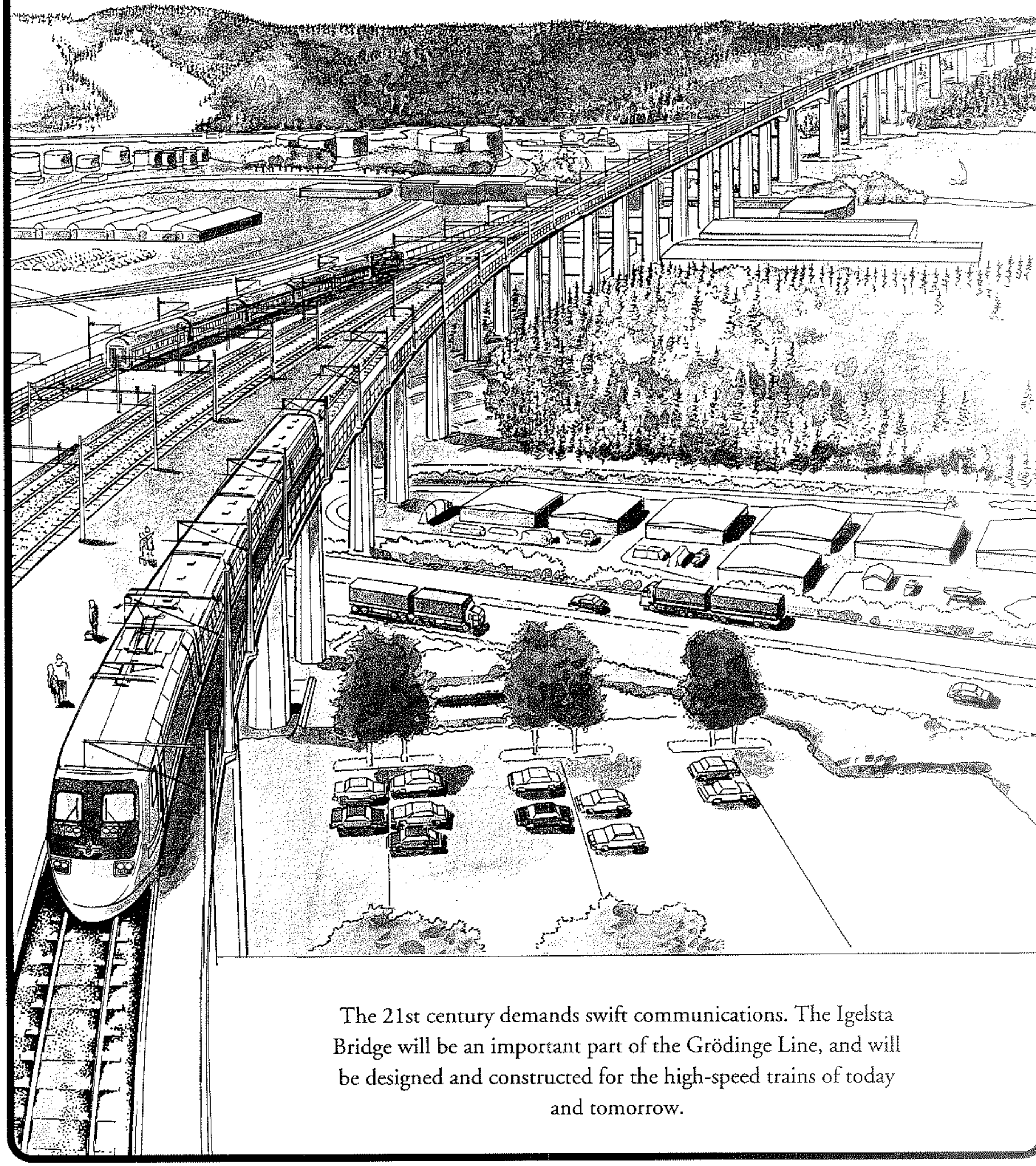
H=1:100
SKALA L=1:2000

1989-05-30

1-550 672-3

THE IGELSTA BRIDGE

For the trains of the next century!



The 21st century demands swift communications. The Igelsta Bridge will be an important part of the Grödinge Line, and will be designed and constructed for the high-speed trains of today and tomorrow.

Long, high and slender...

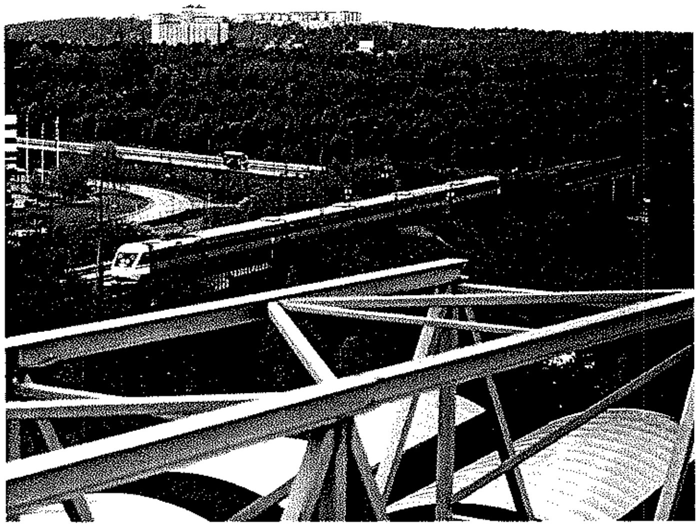
The Igelsta Bridge:

The Igelsta Bridge will be one of the largest railway bridges in Europe. It is designed and constructed for the high-speed trains of the new century to traffic the Grödinge Line between Flemingsberg and Järna.

The total cost is about 700 million Swedish Kronor (in 1990 prices).

The bridge is built as a turn-key contract, which means that the contractor is responsible both for the design and for the construction. The works shall be finished at the turn of the year 1993/94.

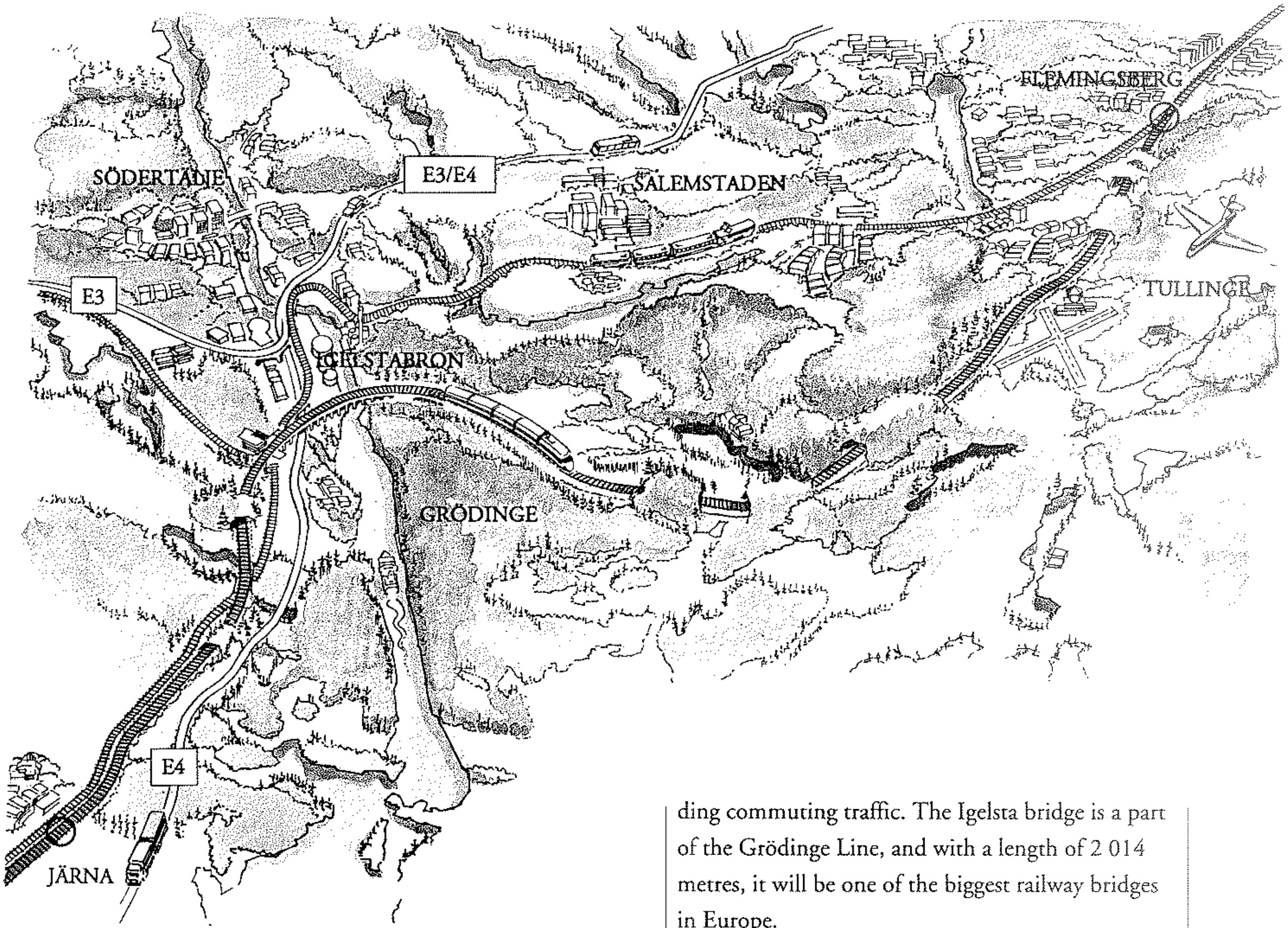
When the tenders were given, several alter-natives were considered. The alternatives with a steel-truss bridge respectively a cable-stayed bridge, though, were both more expensive than the bridge now being constructed. Several inter-national companies participated in the tender competition. In the end the joint venture The Igelsta Bridge Consortium won the contract. (NCC/AKER ENTREPRENØR /EEG-HENRIKSEN).



Technique:

The bridge is founded on 57 supports. Above land the bridgedeck is constructed by a launch-able framework which spans over 2 piers with a distance of 60 metres. Over water the bridgedeck is constructed according to the balanced canti-levered method, which means that the bridge is constructed from the top of a pier outwards to each side in balance. The width of the span between piers is here 158 metres. The main impression of the bridge will be its height and slenderness.

The Igelsta Bridge – an important link in the Swedish railway system!



A project for the railway traffic of the future.

In February 1989 the first steps of the new Grödinge Line was taken. It´s a new double track railway, 30 km long, between Flemingsberg and Järna, south of Stockholm. The new line will be used by the long distance trains to Gothenburg and Malmö and also by the trains of the prospective Svealand Line.

The railway is designed for a top speed of 250 km/h. The old railway will be used for an expanding commuting traffic. The Igelsta bridge is a part of the Grödinge Line, and with a length of 2 014 metres, it will be one of the biggest railway bridges in Europe.

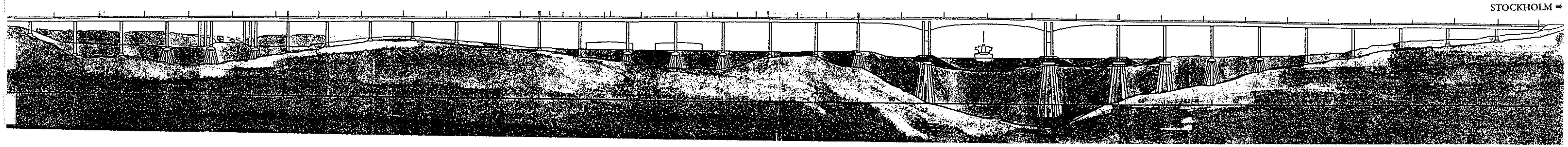
On the west side of the bridge a new long-distance railway station will be constructed, with the name Södertälje Syd, where the prospective Svealand Line will be connected. For the passengers this means a better, more comfortable and faster connection between the Mälar Valley and the Stockholm region.

The construction of the bridge started in August 1990 and it will be finished at the turn of the year 1993/94. During 1994 the Swedish Rail Administration (Banverket) will start the specific railway works, such as tracks, signalling, power supply and telecommunication. The Grödinge Line will be completed at the turn of the year 1994/95. Client is the East Region of the Swedish Rail Administration.

THE IGELSTA BRIDGE – ONE OF THE BIGGEST RAILWAY BRIDGES IN EUROPE.

ERTÄLJE SYD

STOCKHOLM ⇒



Advanced mission for the contractors.

FOUNDATION

The Igelsta bridge has in all 57 foundation footings of which 33 carry the double-track bridge and 24 the single-track bridges. Of these 57 foundations, 38 are placed directly on rock and 13 on concrete piles. 6 of the foundations have been founded on compacted filling. One foundation has steel core piles and the 3 foundations in water have been founded on skinfriction or endbearing steel pipe piles filled with concrete.

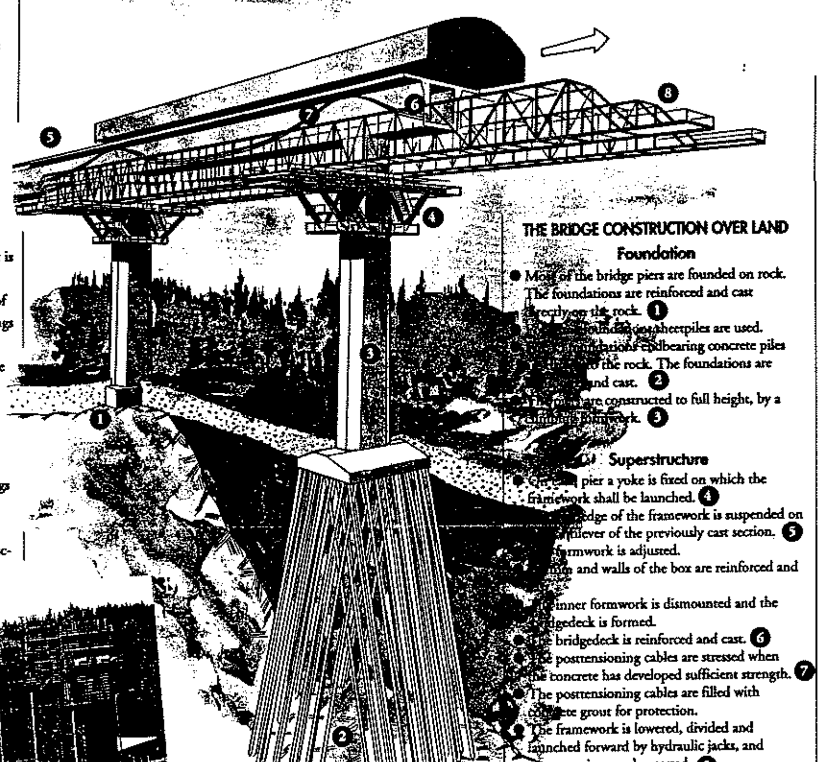
PIERS

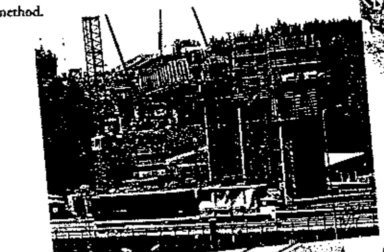
Both hollow and solid piers are used in the structure. The highest are 48 m and the average height is 30 m.

The two free cantilever piers consist of a pair of slender walls, the lower part braced by crossbracings forming a box. The total height up to the upper edge of the bridge-deck is 48 m. Vertical clearance is 40,5 m.

SUPERSTRUCTURE

The superstructure is designed as a posttensioned concrete box section. It will rest on special bearings on 30 of the piers and be cast integral with the others. Over land the superstructure is cast in a launchable framework. Above water the superstructure is constructed according to the balanced cantilevered method.





THE BRIDGE CONSTRUCTION OVER LAND

Foundation

- Most of the bridge piers are founded on rock. The foundations are reinforced and cast directly on the rock. ❶
- ... sheetpiles are used.
- ... endbearing concrete piles ... the rock. The foundations are ... and cast. ❷
- ... are constructed to full height, by a ... formwork. ❸

Superstructure

- ... pier a yoke is fixed on which the framework shall be launched. ❹
- ... edge of the framework is suspended on ... cantilever of the previously cast section. ❺
- ... formwork is adjusted.
- ... and walls of the box are reinforced and ...
- ... inner formwork is dismounted and the bridgedeck is formed.
- The bridgedeck is reinforced and cast. ❻
- The posttensioning cables are stressed when the concrete has developed sufficient strength. ❼
- The posttensioning cables are filled with concrete grout for protection.
- The framework is lowered, divided and launched forward by hydraulic jacks, and a new section can be started. ❽

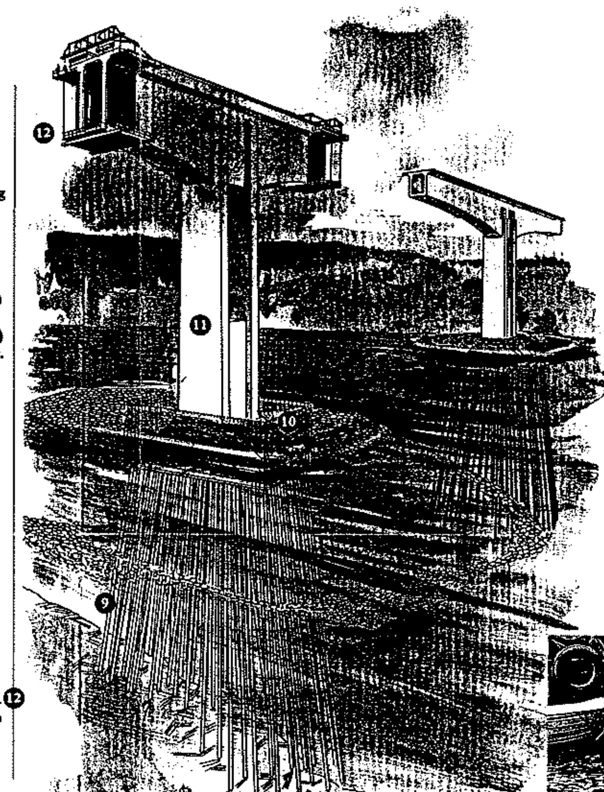
THE BRIDGE CONSTRUCTION ABOVE WATER

Foundation

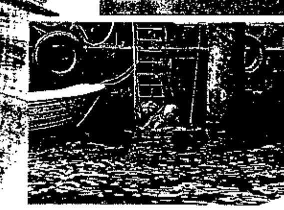
- Mud and clay is dredged down to solid sand and gravel.
- Stone and gravel are filled by bottom opening barges till about 10 m under water level.
- The piles are driven from a pontoon.
- The steel pipe piles are 60 m long with a diametre of 800 mm. ❾
- The bottom is adjusted by divers.
- Prefabricated pile sheet cofferdams (26x17m) with a height of 12 m and a weight of about 240 tons are placed by a pontoon crane. ❿
- A reinforced concrete slab is cast under water.
- The cofferdam and the steelpipe piles are emptied of water.
- Location, inclination and straightness of the piles is controlled.
- The piles are cut to the right level.
- The piles are reinforced and cast.
- The bottom slab is reinforced and cast.
- The piers are constructed to 3,5 m above water level. ⓫
- The cofferdam is removed.
- The rock filling is completed up to 1 metre above water level, thus making a ship collision protection, able to resist the impact of a 100 000 tons ship at 5 knots speed.

Superstructure

- The piers are constructed and cast to full height by a climbing formwork.
- The free cantilever form travellers are erected. ⓬
- The bridge is cast in steps of 5 metres in both directions from the piers in balance.
- The posttensioned reinforcement gives sufficient strength.



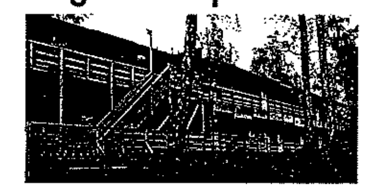
FACTS ABOUT THE BRIDGE



Bridge Constructors - an engaged professional staff with unique knowledge and experience

On the site "Igelstabron" you meet a special professional staff that could be called modern "navvies". They are very competent and experienced people, who hardly could imagine another kind of job for themselves. Most of them have been working all around the world and gathered the kind of know-how necessary for bridge constructions.

On the Site there are a couple of camps where many of the bridge constructors live during the weekdays.



Quality in reality

OAULITY ASSURANCE (QA) and QUALITY CONTROL (QC). At the Igelsta Bridge the Rail Administration has demanded that the Igelsta Bridge Consortium as contractor shall have a system for QA and QC which also will be applied for sub-contractors and suppliers.

The aim of the QA is to have a system to fulfill the demands at the first trial, that is "to do the right thing the first time". To do the right thing includes also to produce the necessary documents required in codes and contract documents.

The aim of QA and QC is to ensure by testing, control and inspections, that the requirements given have been fulfilled according to codes and documents.

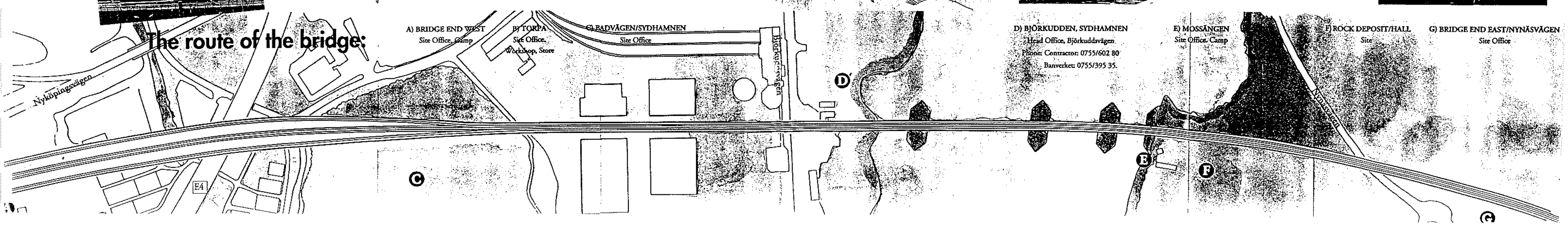
For a turn-key contract like the Igelsta Bridge, the OA and QC include procurement, planning, design, construction and inspection. The project organization has to work systematically to:

a) initiate steps to prevent mistakes and deviations
b) identify and register quality problems
c) provide for solutions
d) verify the proper result
e) carefully follow up a work or supply until possible deficiencies or unsatisfying circumstances have been corrected.

Planning – a qualified puzzle.

In a construction project of such an advanced character as the Igelsta Bridge there is an immense flow of products, services and work phases. It is, of course, very important to have detailed schedules. The timeplanning is computer assisted. All orders, supplies, manpower and other resources are directed according to carefully designed planning systems.

The route of the bridge:



Qualified resources in cooperation!

CLIENT:

BANVERKET
Östra regionen

Client of the Igelsta Bridge is The Swedisch National Rail Administration (Banverket). Banverket is responsible for operation, maintenance and construction of the railway system. The site organization (with a total responsability for technique, economy and quality), in cooperation with the contractor, is responsible for the realization of the project.

COOPERATION ACROSS THE SWEDISH–NORWEGIAN BORDER

The project is built by a Swedish/Norwegian joint-venture with qualified and complementing competencies which together guarantee an excellent final work. The participant companies are:

CONTRACTOR:

KONSORTIET IGELSTABRON

NCC

NCC Bygg AB is the second biggest construction company in Sweden. Within the consortium, NCC is the heaviest partner. The NCC Stockholm Division has during the last years built large communication projects such as Arlanda Domestic Terminal and the North Link Highway in Stockholm.

EEG-HENRIKSEN

Eeg-Henriksen has built many of the largest bridges in Norway. As NCC is a shareholder in Eeg-Henriksen, the cooperation was natural.

Aker Entreprenør

Aker Entreprenør is one of the 4 four largest contractors in Norway. The main market is in the construction field, and Aker has during the last years been well established in the Swedish market.

STRUCTURAL ENGINEERS:

ELU KONSULT AB

The Igelsta Bridge is designed by ELU-KONSULT which is the largest bridge consulting company in Sweden. About 25 structual engineers will be working for two years within the project.

SUPPLIERS/SUBCONTRACTORS

Many suppliers participate in the project on different levels. Among others the following companies are involved:

BINEC

Subcontractor for frameworks on land.

BOA's SMIDE AB

Subcontractor for cofferdams.

Schaktentreprenör Arne Frölander AB Härnösand

Subcontractor for receiving and transport of rock filling in water.

fundia BYGG

Supplies all reinforcement bars.

HAKA
CIVIL AND MARINE CONSTRUCTION LTD

Subcontractor for dredging, filling and steel pipe piling.

HERCULES GRUNDLÄGGNING

Subcontractor for piling on land and at sea.

IGELSTA BETONG

Subcontractor for supply and control of concrete.

JÄRNBOLAGET

Supplies most of the tools and hardware.

RAUTARUUKKI RÖR AB

Supplies the steel pipe piles.

SPÄNNARMERING

Subcontractor for posttensioning cables.

STRÖMSTADS MEKANISKA VERKSTAD AB

Welds steelpipe sections.

SÖDERTÄLJE TRÄVARU AB

Supplies sawn wood and plastic-faced plywood etc.

UNNERÅS

Supplies gravel.

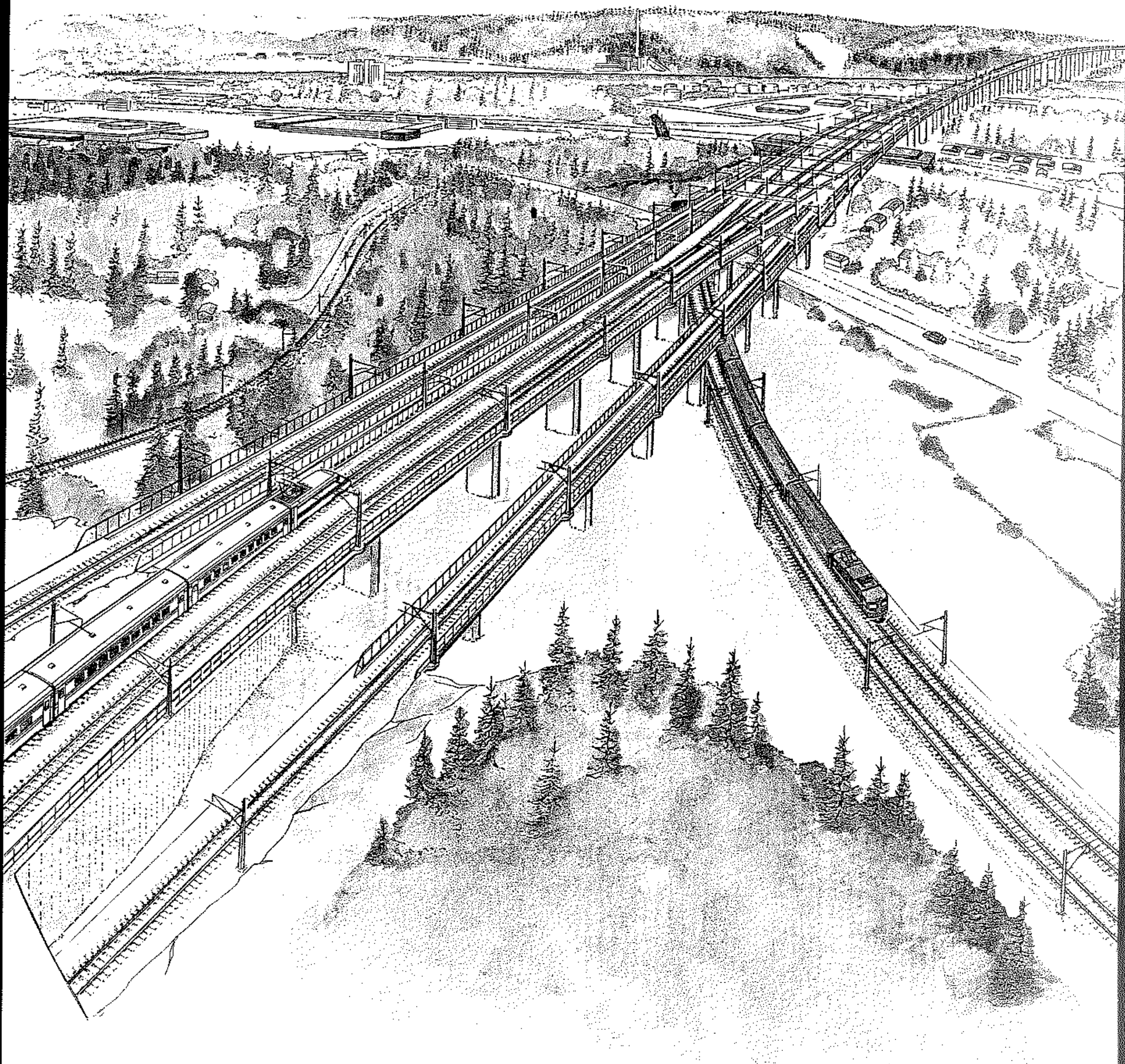
VALVKONSTRUKTION
ERIKSSON & LINDÉN AB

Supplies Peri climbing formwork.

Producerad på initiativ av Banverket och Konsortiet Igelstabron. Idé, text, layout och produktion Hörkell Annonsbyrå AB. Teckningar Ulf Alamaa. Foto Studio Bengtsson. Augusti 1991

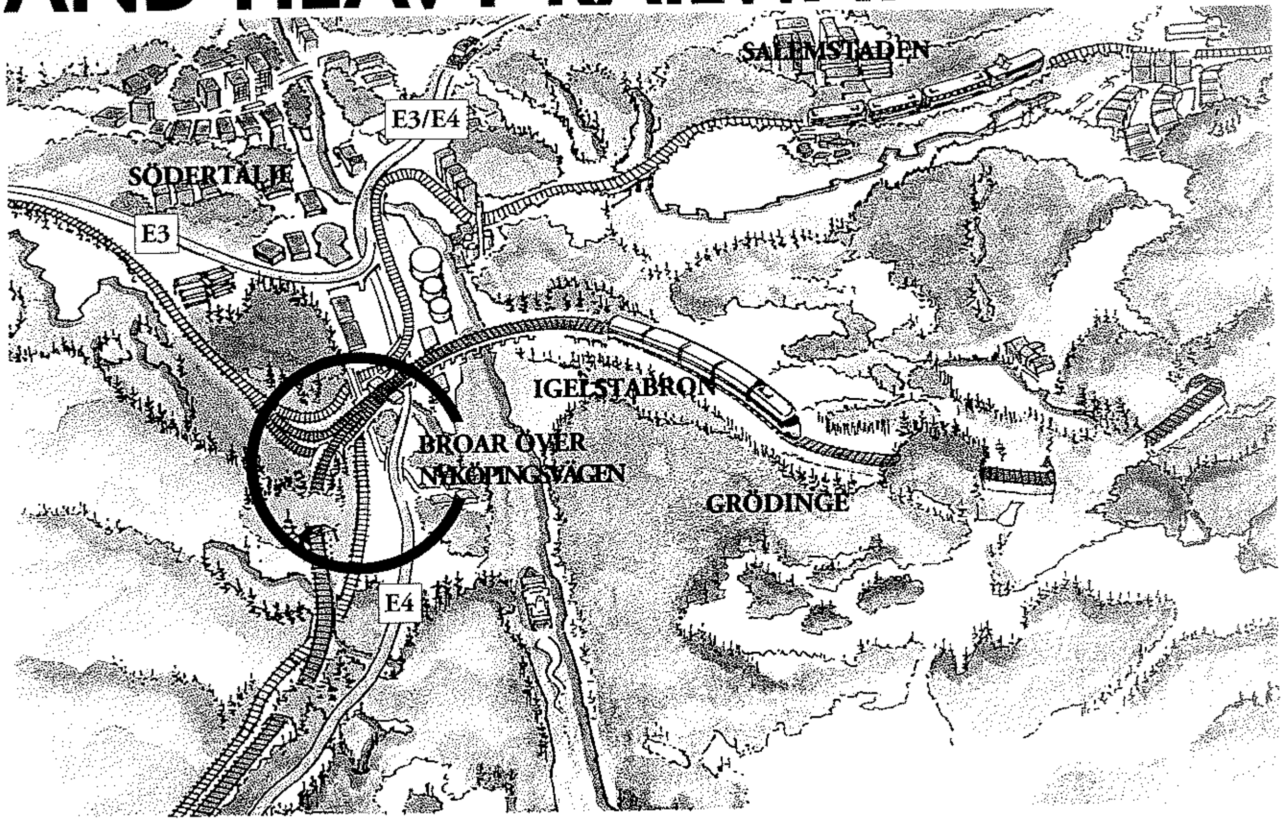
BRIDGES ACROSS THE NYKÖPING ROAD

EXTENSION OF THE IGELSTA BRIDGE SOUTHWARD



The 21st century demands swift communications.To respond to these demands, the Swedish National Rail Administration and the Igelsta Bridge Joint Venture now build the Bridges across the Nyköping road, an extension of the Igelsta Bridge. These three bridges are 325 m long each, implying many interesting challenges for the participants of the project. For instance, the construction has to be carried out without disturbing the traffic on the Nyköping road and the present railway main line.

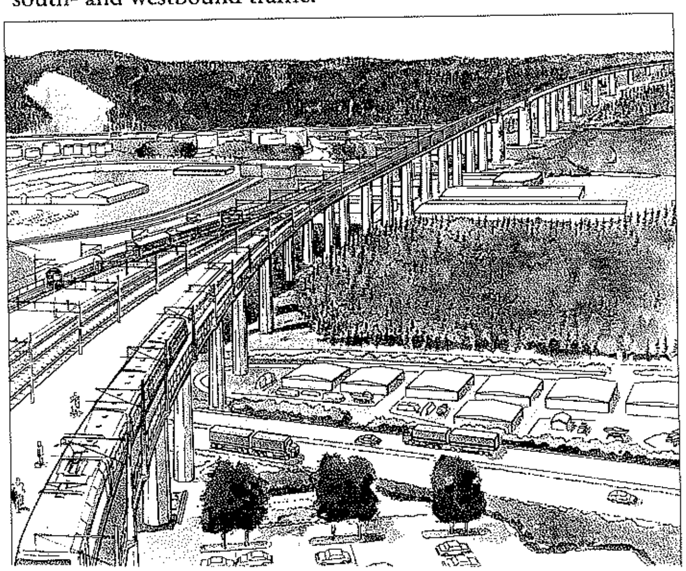
A BRIDGE SYSTEM FOR FAST AND HEAVY RAILWAY TRAFFIC



In Södertälje one of the biggest bridges in Europe is being built. The project is characterized by many interesting construction solutions and advanced technique.

THE IGELSTA BRIDGE...

Across the Igelsta Bay a more than 2 km long railway bridge is built, with a maximum height of 48 m. The main impression of the bridge will be its length, height and slenderness. On the west side a new long distance railway station – Södertälje Syd – is constructed, and this will be the junction of the north-, south- and westbound traffic.



...AND ITS EXTENSION.

As a direct extension west of Södertälje Syd, a 325 m long bridge system will be constructed. The bridges – crossing the Nyköping road and the railway main line – consists of 1 double track bridge, part of the Grödinge Line, and 2 single track bridges connecting to the prospective Svealand Line.

The bridge system is carried by 25 supports founded on rock, firm soil or piles.

TURN-KEY CONTRACT.

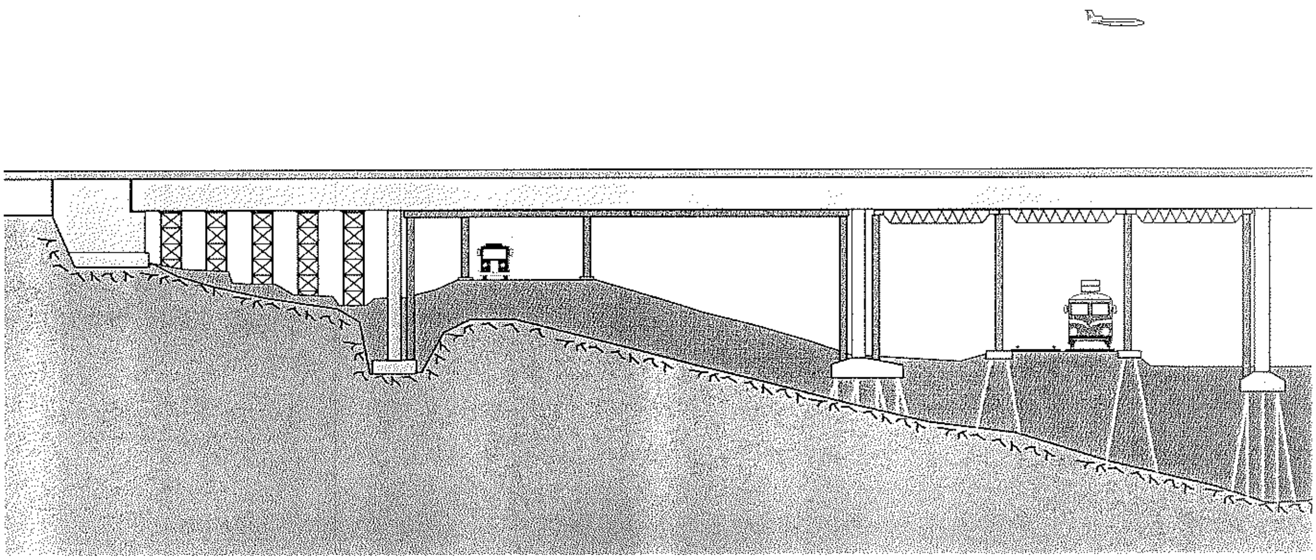
The Igelsta Bridge Joint Venture is building the bridges on a turn-key contract, which means that the contractor is responsible both for the design and for the construction. Several companies competed for the contract with different alternatives in steel and concrete. The Igelsta Bridge Joint Venture was awarded the contract. The total cost is about 120 MSEK (Million Swedish Kronor).

The work was started in August 1991 and is to be completed in October 1993

QUALITY ASSURANCE

For the bridges a comprehensive system for quality assurance and quality control is applied. The system includes all phases from design, construction on to inspection for provisional acceptance – including works done by subcontractors and different suppliers. The aim is to secure that the works are carried

HOW TO BUILD BRIDGES ACROSS TRAFFIC ROUTES!



The construction of the Bridges across the Nyköping road is an exciting challenge for the contractors. The bridge system is crossing two important traffic routes, the Nyköping road and the double track railway main line to and from the south of Sweden.

The bridge work has to be carried out with a minimum of interruptions for the two traffic routes. This will call for high attention regarding both time, planning and technique.

Technique

The bridges are founded on rock, firm soil or piles where 21 columns and 2 abutments are cast to full height. The superstructure is mostly constructed on different kind of scaffolding reaching between two piers.

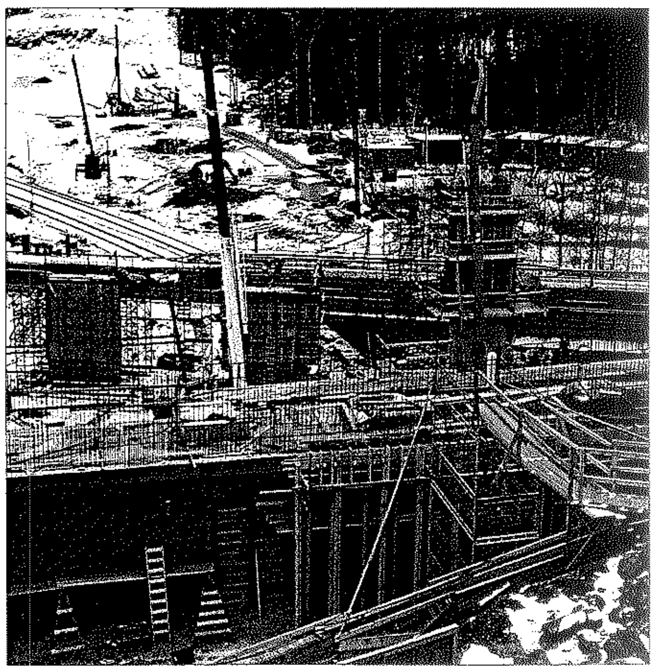
Under the part of the bridge which crosses the Nyköping road, a system of steel beams is constructed, resting on ø 800 mm steel pipes. The supporting elements are prefabricated and prepared for quickest possible erection. One condition for the work is a clearance width of at least 7 m and a height of at least 5,2 m, of the supporting construction, in order not to interfere with the traffic on the Nyköping road.

Over the railway, which is trafficed by about 170 trains per day, is built a self supporting system of framework beams carrying the formwork between two columns.

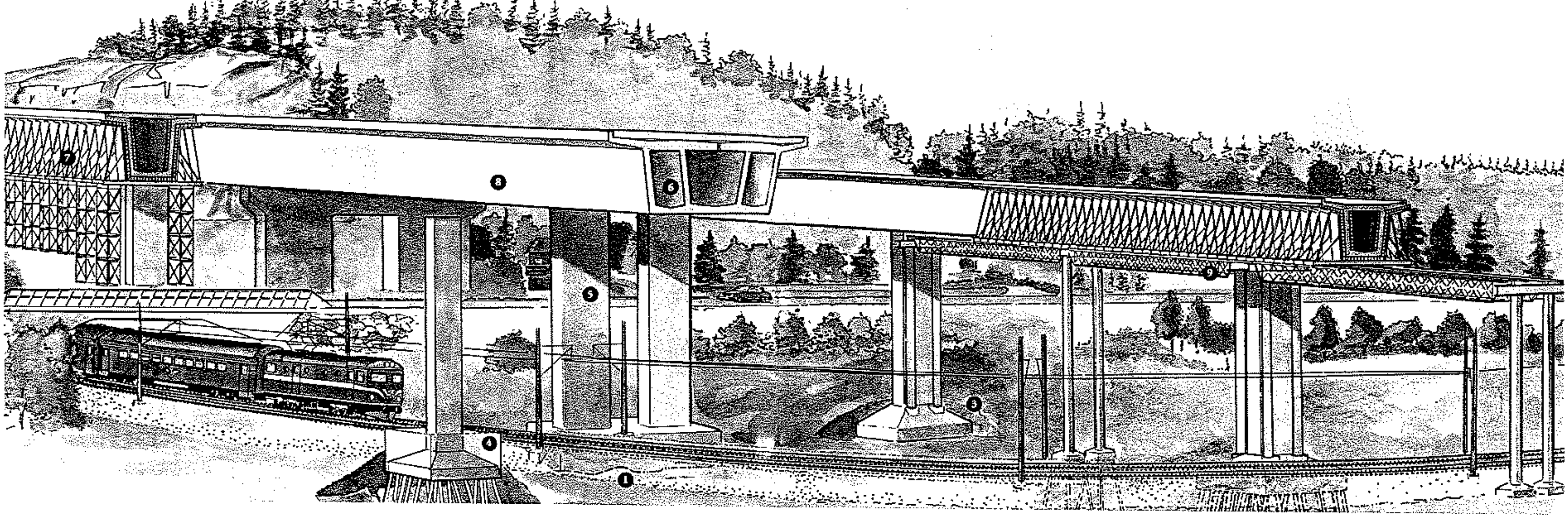
The framework over the railway is erected during low traffic – during nighttime – in order not to interrupt the railway traffic more than necessary. Maximum interruption allowed is up to 3x20 minutes.

Due to the load, auxiliary supports are built between the two supporting columns. These auxiliary supports are founded on piles driven to the rock. During the most intensive construction period, the speed of the trains is reduced from 100 to 70 km/h.

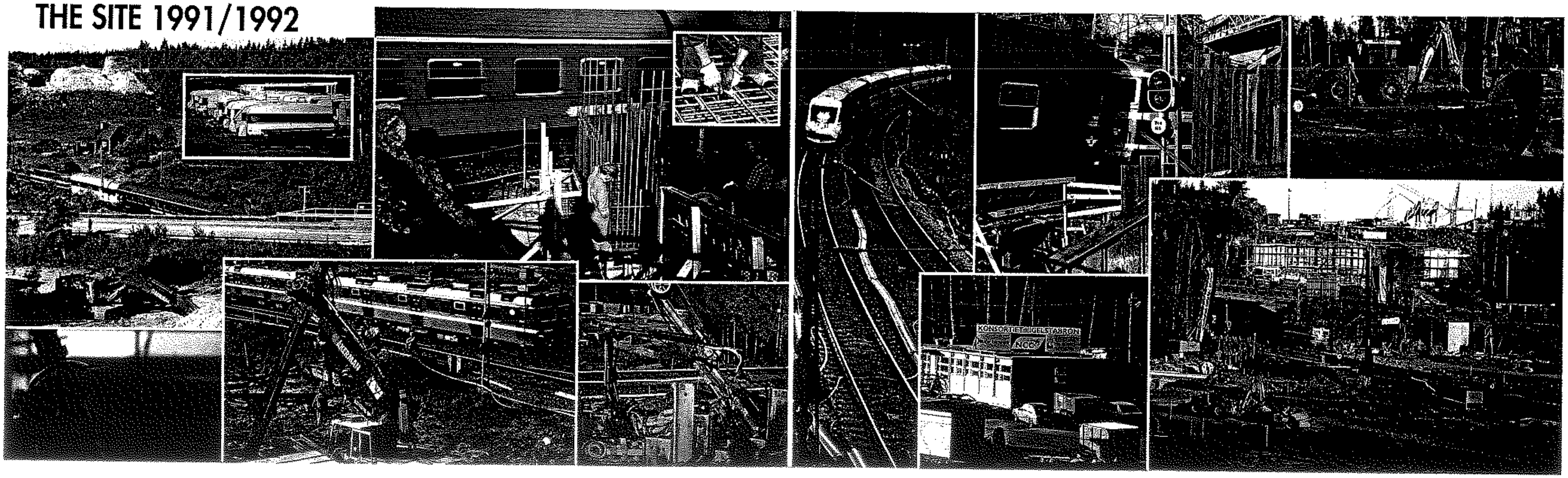
The above illustration shows the construction of the formwork over the trafficed routes.



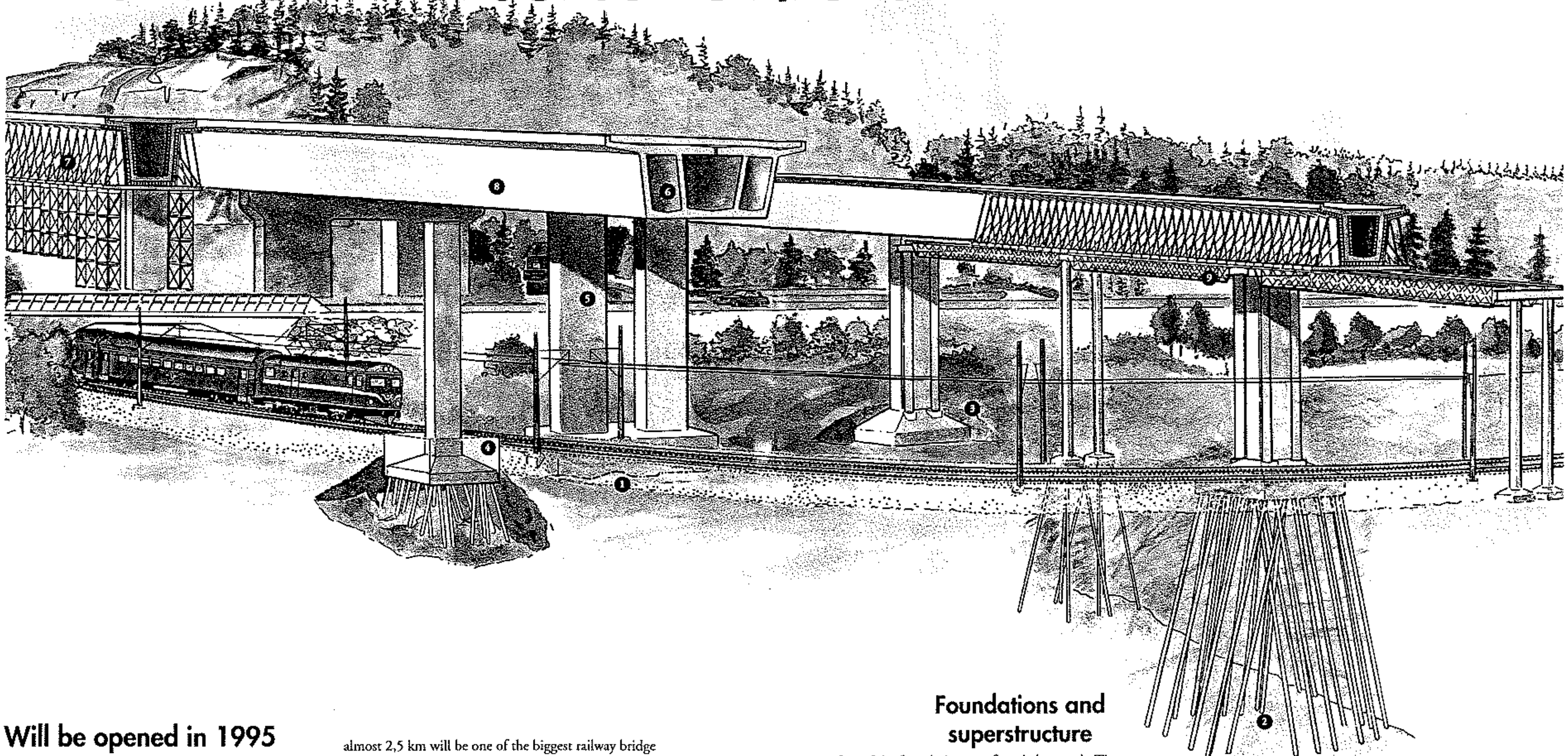
ADVANCED BRIDGE CONSTRUCTION
AN IMPORTANT JUNCTION ON THE GRÖDINGE LINE.



THE SITE 1991/1992



ADVANCED BRIDGE CONSTRUCTION AN IMPORTANT JUNCTION ON THE GRÖDINGE LINE.



Will be opened in 1995

In February 1989 the work started on the new double track railway, 30 km long, between Flemingsberg and Järna, south of Stockholm.

This new line – the Grödinge Line – will be used by regional and long distance trains of the south and west main lines and also of the prospective Svealand Line.

The Grödinge Line is designed for high speed trains. The old railway between Flemingsberg and Järna will be used for the expanded commuting traffic.

The Nyköping and Igelsta Bridges with a total length of almost 2,5 km will be one of the biggest railway bridge undertakings in Europe, In combination with the new long distance railway station, Södertälje Syd, the bridge system will be a modern construction for fast and comfortable transports.

During 1994 the bridges will be completed with specific railway works, such as tracks, switch points, signal system, power supply and telecommunication.

The Grödinge line will be taken into traffic at the turn of the year 1994/95.

Foundations and superstructure

- 7 of the foundations are founded on rock. The foundations are cast directly on the rock. ❶
- For 15 foundations endbearing precast piles are driven to the rock. 1 foundation has steel bored piles. The foundations are cast on top of the piles. ❷
- 2 foundations are founded on moraine gravel. The foundations are cast on the moraine. ❸
- For some foundations sheet piles are needed. ❹
- The solid columns are constructed in steps to full height by a climbing formwork. ❺
- All the bridges have concrete box sections. ❻

Formwork

- Step 1 – from the abutment to support 2 – is carried by shoring towers on the graded ground. ❼
- Step 2 – from support 2 to support 3 – crosses the Nyköping road. This part is carried by steel pipes ø 800 mm and a system of horizontal steel beams. ❽
- Step 3 – from support 3 to support 4 – crosses the railway. This part and the remaining ones are carried by so called H33 which is a selfsupporting system of framework beams with intermediate support of steel pipes ø 800 mm. The intermediate support piles are driven to the rock. ❾

Qualified resources in cooperation.

CLIENT:

BANVERKET
Östra regionen

Client of the Bridges across the Nyköping road is the Swedish National Rail Administration (Banverket), by the Grödinge Line Project. Banverket is responsible for operation, maintenance and construction of the railway system. The site organisation (with a total responsibility for technique, economy and quality) in cooperation with the contractor, is responsible for the realization of the project.

CONTRACTOR:

KONSORTIET IGELSTABRON

NCC

NCC Bygg AB is the second biggest construction company in Sweden. Within the consortium, NCC is the heaviest partner. The NCC Stockholm Division has during the last years built large communication projects such as Arlanda Domestic Terminal and the North Link Highway in Stockholm.

EEG-HENRIKSEN

Eeg-Henriksen has built many of the largest bridges in Norway. As NCC is a shareholder in Eeg-Henriksen, the cooperation was natural.

Veidekke

Aker Entreprenør has during the last years been well established in the Swedish market, the company has now changed its name to Veidekke AB after a recently accomplished merger. Veidekke is today the second biggest civil engineering contractor in Norway.

CONSTRUCTORS:

ELU KONSULT AB

The single track bridges are designed by ELU-Konsult, the biggest bridge consulting company in Sweden.

BROKONSULT AB

The double track bridge is designed by Brokonsult, a company specialized in bridge and house construction within the SCC group.

SUPPLIERS/SUBCONTRACTORS:

Many suppliers participate in the project on different levels. Among others the following companies are involved:

Adema doka
019–32 11 00
Supplies climbing formwork.

BinSell
08–722 85 00
Supplies mobile cranes.

AKTIEBOLAGET BYGG-NATOR
08–707 91 11
Subcontractor for rockblasting.

fundia BYGG
0240–683 00
Supplies all reinforcement bars.

IMA KONSULT AB
0755–744 84
Subcontractor for excavation and transports.

Nilsson & Luthman
0755–325 90
Supplies most of the tools and hardware.

RAGN-SELLS
0755–993 90
Containers and handling of vaste material.

HUDDINGE EL RELAMONTAGE AB
08–711 40 41.
Subcontractor for all electrical installations.

SÖDERTÄLJE TRÄ
0755–399 60
Supplies sawn wood, plastic faced plywood, nails etc.

TIBNOR BYGG
08–702 40 00
Supplies steelbeams, sheet piles, reinforcement bars etc.

UNNERÅS
0755–603 00
Subcontractor for supply of concrete.

Producerad på initiativ av Banverket och Konsortiet Igelstabron. Idé, text, layout och produktion Härkell Annonsbyrå AB. Teckningar Ulf Alanna, Februari 1992

2

Signalling & Train Control

Signalling

Completion of ATC for the fast train

The ATC-system guards besides information from signals also that fixed speed restrictions are followed.As the fast train by the car body tilting system is able to pass curves with higher speed than conventional trains the speed signalling system must be completed. In the ATC-system there are five categories of fixed speed restrictions :

- imperative (T) valid for all trains
- dependent on curves (K); may be exceeded by some trains
- three reserve categories (R1-R3); may be exceeded by some trains

For categories K and R1-R3 a percentage can be set on the driver's panel, which indicates with how many percent the speed restriction can be exceeded.

For the fast trains an adaption was needed. In sections, where the speed for engine driven trains is 130 km/h, the curvature can imply that the speed for the fast train varies in the interval 170–200 km/h. These speed variations are signalled as imperative. Trains without car body tilting are not affected by this speed signalling , as the train's maximum allowed speed is exceeded.

In the interval where the speed for an engine driven train is lower than 130 km/h speeds, which can be exceeded by the fast train, are signalled as dependent on curves or with the reserve category. To be able to get an acceptable adaption to the speed profile of the fast train two percentages have to be used i.e.dependent on curves and the reserve category.

In the original ATC-project only imperative beacons were used for permanent speed restrictions. In these beacons some modules had to be changed at the start of the X2000 traffic. A completion with beacons for the speed register 170–200 km/h for the fast train has been carried out.

Prolonged warning distances

Prolonged warning distances are needed for the increased speed. The braking ability of the fast train has been dimensioned in such a way that the train at 200 km/h is able to stop not quite 2200 m after information about stop has been received from a distant signal beacon.

For 160 km/h the corresponding distance is 1450 m. This distance includes the ' reaction time' of 8 seconds of the ATC-system.

When the fullbrake curve (the limit between conditional and unconditional braking) is released the length of the retardation ways are 1750 m at 200 km/h and 1100 m at 160 km/h. This corresponds to a mean retardation of about 0,9 m/s^2 during the whole braking process.

A warning distance of 1000 m is used on single track. On double-track lines the distant signalling is done either in preceding block signal or in distant signals standing by themselves at entries of stations. The distances between block signals vary but are often between 2000–2500 m. The distant signals standing by themselves are placed about 800 m before the main signal.

The warning distances have in many cases been prolonged. This is done by placing a new distant signal beacon in the needed warning distance. The information in the original distant signal is transferred to the new beacon. The optical distant signal as well as its beacon are not moved. Hereby they function as repeating signals. The fast train gets distant signal information by cab signalling. Also conventional trains get distant signal information as they pass the outer (new) distant signal point but any measures are not needed before the inner (old) distant signal.

In connection with the extension of warning distances comparatively far-reaching works were necessary, where the distances between block signals were short and the extension meant that the blocks were overlapping, e.g. in stations. The higher speed of the fast trains brought about demands that the routes must be set earlier than before.

Chapter 1 - Railway Signalling Principles

Part A

1. Basis of signalling

The signalling philosophy in Sweden is in large parts quite different from that at BR – more like that at DB. Especially when it comes to overlap the functions are different.

In Sweden only **speed signalling** is used.

The optical signals are quite simple and give only the most basic information to the driver with only two speed levels — "line speed" and "40 km/h".

(40 km/h is the speed allowed through a standard, short turnout in reverse position).

A picture of optical signal aspects, see next side.

The ATC system is used as an **extension of the signal system** into the drivers cab. The Swedish ATC system is something halfway between ATP and ATO. It gives considerably more than only protection but less than automatic operation. In the cab 12 different speed levels (40 - 275 km/h) can be displayed to the driver. For a train both maximum running speed and the train's braking curve when approaching a restriction is supervised.

A table of the speed levels is given on page 3.

The ATC system is applied on about 60% of the Swedish network, carrying more than 95% of the total traffic. The non-equipped lines are small county lines with very low traffic volumes – mainly freight traffic.

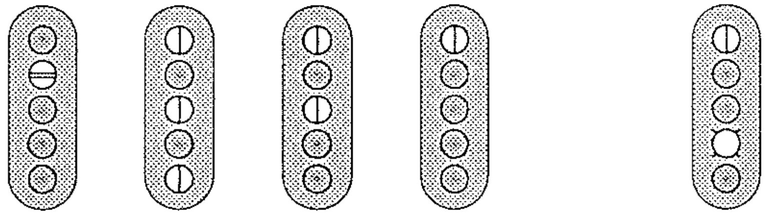
On ATC-equipped lines the use of the system is compulsory. Trains, where the system goes faulty while running, are allowed to continue with reduced speed (80 km/h) to the nearest depot where a switch of traction power or a quick repair can be made.

1.1 High speed signalling

The ATC system makes it possible to run our high speed trains at 200 km/h on normal, quite curvy tracks without any great changes in earlier existing signalling systems. For these high speed trains, where normal warning distances (about 1000m) are quite insufficient, an extra advanced signalling is given in the ATC system.

1.2 Optical signalling

Main signal aspects



M0 M3 M2 M1 M1 + D1

Combined signal:
Top = main signal,
Bottom = built-in distant signal

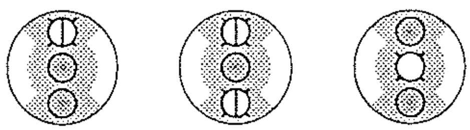
M0	=	red	=	stop and stay
M3	=	3 green lights	=	40 km/h, short route (< 450m), expect stop at next main signal.
M2	=	2 green lights	=	40 km/h, long route (> 450m), expect stop at next main signal.
M1	=	1 green light	=	"clear", information about next main signal is given: - from built-in distant signal or - from a freestanding distant signal.

The different green aspects are inherited from the old semaphore time.

Entrance signals are placed >200m before the outermost turnout to a station.

Starter signals are positioned >4m from the fouling point to the turnouts separating different train routes. Where possible the starter signals are moved back 100-200m from the fouling point in order to get non-conflicting train routes. (For overlap in those situations, see p A4 below).

Distant signal aspects



D0 D2/3 D1

D0	=	1 green flashing light	=	expect stop at next main signal.
D2	=	2 green flashing lights	=	expect "40".
D1	=	1 white flashing light	=	expect "clear".

All distant signal lamps are flashing (80 fl/minit).

Sighting allowance

The desired sighting allowance is depending of the maximum speed of the line. The driver shall if posible see at lest *8 flashes* from a distant signal. The warning distance may be increased to 1500m to reach better visibility.

Maximum speed with only optical signalling.
Speed levels with ATC-signalling in function.

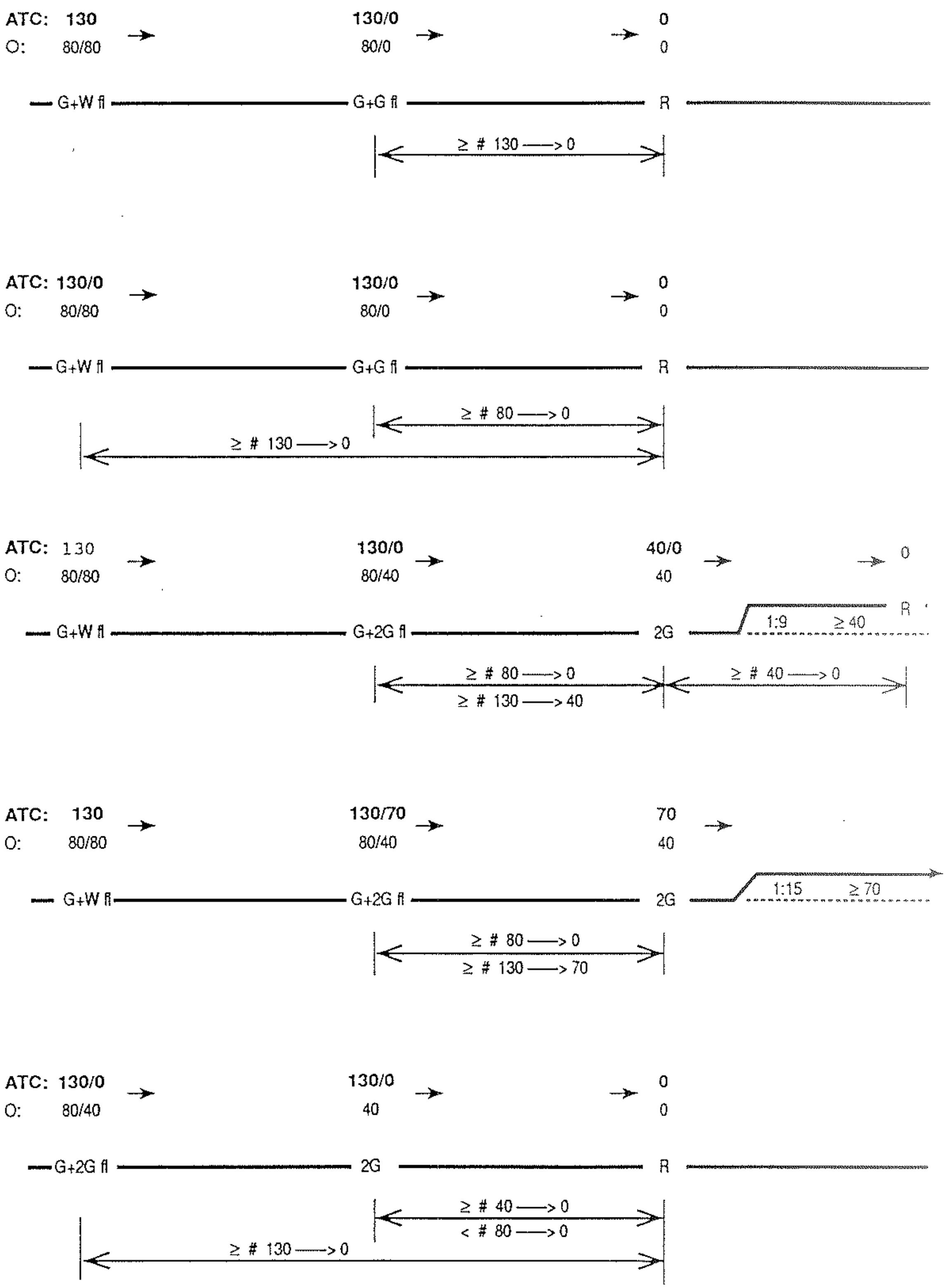
Signal aspect	Meaning to the driver		
	Non-ATC-line	ATC equipped line	
		ATC non- functioning**	ATC in use
Optical	Speed from main signal	Speed from main signal	Indik. in ATC-panel
3 green lights,	40, short route (< 450m) respectively		40 + target
2 green lights	40, long route (> 450m)		50 + target
	Expect stop at next main signal is implied.		60 + target
			70 + target
			80 + target
1 green light	110	80 *	80 + target
[+ distant info]			90 + target
			100 + target
			130 + target
			160 + target
			190 + target
			220 + target
			275 + target

** The use of ATC is compulsory on equipped lines, but faults can occur while running.

* The speed is set down on ATC-equipped lines
  - to enforce the demands on the system to be in working order,
  - to care for possible short block sections in high traffic areas.

Some examples of aspect sequences:

ATC: = ATC-speed level
O: = Optical signalling
= Regular Braking Distance for ...



ATC 40 – 50 – 60 – 70 – 80 = 2G = two green lights,
ATC 80 - - - - 200 = G = one green light.

2. Braking distance

The nominal warning distance is 1000m, with 100 - 150m added for slope conditions.

That warning distance we consider long enough for

- freight trains, 630m long and weighing 1500 tons, running 100 km/h,
- maximum passenger trains with 17 coaches, running 130 km/h,
- short passenger trains with 7 coaches, running 140 km/h.

If 1000m stopping distance is insufficient for a certain train, it's top speed has to be set down.

For high speed trains an extra advanced warning is given in the ATC system as mentioned before.

3. Overlap

The normal overlap (or safety distance) is 200m.

Between low speed routes (< 80 km/h) 100m overlap is accepted on ATC-equipped lines with special supervision (supervision down to 10 km/h towards the stopping point).

Behind a line block signal there is normally no overlap, except where the following block section is so short that a long train can stop with its rear end just behind the signal.

4. Stop and warning signals

See p A1 earlier and p A7 and A8 later.

5. Speed limitation signals

Speed limit through turnouts in reverse position is given by the signals (including the ATC-speed levels 40 - 80 km/h).

On open line and on main routes in stations, speed limit is given by warning boards and speed boards. For permanent restrictions these boards are included in the ATC-system with a special category of beacons.

For temporary restrictions a simplified function is used, with beacons only at the warning boards.

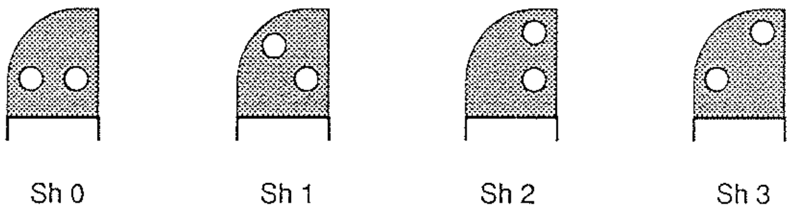
6. Route indicator signals

Are not used. With the type of speed signalling we use, route indicators are normally not necessary.

On some rare locations at junctions with symmetric points a simple light arrow is used.

7. Shunting signals

To control shunting movements on larger junctions position light dwarf signals are used. These are small signals standing on ground between tracks.



Dwarf signal aspects.

The same type of signal is used as a subsidiary signal too.

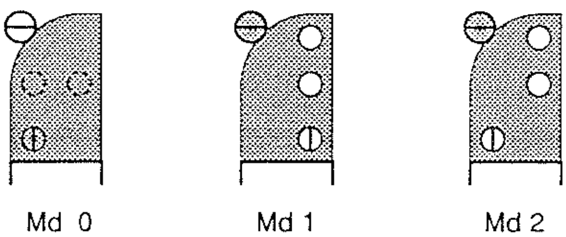
Sh 0 = stop for all kinds of vehicles,

Sh 1 = shunting route set, route may be occupied by other vehicle,

Sh 2 = shunting route set, route free,

Sh 3 = shunting allowed, turnouts are locally controlled.

A dwarf signal can have one red and one or two green lights added to make it a **"main dwarf signal"**. That kind of signal is used as a starter signal from low speed tracks (40 km/h).



Main dwarf signals.

Is in some applications used instead of a normal main signal.

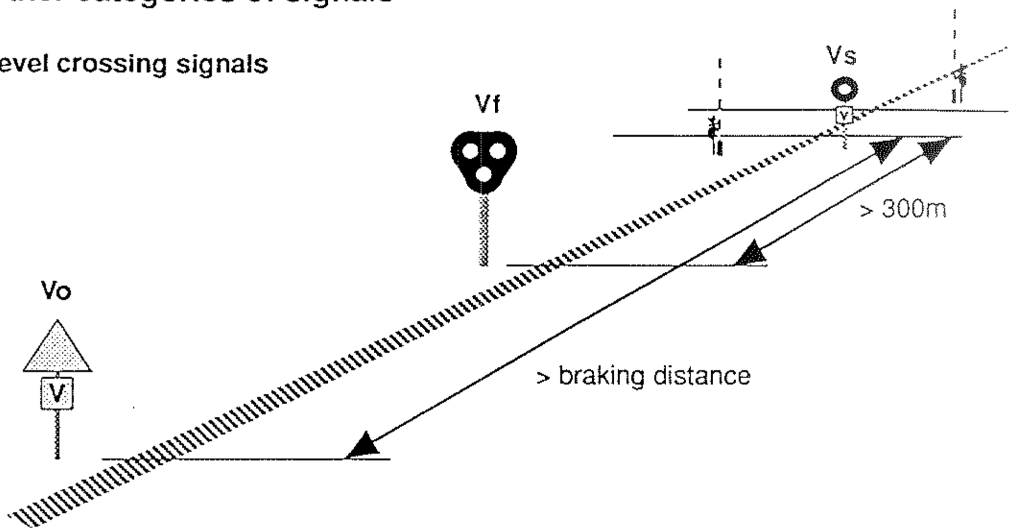
The coloured lights have no meaning for shunting movements.

The position of the green light indicates if the signal is at the beginning of a high speed route (Md 1) or of a low speed route (Md 2).

The green light is flashing if the following main signal is red.

8. Other categories of signals

Level crossing signals



The level crossing signal – Vs – shows a white light (in both directions) when the barriers are closed, otherwise it is red.

The barriers are either
- checked in nearest preceding main signal or
- have a distant signal of their own (as shown here above).

The distant level crossing signal – Vf – shows three yellow lights in V-form. The lamps are flashing when the barriers are open and show a steady light when they are closed. The signal is placed at least 300m before the crossing and should be well seen from braking distance.

9. Bidirectional signalling

Double track lines are built with full signalling for both tracks in both directions.

Running trains in parallel is accepted. That means that – if the traffic situation on the line permits – a high speed train in mixed traffic can pass a slower train even between stations.

Part B

1. Point locking conditions

There is no direct dependency between points to avoid conflicting positions – the individual points may be set in any order, also in an overlap.

The points in a route – including trap points to protect it – are set, if they are allowed to operate, when the route is called. When the points are set and detected the route is locked immediately and that locking includes point locking too.

On smaller stations with no dwarf signals, shunting areas must be separated from train routes by trap points.

2. Signals locking conditions

A main signal is normally cleared directly when the route is locked and the section free. If there are barriers in the nearest part of the section, the signal is cleared only when the barriers are closed.

Signals are not delayed in order to slow down a train (they are approach locked when operated). The permissible speed is indicated in the signal and in the ATC-panel.

A signal can be manually locked in stop position by the signal man to protect a working area.

3. Route locking conditions

Route locking

Some type of NX-system is used for setting train and shunting routes, either
- with direct lever contacts in the indication panel or
- from a keyboard on the dispatcher's desk.

When a route is called the points are set and detected and the route is locked immediately – provided that there is no conflicting route locked. At the same time as the route is locked the overlap is locked too.

The signal is cleared as soon as the foul and flank conditions are fulfilled.

Overlap locking

Locking of the overlap means that any conflicting route ahead is locked out. Previous train or shunting moves must have left that area.

The overlap locking also takes care of the necessary opposing locking.

The points in the overlap are not locked. The overlap area is supposed to be unoccupied but that *isn't always checked.*

That is accepted as a fair risk as

- no routes through that area are accepted,
- the chances for anything standing there is very small,
- the driver always knows where his stopping point is,
- the train has ATC-supervision and the driver will be warned if he approaches the signal with too high speed,
- the risk and consequences of overrunning the signal are minimal.

Automatic functions

If a route call is not accepted by the interlocking, depending on a conflicting route, this call is stored for use at a later moment.

To ease the dispatchers work some automatic functions are installed:

Fleeting is accepted on double track lines.

Single track CTC-lines have "crossing automats". These take information from the interlocking and from the line block system on both sides of the station. If only one train is approaching the automat locks a route straight through. If trains are approaching from both sides and a crossing has to take place the automat issues a command sequence to arrange that crossing.

Route releasing

The route locking is automatically released behind a train as it passes along (automatic sectional, last wheel release).

The overlap locking is released in two different ways:

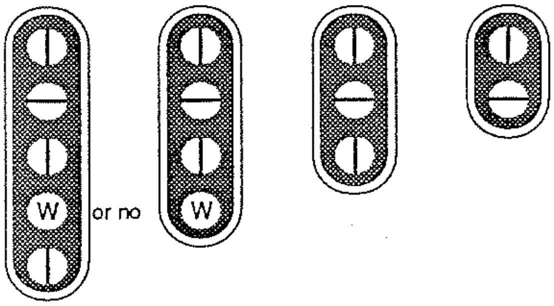
- when the train is estimated to have stopped on the section, if the target signal is not cleared (time release), or
- when next signal is cleared and the train continues without stopping.

The dispatcher can cancel a locked route with a time-release function if no train is to pass or if the route has to be changed. The release time is normally 60 seconds, but extended to 120 seconds on lines with high speed trains and advanced signalling. During that time the signal is replaced.

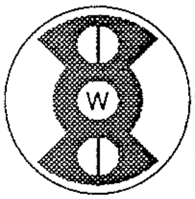
SIGNALS FROM SJ/BV

Different Panel Shapes

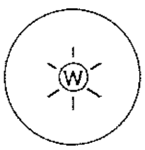
Main signals



Distant signals

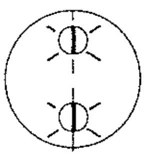


Distant signal functions



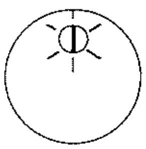
"Vänta kör" (next signal is cleared)

Next main signal shows
1 green light.



"Vänta 40" (expect slow route)

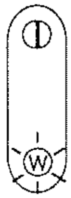
Next main signal shows
2 or 3 green lights.



"Vänta stopp" (next signal is red)

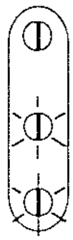
Next main signal shows stop.

Main signal functions



"Kör vänta kör" (booth this and next signal are cleared.

Opt: 80 (110) km/h
ATC: 80 – 200 km/h
as indicated in the ATC panel *)



"Kör vänta 40" (clear, next signal shows a slow route)

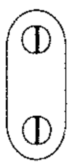
Opt: 80 (110) km/h, expect 40 at next signal
ATC: 80 – 200 km/h,
braking to 40- 80 km/h at next signal
as indicated in the ATC panel *)

"Kör vänta stopp" (clear, next signal is red)

Opt: 80 (110) km/h
ATC: 80 – 200 km/h
as indicated in the ATC panel *)
Prepared to stop at next main signal.

"Kör" (clear, no information of next signal)

Opt: 80 (110) km/h
ATC: 80 – 200 km/h
as indicated in the ATC panel *)

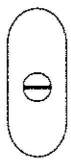


"Kör 40" (slow route, stop in next signal is implied)

Opt: 40 km/h
ATC: 40 – 80 km/h
as indicated in the ATC panel *)
Prepared to stop at next main signal.

"Kör 40 avkortad" (short, slow route)

Opt: 40 km/h, exceptionally short route
ATC: 40 – 80 km/h
as indicated in the ATC panel *)
Prepared to stop at next main signal or maindwarf signal.



"Stopp"

Absolute stop

*) Maximum allowed and target speed are indicated and supervised in the ATC-system.

Chapter 2 - Train Detection

1. Track circuits

Standard for all types of applications in Sweden is a **DC single rail track circuit.**

This solution is choosen because

- its is cheap, simple and has high availability,
- that it has few isolated joints that can cause faults.

  The absence of broken rail detection has not caused any great problems. We have during more than 60 years experience had only a few minor accidents and we think a functioning system is of more value. The most dangerous situation is not a clean break but a rail that has lost part of it's head and that can't be detected by a track circuit.

Track circuit feed:

A simple 7.0V rectifier with backup from a 60 Ah NiCd accumulator.

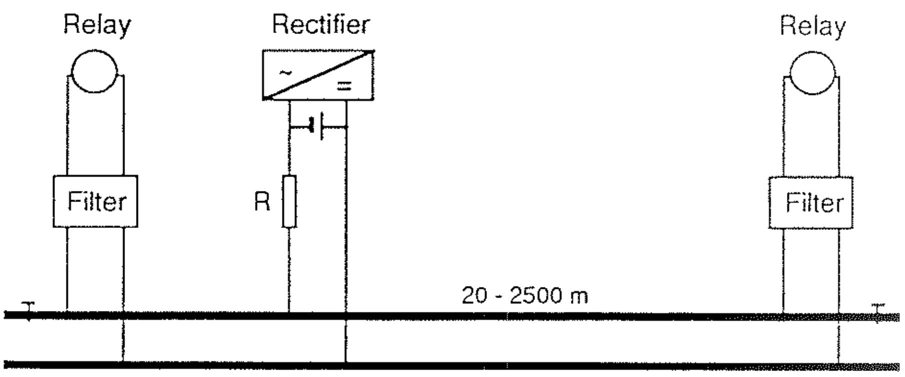
Relay: Plug in type, biased, AC immune relays.
A simple LR lowpass filter as protection against influence from traction currents (AC 16 2/3 Hz traction).

Track circuits longer than 200m have relays at <u>both ends</u> as protection against heavy geomagnetic currents that we have here in Scandinavia.

Maximum circuit length: 2500m, at gravel ballast occasionally shorter depending of track leakage.

Minimum ballast resistance:	macadam	2.0 Ω/km track
	gravel	1,0 Ω/km track.

Function:	Relay drop off at	2,0 V over the rails,
	relay pick up at ~	4,0 V.



No track circuit interrupters at trap points are used.

The minimum train shunt resistance is specified to 0.3 ohm, but we think that the two volts over the rails when the track relay releases is a better criterion of the ability of the circuit with respect to contamination of the rail head.

Wheel – axle – wheel resistance on the vehicles must be below to 0.01 ohm.

About 25 000 track circuits of this type are in use in Sweden.

The track circuits are not used as carrier for any secondary information.

No **JTC** or **HVI** types of track circuits are used.

No **Axle counter** systems are used.

Treadles (pneumatic type) are used only in combination with track circuits for

- measuring train length,
- measuring speed levels,
- for lowering barriers at platform level crossings.

Chapter 3 - Switch and Auxiliary Function

1. Electrically operated points

On account of severe winter conditions in Sweden special precaution steps has to be taken.

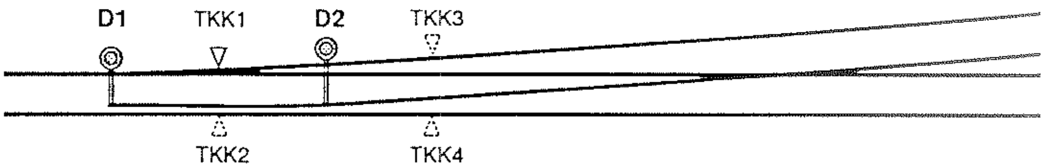
The area between the tongue and stock rail is heated (≥ 7 kW) to free those parts in the turnout from snow and ice as much as possible.

No rail clamps are used at the point machines.

The point mechanism is a closed unit with internal points locking and detection contacts. There is also a small heating element built in (15 W) to avoid frost on the contacts.

In a turnout with long switch blades (> 10m), force has to be applied at more than one point on the blade. Central European practice to distribute the force is to do this with stretcher bars and links. This is impractical in Sweden.

Instead we use two (or more) point machines on the same tongue – one at the tip and the other, with a shorter stroke, halfway to the root.



The TKK:s in the figure above are simple magnet operated contacts with no mowing parts except the tongue itself. The contacts are checked in the detection circuit.

Depending of type of switch and speed (> 40 km/h) through it, one ore more TKK:s are sometimes necessary to check that the track gauge is correct and not too narrow. The contact part of the TKK is mounted in a slide chair at the stock rail and the actuating permanent magnet is fixed to the switch blade.

We are now developing a new turnout for > 100 km/h in reverse. This one needs not less than six point drives – four at the switch blade and another two at the movable point frog.

Mainly two types of electric point machines are used – one is trailable, the other not trailable (see table on next page).

Electro-pneumatic machines are used only in marshalling yards.

Electric point machines:

Feature			JEA52	JEA73	Rem
Speed limit	km/h		130	200	
Locking points			Internal	Internal	
Trailable			(Yes)	No	
Detector			Inside	Inside	
Operating voltage	V		220V=	220V=	(a)
Max imum line resistance	Ω		30	30	
Current during lateral movemnet	A		3.5	3.5	
Operating cycle duration	sec		3.5	3.5	
Electric motor nominal speed	rpm				
Switch travel	mm		170	170	(b)
Maximum load	N		450	700	
Trailing protection load	N				
Overall dimensions:					
length	mm		774	774	
width	mm		905	905	
height	mm		313	313	
weight	kg		160	160	
Number of drive bars			2	2	(c)
Number of lock slides			–	–	
Number of detector slide			2	2	
Emergency operation			crank	crank	

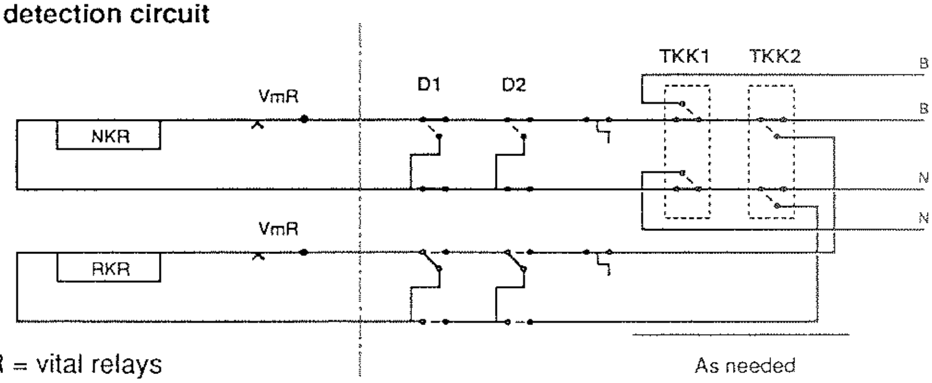
(a) For use in SS-interlockings there is a three-phase motor. The object controller generates this specilally for the point drive.

(b) Different strokes (94, 110, 115, 120 and 170 mm) are employed, depending on where on the switch blade the drive is used.

(c) For use at derailers there is only one throw bar and the motor gearing is different.

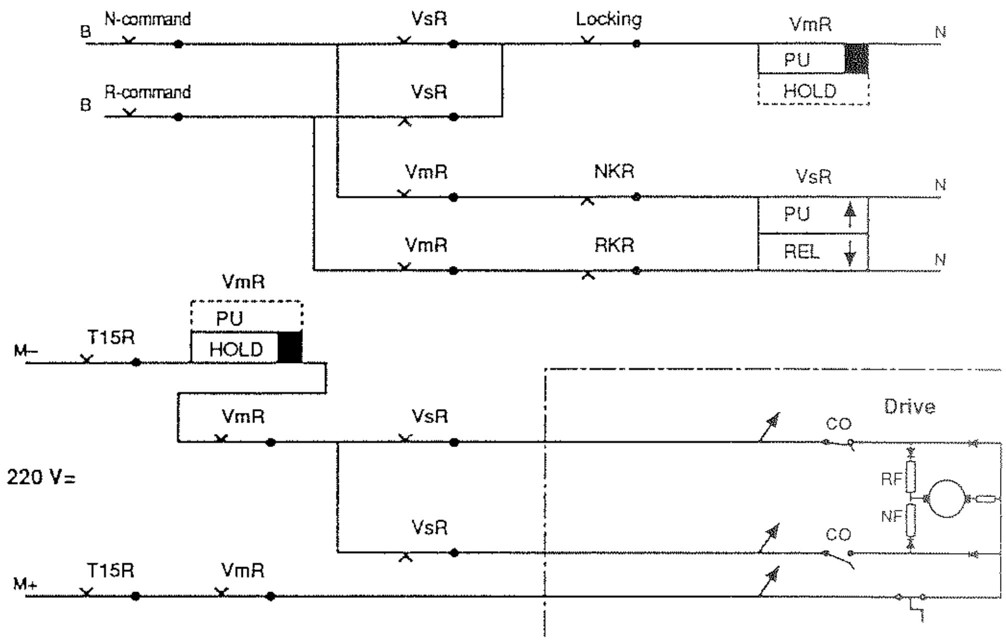
1.1 Main used wire circuits

Example of detection circuit



NKR, RKR = vital relays

Operating circuits



Operating sequence for N ——> R:

1. Command – VmR picks up – delayed release.
2. Detection is cut – NKR is released.
3. VsR picks up – motor starts – VmR holds on current coil till motor is stopped (end position).
4. VmR releases.
5. RKR picks up – reversal completed.

T15R is a timer that stops the drive if the operation isn't competed within 15 seconds (obstruction !).

1.2 Drive for derailer stops.

The same types of drives are used for derailer stops.

These drives have a different gearing and only one throw bar but are basically the same as for points.

2. Locking of manually operated switches / derailer stops

Hand operated switches and derailers are locked with an electric lock device.

The points are fitted with a facing point lock.

The lock device has a horisontal lock bar and a detector rod. A vertical plunger engages the lock bar in locking position. A solenoid is used to lift the plunger and release the lock bar.

The detection circuit has contacts on the detector rod and on the plunger to check that the points are in correct position and locked.

Chapter 4 - Signals

1. Main and distant signals

- In Sweden multi-unit colour light signals are used for both main and distant signals.

  No searchlight signals are used.

  The main and the combined main/distant signals have an oblong back-board. The freestanding distant signal has a circular backboard, black with two white segments.

- The lens system consists of two clear step lenses without any close-up sector. The outer lens has 210 mm (8 3/8") diameter and the inner has 140 mm (5 1/2") diameter. Next to the lamp is (if needed) a coloured glass filter (red C or green B according to DIN 6163).

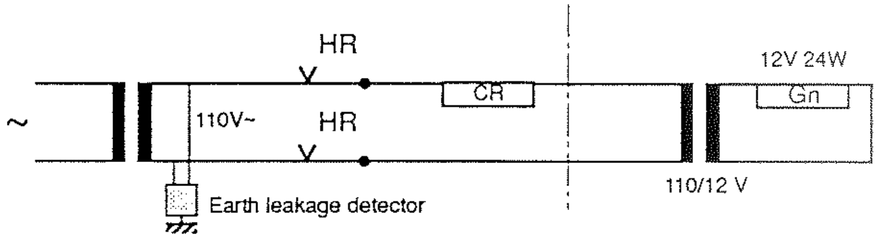
  The light beam spread is about 6°.

- Lamps that are simultaneously lit are spaced at least 700 mm apart. Even if a signal can be percepted at considerably longer distances the signal aspect can not be safely recognised at more than about 700 m.

- The lamps are single filament 12V 24W -lamps. The lamps are gas filled with a nominal expected life of 8000 h.

- During daytime the lamps are driven at about 95% of nominal voltage (to increase lamp life). In darkness the voltage is decreased to about 70% (to avoid dazzling).

- Principal signal lamp circuit:



- The fall-back solution for a burned out stop lamp is a high intensity reflecting border surrounding the backboard of the signal.

- The nominal warning distance is 1000m, with 100 – 150m added for slope conditions.

  This distance may be shorted to 600m on low speed county lines (< 80 km/h).

  The distance may be increased to 1500m to achieve better visibility.

  For high speed trains, where this warning distance is quite insufficient, an extra advanced signalling is given in the ATC system.

- Signals are normally positioned on the left side of the track, but may be positioned on the right side if considerably better visibility is reached.

  On double track lines all signals are positioned outside the tracks.

- The distance between a signal and it's control equipment can be maximum 4000 m.

  The limit mainly depends of voltage drop in the cables, but interference from other circuits in the same cable is of great importance too.

2. Dwarf signals

- These signals have a clear single step lens with 91 mm diameter.

- The lamps are single filament 55V 24W -lamps. The lamps are gas filled with an expected life of 8000 h.

- During daytime the lamps are driven at about 45 – 50 V (to increase lamp life). In darkness the voltage is decreased to about 35 V (to avoid dazzling).

- The lamps are connected directly to the main transformer in the relay room. No lamp transformers are used.

- The distance between a signal and it's control equipment can be maximum 600 m.

- Two lamps are lit in all signal aspects. The two lamps have different fuses. A 'one-eyed' signal implies stop.

3. Signal lamps at solid state object controllers

- All solid state controllers have micro processors for control and test functions.

  The signal object controllers have a special way to treat signal lamps by phase angle control and measuring of the lamp current.

- All signal lamps in a solid state interlocking are 12V 24W. The current for a lit lamp is set to 1.9 A at daytime and 1.3 A at night.

  Controlling the lamp current instead of the lamp voltage, means that the lamp power is always the same, independent of fluctuations in power supply and of cable length.

- The cable length from the controller to the signal may be maximum 50 m.

4. Other signals

Level crossing signals:

These are simple bi-directional searchlight signals.

A red/lunar white glass cylinder surrounds the vertical lamp. Normally the signal shows read in both directions but changes to lunar white when the glass cylinder is lifted by a solenoid.

Multi-Aspect fibre optic indicator signals.

These have a 5 x 7 arrangement of lenses. Letters, figures and other signs can be shown in different colors.

Light to any of the lenses is carried via a number of opto fibres from one or more 70W halogen lamps in the bottom of the housing.

The indicator is used for departure signals and for brake test signals.

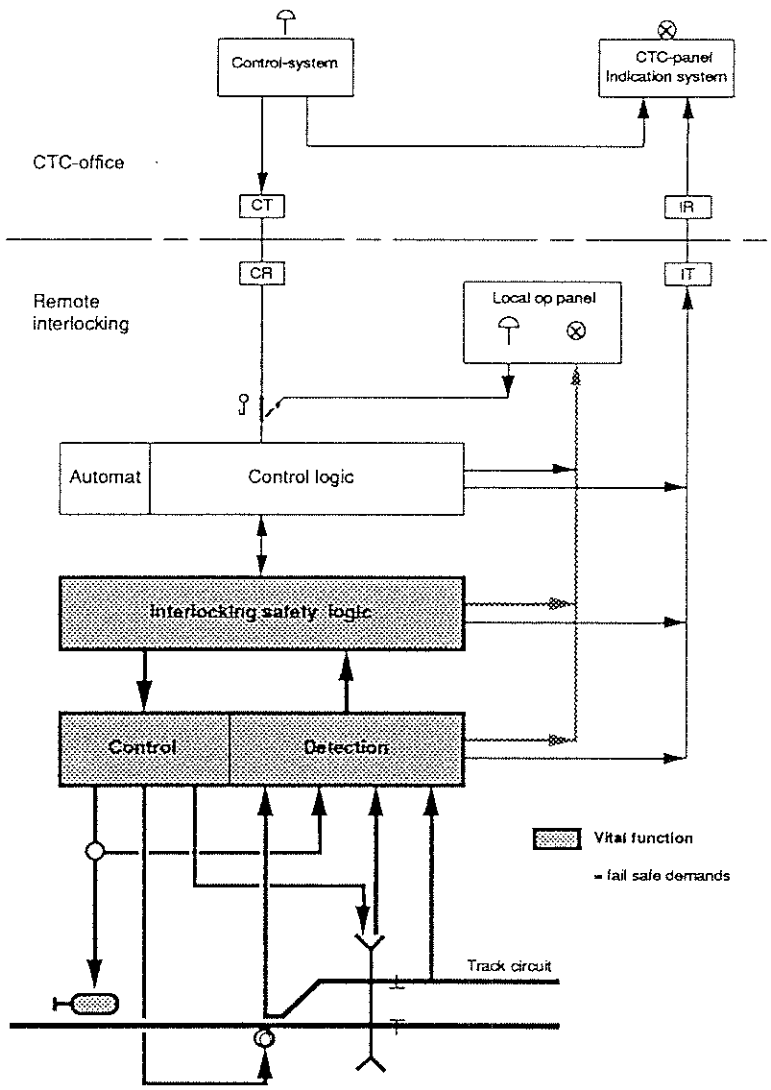
Chapter 5 - Interlocking Cabin

The modern interlockings in Sweden can be divided in three large groups:

1.	Free wired relay interlockings	80%
2.	Geographical interlockings with relay sets	10%
3.	Computer interlockings	10%

0. Common features

- In the interlocking we distinguish between vital and non-vital functions. Vital functions are of course built to normal fail safe standards.
- Non-vital functions, e g CTC-functions and automat functions (see figure here below), are built with good industrial components but without fail safe demands.



A malfunction in a non-vital part will have the same effect as a false move by the operator.

In worst case an unwanted route may be set, but only if it is accepted by the interlocking.

Any dangerous commands are rejected.

Interlocking

- Automatic route setting functions are to a large extent installed to ease the dispatchers work:
  - Fleeting is a standard function in most installations,
  - If a route call is not accepted by the interlocking, e g depending on a conflicting route, this call is stored for use at a later moment.

- Automatic route releasing is standard.

- Power supply is normally from railway's own auxiliary net. Reserve supply from local power net or self-starting diesel generator.

1. Free wired relay interlockings

About 800 installations, mainly on small CTC-stations (type SJ 59).

- Indication panel with NX-switches of lever type.

- Automatic functions (besides those mentioned above):

  Single track CTC-lines have "crossing automats". These take information from the interlocking and from the line block system on both sides of the station. If only one train is approaching, the automat locks a route straight through. If trains are approaching from both sides and a crossing has to take place the automat issues a command sequence to arrange that crossing.

- Operations are recorded in our newest CTC centres.

- Hardware is centralised to the relay room.

- NC signal relays of standard types, conforming to UIC norm 736i, are used in vital functions, cheaper relays for command functions with no fail safe demands.

- Prevention of accidental route release with track circuit power failure is done with a double pass function.

- The main cables have combined use for both signals and point machines.

- Track layout changes includes a lot of work from an experienced signal engineer. Normally no locking or route table sheets are used.

- Assurence of safety and function of interlocking is done on site.

2. Geographical interlockings with relay sets

About 40 installations, mainly on large junctions and terminal stations with dwarf signals for shunting moves (type SJ 65).

- Large indication panel with lamps
- Operation from special keyboard
- Sectional releasing of train and shunting routes
- Hardware is centralised to the relay room.
- Relay sets are used for interlocking logic. The relay sets are sealed units.
- Individualizing is done with soldered straps at one of the connectors.
- The relay sets are designed for bi-directional running. The "track"-cables for the geographical connections between the sets are 40-conductor, crosswired cables.
- The relay sets are built with NC signal relays of standard types in vital functions, cheaper relays for control functions with no fail safe demands.
- Operating relays for signals and point machines (circuits with higher energy levels) are mounted in standardized relay racks.
- Customising e g for level crossings is possible.
- Track layout changes are tolerably incomplex to do. No locking table sheets are used. Tables for signal aspects are made up.
- Assurence of safety and function of interlocking is done partly in workshop, partly on site.
- Prevention of accidental route release with track circuit power failure is done with a double pass function.
- The main cables outside the relay room have combined use for both signals and point machines.

3. Computer interlockings

About 20 installations of all SS type. Today this is our standard type for all new installations, used on all types of stations from the smallest with only two points and a few main signals up to the largest with 200 points and dwarf signals for shunting (type SJ 85).

- Normal VDU-screens for close-ups for the operator.
- Large back projection colour VDU-screen for general overview in the larger signalling Control Centres.
- Operation from standard computer keyboard.
- Sectional releasing of train and shunting routes.
- The operator can build his own "route automats" for automatic functions he wants.
- Train describer with alpha-numeric input.
  The train number can be used for automatic route setting.
- Event recorder, covering the last 24 hours. All commands and all status information are recorded. The recordings can be listed on the printer or replayed' on the installation test system.
- Special console in the relay room for the "technician".
  System printer for logging and maintenance purposes .
- Hardware is decentralised to SS object controllers in the field.
- No relays at all except for track relays.
- The central computer equipment is duplicated in order to increase system availability. The reserve is updated and hot stand by – ready to take over immediately.
- The interlocking computers have battery backup to cover interrupts at changeover in the power supply net.
- Fail safe functions are realised with diversity programming in the computer.
- The interlocking function concept is "geographical".

  The interlocking conditions are described by a number of algebraic equations similar to Boolean algebra. However, each variable can normally take up more than two values.

- The object controllers are housed in cabinets located close to the objects. Each cabinet can hold up to eight controllers and a transmission concentrator.

- The controllers are fail safe all solid state devices – no relays are used. They are of different types depending of the object they are meant for.

  The control module for a point machine generates three-phase current for the motor. The motor circuit is immune to influences from traction currents.

  The signal control module has phase angle control of the lamps and circuits for measuring lamp currents.

  All modules have inputs for contact sensing (from track relays and point detection circuits).

- ATC-code for the signal beacons is generated in the interlocking computer and from there transmitted to the signal controller.

- The interlocking processor communicates with the object controllers via a distributed communications network. A HDLC communications protocol is used.

- In the transmission loop a four-wire telecommunications cable or opto fibre can be used. With opto cables very long distances can be covered.

- The objects connected to a loop are completely independent of track layout.

- The interlocking computer can communicate with the concentrators even if a cable break should occur. At loss of power to a concentrator it is automatically bypassed.

- Prevention of accidental route release with track circuit power failure is done with a double pass function.

- There is an Engineering Work Support System.

  This system generates
  - object data for the site computer,
  - track diagram for the VDU,
  - installation documents,
  - equipment list.

- Assurence of safety and function of the interlocking is done partly in workshop, partly on site.

  For functional pretests a special Installation Test System is used.

- Track layout changes and new functions are run and tested in the Installation Test System before they are used in the actual interlocking.
- Track layout changes are very easy to do. For new objects a spare place in nearest cabinet may be used. Reconfiuration of the interlocking is made by the Engineering Support system.
- The single system capacity is about 400 objects.
  Two or more interlocking processors can be linked together under a common master control and supervisory system.

4. Complementary information on some subjects

- **Ring feeds...** are not used.

- **Button types** (functional):
Geographical relay systems :
Key pad control where objects (e g start and end of a route) are pointed out with three digits after which the desired command is given from a set of control buttons, common for the area.

Computer systems:
Here a standard computer keyboard is used. Objects are pointed out with three digits. The final command is given with a three letter mnemonic code (e g ...TRH to set a high protected train route).

- **Operations** (standard/special/emergency)
No type of "ersatzsignal" is used.

Special:
When a turnout is operated from a nearby ground stand (e g for shunting movements) the track circuit is bypassed.

In some rare situations we have turnouts without ground stands and in those situations we arrange a special locked "track circuit bypass button" in the interlocking cabin. That button is positioned some distance away from the normal operating devices. In case of a track circuit failure the signalman and the dispatcher have to cooperate to throw the turnout.

Emergency:
Manual release of a set train route always includes a time delay of > 90 seconds. The time is depending of maximum train speed and of signal distances.

On our CTC-lines we have a function that might be counted as an emergency-function. If the CTC transmission between a substation and the CTC center is interrupted for more than two minutes the local "station automat" is automatically cut in and takes over the setting of train routes, taking information directly from the interlocking and from surrounding line block (see chapter 11.7).

On a single track line these "automats" are even able to issue a complete sequence of orders for two trains to cross. That means that the trains in most situations can continue to run until some key stations have been manned and the dispatcher has the situation under full control again.

- **Legal requirements**
  In our "Railway Safety Law" from december 1990 *nothing* is said about how a signal installation should be constructed. It is only said that a railway should be safer than any other means of transportation and that the safety should be continuously increased.

  It is the railway company itself that has the responsibility to set the rules and regulations. The "Swedish Railway Inpectorate" is supervising authority to check that the rules are adequate for their purpose and that the railway fully takes the responsiibility it has.

- **Power supply**
  Supply voltage toleranses are ±10%.

- **Responsibility attributed to signalman/driver**
  In case of a signal failure (right side of course) the signalman has to convince himself that there is no danger for the train to continue. After that he may give a vocal permit to the driver to continue to next main signal.

  The driver may – with permission – continue with maximum 40 km/h, prepared to stop within half the distance he can overlook. For any turn-outs in the route the driver must check their position himself. The maximum speed is supervised in the ATC system.

  The dialogue between the signalman and the driver is recorded.

- **No litterature** for the interlocking system is avalable.

- **Author**
  Author for the swedish contributions to The European Signalling Text Book is Curt Fällman.

  Fällman is a senior signal engineer with >40 years experience of swedish signalling, ranging from simple mechanical interlockings over relay interlockings up to today's complex computerised interlockings and ATC.

  Since four years Fällman is Inspecting Officer of The Swedish Railway Inspectorate, specially engaged in railway accident investigations.

Chapter 6 - Block Systems

1. Generalities

1.1 The block system itself

In Sweden only one, basic type of automatic line block system is used, both on single track lines and on double track lines. All line block lines are ATC-equipped.

The track circuits on the line are also used to activate level crossing devices of different types. The function of the level crossing devices are *not* dependent of the line block.

In combination with block direction, the track circuits are used for automatic setting of entrance routes to the stations.

1.2 On single track lines

4470 km = 41% of total network.

The line capacity on a single track line is mainly depending of the crossing facilities at the stations. There is rarely no need for more than one intermediate block signal between two stations.

The block sections are normally about 5000 - 10 000m long.

Block signals and entrance signals to the stations have separate, freestanding distant signals with a warning distance of about 1000m.

1.3 On double track lines

1200 km = 11% of total network.

Double track lines are signalled as if they were two single tracks – full signalling for both directions on both tracks.

Running trains in parallel is accepted.

The lengths of the block sections depend of the required headway between trains. Two minutes headway can be achieved with block sections of 1000m. Normally a block section is not longer than 2500m.

The block signals are of the combined type with both main and distant lights in the same head. Only entrance signals at the stations have freestanding distant signals.

2. Operating conditions

The automatic block is used as a part of our CTC-systems. Long distance mixed traffic with freight trains - 90 km/h and high speed, tilting trains - 200 km/h.

The system is also used in suburban areas with commuter trains running with three minutes and intercity trains with two minutes headway.

If a vehicle enters the block in the wrong direction (against set dir.) all the signals are replaced.

With disturbances in the block equipment the dispatcher can allow a driver (after radio or telephone contact) to pass a block signal with maximum 40 km/h to the next main signal.

3. Implementations

Normally the block signals are placed back to back, but they may be set apart to reach better sighting allowance.

The system is relay-based and uses single rail DC track circuits with relays at both ends.

For transmission between the block posts, the line block uses one pair per track in the railway's own telephone cables.

Criterions for our choice: The system is simple and reliable and it is relatively cheap. The same system is standard for both single and double track lines.

4. Future

We are now developing a new "hybrid line block" where a opto cable is used for serial, fail safe transmission between the block posts.

Chapter 7 - Radio Systems in Signalling

1. Radio for Signalling purposes.

Radio for signalling purposes is today used only on some very low traffic freight lines (type one track – one engine in steam).

The radio is used to set points and to activate level crossing devices from relative short distances. The points and level crossing protection is locked by normal track circuit when the train approaches. The train speed is so low that it can stop on sight.

The range of the radio is short. A 27 MHz channel is used and the commands are coded, but no special fail safe code is used.

2. Radio operated shunting

The shunting engines are in most places radio operated.

The shunter carries the command device with him. That means a better safety because the shunter can be at a place where he has the best overview of the situation at hand.

The transmission between the shunter and the engine is fail safe.

3. Future

For the future we see a much wider use of radio functions.

Then new ATC-version (ATC2, due October -92)) is prepared for a complete new signalling concept for low traffic lines – "Radio Block".

No wayside signals at all are necessary – only plain "section boards" and ordinary ATC-beacons.

The ATC-equipment on board the train is connected to a radio system with a data channel included.

From the beacons along the line the engines pick up information of the trains position. That information is automatically sent to the "Radio Block Centre" along with a request to continue the journey into next "section". If the next "section" is free the centre "books" it and returns a permit to the ATC-equipment on board (not to the driver). The ATC-panel gives the driver information of the situation and of the maximum speed in next "section".

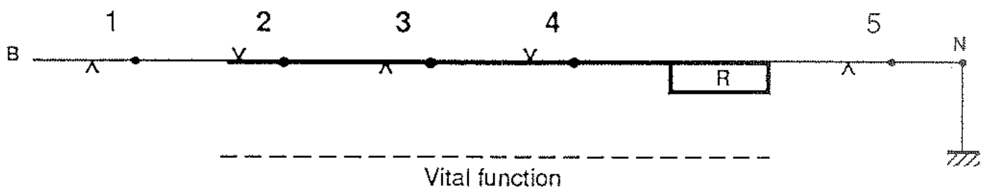
If no answer is returned from the centre the train is stopped at next "section board" , waiting for new information.

All information is sent in special, fail safe codes.

1. Basic Safety Conditions

For inside equipment (interlocking)

The interlocking circuits inside a relay room are often very complex. To avoid too many contacts, single cut circuits are preferred.



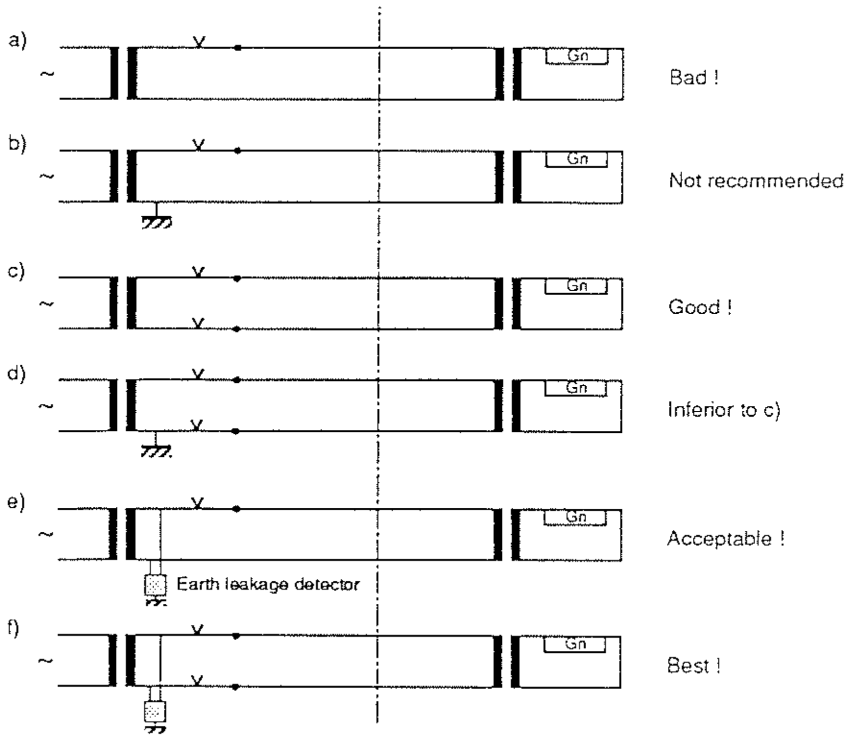
In order to avoid isolation faults to be able to bypass vital contacts, the relays have the return side grounded to a common point. All vital contacts are located on the 'live' side.

Auxiliary contacts may be put at the very beginning of the circuit or in some cases on the grounded side of the relay. Contact 5 in the example circuit above can be bypassed by a isolation fault.

No 'inferior' contacts are accepted inside the vital parts of the circuit.

For outside equipment (track side equipment).

For outgoing circuits, grounding cannot be accepted because of differences in earth potential in different places. Double cut circuits are preferred (c) or f)).



2. One failure theory

By fail-safe we define a characteristic of a system which ensures that any malfunction affecting safety will cause the system to revert to a state that is generally known and accepted to be safe.

Functional safety

Most fatal accidents happens when a safety system fails and is replaced by "manual" procedures. Therefore availability of the system is of great importance.

Manual procedures must be developed and well maintained.

Technical safety

No probable fault including consequential faults shall cause any dangerous situation.

Every fault or a sequence of faults must be detected in a defined time, before a last fault, that is dangerous in combination with the first fault or faults, occurs.

The time of detection shall be such that the probability of a dangerous output from the faults shall be negligible (probability $< 10^{-8}$ for another failure within detection time).

3. Design principles

Standardised, well tested types of interlockings.
Critical examination of new designs from experienced signal engineer team.

Diversity both in hardware and in programs for computer interlockings.

Testable, well defined modules.

Protection against double cable isolation faults in signals, that might be dangerous, can be had in two different ways:

- by a fail safe earth leakage detector that replaces all signals when an earth leak is detected or
- by isolating each signal with a separating transformer (220/110V~).

4. Environment conditions

The conditions are depending of type of equipment and situation.

E g for electronic equipment in a wayside cabinet:

- temperature: - 40 – + 70 C°
- humidity: 10 – 95% RH, condensing
- gas: nitrogen oxides, salt fog
- vibrations: 10 – 1000 Hz, 2 mm amplitude, 30 m/s^2
- shock: 3 x 5 g
- transients: SS 436 15 03, class 3.

5. Electro magnetic conditions

Track circuits are protected against geomagnetic currents.

Protection in power supply distribution against lightning strikes.
Special protection for sensitive solid state devices.

No protection against NEMP.

6. Power supply conditions

Two independent sources. Railway's own auxiliary net and local net or self-starting diesel generator.

7. Choice of components

- Vital = according to UIC norms or equivalent,
- Non-vital = good industrial standard.

8. Earthing conditions

Earthing is done for different reasons:

- Legal requirements for power supply and distribution.
- Staff protection on electric traction lines (15 kV 16 $^2/_3$ Hz)
- Signal safety requirements (see 1 above).

Outside equipment with floating, fail safe circuits have earth leakage detectors.

Chapter 9 - Automatic Train Control

1. Type of system

The Scandinavian ATC system is an intermittent control and supervision system. It is used as an **extension of the signal system** into the drivers cab. The system is something halfway between ATP and ATO. It gives considerably more than only protection but less than automatic operation. In the cab, 12 different speed levels (0 - 275 km/h) can be displayed to the driver.

The optical signals are quite simple and give only the most basic information to the driver with only two speed levels — "line speed" and "40 km/h". The ATC-system gives the driver a lot more information.

2. Basic functions provided

From the track the system picks up information of:

- signalled speed (allowed speed in the section and target speed),
- permanent speed restrictions (speed boards),
- temporary speed restrictions (work areas),
- level crossings that are not secured,
- distance to next signal or restriction,
- slope conditions.

From the engine it has information of:

- maximum speed of the train itself,
- the actual speed of the train,
- the trains braking ability (rate and delay),
- the train length,
- special properties of the train – if any.

For every situation the most restrictive top speed and target speed is presented on a display in front of the driver in the cab. Information changes are indicated with an audible warning tone.

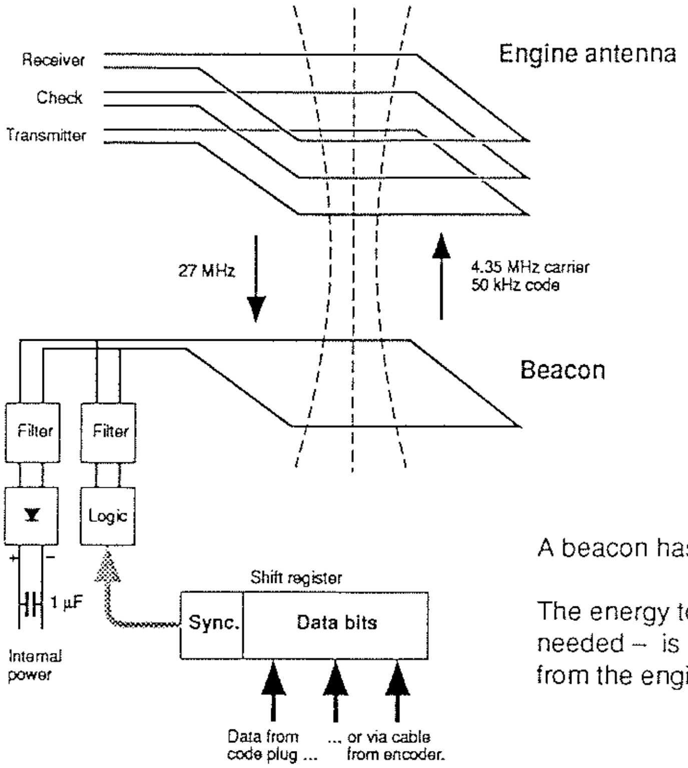
Maximum running speed and the train's braking curve when approaching a restriction are continuously supervised.

3. Type of equipment

On the train

On board is a fail safe micro processor based unit for evaluation of the information received from the beacons in the track and from the engine.

Transmission ground —> train



A beacon has no external power supply.

The energy to the CMOS circuits – when it is needed – is supplied from the 27 MHz signal from the engine.

Fixed installations

An information group i the track consists of 1 – 5 beacons.

The reason for more than one beacon in a group is:

- Safety (a single beacon might be damaged an not detected),
- Information of direction of travel is wanted,
- Need of more information.

In *Relay Interlockings* the changeable signal information for the beacons is fetched from encoders in nearest signal cabinet.

In *Solid State Interlockings* the information is generated in the interlocking processor and from there transmitted via the object controllers to the beacons.

3. Physical characteristics

Data in the beacons can be picked up from a train running 300 km/h. The transmission can penetrate 10 mm of iron ore concentrate or 100 mm of snow and ice.

4. Operational features

- Signal beacons can be programmed for two types of supervision for braking towards the target signal:
  - down to 40 km/h for normal stop situations,
  - down to 10 km/h for dangerous situations (short overlap).

- When approaching a restriction the driver first gets warning beeps. If he doesn't react within 8 - 13 seconds service brakes are applied. The brakes cannot be released until the train is under the indicated speed.

- If the target signal is red the train will be stopped short of the signal.

- If the permitted line speed is exceeded with 5 km/h the driver gets warning beeps. If the speed is exceeded with 10 km/h service brakes are applied.

5. Safety and reliability

- For fail safe information Hamming codes 8/4 and 16/11 – with a Hamming distance of 4 — are used.

- Signal beacon groups are linked to each other – the engine knows where to find next signal. If a beacon (or a whole group) is missing an "error" is indicated to the driver and service brakes are applied.

- For speed boards linking can't be used for different reasons. If the step in speed is great (≥ 40 km/h) the warning board beacon group is duplicated.

- The use of the system is compulsory. Trains, where the system goes faulty while running, are allowed to continue with reduced speed (80 km/h) to the nearest depot where a switch of traction power or a quick repair can be made.

6. Existing applications

The ATC system is applied on about 60% of the Swedish network, carrying more than 95% of the total traffic. The non-equipped lines are small county lines with very low traffic volumes – mainly freight traffic.

Outside Scandinavia the system is used in many European countries as well as in Australia and the Far East.

1. Basic principles

Sweden has very long railway lines but comparatively low traffic volumes. The need for higher speeds is great but we can't afford to build new high speed lines as in other countries.

The solution was to build new unit trains that could run much faster on existing tracks.

2. General operating conditions

These new trains have low axle load (16 tons) and soft bogies and can run 200 – 250 km/h on straight track and 30% faster than normal trains on tight curves. The coaches have a tilting function, but only for comfort reasons.

The top speed – including 30% overspeed in curves – is supervised in the ATC system.

High speed trains are run in mixed traffic with normal intercity trains and freight trains.

3. General sigalling system description

Interlockings

Existing optical signalling, with nominally 1000m warning distance, is kept mainly unchanged. The extended waning distance necessary for higher speeds is given only in the ATC system.

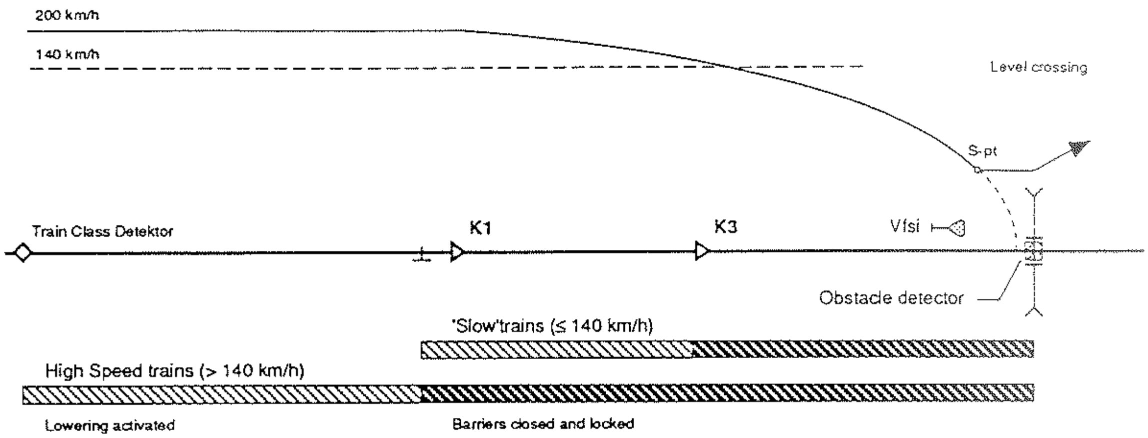
Turnouts have non-trailable point machines.

Level crossings

On the high speed lines we still have a few level crossings.

The crossings are equipped with fully automatic barriers and have road vehicle detection loops in the crossing area. If a road vehicle is standing in the crossing, the off side barrier is not lowered.

If the barriers aren't down in due time for a train the driver gets a warning in the ATC system and the train can be stopped short of the crossing.



On account of the great differences in speed – 200 km/h for high speed trains and 90 km/h for freight trains – the activation of the crossing protection is differentiated.

To avoid that the barriers are being closed for unnecessary long time (> 4.5 minutes for a 'slow' train) the activation is delayed for those trains.

1. Traffic supervision

- The traffic flow is supervised at certain critical points in the rail network. Input to the supervision system is from the train describer system.

  The actual time for a train is compared with scheduled time and the discrepancies, if any, are transmitted to a central data base (TFÖR). From there information of the relevant train situation is continuously sent to all CTC-offices and to station masters on larger stations.

- Some local radio stations are also informed this way.

- All information is normally sent over the railway's own opto cable net work.

2. Time table

- Time tables and train graphs are worked out on a separate, off line system. There is no direct input to the signalling systems.

- No system for automatic route setting assessment in conflict situations is used.

3. Train describer

- Train describer systems are used on all double track lines and on newer single track lines.

- A descriptor berth can accommodate the actual train number (5 digits) and the number may be used for automatic route setting.

- The number is sent ahead of the train (duplicated) as far as the route is clear.

- In suburban services the desciber system is among other things used for automatic setting of train routes for local trains. The route setting is often delayed in order to avoid closing barriers too early when there is a station in the strike-in area.

4. The integrated operators desk

Our four largest CTC-centres all have an integrated master control and supervisory system.

- Overview display for the operators in a centre is arranged in two different ways:

  – as a large common signalling indication panel or
  – with a couple of VDU displays for each workstation.

  The large indication panel is built up of a row of large (140 x 100 cm) back projection VDU colour screens placed close side by side.

  The advantage of the large screens is that they can be seen from a distance without interfering with the operators work. By using different colours and different shapes for the indications a lot of information can be presented in a limited area without losing clarity.

- Each workstation has up to four graphics displays. Normally one is used to show detail views and one is a general purpose display.

- The same type of workstation is used for the central interlocking and for CTC-functions on connecting lines.

- In integrated systems with keyboard commands there is a block up function for signals, points and/or track circuits. This is to prevent the operator to set a route into a maintenance work area by mistake.

- The supervisory system has a log-function. All commands and all incoming informations are recorded and may

  – be listed on the system printer or
  – replayed on a special test system.

  The recordings cover the last 24 hours.

5. Train graph

- Train graph printers have been used but are today abandoned in favour of manual methods.

  The reasons for abandoning the old system were:
  – expensive mechanical maintenance,
  – expensive paper handling,
  – no possibility to mark planned maintenance work or extra trains in advance.

- The manually updated graph is used both for planning and as a record.

6. Passenger information

- Information to the customers is presented on split flap indicators or CCTV:s with double height characters.

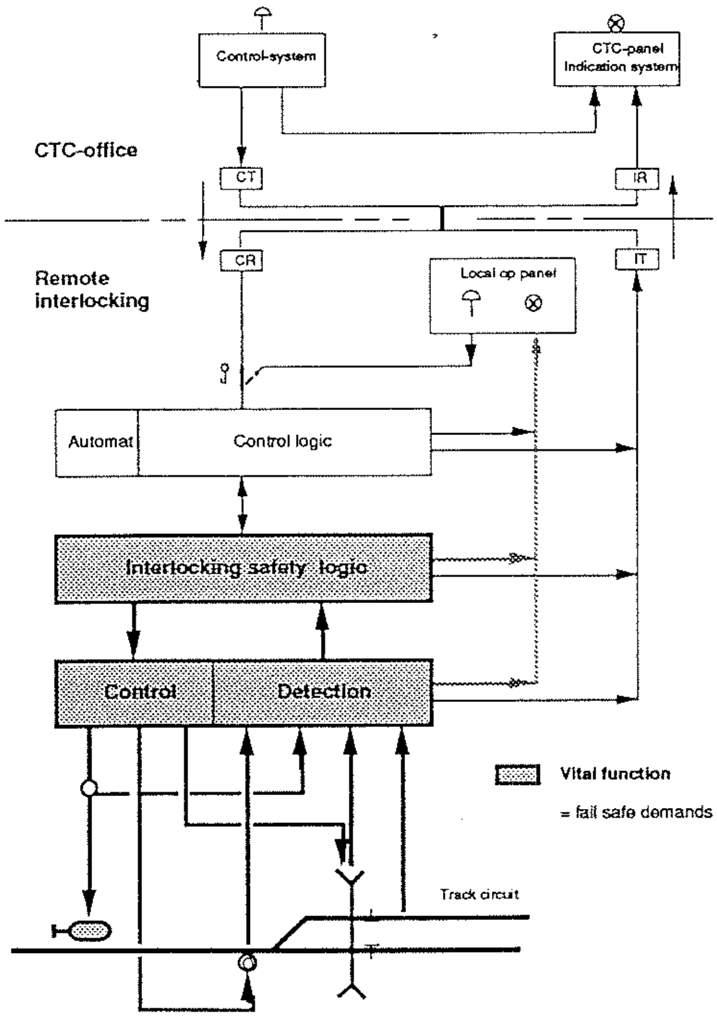
- The information system is normally monitored by a special computer.
- Input from the train descriptor system or from keyboard in delay situa tions.

7. Centralised traffic control

In Sweden we have 11 CTC-centres, each embracing about 300 km in each direction.

- The CTC-transmission types we use are all of the TDM Bi-Directional Multi-Station type.

  There is no direct need for the transmission to be fail safe (see figure below) but the system availability must be high.



A malfunction in a non-vital part will have the same effect as a false command from the operator.

In worst case an unwanted route may be set, but only if it is accepted as safe by the interlocking.

Any dangerous commands are rejected.

We have about 4500 km CTC-equipped lines, mostly single track lines.

- Depending of age the CTC installations are of three basic types:

  1. Old relay transmission systems built with telephone type relays. Long indication panels with lamps.

     This system is quite slow and used only on single track CTC-lines.

  2. Electronic transmission systems with Phase Shift Keying and 1000 baud transmission.
     Large indication panels with lamps and train describers berths.

  3. Modern integrated electronic systems with Phase Shift Keying. 1200 baud transmission with central processor for supervising functions.
     Large back projection colour screen panels for overview.
     Standard VDU:s for detail display of single station at each work-station.

- With keyboard commands there is a block up function for points, sig nals and/or track circuits in the local interlocking. This function is used to protect e g maintenance work. The operator cannot by mistake set a route into a protected area.

  The keyboard operator has no separate buttons or levers he can mark to protect a work area.

- To relieve the operator from frequently used command sequences some automatic functions are installed:

  – All level crossing protection is fully automatic.
    No CCTV supervision is used.

    The operator only has an auxiliary command for activating the protection if he – for some reason – can not set a normal train route.
    In addition he has an alarm indication of barriers in closed position more than 10 minutes.

  – Fleeting or automatic route setting is accepted.

  – Single track CTC-lines have "crossing automats". These take information from the interlocking and from the line block system on both sides of the station. If only one train is approaching, the automat locks a route straight through. If trains are approaching from both sides and a crossing has to take place the automat issues a command sequence to arrange that crossing.

    The automatic functions are so effective that on holidays, when no maintenance work is done, a single operator can handle all traffic in the CTC-office (80 substations with moderate traffic).

- The operator can override the automatic functions if he wants different dispositions.

  E g if he on a single track CTC-line wants the fist train to take the main track he sets that route first and the whole crossing is rearranged.

  In automatic functions, entrance routes have preferences over exit routes – the line must be 'emptied' first.

- The modern electronic systems have a loop transmission in order to improve availability. If the transmission line is cut all substations can still be reached one way or the other.

- If the transmission fails completely, the automatic route setting functions are cut in after a certain delay (also in relay CTC).

ME John Hammargren/SDH 1991-09-13

SIGNALLING FOR HIGH SPEED LINES WITH MIXED TRAFFIC

Introduction of high speed trains on the line Stockholm-Gothenburg shows that high speed trains in mixed traffic with other trains put several new demands on the signalling. Such demands are e.g.:

- New speed levels with extended advanced signalling
- Optional alarm distances and increased protection of remaining level crossings
- Optional speed reduction depending on type of train
- Platform protection
- Extended need of communication along the line
- Increased protection in the stations
- Overview of the whole line from one or a few control centres.

The existing installations on the line were of various standards and they had now to be standardized to meet the above demands.

Quite extensive adaptation has, therefore, been made on the interlockings, block systems and level crossing protections. The grade of modification has depended on the age and condition of each separate installation. In some cases the installation has even been exchanged for economical and safety reasons such as the CTC installations.

The measures which have been taken are:

- Adapt/substitute interlockings and block systems
- Adapt the ATP system
- Reduce the quantity of level crossings from about 300 to 90
- Upgrade the remaining level crossings
- Introduce/adapt the protection at the platforms
- Turnouts have been equipped with non-trailable point machines and control contacts
- Flank protection with locked points
- Exchange of older CTC-installations to new computerized systems.

ME John Hammargren/SDH 1991-09-13

ATP-system on the Swedish national rail network

After some serious accidents in the 1970's the Swedish administration decided to speed up the installation of an Automatic Train Protection System (ATP/ATC) in order to prevent the consequences of driver errors. The installed system, EBICAB 700, was delivered by EB Signal AB.

The system is based on beacons strategically placed over the rail network, mainly at signal points. A communication link carries data from the trackside beacons to the trains. In addition to the received trackside data, a trainborne computer equipment collects data from the train speedometer, about the train's braking capabilities, from brake pressure gauges and other on-board data sources. Based on this information the train computer computes the train location to the next restricted point and the momentary permissible maximum speed, thus checking continuously that the train driver keeps the train within permissible speed. On a panel the driver is informed about the momentary permissible speed and the speed restriction at the next signal point. If the driver fails to obey the speed limitation, the ATP equipment will automatically brake the train.

The panel information makes it possible to put in "fictive" signal points on the line, points equipped with beacons but without trackside colour light signals.

Advanced fictive signals

A normal distance from an advanced signal to a main signal is about 1000 meters. When introducing the high speed train the advanced signal for these trains has to be at least 2000 meters ahead of the main signal. This advanced signal may be a block signal if there is one. Normal distance between two block signals is about 2400 meters. In other cases a fictive advanced signal is put in about 2500 meters ahead of the main signal. The value is depending on the line slope in advance of a home signal. The information at the fictive signal point may be the restrictions up to the main signal, "through signalling", or up to the "normal" advanced signal, "~~trap~~ step signalling".

Nbk: The system automatically can also be programmed to send speed signals instead of only train identity in case a high speed train is travelling at low speeds and vice-versa.

Speed restrictions

The beacons are indicating permitted speeds to the train. However, some beacons are indicating that the permitted speed may be exceeded by the high speed trains. E.g. on the line Stockholm-Gothenburg the speed at curves may be exceeded up to 30%.

Level crossings

When introducing high speed trains on a conventional track network with mixed traffic a problem arises where level crossings exist. A high speed train approaching a level crossing has to activate the level crossing protection equipment far sooner than slower trains. On the line Stockholm-Gothenburg a high speed train approaching a level crossing will be recognized by sending its identity to a track side receiver beacon in due distance from the level crossing, thus activating the protection equipment. A check beacon at braking distance informs the train about the level crossing status. Slower trains will activate the protection equipment as before.

A level crossing normally is equipped with full barriers and red flashing lights against the road. When the protection equipment is activated the red light starts to flash and a bell starts to ring until the barriers are down. Against the line there are signals including advanced signals showing the status of the barriers.

At level crossings carrying more than 50 road vehicles/day or at special risks for blocking road vehicles, detector loops are placed in the area between the barriers on each side of the tracks. If the detectors are registrating vehicles in the track area only the entrance barriers are activated. The exit barrier will then be activated when the hindrance has moved away.

The barriers are provided with built in detectors indicating broken barriers.

Platforms

At stations where the speed of passing trains will exceed 130 km/h signs indicating passing high speed trains shall be placed on the platforms and a safety zone shall be painted on the platforms. In exceptional cases the platforms will be provided with flashing light signals sometimes combined with an acoustic signal.

As a rule the level transit ways between platforms will be provided with barriers. The barriers will be activated by approaching high speed trains.

Miscellaneous

Where the speed exceeds 130 km/h the points shall be provided with non-trailable point machines and locked points as flank protection.

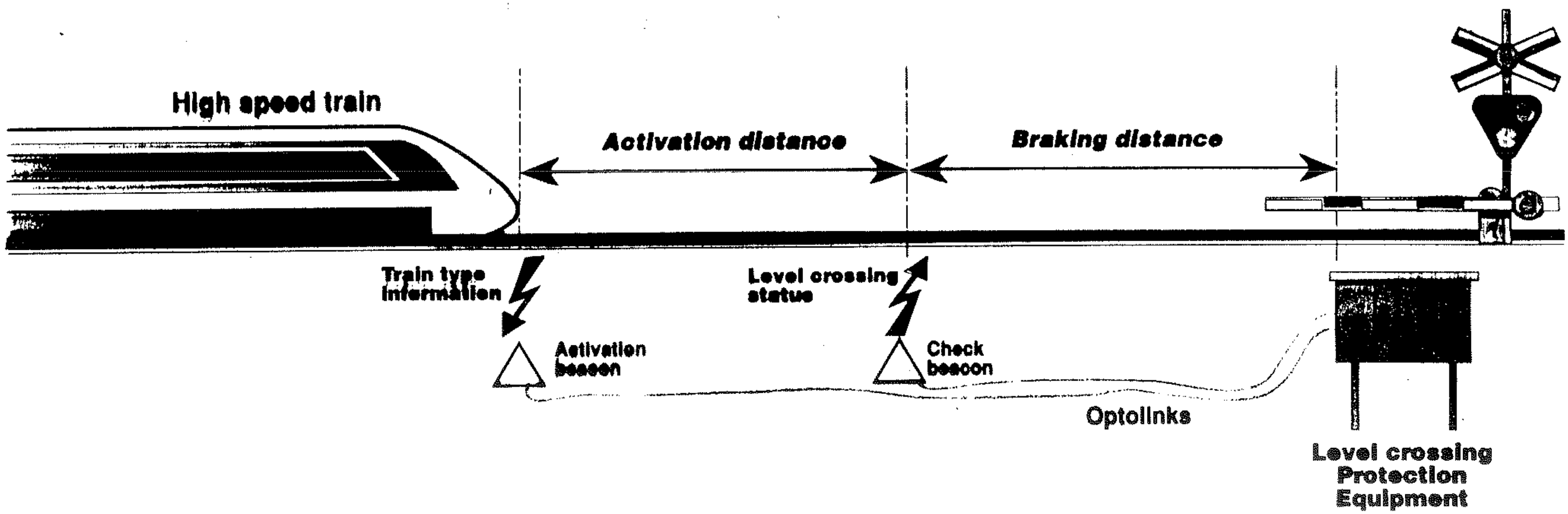
Emergency release has been extended from 1 minute to 2 minutes.

Summary

The introduction of high speed trains on conventional lines demands extensive changes in the signalling installations. New technical solutions, e.g. the train identification function and the use of optical fibre cable, have made it necessary to upgrade the training level of the engineers.

An extensive planning work has been done and special rules for the engineers' work had to be written in order to get standardized solutions throughout the line.

Level crossing control
for High Speed Trains



TRAIN IDENTIFICATION SYSTEM

Contents

1 INTRODUCTION

This description is divided into two parts. The first part describes the general features of the Train Identification System. The second one concentrates on the specific features of the system developed for SJ/BV in 1989.

2 TERMINOLOGY

TIS	Train Identification System
TDT	Train Data Transmitter
EU	Evaluation Unit
ATC	Automatic Train Control

3 GENERAL SYSTEM DESCRIPTION

3.1 SYSTEM

The Train Identification System consists of three main parts, the Train Data Transmitter, the Train Data Receiver and the Evaluation Unit. The TDR and the EU are interconnected by an optical cable. The system also utilizes the antenna and 27 MHz transmitter of the ATC system.

3.1.1 Train Data Transmitter

The TDT is mounted in a vehicle and connected to the ATC equipment there. The information is transmitted by the receiving part of the ATC antenna. When activated the TDT continously sends its information as long as ATC is active.

The function of the transmitter is monitored by a supervision function. Error and activation indications can be output from the transmitter for connection to other equipment in the vehicle.

The transmitter can be activated from an external input.

3.1.2 Train Data Receiver

The TDR is mounted in the track the same way as an ATC beacon. It is powered by the ATC 27 MHz signal.

It converts the 460 kHz signal from the TDT to an opto signal. The function of the TDR is independent of the telegram format and information.

3.1.3 Evaluation Unit

The EU is mounted in a rack near the track. It receives the opto signal and evaluates the information. The received information is compared to information programmed to the EU at installation. Other equipment can be activated using two relay outputs.

3.2 TELEGRAM FORMAT

Data is sent as a 44 bits telegram including 8 bits synchronization flag and two checksums. To prevent data from beeing interogated as a flag the TDT will add an extra "0" after five consecutive "1"s elsewhere in the telegram. There can be no more than five such extra bits in one telegram. Figure 1 shows the telegram structure.

0111 1110	ZZZZ 1	YYYY 2	YYYY 3	0 4	XXXXX 5	ZZZZ 1	YYYY 2	YYYY 3	0 4	XXXXX 5
S	A					B				

S Synchronization flag
A A-message
B B-message

1 Telegram type. The four bits in A are information and the four in B are redundancy bits in a Hamming (8,4) code.

2 Information.

3 Information.

4 Always "0". Check that the telegram is not inverted.

5 Checksum for each half of the telegram.

Figure 1. General telegram structure

3.3 SIGNAL MODULATION

3.3.1 <u>460 kHz signal</u>

The TDT sends a pulse phase modulated 460 kHz carrier signal to the TDR. Logic "1" is transmitted as 10 us 460 kHz carrier followed by 10 us pause. Logic "0" is 10 us pause followed by 10 us carrier. The data is synchronized with the ATC 50 kHz clock.

3.3.2 Opto signal

The opto signal from the TDR to the EU is on/off modulated. Logic "0" is sent as a 2-3 us optical pulse. Logic "1" is sent as no optical power. Data frequency is 50 kHz. The optical wave lenght is 890 nm.

3.4 CONTACT VOLUME

Distance between bottom of ATC antenna and the mounting plane of the TDR is 250 - 430 mm.

Maximum lateral displacement between centers of antenna and TDR is ± 180 mm.

Maximum longitudinal displacement between centers of antenna and TDR is ± 250 mm.

3.5 OPTICAL CABLE

Maximum attenuation of the optical fibre between TDR and EU is 25.25 dB. This includes aging and repairs.

3.6 SAFETY

The TIS is not a failsafe system. Correctly installed it does not influence the function or safety of the ATC system.

4 SPECIFIC SYSTEM DESCRIPTION

4.1 INFORMATION

The information transmitted in this system is the maximum vehicle speed.

4.2 TELEGRAM FORMAT

Figure 2 shows the telegram format used in this application. Only one telelegram type is used. The second information field (A3, B3) is not used.

0111 1110	0001 1	YYYY 2	0000 3	0 4	XXXXX 5	0111 1	YYYY 2	0000 3	0 4	XXXXX 5
S	A					B				

S Synchronization flag
A A-message
B B-message

1 Telegram type. The four bits in A are information and the four in B are redundancy bits in a Hamming (8,4) code.

2 Maximum vehicle speed. The same in both halves of the telegram.

3 Not used.

4 Always "0". Check that the telegram is not inverted.

5 Checksum for each half of the telegram.

Figure 2. Specific telegram structure

4.3 SPEED INFORMATION INPUT

The speed information (A2, B2) and checksums (A5, B5) in the telegram are programmed in the TDT at installation. There are sixteen different telegrams.

4.4 OUTPUT ACTIVATION CRITERIA

The outputs of the EU are activated if the speed value in the telegram is higher than, or equal to, a value programmed in the EU at installation. Two out of five consecutive telegrams must be correctly received to activate the outputs.

4.5 VEHICLE SPEED

Maximim vehicle speed for the system is 300 km/h. At this speed the EU will receive at least five telegrams.

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Dokansv/Godk - Doc respons/Approved	Kontr - Checked	Datum - Date	Rev	File
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4.6 APPLICATION OVERVIEW

The system is used to activate level crossing protections at an earlier stage if a high speed train is approaching.

The speed value programmed to the EU is the normal train speed (160 km/h). When a high speed (200 km/h) train passes the TDR the outputs of the EU will activate the level crossing protection.

When the protection has been activated the speed information of an ATC beacon, positioned between the TDR and the level crossing, will be increased from normal speed to high speed.

If the information from the train is not correctly received, or the protection is not activated in time, the normal speed value of the beacon will remain. This will force the ATC to brake the train to normal speed. At this speed the level crossing protections will be activated the normal way.

3

Level Crossing Protection

Chapter 12 - Level Crossing Protection

1. Introduction

Our experience in Sweden is that automatically operated crossings give the best protection. Attended barriers are very seldom used.

Level crossings can be divided into four main groups with respect to how they are protected:

• Full barriers	about	1200	crossings
• Half barriers		800	
• Open crossings with road signals		1700	
• Open crossings with no controls		12000	
	(about	11000	km of tracks)

Full barriers are used at all level crossings
- where allowed train speed exceeds 140 km/h,
- with heavy road traffic,
- with big pedestrian and cyclist traffic.

Half barriers are used where full barriers are not required
- at intersections with main lines,
- at intersections of county railway lines and public roads.

Open crossings with road signals
- are mainly used at crossings between county railway lines and small private roads.

Type of protection is normally decided from a risk factor (number of trains X number of road vehicles pro day) and types of road vehicles. E. g. a factor >1600 or slow vehicles indicates half barriers instead of an open crossing.

The first automatic half barrier installations were made in the early 1950:th.

2. Level Crossing - Roadside

- On the right nearside of a crossing there shall always be a St Andrew's Cross sign (we have right hand driving on our roads).

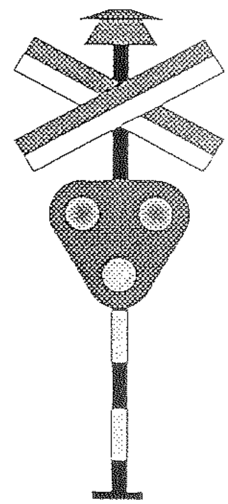
Signals
- For level crossings with any type of signal protection the signals are positioned just under the cross sign and a bell for audible warning is put at the top of the near side posts. The signals have a triangular back-board with two red jumping lights (80 fl/minute) in the upper half and a single lunar white light (40 fl/minute) below.

- The flashing white light indicates that the equipment is in function and that no train is approaching.

- If the road is more than 5 meters wide or if the visibility is considerably better from the left side of the road, a second off side signal will be arranged. The off side signal does not need the white light.

- The lens aperture shall be circular with at least 200 mm diameter. The light shall by daylight and fair weather be visible from at least 100 m distance. The warning bell shall give about100 strikes pro minute and normally be heard by a pedestrian from 50 m distance.

- Older full barrier installations may have only a single red light on each side instead of the jumping lights.



Near right side signal

- No signs or signals for "ANOTHER TRAN COMMING..." are used.

Barriers

- A barrier shall be yellow with at least three red, high reflecting plates (500 x 100 mm) on the near side. A red boom lamp is positioned over the middle of the approach lane.

- No minimum open time is required. A new warning sequence can start before the barriers are in full up position.

- No CCTV supervision of the level crossings is used.

Warning sequences for single/double tracks

[ ] = times for double track

For full barriers.

- The crossing is initiated so early that the crossing is secured when the train still is at braking distance. The crossing is safeguarded by
  - main signals or
  - separate level crossing distant signals (see 'railwayside').

- Red road lights and audible warning are started at least 10 [15] seconds before the barriers (on the near side) are being lowered. If there are separate booms for the near and for the off side, the nearside booms may be lowered after only 5 seconds (same as for half barriers).

- The audible warning is cut off when the barriers are in down position. The red lights are on until the barriers again are in upright position.

For half barriers.

- Red lights and audible warning are started at least 20 [25] seconds before the train arrives to the crossing. The booms commence lowering after 5 seconds.
- The audible warning continues until the whole train has cleared the crossing. The red lights are on until the barriers again are in upright position.

For open crossings.

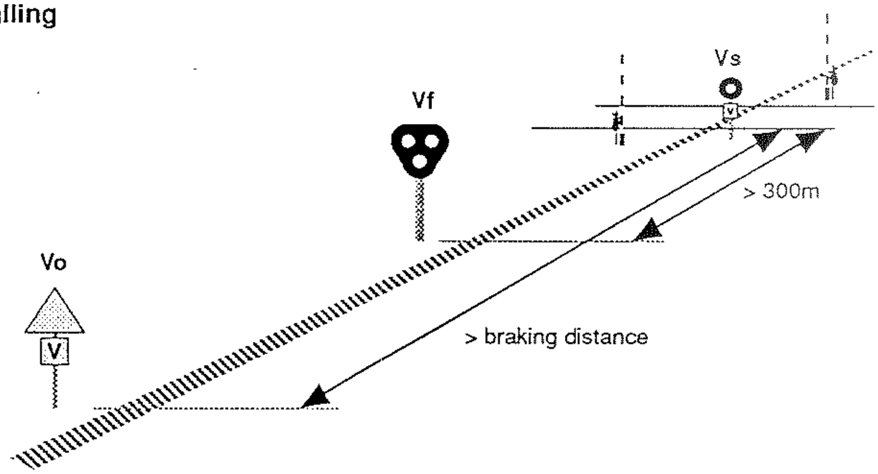
- Red lights and audible warning are started at least 20 [25] seconds before the train arrives at the crossing.
- Red lights and audible warning continue until the whole train has cleared the crossing.

Increased warning time.

- With more than one track or with a small crossing angle the warning time is increased with 1 second for each additional meter.

3. Level Crossing – Railwayside

Rail signalling



- All protected level crossings have a rail signal – Vs – informing the driver of the situation at the crossing.

  This signal is a simple double-sided search light signal, showing lunar white light to the engine driver when the road traffic is stopped and red when the road is open.

For full barriers

- Full barriers are preferably guarded by main signals. If this is not suitable or possible a special distant signal may be used.
- The distant level crossing signal – Vf – shows three orange-yellow lights in V-form. The lamps are flashing when the barriers are open and show a steady light when they are lowered. The signal is positioned at least 300m before the crossing and shall be well seen from braking distance.

For half barriers

- For half barriers the rail signal is cleared when the booms have reached 70° from horizontal.

For open crossings

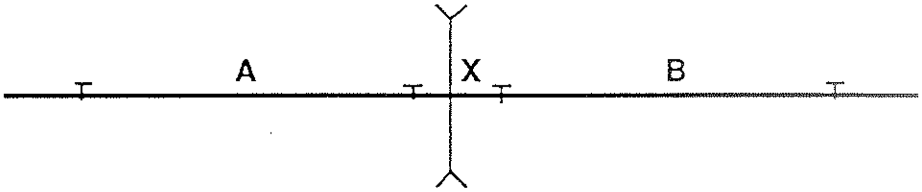
- The rail signal is cleared immediately as the warning starts.

Technology

- Level crossing functions are integrated in the signal system. Standard signal relays are used.

  The normal track circuits that are used for interlockings and for line block systems are used for level crossing functions too.

- The lengths of the track circuits are adjusted to fit the needs for the level crossings. For an automatic level crossing at least three track circuits are needed.



- All automatic level crossing functions are built for bi-directional working. The function is independent of driving direction of line block systems.

- The strike-in direction is set when the first track circuit is occupied by a train.

- For strike-out function a double passing A—>X and X—>B (or reverse) over the crossing is required.

- In the event of an intermittent right-side failure of a strike-in track circuit, the crossing will be initiated; however once the failure clears, the crossing will reset after two minutes without other intervention.

- Should the running-out track circuit fail under a train this would mean that the equipment is locked up and that next train will not be detected if it comes from the opposite direction.

  Dangerous situations from this reason are prevented in two different ways:

  - Checking of crossing function in surrounding main signals. A signal cannot be cleared if the crossing functions are locked up.

  - If checking in surrounding signals is impossible, e. g. on lines without line block, the equipment is reset after 2 minutes (before a train in opposite direction can appear). As the fault remains the crossing will be re-initiated as for a new train and the road traffic stopped until the fault is repaired.

- Unit barrier drives are used, one for each boom. The drives have shunt motors for either 24V DC (battery reserve) or 220V DC (dual supply networks). The drives have integrated detection contacts.

  The booms are not lowered at complete power failure.

4. Level crossings on high speed lines

We still have a few level crossings on what we call high speed lines (>140 km/h). Only full barriers are accepted and these are specially equipped to get best possible protection.

- The crossings are included in the ATC system. If the barriers don't operate properly the train is stopped short of the crossing (see figure below).

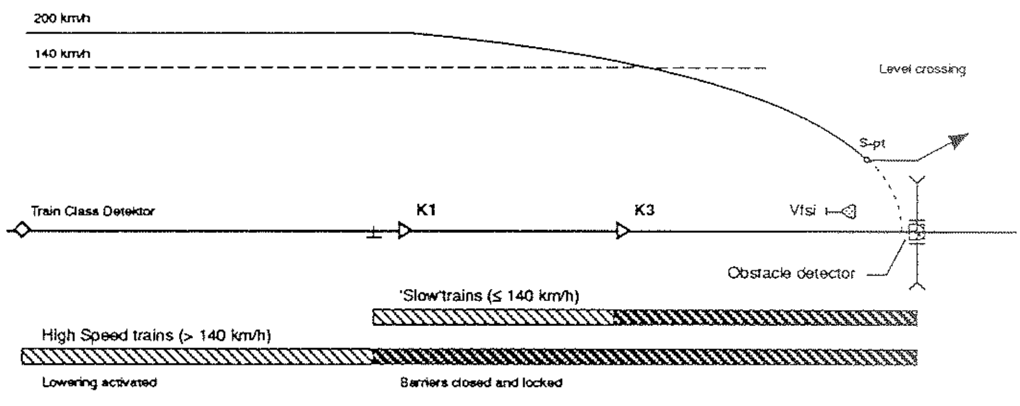
- Crossings with heavy lorry traffic are equipped with obstacle detectors in the crossing area. If a road vehicle is standing in the crossing the (off side) barriers do not commence lowering and the train is stopped.

- High speed lines have a mixed traffic with both fast intercity trains and slow freight trains.

  Becayuse of the great differences in speed – 200 km/h for high speed trains and 90 km/h for freight trains – the activation of the crossing protection is differentiated.

- Strike-in and locking of the barriers for 'normal' trains are by track circuits. That the barriers are lowered is checked at K3 (see below).

- High speed trains have an outer strike-in point from a "train class detector" about 6000m from the crossing. This equipment is not fail-safe but this fact is not dangerous as the crossings are supervised in the ATC system. The barriers are supervised at K1 (and K3).



LEVEL CROSSINGS

All remaining level crossings will be equipped with full length barriers or double pairs of half-barriers. Except for some small country lanes all crossings will furthermore be protected by sensors indicating the presence of a road vehichle on the track and preventing the exit barrier being lowered until the crossing is free.

There is also a "broken barrier sensor" which immediately returns all train signals at the crossing to danger if a road vehicle passes through closed barriers.

The crossings are monitored by the ATC-system.ATC-transponders are also used for activating barriers by the high speed trains.

The accompanying picture shows the priciples used when adapting the crossings for higher speeds.

A high speed train passes a transponder at 4,5 - 6 kms before the crossing. The train identifies itself automatically as a high speed train and the crossing is activated. At 2,8 kms from the crossing the conventional track cicuit begins for regular trains and the barriers start lowering if not already activated by the transponder.

About 100 m further ahead a transponder is situated giving the high speed train either a "proceed at normal speed" indication if the crossing is closed and free from obstacles or a "brake to max 45 kph" if the crossing is not free for trains to pass. If a warning from the ATC system is ignored, the train brakes automatically.

About 1,7 kms from the crossing there is a third transponder giving the same indications as the one above but programmed to give information to all kinds of trains. This transponder serves the double purpose of giving warnings to slower trains if something is amiss at the crossing and giving high speed trains a "increase to normal speed" indication if the former warning was due to , for example, a slow moving tractor not being able to clear the crossing in time.

Should the obstacle remain at the crossing, any train approaching cannot exceed 45 kph just before the crossing and can thus in most cases be able to stop before running into whatever might block the crossing.

Should the indication be due to some minor malfunction of the warning equipment at the crossing, lamp failure for example, the train can pass at slow speed and resume full line speed as soon as the crossing is reached.

GRADE CROSSING SAFETY IN SWEDEN AND ITS APPLICATION ON THE HIGH SPEED PROJECT X2000.

1. Background

Due to the big amount of grade crossings in Sweden great efforts have been made to form a policy and to apply it in practice. As a whole Sweden has almost twice as many crossings per mile as the U.S. does.

Ever since grade crossings have been equipped with protective devices, attempts have been made to find rules to give priority to safety measures, taking in account the different physical conditions at the places considered.
Many analytical formulae have been prepared to asses the accident probability. An other possibility is to use regression analysis.The number of accidents in Sweden is too small to permit such an analysis.Nevertheless the DOT Rail-Highway Crossing Resource Allocation Procedure has been studied with interest but it is dobtful if an American formula can be used in Sweden.

Instead Sweden has over the years made a practice based principally on experience but also on Swedish invesitigations.

2. The Swedish method

The determining factors that are to be considered in detail are shown with explanations in Appendix 1.

The safety device options available are shown in Appendix 2.

The factors for an inventory are specified in the inventory form (Appendix 3).

The normal method to determine the type of protection is shown in a flow chart (Appendix 4). The chart should be read from left to right and from the top down. The protection options arrived at using the flow chart, must always be regarded as a guide that the person taking the decision must examine critically as there may be local conditions that cannot be taken into account in the general schedule.

3. The application on the X2000 Project

The line Stockholm–Göteborg which is the line where X2000 trains are now running has a route-length of 456 km (283 miles). In 1983 there were in total 303 grade crossings on this line.110 of them had active protection (full-barriers, half-barriers or flashing lights and bells). 193 crossings were unprotected, most of them local agricultural / forest access roads.

During the years before the scheduled start for the high speed traffic the first item was to close as many crossings as possible and build frontage road connections to protected crossings or to grade-separated crossings.

When in July 1992 the running time between Stockholm and Göteborg will be 2 hours 59 minutes about 80 grade crossings will exist.
All of them have full-barriers, some quad-barriers but some on small roads have a single full-barrier over the whole road.

According to the flow chart appendix 4, one has to choose between a full-barrier, a full-barrier with obstacle detector both sometimes combined with prolonged warningtime.
Of the total of 80 full-barriers about 60 will also have the obstacle detector.
The cost for a full-barrier with detector is about $240,000.
The crossings have devices that can select if there is a fastrunning train approaching or a slowrunning.

As grade separations are costly not so many were involved in the project but about ten have been built on this line since 1983 to some extent due to the project.

As an additonal safety effort some crossings have got extra lights over the normal lights.

Also as an additional effort the protective framing for the catenary has in some crossings been given a strengthened indication with reflecting material in blue and white to give better visibility.

Determining factors

The factors are listed in alphabetical order of their Swedish abbreviations in the flow chart.

The inventory record form is shown in Appendix 4.

Blocking road vehicles

There is a large risk that vehicles can become stuck on a crossing as a result of, for example, a traffic jam or a stop sign at the point of access to a major road. As the risk of blockage implies a demand for especially extensive safety devices, it is important that other methods of solving the problems be used.

CD is missing

This factor is included because of the arrangement of the decision to modify the CD installations. Whenever the modifications are complete the factor will become irrelevant.

Double track

At the crossing there are two or more tracks on which trains can pass, independent of one another.

If the system of tracks is such that there is in fact more than one track at the crossing but only one train can pass at a time, the crossing shall be regarded as a single-track crossing.

Only occasional traffic

Vehicular traffic is possible but does not normally occur due, for example, to the poor condition of the road or because the road is closed by locked gates.

Dangerous road vehicles

The proportion of vehicles that can result in serious consequences in the event of an accident (vehicles carrying dangerous goods, other heavy transport vehicles, buses, school buses) is considerably greater than the average on corresponding roads.

Dangerous cycle traffic
Dangerous pedestrian and/or cycle traffic
Dangerous pedestrian traffic

Either the road users come in groups or they are largely specially inexperienced. This applies to crossings close to large workplaces, sports facilities, swimming facilities, care institutions, schools, etc.

Train in view of cardriver approaching crossing

The vehicle driver shall, 50 m from the crossing and without turning his head, be able to see trains that will arrive at the crossing within 10 seconds. The train shall be visible with peripheral sight.

Main lines

The Swedish State Railway's national network, with the exception of lines for goods traffic but in addition to passenger train lines, in accordance with long-term agreements with principals for county traffic or their equivalent.

The factor will become irrelevant at the same time as "CD removed" factor.

Local road

Forest/agricultural access roads and exits from individual properties where there are no activities that generate considerable traffic (Road 4 in accordance with the inventory record).

Slow road vehicles

The proportion of tractor trailers, agricultural machines, forestry machines, etc. is significantly higher that the average for similar roads.

Motor driven vehicles

Traffic with motorized vehicles is not prevented by the nature of the road or permanent devices to close the road.

Motor driven vehicles more than 20

The annual average daily traffic (AADT) exceeds 20 vehicles. Irrespective of the magnitude of the railway traffic, it is considered reasonable that a road safety installation be arranged wherever the motor-vehicle traffic is not insignificant, because the view may be reduced as a result of poor weather or other considerations.

Motor driven vehicles more than 50

The AADT exceeds 50 vehicles.

Train in view of cardriver approaching crossing

Vehicles drivers shall, 5 m from the crossing, be able to see a train that will reach the crossing within 10 s. An exact definition is given in the explanation of the concepts.

Rebuilding planned

Existing safety devices need to be modified as a result of their age, changes in other railway signal devices, etc. The factor will become irrelevant at the same time as the "CD removed" factor.

Maximum speed more than 140 km/h
Maximum speed more than 160 km/h

The maximum train speed at the crossing will exceed 140 or 160 km/h respectively, but not 200 km/h.

Disturbed traffic environment

The conditions are such that drivers' attention may be expected to be distracted considerably from the road safety device or an approaching train. This may apply to plan or profile conditions, connecting roads, other traffic, advertising signs or anything alongside or on the road.

TFP more than 1200
TFP more than 1600

The traffic-flow product (TFP) exceeds 1200 or 1600 respectively. The product is the annual average daily traffic on both the road and railway, unless especially irregular traffic conditions justify something else. One extreme example is a entrance to a leisure installation that is only used on Saturdays and Sundays and that crosses a track that is not normally used on these days.

Train fewer than 10

In a study made by the Transport Research Delegation (TFD S 1983:2, Item 4) it was pointed out that a small number of trains makes vehicle drivers less cautious.

Road width not less than 4 m
Road width not less than 5 m
Road width not less than 6 m

The road width is of significance in deciding whether B can be arranged, as a free exit lane is required.

Safety device options

The devices are listed in alphabetical order of their Swedish abbreviations in the flow chart.

A
Full barriers

AF
Full barriers with prolonged warning time.

AFH
Full barriers with prolonged warning time and obstacle detectors in the region of the crossing.

AH
Full barriers with obstacle detectors in the region of the crossing.

B
Half barriers.

BF
Half barriers with prolonged warning time.

CD
Automatic open crossing (flashing lights and bells)

D
Bells

E
Simple light signal

TRAP or PEDESTRIAN GATE
Pedestrian gate that draws the attention of pedestrians and cyclists to the fact that there is a track that prevents vehicles from using the crossing.

NOTHING
No protection is required. In the case of an electrified rail system, however, special warning devices to indicate the danger of electrical installations shall be installed.

K
St. Andrew's Cross

SOUND SIGNALS FROM TRAINS

LEVEL CROSSING INVENTORY FORM

Line . . . .
Section . . . .
Km No. . . . . +

View, m

Left-hand side of railway (with back to 0-km point)

50 m before crossing, to the left (without turning the head) . . . .
50 m before crossing, to the right (without turning the head) . . . .
5 m before crossing, to the left . . . .
5 m before crossing, to the right . . . .
At the crossing, to the left . . . .
At the crossing, to the right . . . .

Right-hand side of railway (with back to 0-km point)

50 m before crossing, to the left (without turning the head) . . . .
50 m before crossing, to the right (without turning the head) . . . .
5 m before crossing, to the left . . . .
5 m before crossing, to the right . . . .

Number of trains . . . .
Highest train speed, km/h . . . .
Road width, m . . . .
Road traffic, AADT, counted . . . .
Road traffic, AADT, estimated . . . .

Y N

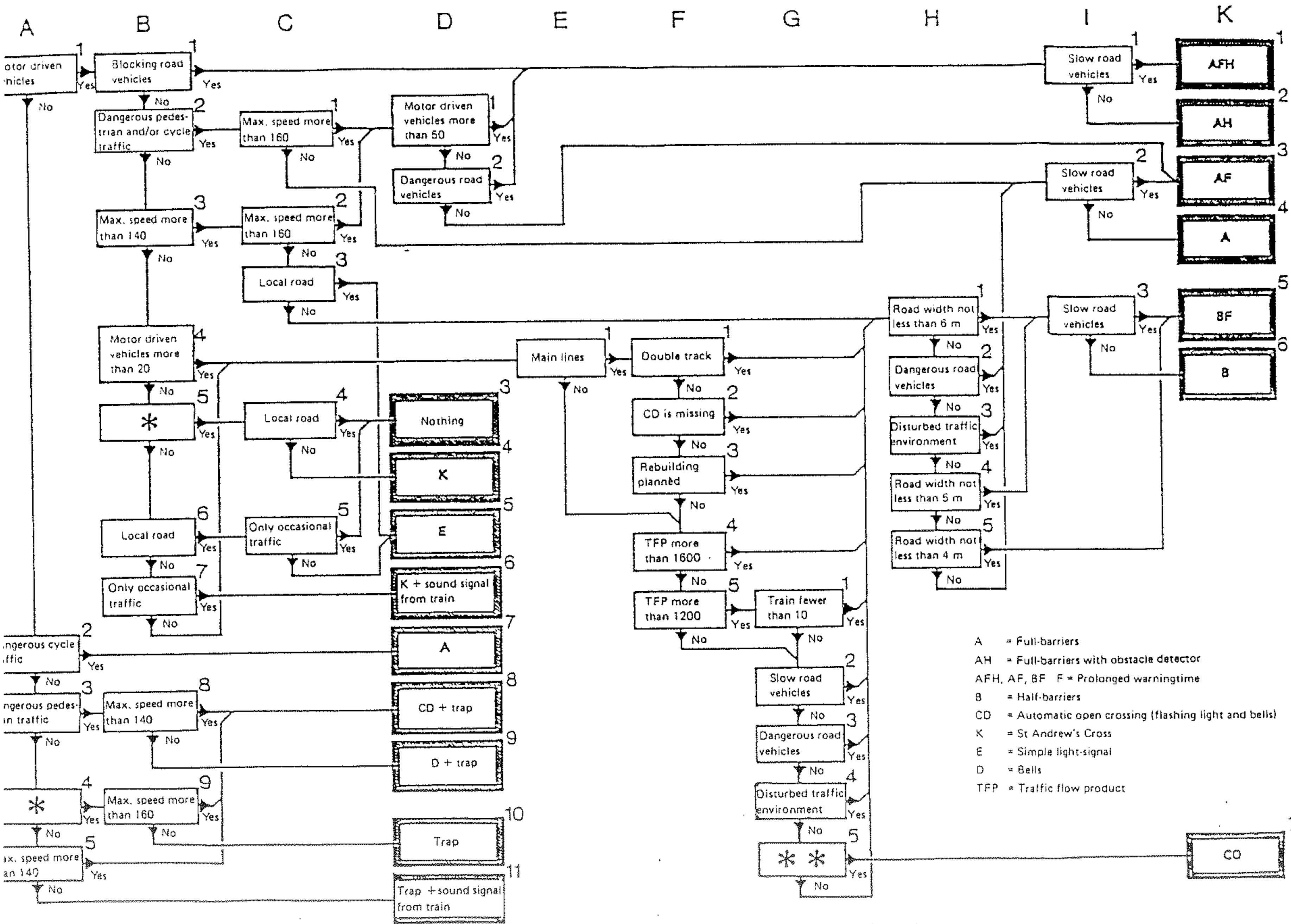
Only sporadic traffic . . . .
Road vehicles blocking tracks . . . .
Dangerous road vehicles . . . .
Slow-moving road vehicles . . . .
Disturbed traffic conditions . . . .
Dangerous cycle traffic . . . .
Dangerous pedestrian traffic . . . .
Motor vehicle traffic . . . .
Modification of the road-safety facilities being considered . . . . . .

Take from administrative data:

SJ trunk network . . . .
Double track . . . .
Forest/agricultural access road . . . .

From the above, calculate:

Good view . . . .
Train approaching crossing visible to car driver for 10 s or more . . .
Traffic-flow product . . . .



* Train in view of cardriver approaching crossing
Not less than 10 s. Distance to nearest rail 5 m.

** Train in view of cardriver approaching crossing.
Not less than 10 s. Distance to nearest rail 50 m.

Appendix 4

4

Other Safety Systems

Chapter 13 - Other Safety Systems

1. Hot box detector and Dragging brake detector

These two detector types are often combined in one place, normally positioned about 4 - 8 km before a station where a train can be stopped and examined.

Each detector has two alarm levels:

The hot box detector:

High level alarm	=	> 85° C overtemperature,
Low level alarm	=	> 20° C overtemperature,

The dragging brake detector:

High level alarm	=	> 400° C overtemperature,
Low level alarm	=	> 180° C overtemperature.

It is desired to have the detectors at shorter intervals – a hot box condition can develop very rapidly.

2. Land slide detector and warning

A detector cable with bronze conductors is buried in zig-zag configuration and anchored between the track and the dangerous area.

When a land slide occurs the cable brakes and sets the protective signals to stop.

The stop signals and their corresponding warning signals are battery supplied – normal power supply may be cut off.

The land slide signals are ATC-equipped.

3. Tail detector

Tail detector systems are not used in Sweden.

SJ regulations are built on the assumption that we don't drop any cars without the driver knowing it. The last car in a train must be connected to the main brake pipe.

4. Staff warning systems

- Automatic warning signals – vertical jumping yellow – are used at level crossing for platform trucks.

- In narrow tunnels we have automatic warning systems with lamps and warning bells distributed along the tunnel walls.

  The system is normally disconnected and opened only for staff protection when work is going on in the tunnel.

Chapter 14 - The Future

Signalling in the future is "High Technology" at it's best.

Relay technology is replaced by solid state devices and computer technology.

For the future in Sweden we see a development along two different forks:

1. Signalling for high traffic lines

Solid state, distributed geographical systems with

- integrated safety logic and object controllers positioned next to the object they control,
  - Controllers for: points
    signals
    level crossings
    special objects
- the object controllers connected to the control centre and to each other via a fail-safe multi channel network.
  - the physical transmissions can have almost any configuration and will be looped to get better system availability,
  - the logical channels between the controllers will have a geographical concept and follow the track layout.
- Opto cables will be used to a large extent for the transmissions.
  - a new fail-safe multiplexor for the opto transmissions has to be developed.

This project was started 1991 under the name ELVIS.

2. Signalling for low traffic lines

Radio based signalling systems without optical signals.
No conventional signalling at all.

All equipment concentrated to the control centre and to all tractive units on the line.

- beacons in the track for position information,
- radio for fail-safe data transmission between centre and ATC-equipment on the trains.
- A fail-safe central computer system that keeps track of everything that happens along the line and authorises train movements.

This project is partly implemented in RADIO-BLOC.
A specification group is working on the specification of the computerised control centre.

3. Modern technology

- Semiconductors are not inherently fail-safe in he same way as safety relays are. When a transistor fails it might as well go to a conductive state as to an open state.
- Integrated logic and processor circuits are low voltage, low power cir cuits and thus sensitive for differences in power supply and in return feeder potentials.

  They are also very sensitive for influence from contiguous circuits and for transients.
- Availability is of vital importance.

  A failure in a central computer will strike a large number of objects at the same time.

All this must be considered in developing new fail-safe devices.

- The evolution of computers and electronic components is very rapid. A device more than five years old is obsolescent.

  Therefore modularity with well defined boundaries is necessary. It must be possible to convert a module to more modern technology without affecting other parts of the system.

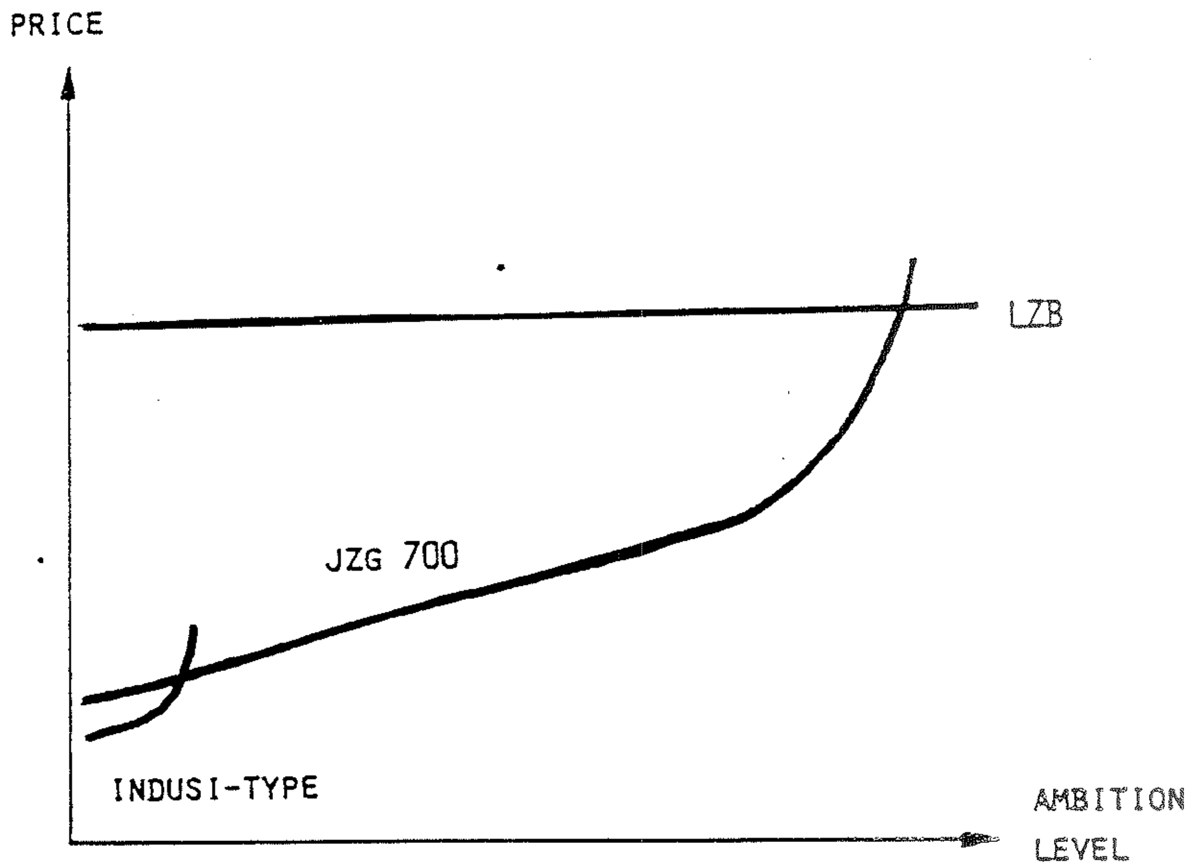
4. Maintenance.

- Maintainability has to be built in from the very beginning.
- Fault seeking aids and suitable tools must be developed and introduced, both for hardware and for software.
- Principles for handling and storage of software must be determined.
- Modularity means connectors between different modules – but contacts mean trouble in the long run if not suitable types are used. Gold plated contacts are most often used but gold is soft and wears rapidly.

5. Signal engineers

A signal engineer is no longer a mere "circuit maker". A modern signal engineer must be a high educated, well trained electronic expert.

ATC - COSTS



ATC - Requirements

Primary:
- one man driving
- higher safety
- low cost

Secondary:
- driver friendly
- facilitate higher speeds
- facilitate simpler optical signals
- facilitate economical traffic controle on low traffic lines
- extension of the signalling system into the locomotive
- new fail-safe, high capacity, link from track to train
- basic component for future signalling

∴ Intermittent system with large amount of information

Gross cost

900	locos	125 msek
12 000	signals	
10 000	speed restrictions	270 msek
Training of drivers		15 msek
Training for installation		
Training for maintenance		6 msek
Total investments		416 msek
Annual costs		7 msek

Economical benefits from ATC

	Avoided investment	Annual saving
- single driver		150 msek
- no general resignalling	500 msek	
- reduction of accidents		30 msek
- track	30 msek	6 msek
- signalling	90 msek	5 msek
- miscellaneous	?	?

Reduced signalling costs

	Avoided investment	Annual saving
- demounted speed signals		0,1 msek
- high speed signalling	80 msek	4 msek
- point speed signalling	20/2 msek	1 msek
	90 msek	5,1 msek

Reduction of accidents

	Annual saving
- train collissions	22 msek
- entrance derailments	6 msek
- material stress derailments	3 msek
- goods damages	0,2 msek
	31,2 msek

Reduced track costs

	Avoided investment	Annual saving
- reduced track maintenance		2,6 msek
- reduced point maintenance		3 msek
- not needed turn out points	20 msek	0,2 msek
- reduced safety distance	24/2 msek	
	32 msek	5,8 msek

Miscellaneous benefits

- safety good will
- less stressed drivers
- less days of sick leave
- protection during track maintenance
-
-
-
- costs posed on society
- future signalling

THE ATC-SYSTEM SHALL

- DISPLAY MAXIMUM ALLOWED SPEED
- WARN AND BRAKE IF THIS SPEED IS EXCEEDED
- WARN AND BRAKE IF THE DRIVER DOES NOT REDUCE THE SPEED BEFORE REACHING A SPEED RESTRICTION
- ACTIVATE THE EMERGENCY BRAKES IF A SIGNAL SHOWING STOP IS PASSED.

ACCURATE SUPERVISION

NEEDS ACCURATE INFORMATION ABOUT:

- MAX ALLOWED SPEED

- TARGET SPEED

- TARGET DISTANCE

- GRADE

- TRAIN DATA

ADVANTAGE WITH LARGE INFORMATION CAPACITY

SAFETY/CAPACITY

- ACCURATE SUPERVISION MEANS: SAFE SUPERVISION BUT WITHOUT UNNECESSARY RESTRICTIONS
- HELPS THE DRIVER AND CONTINUOUS SUPERVISION
- FIXED SPEED RESTRICTIONS DUE TO CURVES, TRACK MAINTENANCE ETC.
- A MISSING BEACON WILL BE DETECTED
- A MISSING PAIR OF BEACONS WILL BE DETECTED

FUNCTION/CAPACITY

- MANY DIFFERENT SPEED LEVELS
- EXTRA INFORMATION DIRECT FROM INTERLOCKING
- REASONS FOR THE SPEED RESTRICTION
- DIFFERENT LEVELS OF BRAKING

EXPANDIBILITY

- EASY TO EXPAND IN DIFFERENT STEPS
- COMPATIBILITY BETWEEN DIFFERENT LEVELS OF AMBITION

ADVANTAGES WITH INTERMITTENT ATC

- PRICE

- MAINTENANCE COSTS

DISADVANTAGES

- INFLUENCE ON LINE CAPACITY IF THERE ARE LESS THAN 2 MINUTES BETWEEN THE TRAINS

- REPEATER BEACONS BEFORE AND AFTER STATIONS ARE OFTEN NEEDED IN DENSE AREAS

INSTALLATION

- THE BEACONS CAN BE PLACED NEAR THE SIGNALS WHICH GIVES SHORT CABLES

MAINTENANCE

- AUTOMATIC DIAGNOSIS AND FAULT INDICATION

MISCELLANEOUS

- THE TRANSMISSION LINK CAN ALSO BE USED FOR OTHER THINGS AS RADIO CHANNEL CHOISE, POSITION, BLOWING OF THE HORN ETC

SJ ATC SAFETY ACTIVITIES

- SPECIFICATION GROUP
- DESIGN PRINCIPLE DISCUSSIONS: RULES, DIVERSITY, TESTS

- PARTICIPATION IN SUPPLIERS VERIFICATION
- PARTICIPATION IN FAULT TREE ANALYSIS
- PARTICIPATION IN FAULT EFFECT ANALYSIS

- NTH AS CONSULTANTS FOR TRANSMISSION SAFETY (4 MANYEARS)
- TRANSMISSION LAB TESTS
- TRANSMISSION FIELD TESTS
- TRANSMISSION PROTOTYPE TEST LINE
- TRANSMISSION 0-SERIE TEST LINE

- NTH AS CONSULTANTS FOR EVALUATION UNIT (3 MANYEARS)
- PROTOTYPE TEST LINE
- LOCO DRIVER TEST
- 0-SERIE TEST LINE
- SIMULTATION TEST LINES

- EXPERIENCE FROM OPERATION

SIMULATION TRACKS

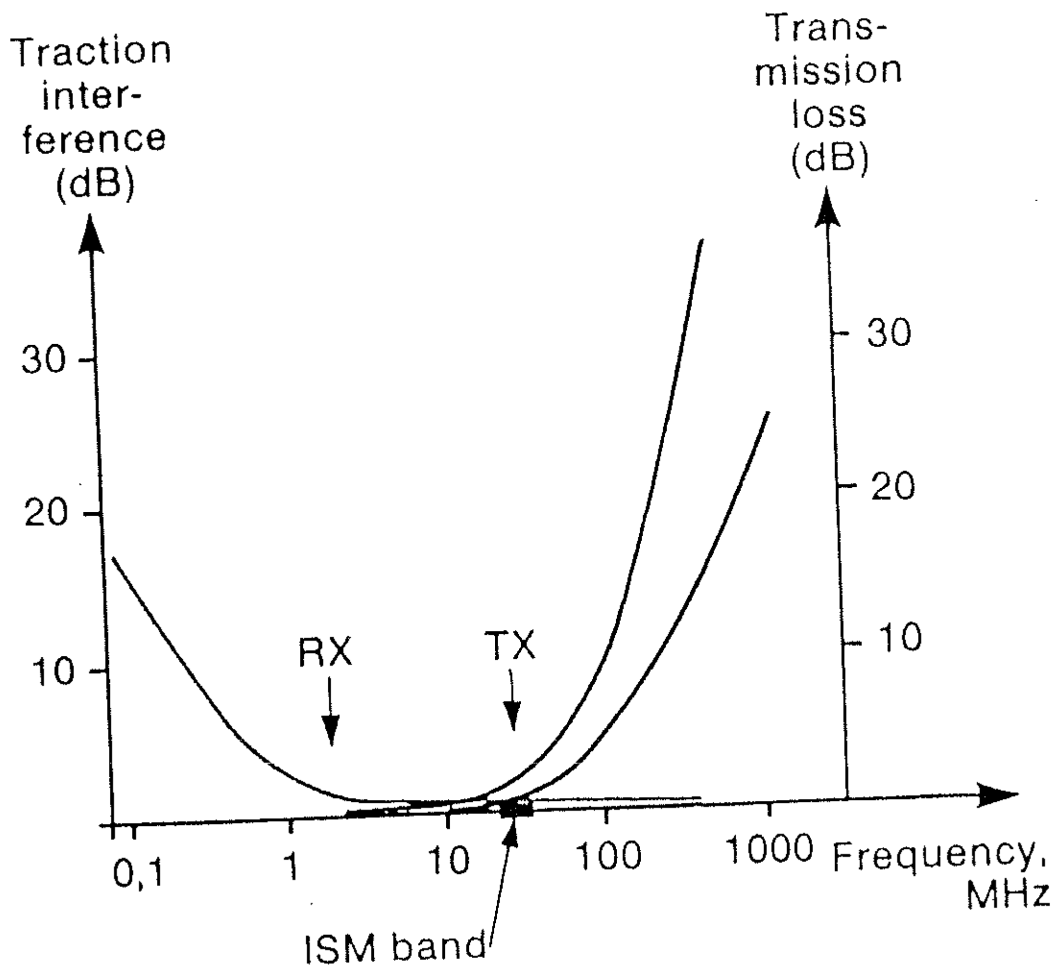
- SUPPLIERS SYSTEM TEST

- ACCORDING TO SPECIFICATION

- REAL LINES

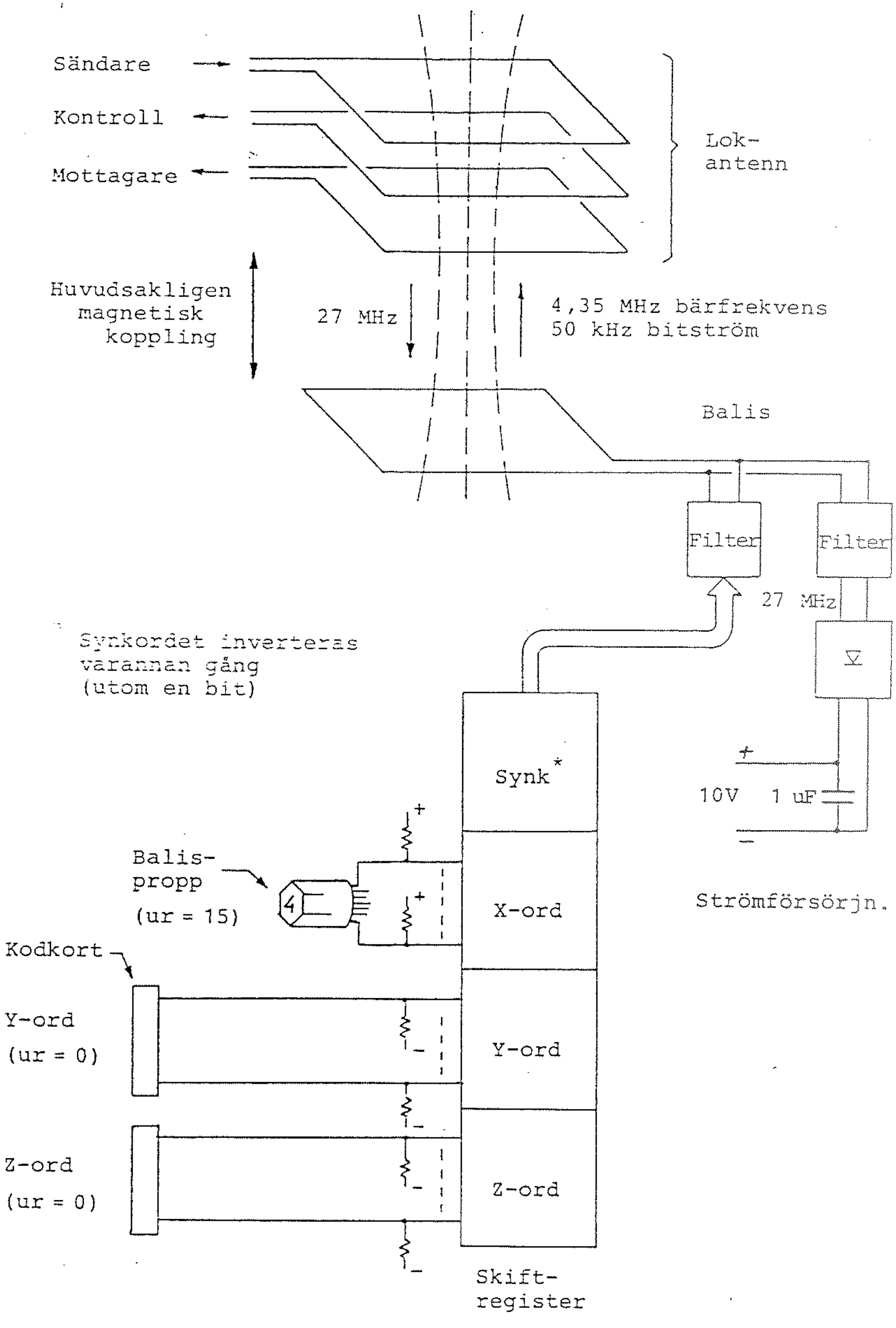
- ODD CASES

CBS/A SJÖBERG, 86-03-18

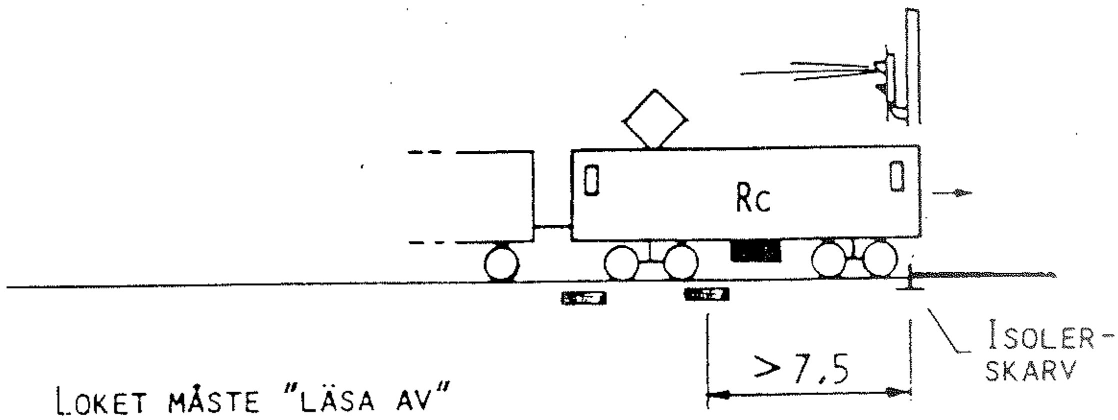


Choice of frequencies for JZG 700

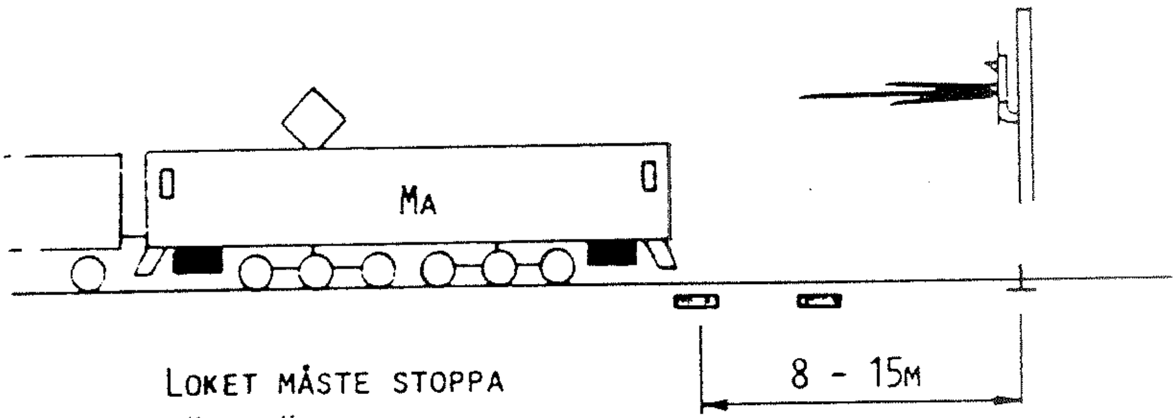
———	Relative interference level from the traction current
———	Attenuation by 10 mm iron ore concentrate
———	Attenuation by 100 mm water
RX	Information frequency
TX	Scanning frequency



ATC-transmission

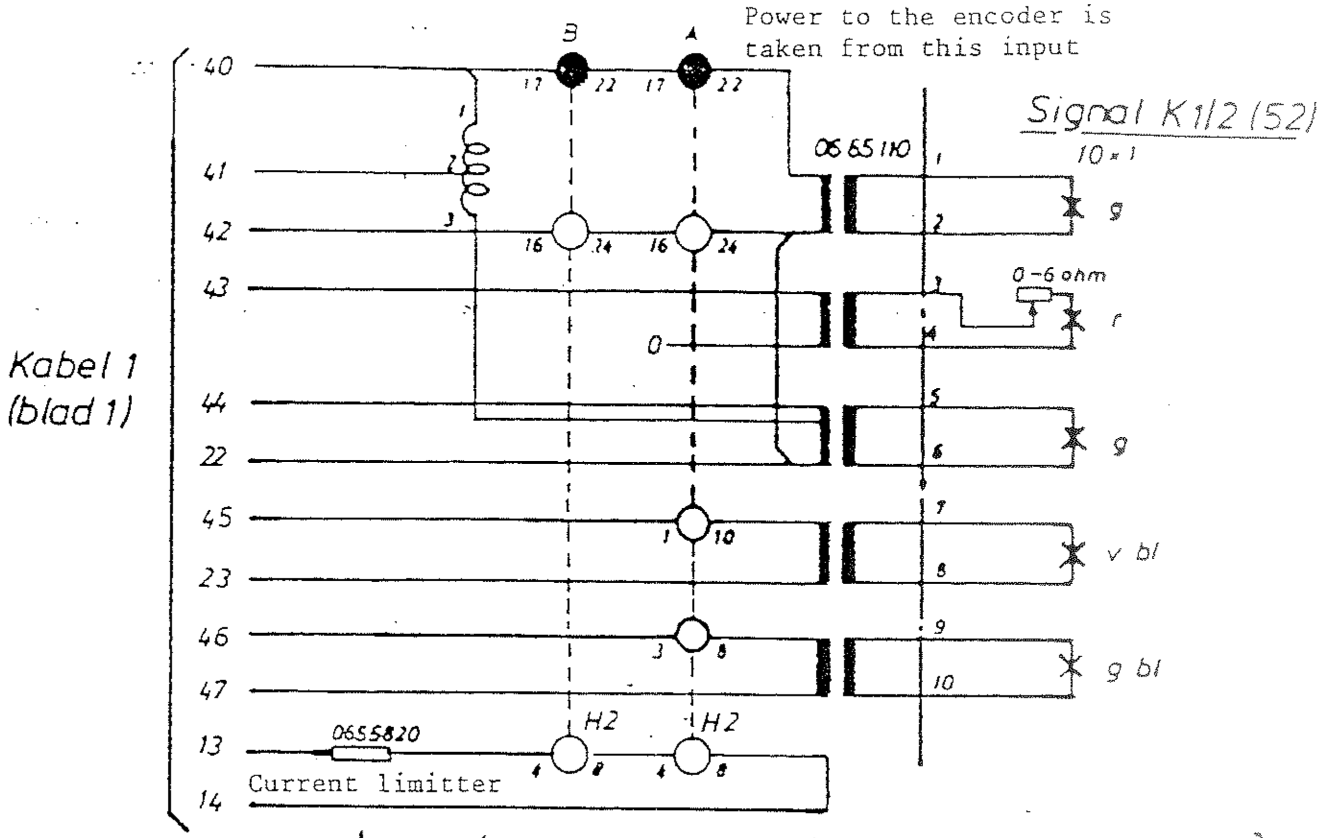


LOKET MÅSTE "LÄSA AV"
ALLA BALISER INNAN SIGNALEN
STÄLLS TILL STOPP.



LOKET MÅSTE STOPPA
FÖRE FÖRSTA BALISEN.

BALISPLACERING VID SIGNAL



All inputs are current sensing

A encoder = speed info

B encoder = distance info

På anläggningsritningar ritas kodaranslutningarna på detta sätt. Rita inte cirklarna för stora så att de förväxlas med reläer.

De normala kodaringångarna behöver inte ges funktionsbeteckningar -- deras funktion framgår av anslutningen i signalen.

Styrsignalingångarna däremot måste ha sina beteckningar utsatta enligt fig.

För styrsignalmotstånden anges artikelnummer och ev motståndsvärde.

Motståndets effekt anges inte -- den är inte entydigt definierad:

16 W = normalt utvecklad effekt.

60-120-150-190 W är vad motstånden enligt katalogdata tål beroende av hur de är monterade och kylda.

Vid fler motstånd i samma skåp numreras motstånden i löpande följd 1, 2, 3, ...

Att välja motståndsbeteckning efter signalens beteckning är olämpligt eftersom

a. samma styrsignal kan styra flera olika signaler.

b. en signal kan ha flera styrsignaler.

Kontaktfel på anslutningsdon till ATC-kodare
Fel som finns rapporterade i BV rapportsystem (SIFE).

Fördelning på år och olika kodartyper.

År	Kodartyp V1	V3	V4	L1	L2	L3	F1	F2	D1	D2	Totalt antal kont-fel	balis-fel
1985	9	1	14	3	5	–	5	–	–	1	38	355
1986	11	–	14	–	1	–	3	1	–	–	30	364
1987	13	–	13	–	3	–	1	2	–	1	33	391
1988	4	3	14	3	3	–	1	1	–	1	30	470
1989	9	–	15	3	2	1	–	4	–	–	34	443
	46	4	70	9	14	1	10	8	–	3	165	2023

2,5% av alla signalfel är ATC-fel

8% av ATC-felen är fel på anslutningsdon till kodare.

35 fel/år = felfrekvens 2,5 °/oo.

Typ	Antal	Ca-pris/st
V1	3675	800
V3	3350	4425
V4	1550	17349
L1	835	1000
L2	1030	2341
L3	335	9610
F1	1079	800
F2	1809	1700
D1	1032	1800
D2	255	4000

Ca 15 000 kodare i bruk

JA 90-05-31

Tvneär utspåring pga
varmgång.

ABr 4793

85-01-17
Rc5 1327
Tåg 5207
i Hallsberg

U

REDIGERAT REGISTRERAT DATA

STATUSFÄLT=
Statusfield

SRT ANSLUTEN =1	Type of ATC unit	
LME ANSLUTEN =0		
ATC MINDRE FEL =0	No faults registered	
REG.MINNESFEL =0		
REG.BATTERIFEL =0		
ATC-REG KOM.FEL=0		
TACHOBYGEL FEL =0		
TACHOMETER FEL =0		

ÅTERSTARTSADRESS =1651H
ÅTERSTARTSRÄKNARE = 93
ANTAL ATC-KOM-FEL = 0
HÖGSTA CPU BELASTN.= 29

TUMHJULSDATA
Thumbwheels

STH 1= 0 STH 2= 9	Max train speed limit = 90 km/h
LÄNGD= 6	Train length = 600 m
RET 1= 0 RET 2= 6 RET 3= 7	Retardation = 0,67 m/s^2
ANS 1= 1 ANS 2= 1	Brake delay time = 11 seconds
KURVA= 0 R1 = 0 R2 = 0 R3 = 0	No overspeed in curves.

TACHOBYGEL= 0FH

HAST.VID SENASTE BALISFELET = 0
VÄGM.VID SENASTE BALISFELET = 0

BALISDATA	X	Y	Z
A	00	09	00
B	84	00	F7
C	00	00	00
D	00	00	00
E	F7	00	F7

TID Time	/ST/HAST. Speed	VÄGM/ Place	BROMS Brake	NTSO<	PANEL INFORMATION Panel information		>ÖVRIG INFO.
1.34,5	14		T193	<	80		>
1.33,0	21		T193	<	80	URFAS STH 1=0 STH 2=6 LÄNGD=7 RET 1=1 RET 2=1 RET 3=0 ANS 1=0 ANS 2=0 R1 =F R3 =1 TABY1=0	>
1.33,0	21		NT193	<	80		>
1.31,5	27		NT193	<	80		>
1.30,0	33		NT193	<	80		>
1.29,0	38		NT193	<	80		>
.27,5	42		NT193	<	80		>
..26,0	47		NT193	<	80		>
1.24,5	51		NT193	<	80		>
1.24,5	53		NT137	<	80		>
1.24,0	54		T137	<	80		>
.22,5	59		T125	<	80		>
1.21,0	62		T106	<	80		>
1.20,5	63	12631	T 87	<	80		> BALIS X Y Z D4 3C 8E 99 71 3C
1.20,0	63		T 87	<	80		>
1.19,0	65		T 68	<	80		>
1.18,0	69		T 50	<	80		>
1.17,5	71		37	<	80	STH 2=9 LÄNGD=6 RET 1=0 RET 2=6 RET 3=7 ANS 1=1 ANS 2=1 R1 =0 R3 =0 TABY1=F	>
1.15,0	72		6	<	80		>
0.49,5	77	11994		<	80		> BALIS X Y Z 99 B2 C3 D4 00 8E
0.31,0	75	11602		<	80		> BALIS X Y Z 99 17 C3 D4 00 8E
0.30,0	75	11587	6	<	80		> BALIS X Y Z D4 3C 3C 99 D4 2E
+3.30.12,5	77			<	80		>
1.50,5	81		6	<	80		>
1.41,0	83	10524	T	<	80		> BALIS X Y Z D4 8E 3C 99 A5 71
1.31,5	84		T	<	80		>
1.26,5	84			<	80		>
1.10,5	80	9833		<	80		> BALIS X Y Z D4 8E 8E 99 C3 4D

Train direction

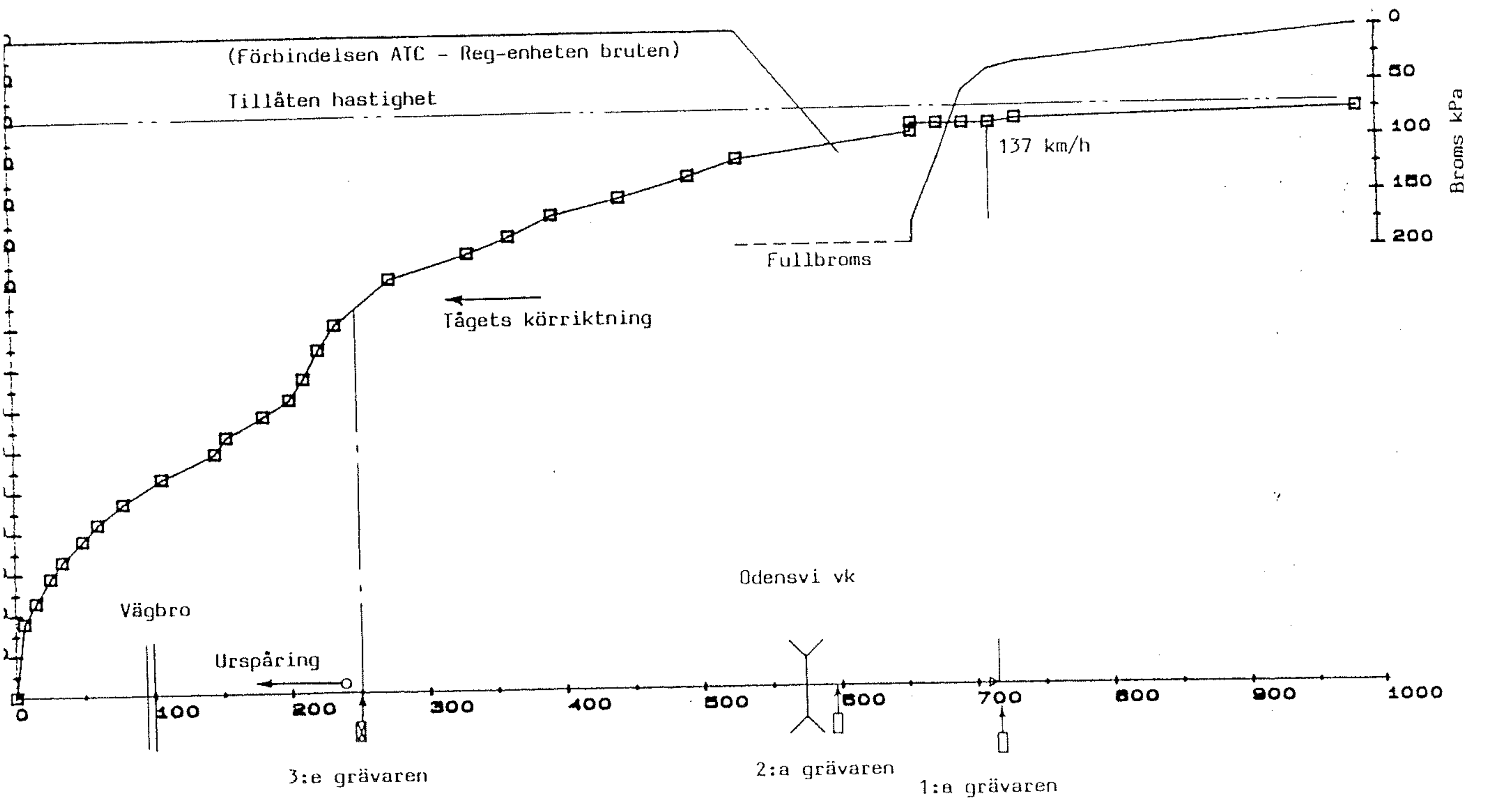
Balis info in hexadecimal form

First digit in pair is checknumb.

4-C-E = signal, full speed and no adv signal info.

9-1-C = distance to next signal = 325 m.

Opposing signal



Vretstorp - Östansjö

Tåg 134 1990-09-20,
kollision med tre grävmaskiner
Väg - hastighetsdiagram

JRU 901002

ATC HASTIGHET - DISTANS

5

Catenary/Substations

Catenary system

A catenary system for very high speeds (over 200 km/h) is characterized by a high tensile force in the catenary wire and the contact wire, uniform elasticity and very small assembling- and maintenance tolerances. At speeds up to 200 km/h you can call for somewhat lower demands.

The existing catenary system on the main lines utilizes the allowed tensile force of the catenary wire entirely (7,2 kN). The tensile force of the contact wire is also 7,2 kN against allowed 10 kN if you allow 20 % wear of the wire.

The catenary system consists of Y - suspension and an additional tube to increase the uniformity of the elasticity. To get an uniform elasticity a considerable increase of the tensile strength is needed. But by placing the contact wire with a certain sag the variations of elasticity can to a certain extent be compensated.

In stations with portals it has not been possible to install Y- suspension to decrease variations of elasticity. Here the catenary wire has instead been made of cadmiumbronze with higher tensile strength but also with much lower conductivity. The tensile force has by this been increased to 10 kN , which together with the corresponding increase of the tensile force in the contact wire has given a catenary system with almost the same variations of elasticity as the catenary system on theline. The reduced conductivity of the alloyed catenary wire is of no importance in the station sections where the main current passes through a by-pass cable.

Henceforth the cadmiumbronze wire is replaced with a 70 mm^2 copper wire with 19 threads.

On the line sections the adaption for the fast train has consisted of an increase of the tensile force to 9,8 kN in the contact wire. To be able, from an economical point of view, to keep the hangers a smaller reduction of the tensile force from 7,2 kN to 7,1 kN has been done.

Transformer substations

The demand of power and energy for a fast train is relatively great because the air resistance grows with the square of the speed. But one can compensate for this by giving the train a good aerodynamical design. One also tries to keep the train resistance down by making the train light which also decreases the forces to the track.
Even if a conventional electric engine (Rc) shortly gives a greater need of power when the adhesion is good, the fast train gives a more prolonged power peak.

To get a better basis in the design phase concerning the need of transformer power and energy two computer programs were used:

- a variant of the travelling time program
- the voltage drop program

In the first program you get as a result the energy consumption at wheel periphery, i.e.exclusive of losses in locomotives and without taking into consideration the energy consumption at starts after stops.
In the second program losses in the locomotive are also included, i.e. the energy consumption is calculated at the pantograph.
To be able to use this program you have to make a complete time-table design for different alternatives.

Calculations were made for the whole fast train net which in the design phase consisted of following lines:

Stockholm – Göteborg
Stockholm – Malmö
Göteborg – Malmö
Stockholm – Sundsvall

The calculations and other experience showed

- that the alternative fast train at maximum 200 km/h gave an increased demand for power mainly due to a concentration of freight trains called for to give space for increased passenger traffic late at nights,

- that an improved power factor for the fast train in view of this has small influence on the demand for power but is of interest to reduce the voltage drop in the catenary system and losses in substations and catenary.

- that the increase in the demand for power measured as 6 – min. – power in the substation at issue can vary from about 15 to about 25 %.
  The 1 – min. – power shows slightly lower figures.

Later it was decided to build a new transformer substation at Alingsås and some other investments in energy supply have been decided.
The investments in power supply on the line Stockholm – Göteborg line are mainly due to a general wish to increase power supply, to a slighter extent due to the fast train.

6

Station Platforms

Platforms

General

The airflow from a passing train depends on its form and speed. The fast train X2000 has a streamlined form which is much better than the conventional trains forms from the aerodynamical point of view. Foreign studies have shown that a fast train at high speed gives considerably less gusts and turbulence than a freight train at normal speed. The element of risk consists not only of the airflow but also of how quickly the train appears and which possibilities there are to avoid dangerous areas.

Before the start of the project the problem was studied in France and Germany by a special group. A special study was a also done by the Swedish Road and Traffic Research Institute.

Rules valid for platforms on the line Stockholm–Göteborg

1 Width of platform

The demands for width shall be kept in a length of at least 200 m.At the ends of platforms the width can be decreased by 2 m at most , however not at platform level crossings or stair-wells.

The demanded width is determined by adding the following factors.

–	Protection area (warning marking) see paragraph 2	0,5–1,5 m
–	Walking area for passengers	2,0 m
–	Addition for traffic with truck or other motor-driven vehicle	1,0 m
–	Other area for travellers :	
	o minimum area (up to 100 passengers)	0,5 m
	o addition for amount of travellers more than 100 with 0,5 m for each extra hundred travellers	x m

If the platform is shorter than 200 m the calculation is done in the following way :

Number of travellers / length of platform = y. If y (rounded off to nearest whole- or halfnumber) is more than the addition x as above, this bigger measure shall be used.

Example :
Island platform :
Maximum allowed speed on adjacent tracks : 40 and 200 km/h respectively.
450 travellers.
Truck traffic exists.
This gives the width :

– protection area 0,5 and 1,5 m respectively =	2	m
– walking area for travellers	2	m
– truck traffic	1	m
– area for travellers 0,5 m + 4 x 0,5 m =	2,5	m
Total :	7,5	m

If sufficient width can not be obtained , the speed on the adjacent track shall be reduced or other measures should be taken in every single case.

One square meter per person has been the basis for calculation of demanded area for passengers.

Objects on the platform

Objects with short extension, for example poles for the catenary system, should be placed at least the following minimum distance from the inner edge of the protection area :

- 1,5 m
- 2 m, when traffic with trucks takes place.

Buildings, houses etc; may be placed at the following distance from the inner edge of the protection area :

- 2 m
- 2,5 m, when traffic with trucks takes place.

If the amount of passengers is more than 200 the distances above should be increased by 0,5 m per 200 travellers.

The length of houses etc; shall not be more than 20 m.

If the minimum distances can not be reached special measures should be taken e.g. :

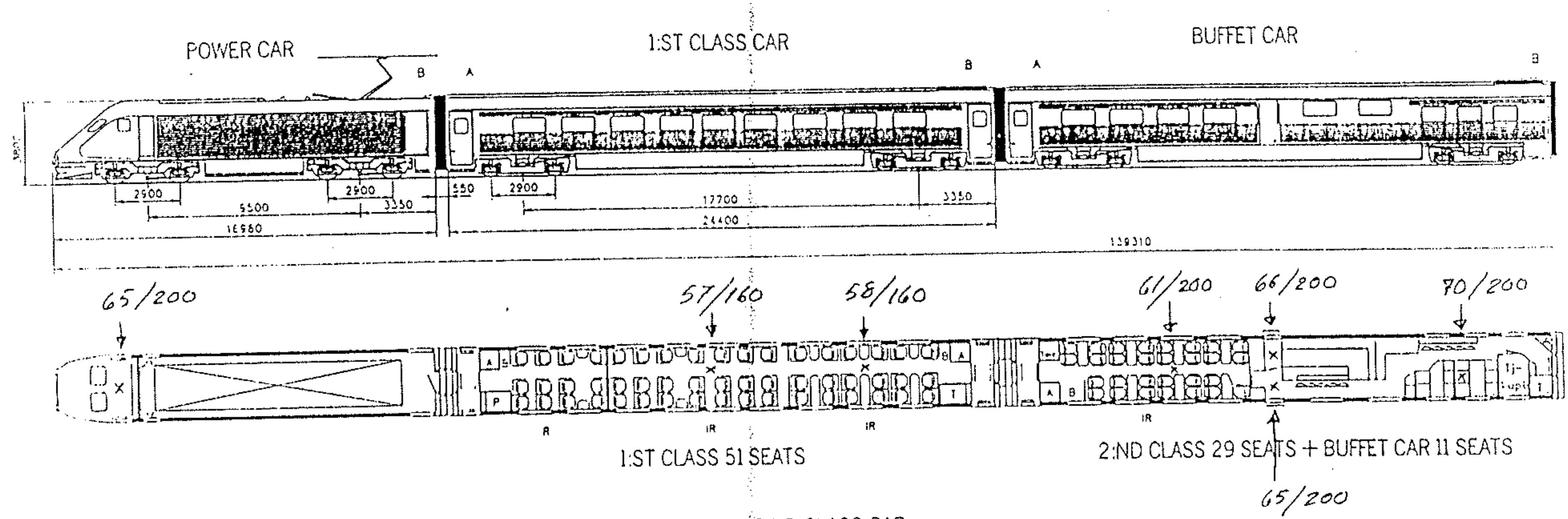
- warning signalling
- reduced speed on adjacent track
- truck traffic forbidden (when trains are running)

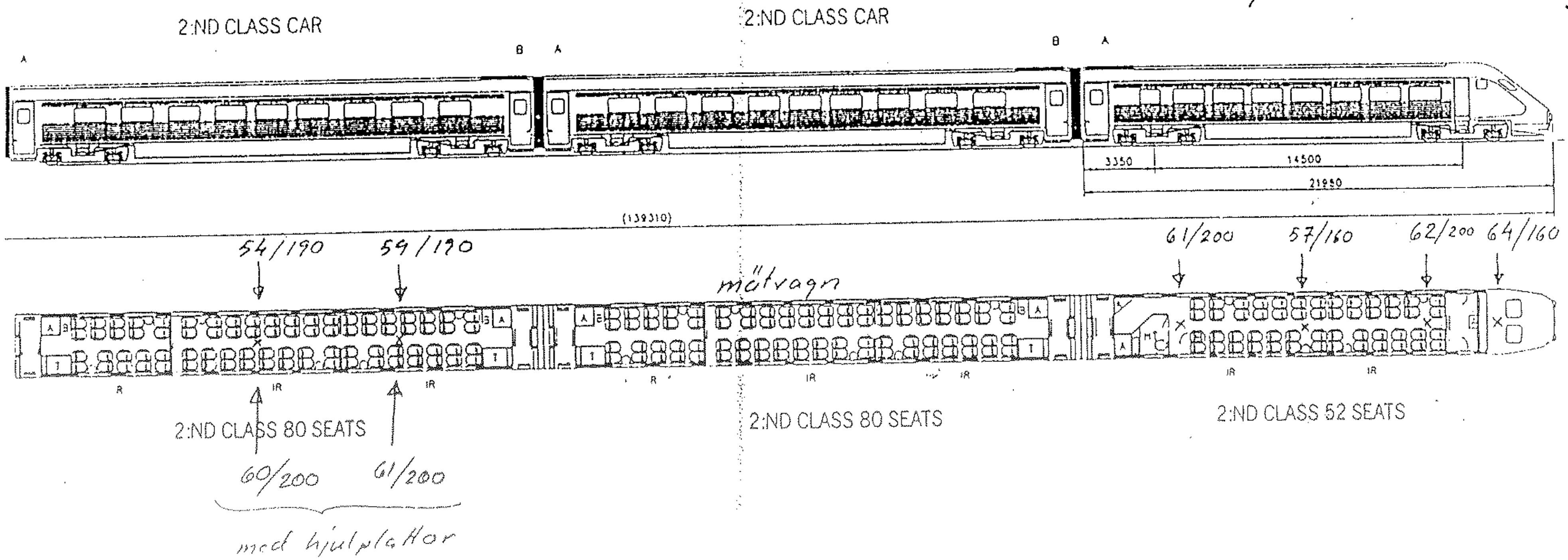
7

Noise & Vibration

Train configuration

Ljudnivå i dBA / hastighet i km/h





Resultat: invändiga mätningar

Mätposition	dB(A)	hast	bilaga
Förarhytt	65.4	200	5:1
Första klass: mitt	57.3	160	5:2
Första klass: upplag	58.3	160	5:2
Cafeteria	70.3	200	5:3
Cafeteriavagn: 2:a klass	61.1	200	5:3
Cafeteria: kök	65.8	200	5:4
Cafeteria: passage	65.3	200	5:5
Andra klass: plats 74	59.1	190	5:6
Andra klass: mitt	54.2	190	5:6
Manövervagn: fram	62.0	200	5:7
Manövervagn: bak	60.6	200	5:7
Manövervagn: mitt	57.2	160	5:8
Manövervagn: förarhytt	63.5	160	5:8
Från Katrineholmsmätningen:			
Andra klass: plats 45	59.5	190	5:9
Andra klass: plats 74	61.4	190	5:10

Extern ljudnivå

Ljudvnivåupptagningar i dB(A) från passager av olika tåg visas i ett
(6) dB(A)/tid-diagram i bilaga 6. Motsvarande frekvensanalyser i $dB(A)_{max}$
(7) visas i bilaga 7.

Att mäta maximala dB(A)-nivåer vid exempelvis tågpassager innebär komplikationer. Om man mäter den rena RMS-signalen efter A-filter får man det rätta värdet. Mäter man emellertid i oktavband (eller tersband) erhåller man en dB(A)-nivå som är summan av frekvensbandsnivåerna. Eftersom max nivå kan inträffa i resp oktavband vid olika tidpunkter blir det sålunda från oktavband beräknade dB(A)-värdet större än det icke frekvensuppdelade värdet. Skillnaden är liten (≈ 1 dB) men signifikativ vid utvärdering.

Nedan redovisas i tabell resultatet i $dB(A)_{max}$ av olika tågpassager. Ljudnivån redovisas dels som den icke frekvensuppdelade dB(A)-nivån, dels som den från oktavband beräknade maximala dB(A)-nivån. Mäthöjden är + 3.5 m.Tåg angivna inom parentes anger att de gick på fel spår. Avståndet blir då 29.5 m istället för 25 m.

Passage	hast (km/h)	$dB(A)_{rms}$	$dB(A)_{oktavband}$	Bilaga
$X2_2$	200	91.0	91.2	7:1
Rc + 8	141	92.0	93.3	7:1
$X2_3$	200	90.3	90.5	7:1
(Rc + 7)	≈130	91.8	92.1	7:2
$X2_4$	200	90.5	90.8	7:2
(2Rc + 35)	≈ 80	89.4	90.0	7:2
$X2_5$	200	90.2	90.4	7:3
(Rc + 34)	≈ 80	89.9	90.1	7:3
$X2_6$	200	90.5	90.7	7:3
Rc + 7	126	91.8	92.1	7:4
Rc + 22	≈ 80	88.2	88.5	7:4
Rc + 7	130	91.8	92.1	7:4
(Rc + 7)	≈130	90.9	91.6	7:5
Diesel + 2	≈ 80	87.3	87.9	7:5

5 UTVÄRDERING

Utförda ljudmätningar visar att kraven innehålls såväl internt som externt. Nedan kommenteras dock resultaten mer utförligt.

Intern ljudnivå

I samtliga resandeavdelningar underskrider resultaten klart 65 dB(A). Typiska värden är ca 60 dB(A) vid upplagen och något lägre nivåer mitt i vagnen. Även i förarhytten är resultatet bättre än kravet 70 dB(A). Typiska värden är här ca 65 dB(A).

Alla mätpositioner har inte kunnat mätas vid 200 km/h. En jämförelse med ljudnivåerna uppmätta vid 200 km/h visar emellertid att ingen risk finns att 65 dB(A) skulle överskridas i någon mätpunkt. Ljudnivå/tids-diagrammet i bilaga 3 visar de två mätpositionerna där högst ljudnivå uppmätts. I accelerationsfasen kan man där se att skillnaden mellan ljudnivån vid 160 km/h och den vid 200 km/h är ca 4 dB(A)-enheter. Adderas denna skillnad till de vid lägre hastighet uppmätta ljudnivåerna (som alla är lägre än 60 dB(A)) erhålls maximalt ca 64 dB(A). I verkligheten upplevs emellertid tillskottet i ljudnivå som nästan obefintlig. Detta bekräftas i någon mån även av mätningarna i Katrineholm där ljudnivån under vagnen var betydligt högre p.g.a hjulplattor. Se bilaga 5:9 och 5:10.

Rentonsljud från hydraulkompressor och fläktmotorer kan skönjas i resp vagn. Tersbandsresultatet från en typisk ljudmätning har lagts in i SJ-ritning
(8) 4MA-19329 blad 11 i bilaga 8. Resultatet visar att inget tersbandsvärde överskrider kurvan 65. Därmed uppfylls kravet enl specifikationen punkt 42.04.5.1.

VIBRATION AND COMFORT

In Sweden:

Wz<2,6 mean value over 10 km (lateral and vertical)

Tests in Germany, Trier-Dillingen:

RMS accelerations acc. to ISO 2631
Lateral <0,1 m/s^2
Vertical <0,15 m/s^2

Recommended by DB <0,2 m/s^2

VersA Minden - L1 L1 - Ftel 151005	X 2000	Anlage S.3.8 1 S

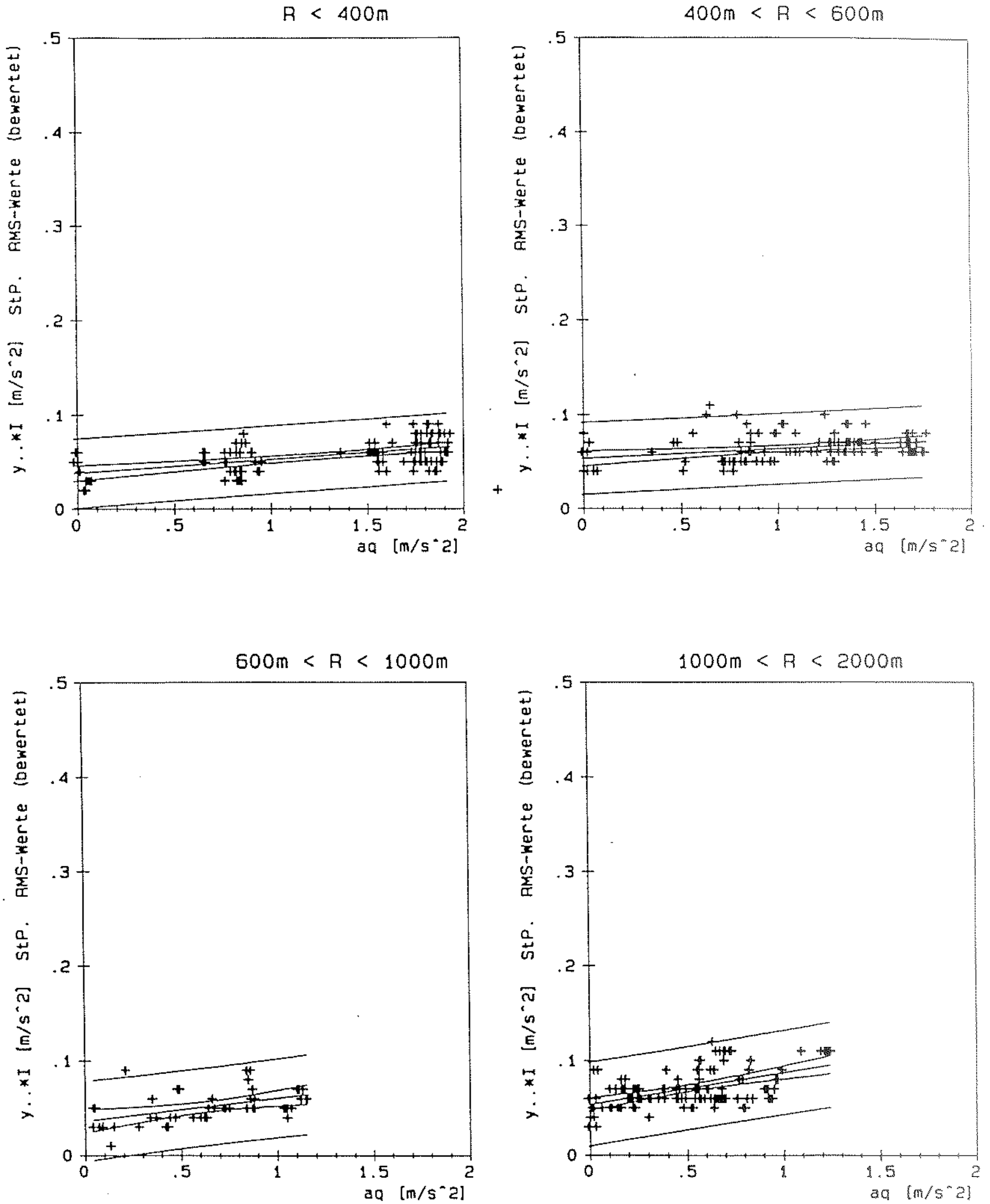
Y-Beschleunigungen im Wag.3 - RMS-Werte (ISO bewertet)

Meßgröße y..*I - Wag.3 - StP. - RMS-Werte (ISO 2631)

Strecke Trier - Dillingen

Vollbögen

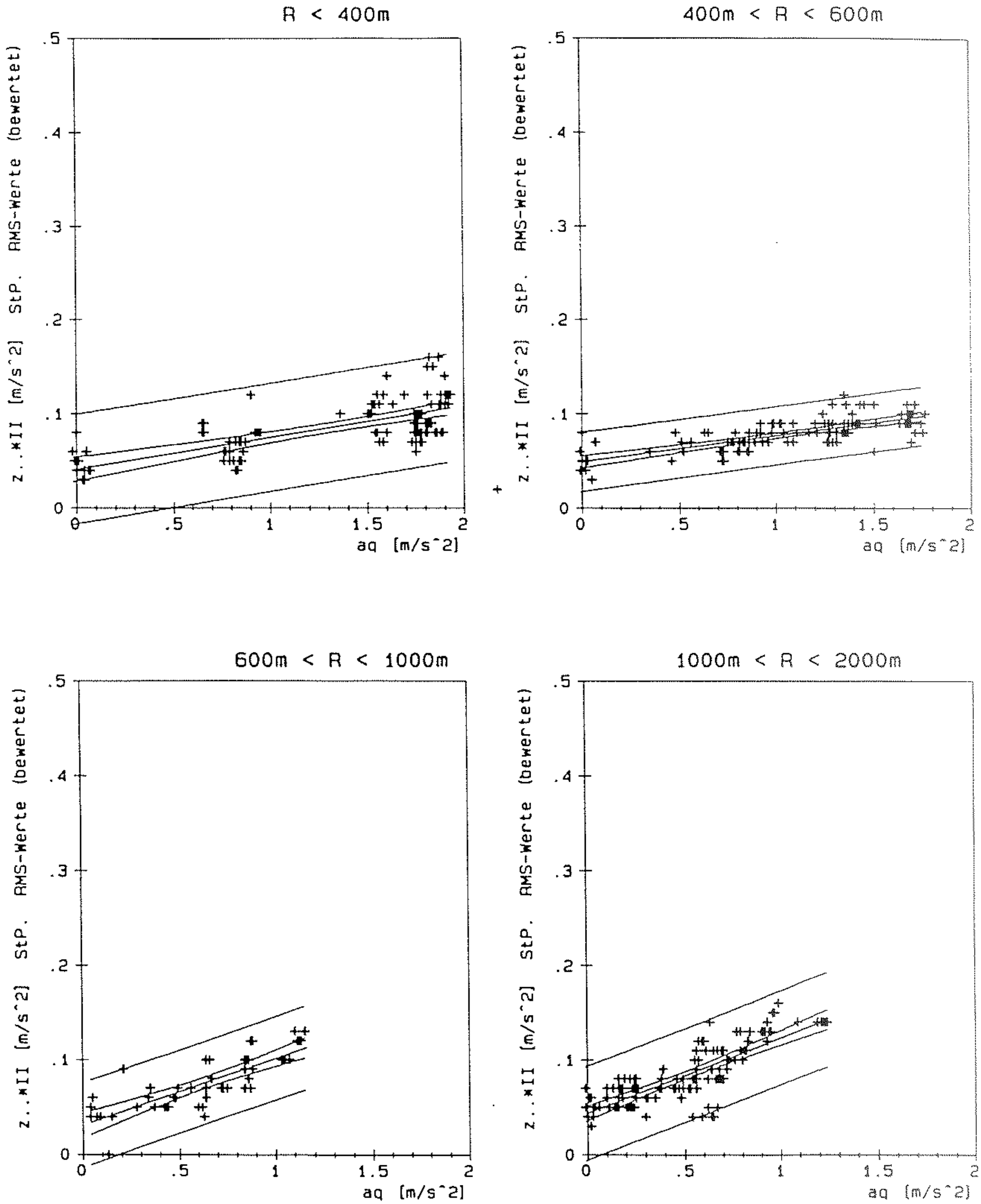
(Meßwerte der Linksbögen als Rechtsbögen dargestellt)



VersA Minden - L1 L1 - Ftel 151005	X 2000	Anlage 5.3.9.2.5

Z-Beschleunigungen im Wag.3 - RMS-Werte (ISO bewertet)
Meßgröße z..*II - Wag.3 - StP. - RMS-Werte (ISO 2631)
Strecke Trier - Dillingen
Vollbögen

(Meßwerte der Linksbögen als Rechtsbögen dargestellt)

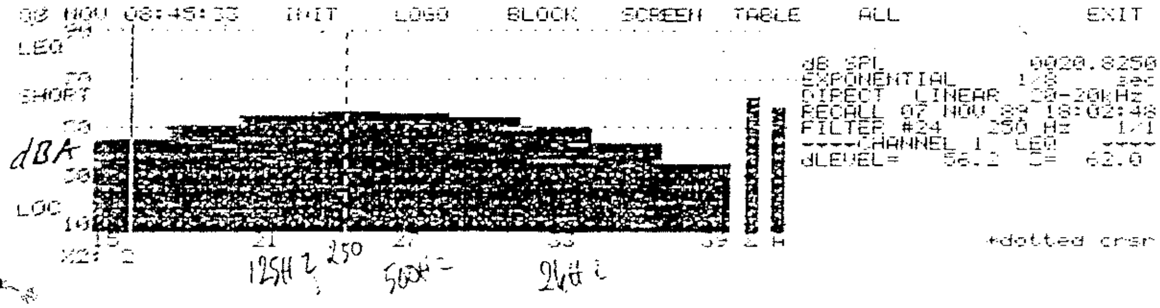


TRKBM89-019 *bilaga 5:4*

X2 INTERNAL +1.2 M 3100 RTA

Date and Time: 08 NOV 89 08:45
Recalled from register number 27

Control car: front 200 km/h

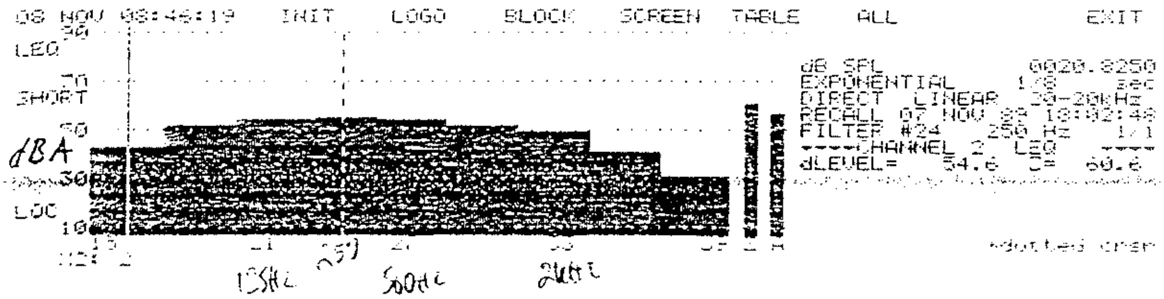


62,0 dBA

X2 INTERNAL +1.2 M 3100 RTA

Date and Time: 08 NOV 89 08:46
Recalled from register number 27

Control car: rear 200 km/h



60,6 dBA

DATA TYPE: LEQ spectra

	CHANNEL 1							CHANNEL 2						
#	FREQ	DISP-dB	RMS-dB	#	FREQ	DISP-dB	RMS-dB	#	FREQ	DISP-dB	RMS-dB	#	FREQ	DISP-dB	RMS-dB
15	31.5 Hz	44.9	44.3	18	63.0 Hz	50.4	50.4	15	31.5 Hz	42.4	42.4	18	63.0 Hz	51.2	51.2
21	125 Hz	54.8	54.8	24	250 Hz	56.2	56.2	21	125 Hz	54.0	54.0	24	250 Hz	54.6	54.6
27	500 Hz	55.5	55.5	30	1.00kHz	54.0	54.0	27	500 Hz	53.6	53.6	30	1.00kHz	51.5	51.5
33	2.00kHz	49.9	43.9	36	4.00kHz	42.6	42.6	33	2.00kHz	49.1	49.1	36	4.00kHz	40.5	40.5
39	8.00kHz	34.3	34.3					39	8.00kHz	30.5	30.5				
SUM		62.0	62.0	~~A-WEIGHT~~		~~[illegible]~~	~~[illegible]~~	SUM		60.5	60.6	~~A-WEIGHT~~		~~[illegible]~~	~~[illegible]~~

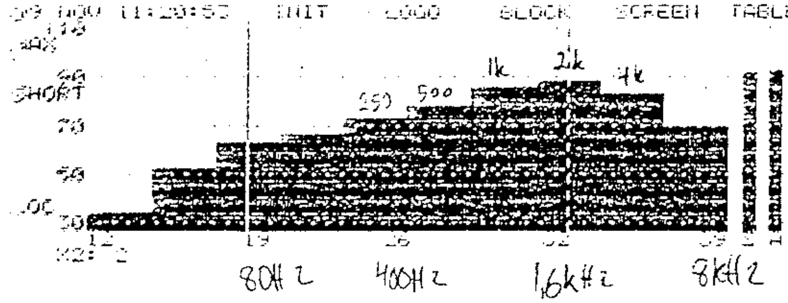
EXTERNAL TRKBM89-019 6/1989 f:1

MOHOLM 22 SEPT 1989 3100 RTA

Date and Time: 09 NOV 89 11:20
Recalled from register number 31

X2₂ 200 km/h

09 NOV 11:20:53 INIT LOGO BLOCK SCREEN TABLE ALL EXIT
RECALLED FROM # 31



dB SPL 0012.1525
EXPONENTIAL 1/8 sec
DIRECT LINEAR 20-20kHz
RECALL 09 NOV 89 09:15:16
FILTER #33 2.00kHz 1/1
----CHANNEL 1 MAXIMUM----
dLEVEL= 88.2 Σ= 91.2

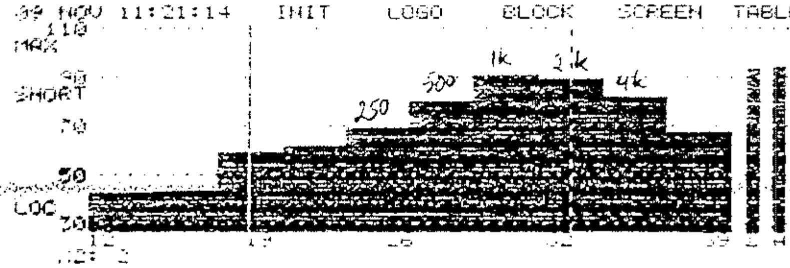
*recall data

MOHOLM 22 SEPT 1989 3100 RTA

Date and Time: 09 NOV 89 11:20
Recalled from register number 32

Rc+8, 141 km/h

09 NOV 11:21:14 INIT LOGO BLOCK SCREEN TABLE ALL EXIT
RECALLED FROM # 32



dB SPL 0028.3825
EXPONENTIAL 1/8 sec
DIRECT LINEAR 20-20kHz
RECALL 09 NOV 89 09:16:11
FILTER #33 2.00kHz 1/1
----CHANNEL 1 MAXIMUM----
dLEVEL= 89.1 Σ= 93.3

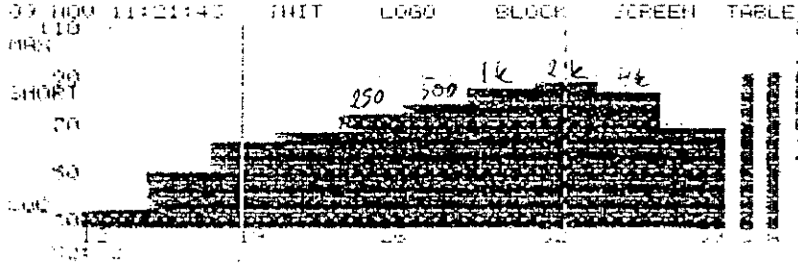
*recall data

MOHOLM 22 SEPT 1989 3100 RTA

Date and Time: 09 NOV 89 11:20
Recalled from register number 33

X2₂, 200 km/h

09 NOV 11:21:40 INIT LOGO BLOCK SCREEN TABLE ALL EXIT
RECALLED FROM # 33



dB SPL 0014.1275
EXPONENTIAL 1/8 sec
DIRECT LINEAR 20-20kHz
RECALL 09 NOV 89 09:16:11
FILTER #33 2.00kHz 1/1
----CHANNEL 1 MAXIMUM----
dLEVEL= [illegible] Σ= 90.5

*recall data

ASEA BROWN BOVERI

Teknisk rapport
Technical Report

TR P 9213

Författare - Author
PKD Henrik Tengstrand

Godkännare - Approved by
PK Hans Olsson

Uppdragsgivare - Requested by
RTU Åke Alexandersson

Titel - Title
Noise measurements of X2000 in Germany

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Datum - Date: 92–07–08

Reg.

Sida - Page: 1

[ ] Utredning, teoretisk undersökning - Analys, theoretical investigation

[X] Provning, experim. undersökning - Test, experimental investigation

[ ] Delrapport

[X] Slutrapport

Provning/undersökning avslutad
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Antal textsidor - No. of pages of text: 8

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Sammanfattning – Summary

Internal and external noise measurements were carried out 91–07–29 — 91–08–01 on X2000 during test runs on the Neubahnstrecke in Germany.

For comparison measurements were also carried out on ICE–V and ICE in regular service.

For external noise, at 25 m from center of track, the measurements show 89 dBA at 200 km/h for X2000. This is 2 dBA lower than has been measured in Sweden and the better result is probably because of the excellent track quality on the Neaubahnstrecke. The noise from the motor car was observed to be about 6 dBA higher than noise from the trailer cars.

Comparable measurement for ICE–V shows about 2 dBA lower levels than X2000. The ICE–V is equipped with noise reduction wheels and has a shorter train (only 2 middle cars).

The internal noise measurements in first class saloon on X2000 in speeds of 220 – 230 km/h show typical 59 dBA in free field conditions and 65 dBA in tunnels.

Comparable measurements for ICE in regular service at 250 km/h show typical 70 dBA in free field conditions and 71 dBA in tunnels. The high levels in ICE is dominating by low frequency (125 – 250 HZ) structure born noise.

For future development and to meet higher requirements on external noise on X2000 it is recommended that both motor car and trailer car noise have to be reduced with 4 – 5 dBA.

To reduce the noise in the motor car the wheel/rail noise and the gear box noise have to be reduced. The whistling noise from the traction motor has also to kept in mind if higher rotation speed is introduced.

Distribution
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Enbart sida 1 - Page 1 only
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Nyckelord - Ämnesord

Keywords
X2000
Noise measu...

Övriga nyckelord

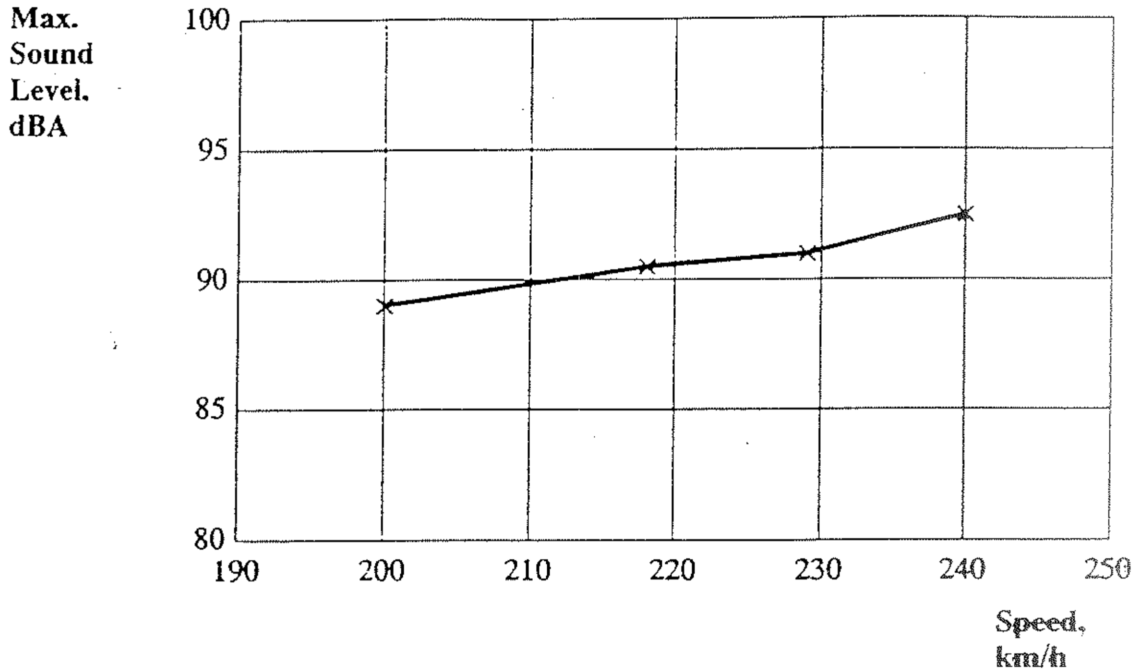

Figure 2. External noise level measurements at 25 m from center of track 1 for X2000 at passage of different speed with motor car first.

7. Frequency analyses

The reason for carrying out frequency analyses of the sound recordings, was the interest in pointing out the sound generating sources – if possible. This requires that the analysis is based on periods of time corresponding to passages of specific trailer or motor bogies. Therefore the following choices were made:

The analyses were only carried out for the 4 m distance, as the bogies play a relatively larger sound generating role, this close.

Each passage was studied in the time domain. The motor bogie was hereby easily identified (being the noisiest one). Together with the motor bogie, a "suitable" trailer bogie was chosen.

X2-tåg, högre prestanda	Prediktering av ljudeffektnivåer från källor i boggi samt externljud för komplett fordon.

3. Predikterade ljudeffektnivåer

I tabell 1 redovisas predikterade medelvärden för ljudeffektnivåer från boggikällor i aktuella **X2000-tåg**.

trailer bogies (total)
drive system
powered bogies (total)

Ljudkälla	X2-tåg,hp,5-8v 250 km/h	X2-tåg,hp,5-8v 200 km/h	X2-tåg,sd,5v 200 km/h
Löpboggi/hel	123 dBA	120 dBA	120 dBA
Drivsys/1st	125 dBA	123 dBA	122 dBA
Drivboggi/hel	**129 dBA**	**127 dBA**	**126 dBA**

Tabell 1 Predikterade medelvärden för **ljudeffektnivåer** från boggikällor i aktuella **X2000-tåg**.

4. Predikterade ljudnivåer

Max. ljudnivåer inträffar mitt för den 2:a drivna boggin i motorvagnen (=den som gränsar mot 1:a löpboggin efter drivenheten).

I tabell 2 nedan redovisas en sammanställning över predikterade medelvärden för externljudnivåer bl.a. enligt ovanstående förutsättningar.

Ljudkälla	X2-tåg,hp,5-8v 250 km/h	X2-tåg,hp,5-8v 200 km/h	X2-tåg,sd,5v 200 km/h
Boggi	90,8 dBA	87,8 dBA	87,8 dBA
Drivsys	92,1 dBA	90,1 dBA	89,1 dBA
Aerodyn	86,8 dBA	79,6 dBA	79,6 dBA
Totalt	**95,2 dBA**	**92,3 dBA**	**91,8 dBA**

Tabell 2 Predikterade medelvärden för externljudnivåer gällande aktuella **X2000-tåg**. Mätavstånd: **25 m** från spårmitt.
Obs! Samma resultat för 5-8v.

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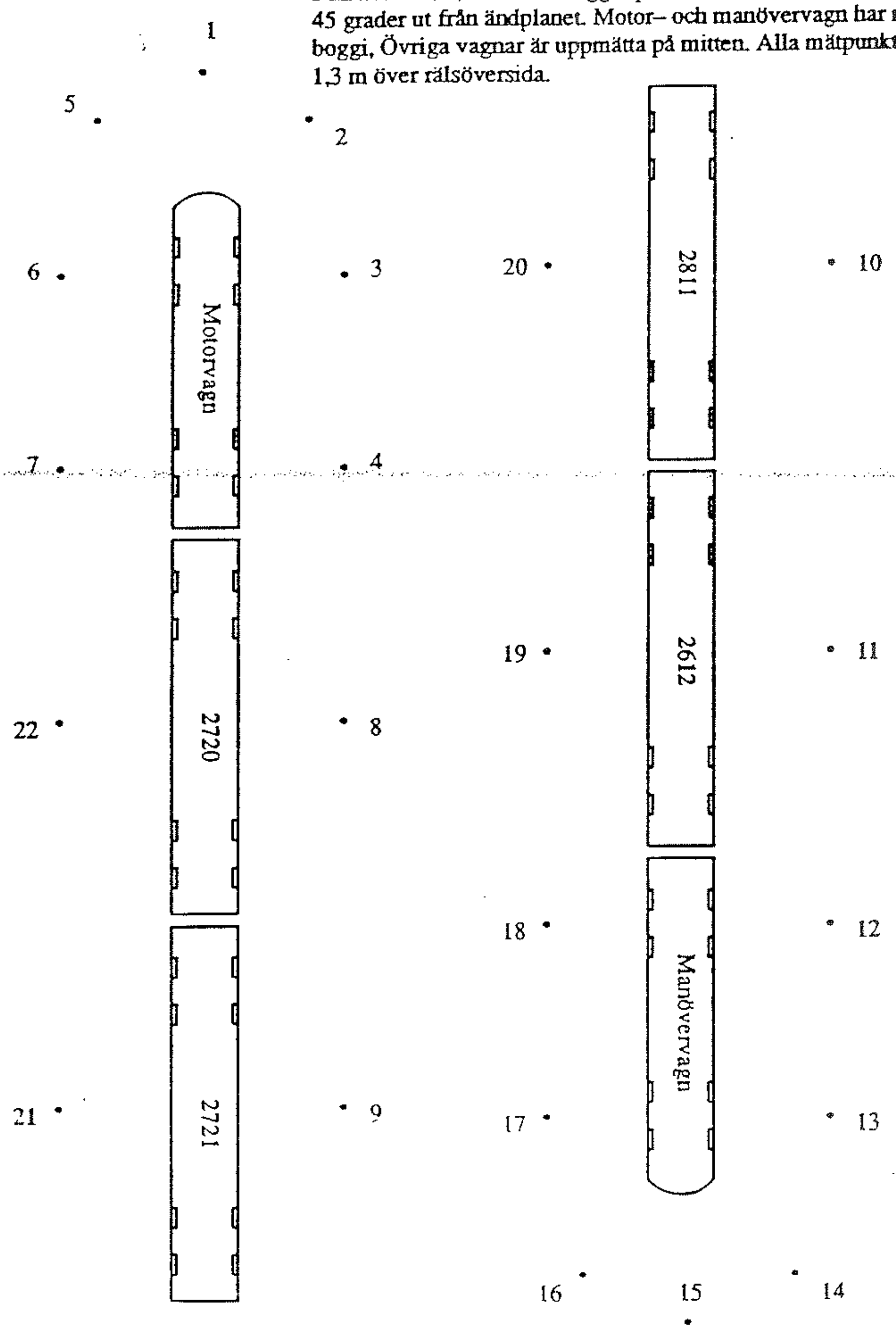
X2 Portugal	Mätresultat från ljudmätning av stillastående fordon

Figur 1 Placering av mätpunkter

Samtliga punkter placerades 5,96 m från korgsidan , motsvarande 7,5 från spårmitt. Punkterna 2, 5, 14 och 16 ligger på en tänkt kontur 5,96 m ut från korgsidan, och 45 grader ut från ändplanet. Motor– och manövervagn har mätts mitt för varje boggi, Övriga vagnar är uppmätta på mitten. Alla mätpunkter ligger på en höjd av 1,3 m över rälsöversida.



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X2 Portugal	Mätresultat från ljudmätning av stillastående fordon

Resultat

Uppmätta ljudtrycksnivåer i de olika mätpunkterna redovisas i tabell 1.

Mätpunkt nr:	Medelvärde dB(A)
1	71
2	78
3	84
4	84
5	77
6	84
7	86
8	77
9	73
10	71
11	57
12	67
13	60
14	49
15	47
16	50
17	53
18	62
19	68
20	70
21	72
22	77

De ovan angivna mätresultaten är framtagna enligt normen, d v s i varje punkt har tre "subjektiva" medelvärden noterats. Det avrundade aritmetiska medelvärdet av de tre värdena har avrundats till närmaste hela dB.

Kommentarer

Variationen i mätpunkterna var mycket låg. Den högsta förekommande spridningen, en differens om 2 dB(A) mellan högsta och lägsta värde, uppmättes i punkt nr 12.

Vid mätningarna längs tågets vänstra sida (motorvagnen framåt) placerades stativet med ljudmätaren i en rapsåker. Detta skulle teoretiskt kunna

Railway noise (dB(A))

Objectives for Banverket

	L_{eq}		L_{max}
	out of doors	indoors	indoors
New line	60	30	50
Upgrading	70	40	55
Existing environment	75	45	60*
New environment	60	30	50

* Can be exceeded twice / night

PREDICTION METHODS OF INTERNAL AND EXTERNAL NOISE LEVELS OF RAILWAY VEHICLES

PART 1

OBJECTIVE

COMPUTER CODE (APOLLO/FORTRAN)

- MAIN CODE: THE PROBLEM STRUCTURE AND METHODOLOGY

- SUB CODES: CALCULATION FORMULAS AND GENERALIZED MEASURED DATA

THE COMPUTER CODE WILL MAKE IT POSSIBLE TO:

* PREDICT SOUND POWER LEVELS OF INDIVIDUAL SOURCES (I.E. PREQUALIFICATION TESTS)

* PREDICT INTERNAL AND EXTERNAL NOISE LEVELS

* IDENTIFY AND EVALUATE CRITICAL NOISE SOURCES

* EVALUATE THE EFFECT OF CHANGING THE MAGNITUDE OF SPECIFIC STRUCTURAL DESIGN AND DYNAMIC LOAD QUANTITIES

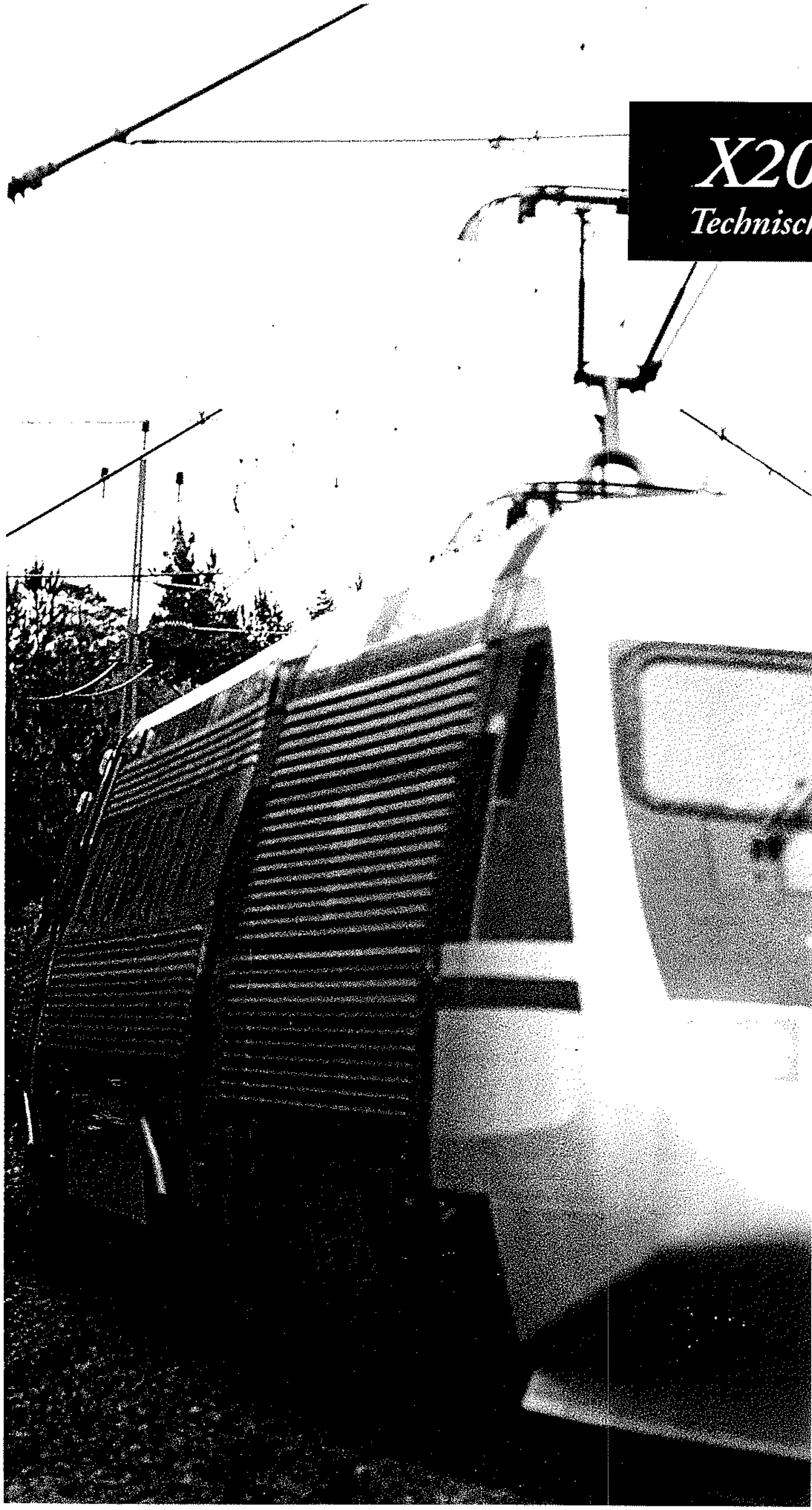
PART 1

RESULTS

* MAIN RESULT: COMPUTER CODE
* USERS MANUAL
* TECHNICAL BACKGROUND DOCUMENTATION
* IDENTIFIED PROBLEM STRUCTURE
* SUMMARIZED FINAL REPORT

8

Vehicles



X2000 DATA

Technische Daten des X2000

ABB tilting train technology cuts travel times by up to 30% on existing main line track.

In Sweden, the X2000 tilting train was put into revenue service in September 1990, reducing travel time on the Stockholm to Gothenburg route from four to less than three hours.

The train is already a great success, winning the competition against road travel and the airlines.

Die von ABB eingesetzte Technik der gleisbogenabhängigen Wagenkastensteuerung bei Reisezügen verringert die Fahrzeit auf den vorhandenen Gleisanlagen der Fernstrecken um bis zu 30%.

In Schweden wurde der mit dieser Technik ausgerüstete Zug X2000 im September 1990 in Dienst gestellt, wo er auf der Strecke Stockholm-Göteborg die Reisezeit von vier auf weniger als drei Stunden reduziert.

Der Zug hat sich bereits bestens bewährt und die Konkurrenz gegen die Verkehrsmittel Auto und Flugzeug für sich entschieden.

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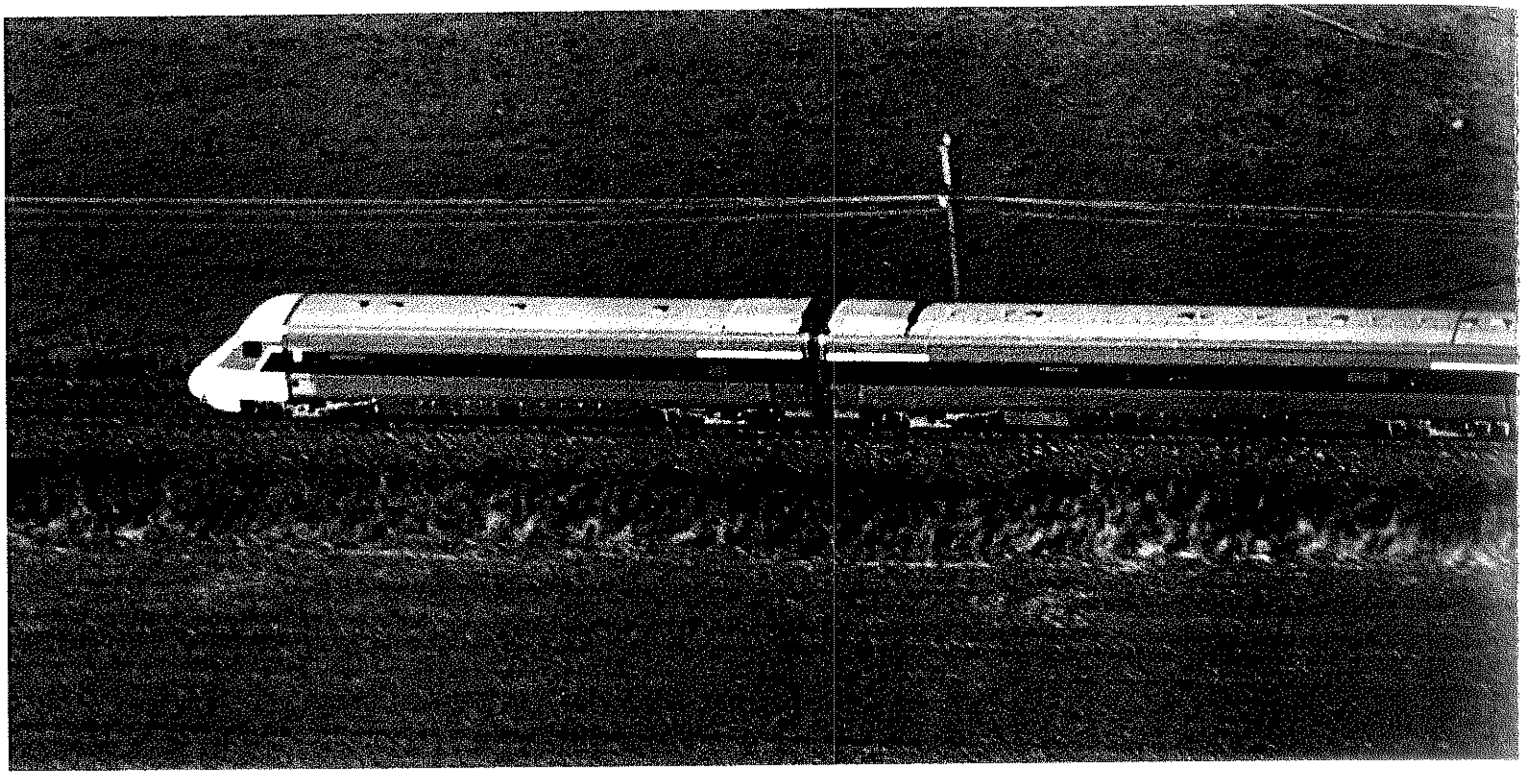


FLEXIBLE TRAIN CONFIGURATION

- 1 power car, up to 5 passenger cars, 1 driving trailer.
- 2 power cars, up to 12 intermediate passenger cars.

Weight empty power car	73 000 kg
Weight empty 1:st and 2:nd class car	47 000 kg
Weight empty buffet car	49 000 kg
Weight empty driving trailer	55 000 kg
Bogie distance power car	9.5 m
Bogie distance trailer car	17.7 m
Bogie distance driving trailer	14.5 m
Maximum width of train	3.08 m
Maximum speed	210 km/h
Maximum cant deficiency in operation	1.65 m/s²
Maximum cant deficiency, safety verified in tests	1.86 m/s²
Noise level in passengers compartments at 200 km/h	< 65 dBA
Noise level in drivers cab at 200 km/h	< 70 dBA

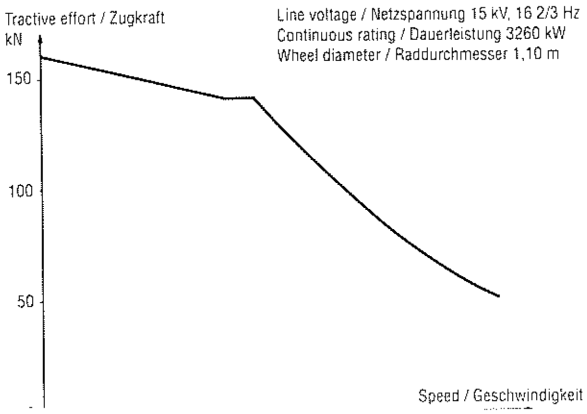
PROPULSION

Line voltage	15 kV (+ 20%/- 15%, 16 2/3 Hz)
Maximum power rating / power head	4.0 MW
Continous power rating /power head	3.3 MW
Intermediate link voltage	2400 V
Regenerative electric brake	

AUXILIARY POWER SUPPLY

Single central inverter for 3 x 380 V, 50 Hz, 360 kW/power head
1000 V, 16 2/3 Hz power for heating, battery charging etc.

110 V battery in power car	55 Ah
24 V battery in passanger cars	344Ah



FLEXIBLE ZUGZUSAMMENSTELLUNG

- 1 Triebkopf, bis zu 5 Mittelwagen, 1 Steuerwagen
- 2 Triebköpfe, bis zu 12 Mittelwagen

Leergewicht Triebkopf	73.000 kg
Leergewicht Wagen der 1 und 2 Klasse	47.000 kg
Leergewicht Speisewagen	49.000 kg
Leergewicht Steuerwagen	55.000 kg
Drehgestellabstand Triebkopf	9,5 m
Drehgestellabstand Mittelwagen	17,7 m
Drehgestellabstand Steuerwagen	14,5 m
Maximale Breite des Zuges	3,08 m
Höchstgeschwindigkeit	210 km/h
Max Überhöhungsfehlbetrag im Betrieb	1,65 m/s²
Max Überhöhungsfehlbetrag, Sicherheit in Prüfungen nachgewiesen	1,86 m/s²
Geräuschpegel in den Fahrgastabteilen bei 200 km/h	< 65 dBA
Geräuschpegel im Führerstand	< 70 dBA

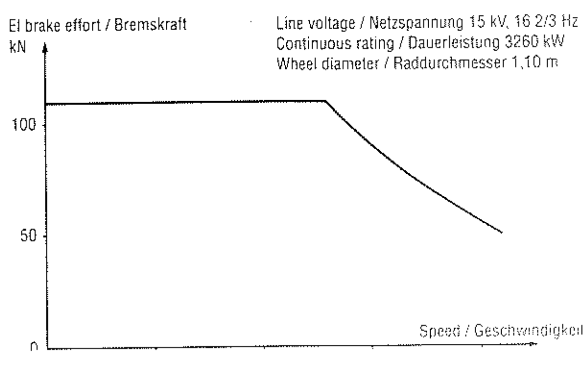
ANTRIEB

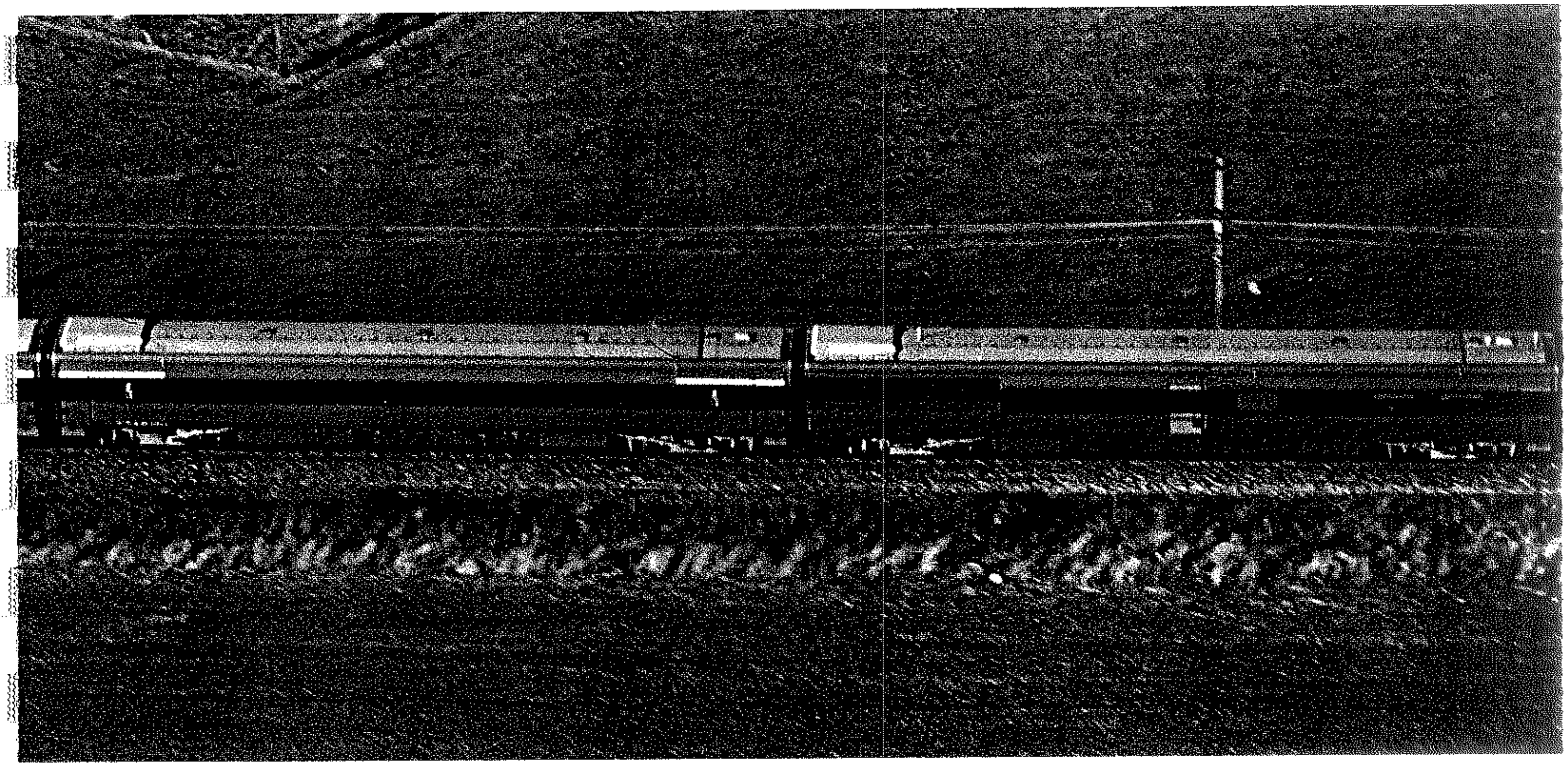
Fahrdrahtspannung	15 kV (+20% / -15%, 16 2/3 Hz)
Maximale Leistung / Triebkopf	4,0 MW
Dauerleistung / Triebkopf	3,3 MW
Zwischenkreisspannung	2.400 V
Elektrische Nutzbremse	

HILFSBETRIEBEVERSORGUNG

Ein einziger zentraler Wechselrichter für 3 x 380 V, 50 Hz, 360 kW pro Triebkopf.
1.000 V, 16 2/3 Hz-Versorgung für Heizung, Batterieladung, und so weiter.

110 V-Batterie für Triebkopf	55 Ah
24 V-Batterie in den Mittelwagen	344 Ah





CONTROL SYSTEM

ABB Tracs system
2-wire data bus
Fault indication/diagnosis system integrated in control system

BRAKE SYSTEM

Retardation, service brake	1.1 m/s²
Retardation, emergency brake	1.4 m/s²

Electropneumatic brake system with all-pneumatic backup
Regenerative electric brake, prioritised
Disc and thread brake on power car bogies
Disc and magnetic track brake on passanger car bogies
Screw air compressor

BOGIES

Axle distance, power car and passanger car bogie	2,9 m
Wheel diameter, power car bogie (new/worn)	1100/1040 mm
Wheel diameter, passanger car bogies (new/worn)	880/820 mm

LEITSYSTEM

ABB-Tracs-System
2-Leiter-Datenbus
Störungsanzeige- und Diagnosesystem ist in das Leitsystem integriert

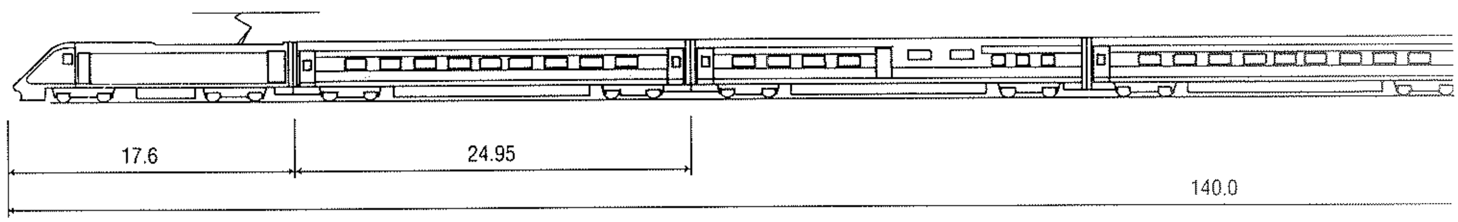
BREMSSYSTEM

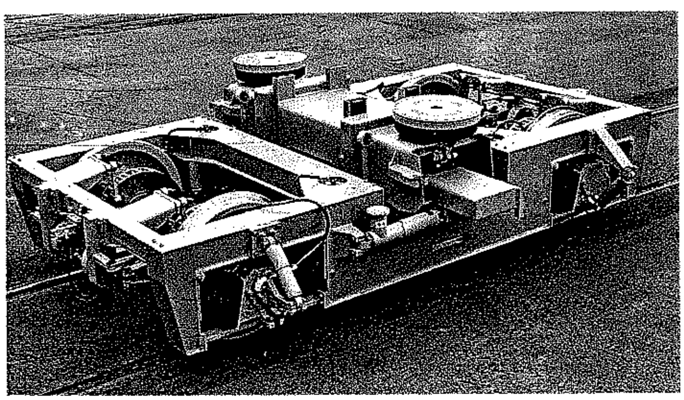
Verzögerung, Betriebsbremse	1,1 m/s²
Verzögerung, Notbremse	1,4 m/s²

Elektropneumatische Bremsanlage mit pneumatischer Reserve
Elektrische Nutzbremse, wird vorrangig benutzt
Scheiben- und Klotzbremse an den Drehgestellen des Triebkopfes
Scheiben- und Magnetschienenbremse an den Drehgestellen der Mittelwagen
Schraubenverdichter

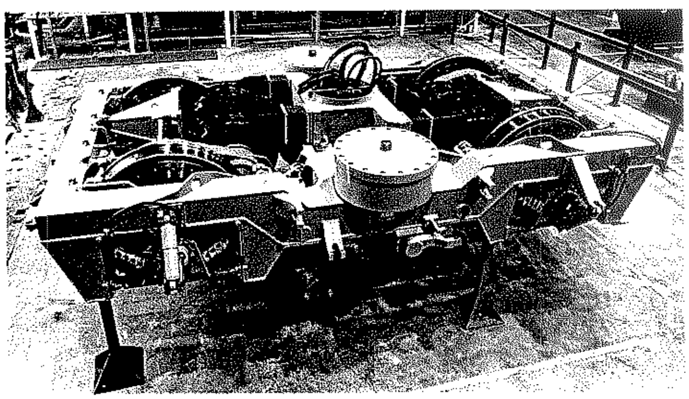
DREHGESTELLE

Achsabstand Drehgestell Triebkopf und Mittelwagen	2,9 m
Raddurchmesser, Drehgestell Triebkopf (neu/abgefahren)	1100/1040 mm
Raddurchmesser, Drehgestelle Mittelwagen (neu/abgefahren)	880/820 mm

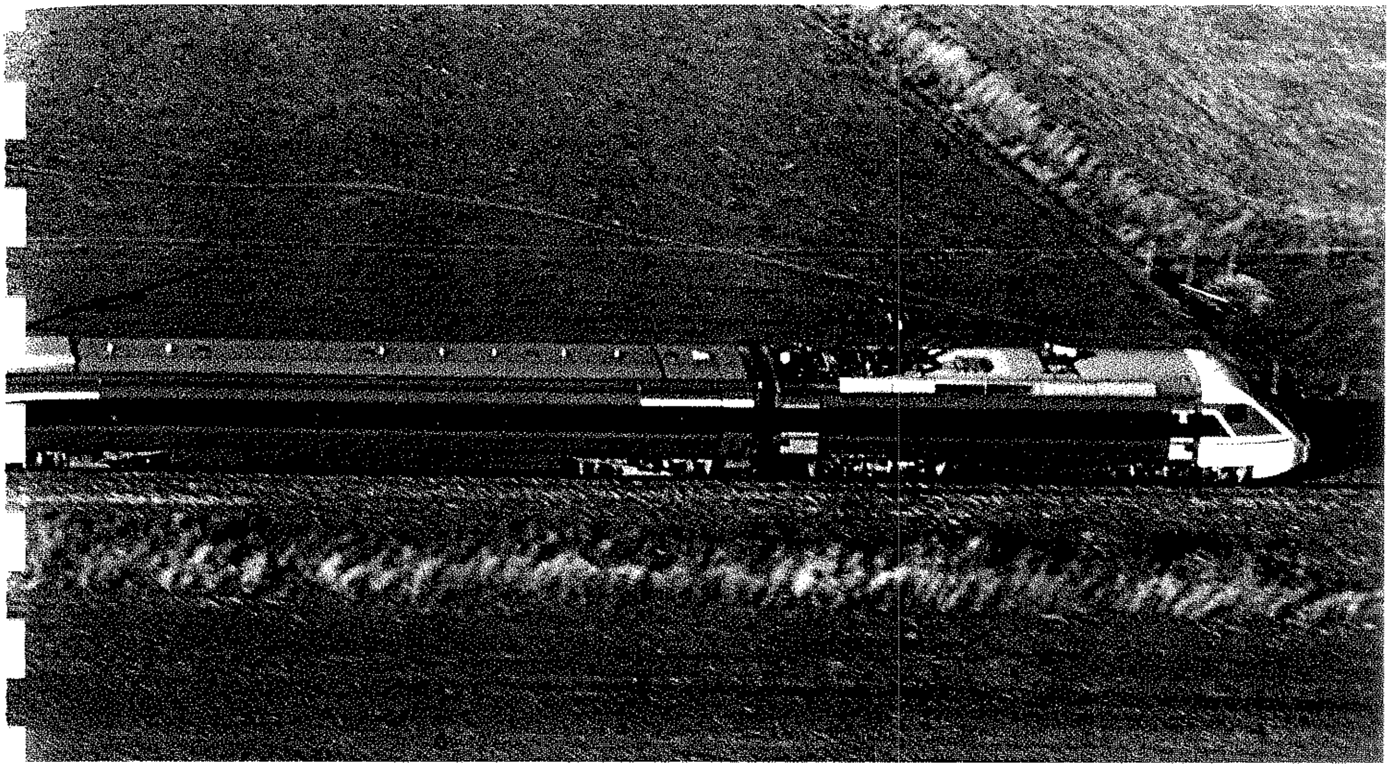




Passanger car bogie



Power car bogie

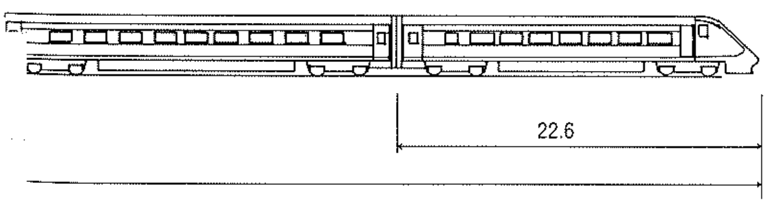


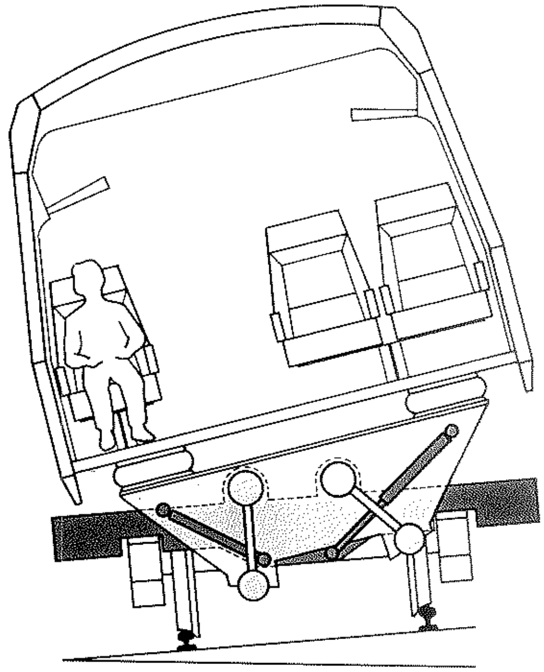
CARBODY TILTING SYSTEM

Active tilting system of all passanger cars	
Separate hydraulic system on each car	
Maximum tilting angle	8°
Maximum tilting speed	4° /second
Compensation factor	70%

SYSTEM FÜR WAGENKASTENNEIGUNG

Aktives Wagenkastenneigungssystem für alle Mittelwagen.	
Getrenntes hydraulisches System für jeden Wagen.	
Maximaler Neigungswinkel	8°
Maximale Neigungsgeschwindigkeit	4°/s
Kompensationsfaktor	70%





CARBODIES

Stainless steel 18% Cr, 8% Ni
UIC 566 strength requirements
Loads above sidesill, UIC 566, requirements +50%

COUPLERS

Automatic couplers at train ends
Semipermanent couplers between cars

DOORS

Automatic sliding-plug exterior doors
Automatic sliding interior doors

AIR CONDITIONING AND VENTILATION

Air volume per intermediate passanger car 3200 m^3
Maximum 50% recirculation
Compressor condensor unit in underframe
Evaporator, ventilation fans overhead mounted

WAGENKASTEN

Rostfreier Stahl 18% Cr, 8% Ni
Festigkeit nach UIC 566
Last über Längsträger nach UIC 566 + 50%

KUPPLUNGEN

Automatische Kupplungen an den Zugenden
Halbdauerkupplungen zwischen den Wagen

TÜREN

Automatische Schiebe-Falt-Türen aussen
Automatische Schiebetüren innen

KLIMATISIERUNG UND BELÜFTUNG

Luftmenge pro Wagen 3200 m^3
Luftumwälzung maximal 50%
Verdicher-Kondensator-Aggregat im Rahmen
Verdampfer, Lüfter oben im Wagen

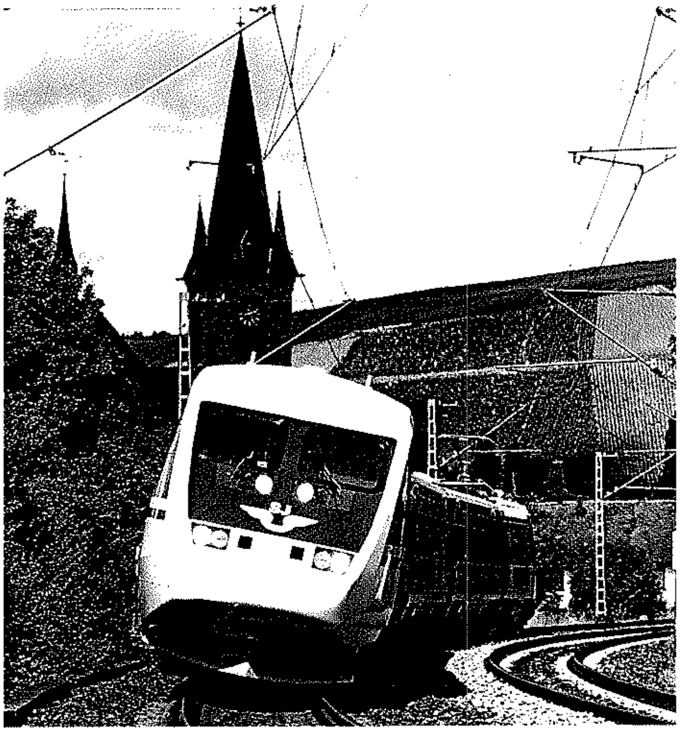


ABB Transportation Management
and Systems Development GmbH
Gottlieb Daimler Str. 6
P.O. Box 10 01 63
6800 Mannheim 1
Germany
Telephone (0621) 468 200
Telefax (0621) 468 298

ABB HENSCHEL Lokomotiven GmbH
Neustadter Str. 62
P.O. Box 10 03 51
6800 Mannheim 31
Germany
Telephone (0621) 381 1
Telefax (0621) 381 7271
Telex 462 411 113 ab d

ABB HENSCHEL Waggon Union GmbH
Neustadter Str. 62
P.O. Box 10 03 51
6800 Mannheim 31
Germany
Telephone (0621) 381 4477
Telefax (0621) 381 7204
Telex 462 411 113 ab d

ABB Traction AB
721 73 Västerås
Sweden
Telephone (021) 32 20 00
Telefax (021) 12 35 43
Telex 40847 abbtrc s

Asea Brown Boveri Traction Pty Ltd
509 Zillmere Road
P.O. Box 291
Zillmere, QLD 4034
Australia
Telephone (07) 263 3133
Telefax (07) 857 0007
Telex A4 40424

ABB Verkehrstechnik GmbH
Brown Boveri Str. 1
2351 Wiener Neudorf
Austria
Telephone (02236) 404
Telefax (02236) 24 417
Telex 79 114 atabb a

Asea Brown Boveri S/A
Divisão de Transportes
Caixa Postal 975
06020 Osasco-SP
Brazil
Telephone (011) 702 2111
Telefax (011) 702 4523

Asea Brown Boveri Inc
10300 Henri-Bourassa Blvd West
Saint-Laurent, Quebec
Canada
H4S 1N6
Telephone (514) 332 0330
Telefax (514) 332 2023
Telex 05-824043

ABB Scandia A/S
Toldbodgade 39
8900 Randers
Denmark
Telephone (86) 42 53 00
Telefax (86) 41 57 00
Telex 65145 scansk dk

ABB Strömberg Industry Ltd
Traction
P.O. Box 204
00381 Helsinki
Finland
Telephone (90) 5069 1
Telefax (90) 5069 6369

Asea Brown Boveri Ltd
5 Som Dutt Chambers, II Floor
Bhikaji Cama Place
New Delhi - 110066
India
Telephone (011) 687 27 37
Telefax (011) 671 405
Telex 031-62561 ABBD IN

ABB Trazione Srl
P.O. Box 13081
201 00 Milan
Italy
Telephone (02) 55 00 91
Telefax (02) 55 00 92 61
Telex 35 33 47

Asea Brown Boveri BV
P.O. Box 301
3000 AH-Rotterdam
Netherlands
Telephone (010) 407 84 31
Telefax (010) 456 69 27
Telex 21539 abb nl

EB Strømmens Verksted
Postboks 83
2011 Strømmen
Norway
Telephone (06) 80 96 00
Telefax (06) 80 96 01
Telex 71551 svstr n

EB Signal AS
Bergerveien 12
Postboks 86
1361 Billingstadsletta
Norway
Telephone (02) 84 30 60
Telefax (02) 84 48 38

Asea Brown Boveri Lda
Divisao de Traccao
Rua Sã da Bandeira 481-2
4000 Porto
Portugal
Telephone (02) 20 22 802
Telefax (02) 32 58 81

Asea Brown Boveri Holdings
SEA Pte Ltd
Regional Traction Office East Asia
21 Collyer Quay 15-03
Hongkong Bank Bldg
Singapore 0104
Telephone 22 51 000
Telefax 22 40 830
Telex 55172

Asea Brown Boveri S.A.
Tracción (B)
Apartado 29016
28080 Madrid
Spain
Telephone (01) 581 93 93
Telefax (01) 581 93 94

ABB Transportation Systems Ltd
Affolternstr. 52
P.O. Box
8050 Zürich
Switzerland
Telephone (01) 318 22 01
Telefax (01) 312 61 59
Telex 755 749 abb ch

Asea Brown Boveri Holding A.S.
Kasap Sokak No 2
Özden Konak Is Hani, Kat:9.
80280
Esentepe - Istanbul
Turkey
Telephone (1) 175 28 11
Telefax (1) 175 28 21
Telex 27253

ABB Traction Ltd
Orion House
5, Upper St. Martin's Lane
London WC2H 9EA
United Kingdom
Telephone (71) 753 2000
Telefax (71) 753 0204
Telex 290 288

BREL Group Ltd
St. Peter's House
Gower Street
Derby DE1 1AH
United Kingdom
Telephone (332) 383 850
Telefax (332) 291 579
Telex 377 693

ABB Traction Inc
East 18th Street
Elmira Heights, NY 14903
USA
Telephone (607) 732 5251
Telefax (607) 732 6614

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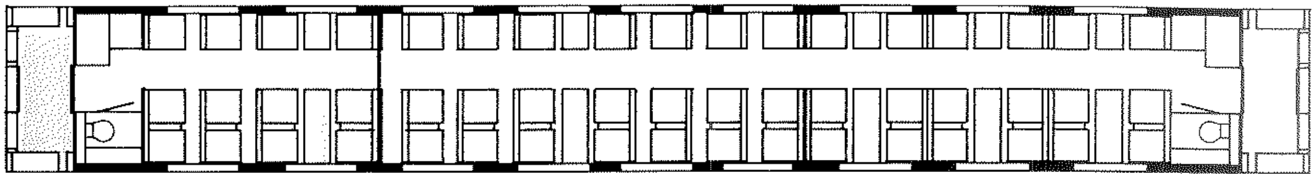
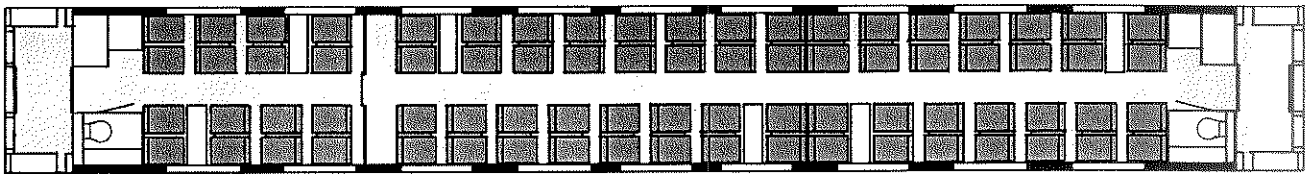
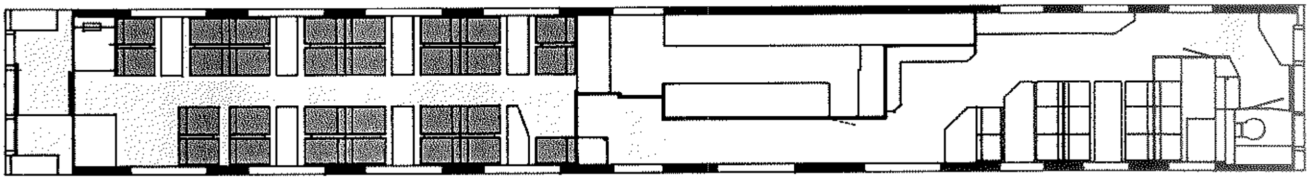


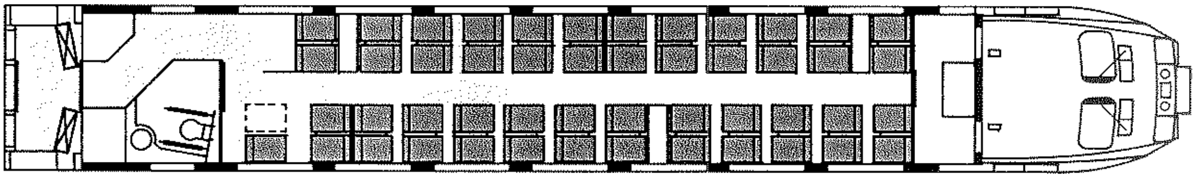
1:st class car, 51 seats
1 Klasse Wagen, 51 Sitzplatze



2:nd class car, 76 seats
2 Klasse Wagen, 76 Sitzplatze



Buffet car / 2:nd class car, 11+29 seats
Speisewagen / 2 Klasse Wagen, 11+29 Sitzplatze

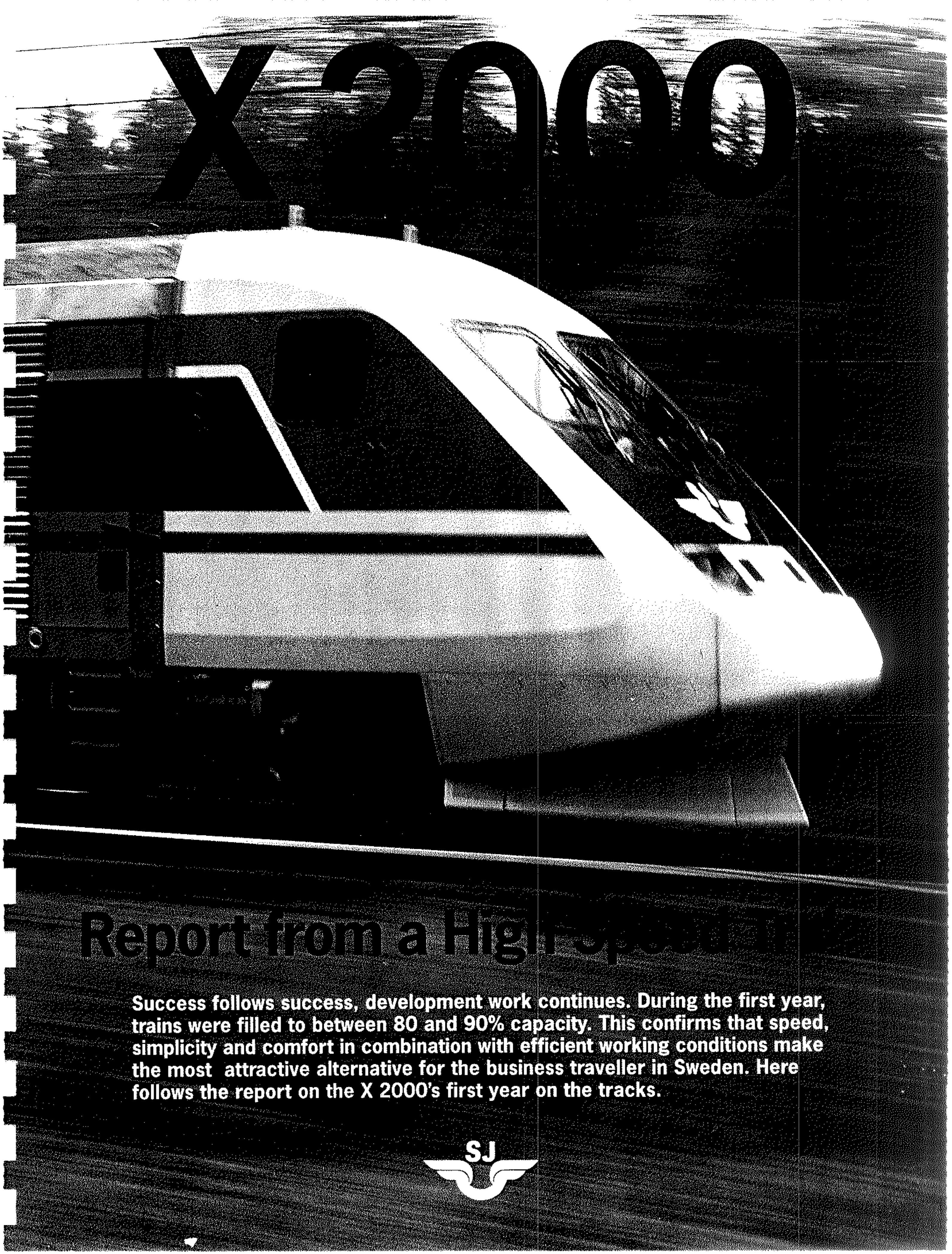


Driving trailer / 2:nd class car, 49 seats
Steuerwagen / 2 Klasse Wagen, 49 Sitzplatze

MISCELLANEOUS SYSTEM
Flourescent lights, individual reading lights
Closed water and sewage system (vacuum type)
Announcements over loudspeakers
Intercommunication for crew over internal phone system
Music entertainment system at seats, 3 channels
Electronic information signs
Telephones to general telephone network
Onboard telefax
Fire indication system
Automatic fire extinguishing system for power car

VERSCHIEDENE EINRICHTUNGEN
Leuchtstoffleuchten, Einzelleselampen
Geschlossenes Wasserversorgungs- und Abwassersystem (Vakuumtechnik)
Ankündigungen über Lautsprecher
Interne Fernsprechanlage für den Sprechverkehr zwischen dem Zugpersonal
Anlage zur musikalischen Unterhaltung an den Sitzen, 3-Kanäle
Elektronische Mitteilungszeichen
Telefone für den Verkehr mit dem öffentlichen Telefonnetz
Telefaxgerät
Brandmeldeanlage
Automatische Brandlöschanlage für den Triebkopf

X 2000

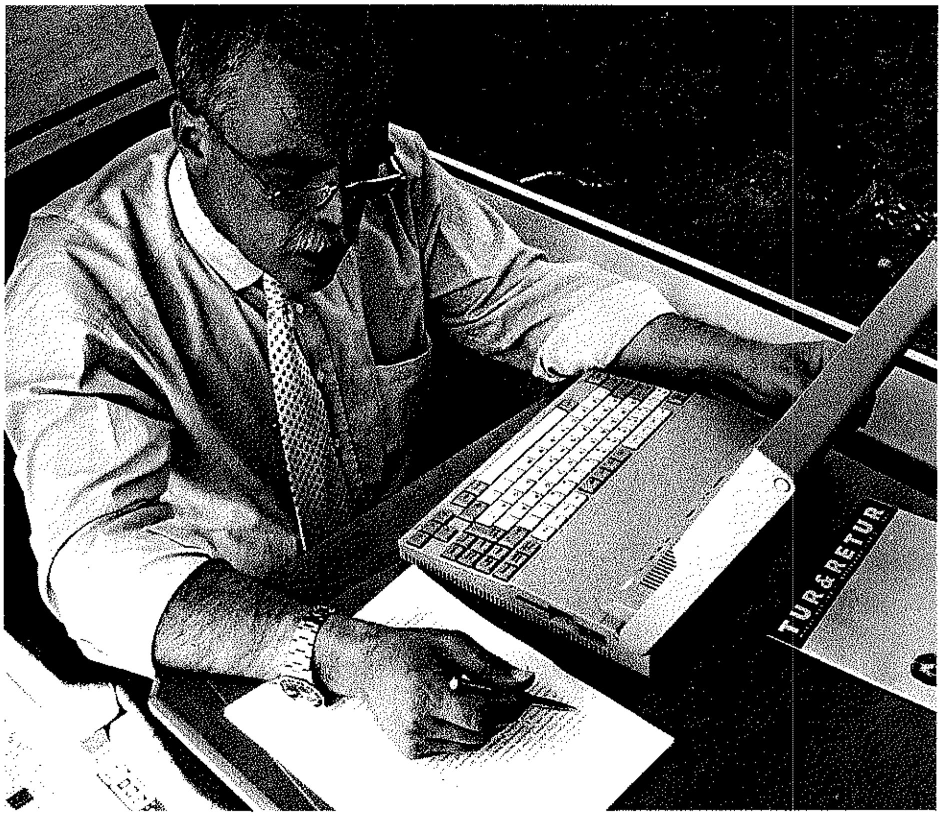


Report from a High Speed [illegible]

Success follows success, development work continues. During the first year, trains were filled to between 80 and 90% capacity. This confirms that speed, simplicity and comfort in combination with efficient working conditions make the most attractive alternative for the business traveller in Sweden. Here follows the report on the X 2000's first year on the tracks.

SJ

The efficient way of travelling.



With the X 2000 you go directly from city to city. Forget about queues, waiting, luggage, check-in and check-out, endless changes with taxis and busses and travelling time that can be used to nothing but stress.

Make your travelling time working time with access to copying machine, fax and phone by your table.

Relax in your comfortable chair with a wide selection of newspapers and a choice of several music and radio channels.

Enjoy a healthy breakfast with freshly pressed juice, bread from the oven with a choice of extras, specially composed lunches and dinners served at your seat. All included in the price, naturally.

The X 2000 is the efficient way of travelling, both when it comes to cutting costs and using time.

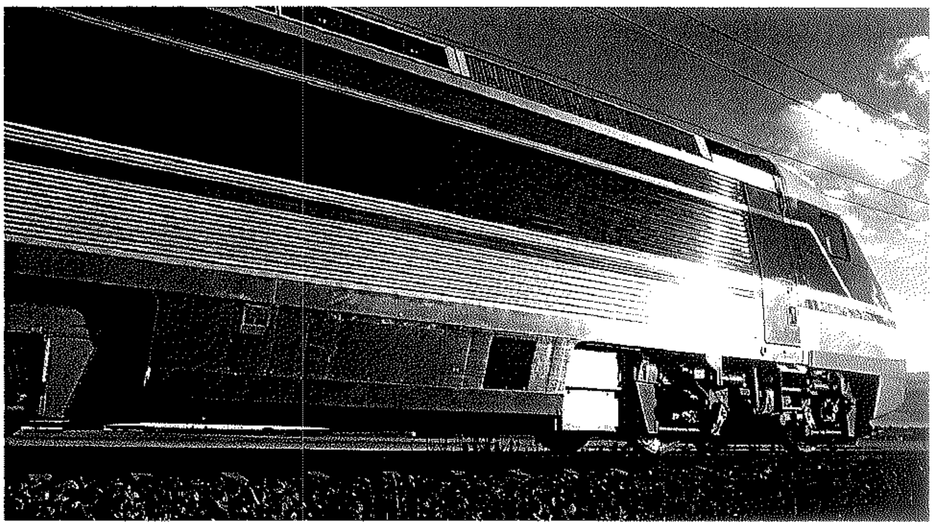
The X 2000. A safe way of travelling fast.

The X 2000 is the world's most advanced high speed train. Its technical construction, as well as its safety systems have attracted worldwide attention.

Safety has been as much a guiding principle as technology in the development of the X 2000. For example, the train is equipped with three different brake systems, all working independently if necessary. Normally, the brakes are applied automatically one after the other, depending on how hard the train needs to brake.

A special component signals to all level crossing gates that a high speed train is approaching, so that they close well in advance.

Thanks to the advanced ATC-system, the X 2000 receives information about what is happening along the tracks, 3-4 kilometres ahead. If for some reason the driver does not react to the warnings given, the ATC, "Automatic train control", is automatically alerted and the brakes are applied.



Environmentally friendly and energy saving compared with the aeroplane.

Speed, efficiency, comfort and simplicity weren't the only guiding principles when we developed the X 2000. Another main principle was to ensure that technical developments would be in harmony with tomorrow's view on energy and the environment.

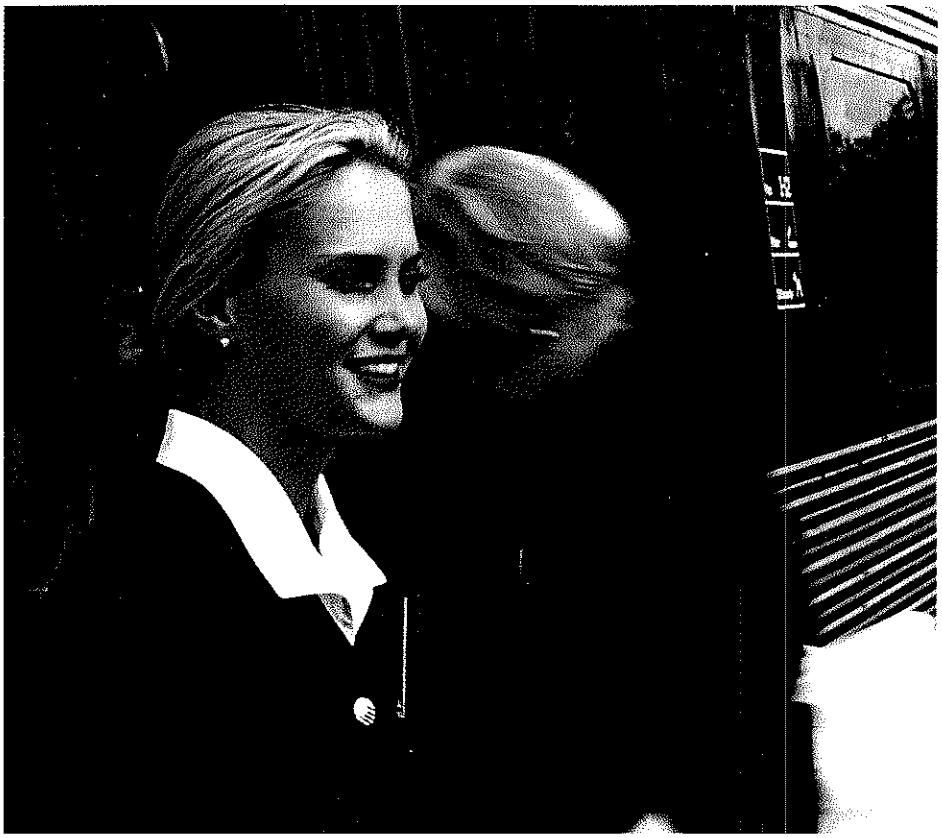
The X 2000 uses a ninth of the energy a plane uses. During the run Stockholm – Gothenburg, the X 2000 uses 10,000 kWh. With a maximum of 240 passengers on board, that means 40 kWh per passenger. A plane uses 60,000 kWh, which means about 375 kWh/passenger on board a 160 seater plane.

The same is true of environmental aspects. The X 2000 has no harmful pollutants at all. The flight between Stockholm and Gothenburg emits about 58 kilos of carbon monoxide and 12.6 tons of carbon dioxide.

Another example of energy-saving way of thinking is the electricity feed-back. When the X 2000 brakes, the energy is re-used and fed back into the electricity cables. In other words, the X 2000 is so energy saving it can even give energy back. Yet another example of how an innovation puts the future way of travelling miles ahead of its predecessors.

A plane uses about nine times more energy than the train.

A passenger on board the X 2000 between Stockholm and Gothenburg uses about 40 kWh. A flight passenger on the same route uses about 375 kWh.



High scores from the start.

The first six months were a test period. The idea was that our travelling "test pilots" would help us shape the future life of the X 2000 by contributing their ideas and comments on travelling, service and choice of food and facilities on board. On a scale from 1 to 5, where 5 represented the highest score, the testpilots gave us 4s and 5s on almost every point. Thanks to their comments we have improved what was not quite satisfactory and added to what was appreciated. For example, we now offer a wider selection of papers to read. We have introduced Radio 1, Radio 3 and a classical music channel and we have added to the menu in the Bistro.

After the first six months, 90% of our travellers wanted to continue travelling on the X 2000. This figure has now risen to 96%.

At the start five out of ten travellers came from air travel. Today, six out of ten are ex-flyers.

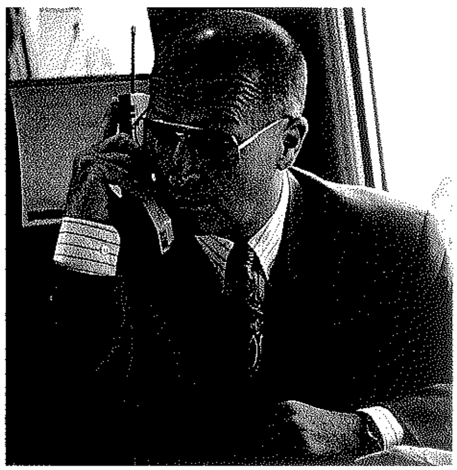
SIFO (The State Institute for Research and Opinion) reports that the X 2000 is considered the most comfortable, modern, easy, quiet and spacious way of travelling today.

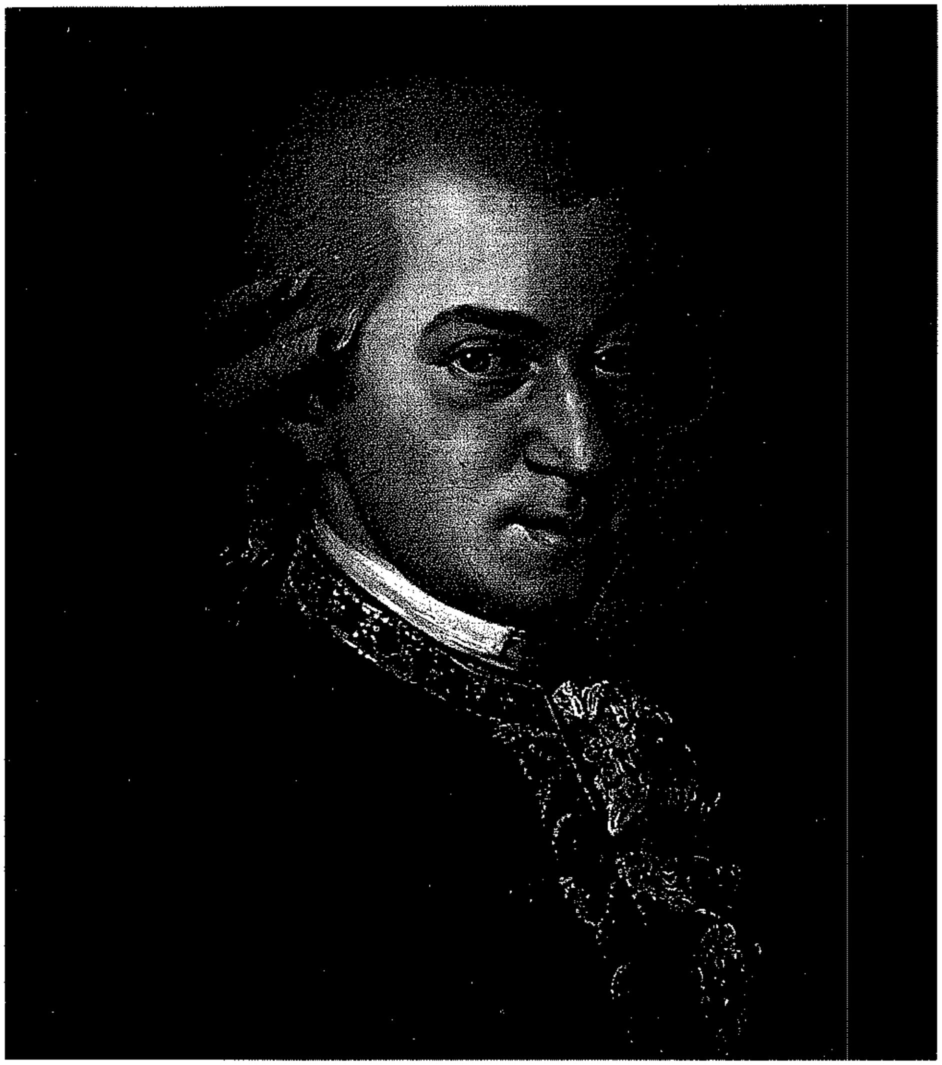
However, it was neither technology nor comfort that scored the highest. It was our service and our staff that won the highest scores. After all, they are the most important factors for a good journey.

After the first six months, 90% of our travellers wanted to continue travelling on the X 2000, this figure has now risen to 96%.

Telephone, fax and photo copying.

You're never far from your office or home, once you're on board the X 2000. You have access to phones, faxes and photocopiers. Just talk to our staff, and they'll bring a phone at your table. If you need to fax or photocopy a document, just leave it with our staff. In other words, it's easy to work efficiently on board the X 2000.





Mozart would have loved the X 2000.

There are many theories about creativity, but basically they all stem from the same idea. That the best conditions for creativity, ingenuity, good ideas and the possibility to do a good job are peace and quiet, a change of scenery, possibilities to take a break to do something else, like listening to music or going for a walk. The worst conditions are usually stress, anxiety and having to sit still. Mozart wrote: "When I'm on my own and in a good mood, when out travelling or strolling after a good meal, that's when the ideas come most frequently and abundantly".

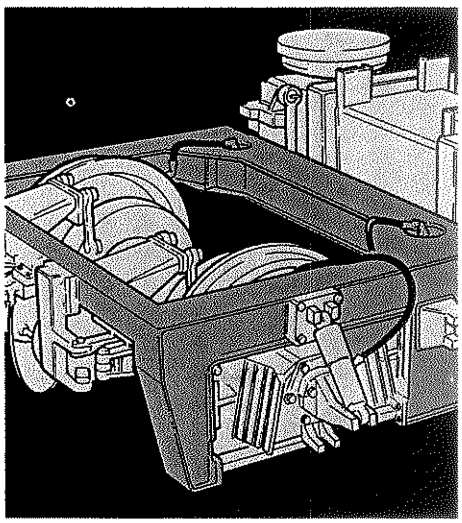
Mozart would have been able to enjoy a walk after a good meal on board the X 2000. He could have rested in a comfortable armchair, got inspiration from classical music in Sony earphones or taken a nap in the quiet compartment. What his music would have sounded like had he composed it in taxis, check-ins and check-outs, queues and cramped, noisy aeroplanes, we dread to think.

Technology puts the X 2000 in a category of its own.

As the X 2000 runs on traditional tracks, it has many technical features distinguishing it from other highspeed trains. The two greatest differences are the bogie and the tilt of the wagons.

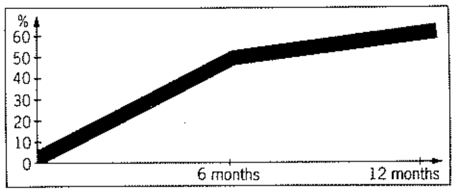
There are two kinds of bogies: stiff ones which are found on conventional trains, and soft bogies. Soft bogies adjust to curves which means speed can be increased by about 40% without increasing the force on the rails compared to a conventional train.

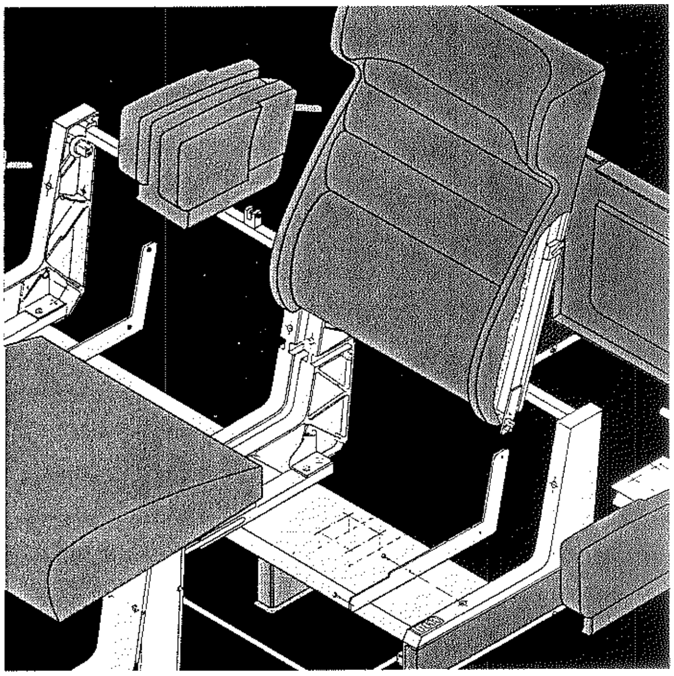
To prevent passengers from experiencing this, there is a compensation in the tilt of the train. The maximum angle is 6,5 degrees, the maximum speed when tilting is 4 degrees/ second.



We welcome more and more ex-flyers.

After the first six months, five out of ten X 2000-passengers were ex-flyers. Today, after a year, the number has risen to six. We also note that it's the ex-flyers who are most positive about their new way of travelling. Comfort, simplicity and the working facilities on board, in combination with a high level of service are some of the points noted and appreciated. All this coupled with our continual improvements in speed and the time table will no doubt increase the number of ex-flyers on board the X 2000 in the future, too.





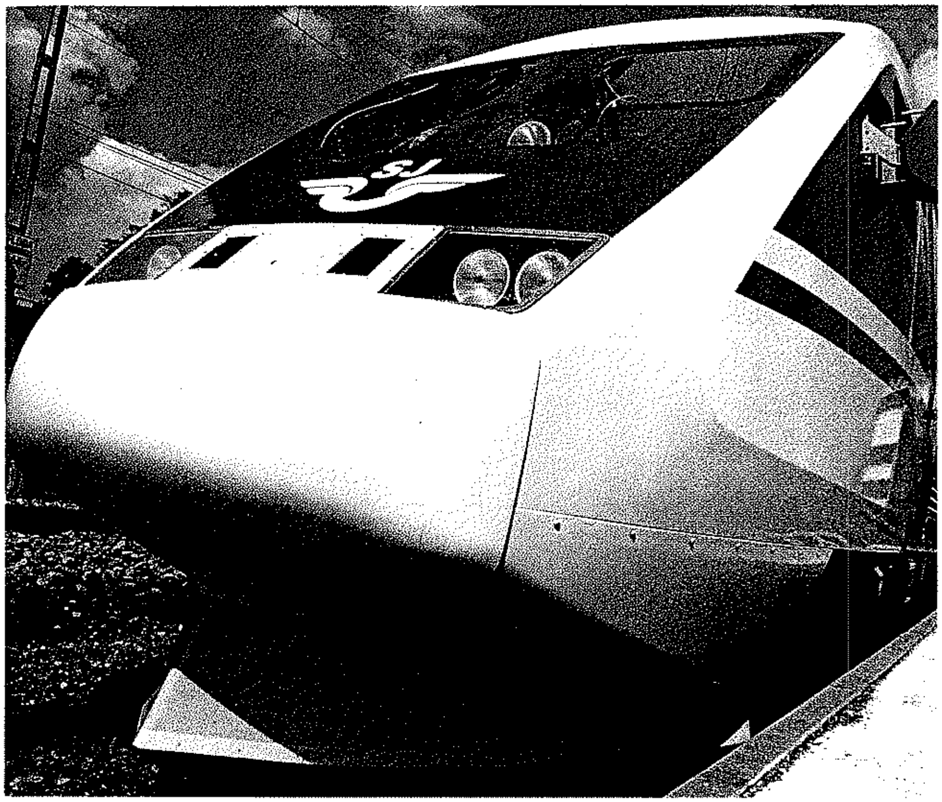
Rest and relax.

The low level of noise at only 65 decibel, helps you to relax during your journey. The comfortable, specially designed armchairs from Dux, help you sit comfortably, too, whatever your height or whether you want to recline and stretch your legs or just sit upright and work.

If you just want to relax you have a choice of several music and radio channels in your Sony earphones. If you want to read a morning or evening paper, there is a wide selection available on board.

Enjoy your meal. There's more to come.

After the first six months we asked our "test pilots" what they thought of the food. There was only one complaint: There's too much of the good things. We decided not to change that. On the contrary. When extending our time tables, we also extended our menus to include breakfast, lunch and dinner. Apart from a filling breakfast of freshly pressed juice, bread straight from the oven and extras to go with the bread, you can now also enjoy specially composed lunches and dinners served at your table. As for serving too much of the good things in life, we're willing to take that risk.



The X 2000 – the cost-efficient high-speed train.

Other high-speed trains require completely new track in order to manage the high speeds. In this respect, the X 2000 is unique. It runs along existing, conventional track. The carriages, on the other hand, have been specially constructed to lean in the curves to compensate for the strong forces which result from the high speed. By adjusting the train to the tracks, rather than the other way round, billions of Swedish crowns have been saved in construction work.

The track alone is cost-efficient – the Stockholm to Gothenburg run cost 0.5 billion for 456 kilometres and the X 2000 will soon cover the distance in 2 hours 55 minutes. For comparison, the investment in track is only 2% of the cost of building new track for the German high-speed train, the ICE. The 420-kilometre-long journey between Hamburg and Fulda to Frankfurt am Main takes 2 hours 39 minutes. Of these kilometres 239 are run on new tracks at a speed of 250 km/h. On the remaining track there is a 200 km/h speed limit.

French investments in the TGV total 10.7 billion Swedish crowns from Paris to Lamballe, a distance of 454 kilometres. The TGV does this run in 2 hours 41 minutes.

The X 2000 gained world-wide recognition for this method of combining cost-effiency with speed. In fact, many countries around the world are interested in having their own X 2000 trains.

X 2000 in the US.

The most heavily frequented rail way line in the US – New York – Washington DC – is about to be equipped with high-speed trains. In connection with this, Amtrak has decided to test run the X 2000 on this route. Paying passengers will be allowed on board at the end of 1992 or at the beginning of 1993.

It looks as if the X 2000 is about to conquer the other side of the Atlantic as well.

New speed record for the X 2000.

During the summer of 1991 the old Swedish speed record of 238 km/h was easily broken. Without changing the gears or making modifications, as is normally the case, the X 2000 reached 251 km/h during a test run in Germany. The engines managed 20% inclines, without any difficulty.

However, the X 2000 shows its real strength on a curved track. This was also confirmed during the test run in Germany, between Trier and Dillingen in the Mosel Valley. Normally the speed limit here is 125 km/h, but the Deutsche Bundesbahn made an exception for the X 2000. It touched 160 km/h on the winding tracks without any Mosel spilling out of the tall wine glasses. In other words, the X 2000 can run on conventional and winding tracks despite its speed.

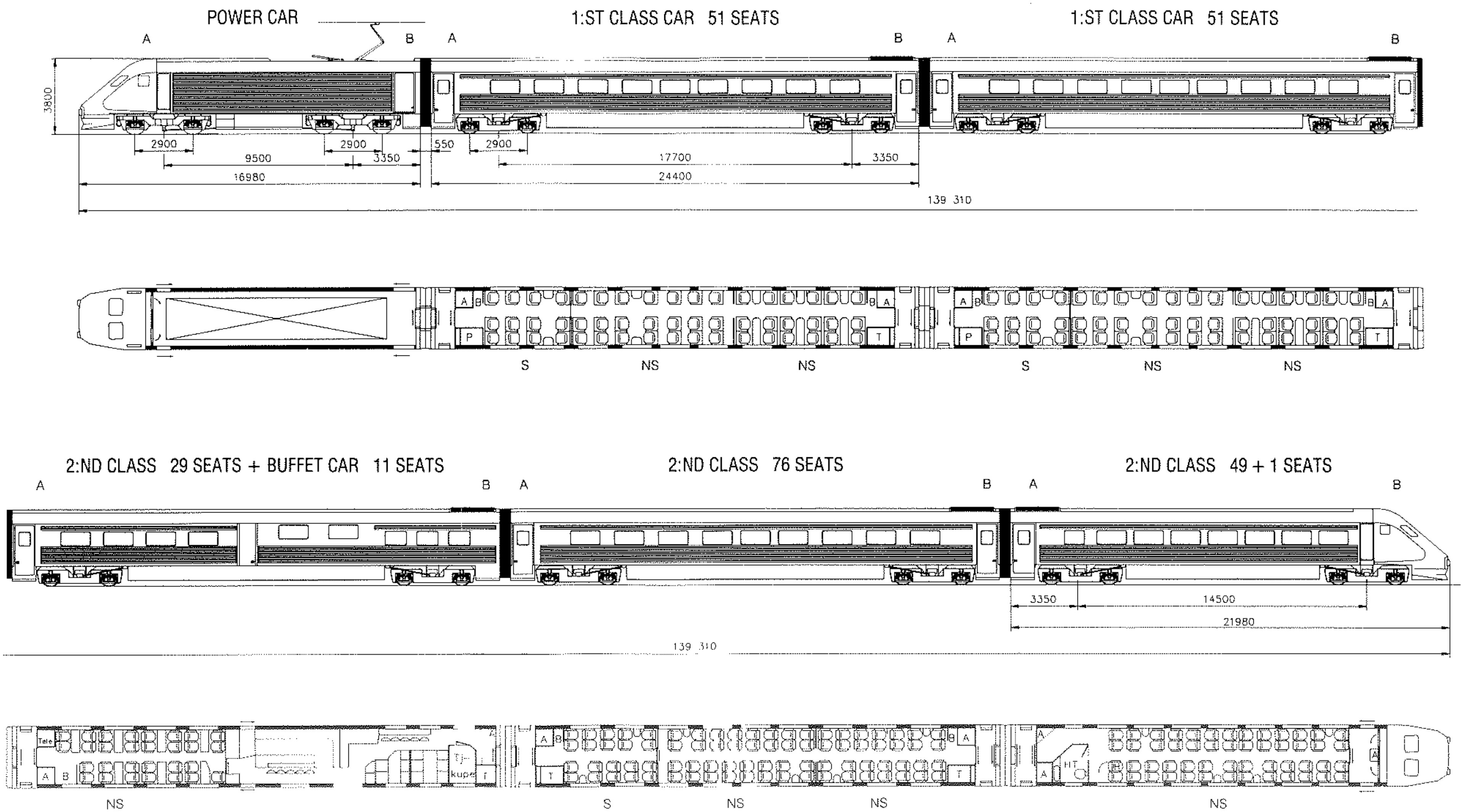
X 2000

SJ PERSONTRAFIKDIVISION, AFFÄRSOMRÅDE X 2000, 105 50 STOCKHOLM.

WEIGHTS

Power car total	73 t
Bogie	12,8 t
Unsprung/axle	1,8 t
Trailer car	47 t
Bogie	8,3 t
Unsprung/axle	1,4 t
Driving trailer	55 t
A-Bogie	8,3 t
B-Bogie	13,8 t
Unsprung/axle	1,4 t

Train configuration



T-F2790

Class X2000 fast train for Swedish State Railways (SJ)

During 1990 the first out of 20 fast trains was delivered to SJ for operation between Stockholm and Gothenburg. Travelling time will be reduced by more than 25% after adjustment of some of the fixed installations and signal systems.
Later trains are intended for traffic on the Stockholm–Malmö and Stockholm–Sundsvall lines with similar reductions in travelling times. The trains will run on existing tracks and the time reduction is mainly achieved by utilizing ABB Traction's bogies with radially self-steering axles and an active tilting system permitting considerably higher curving speeds. A three-phase asynchronous propulsion system is used. The micro-computer based control system handles all the control functions of the trains and includes also an advanced fault diagnosis and announciation system.

T-F2762

Main data for a 6-car unit

First delivery	1990
Normal train configuration	One power car and five trailercars (of which one is a driving trailer)
Line voltage	15 kV
Line frequency	$16^2/_3$ Hz
Gauge	1 435 mm
Wheel diameter (new), power car	1 100 mm
Wheel diameter (new), trailer cars	880 mm
Bogie wheelbase	2 900 mm
Height with pantograph down	3 800 mm
Max. width	3 080 mm
Height of floor from top of rail	1 220 mm
Total length over couplers	140 m
Total weight (no load)	317 000 kg
Number of first class seats	102
Number of second class seats	154
Number of buffet car seats	11
Max. speed	200 km/h
Rating, continuous	3 260 kW
Number of traction motors	4
Maximum tractive effort	160 kN
Max. acceleration on level tangent track	0,4 m/s^2
Carbody material	Stainless steel
Propulsion system	Three-phase asynchronous motors, GTO-thyristor converter
Transmission	Fully suspended drive system with quill tube
Brake system	Regenerative braking, disc brake on all wheels and electromechanical track brakes

TRACS

General purpose computer systems for Railway Vehicles

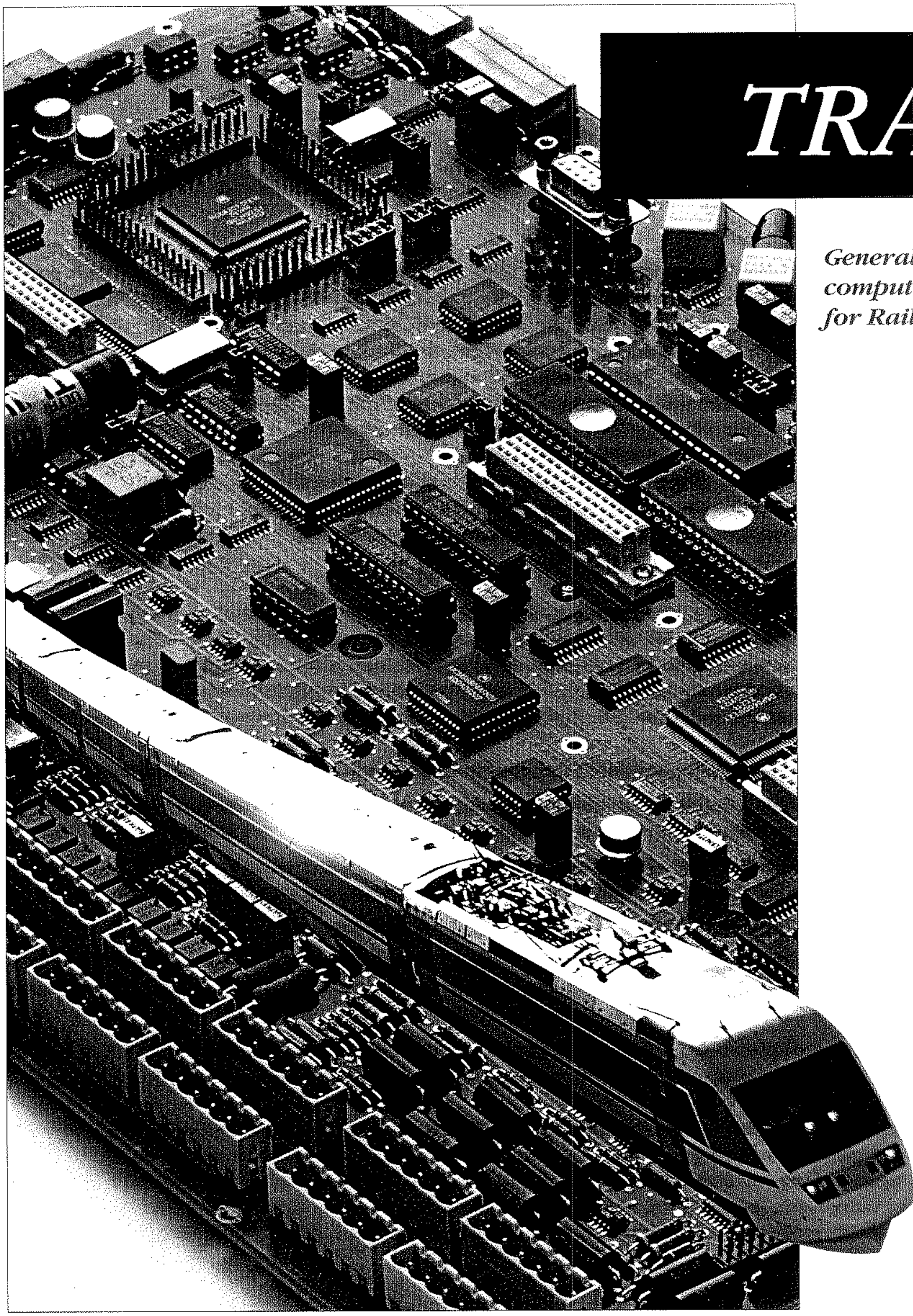


ABB Traction

ASEA BROWN BOVERI

Computers in trains

The introduction of computers in railway rolling stock began in the early 1980s. In the initial stages, computers were used as "intelligent black boxes" that carried out isolated tasks. Development has led to a powerful distributed general purpose computer systems that control and supervise the complete train. The control tasks are implemented in software that controls a variety of input/output units, controllers, displays, etc., dispersed around the train, at points where they carry out their tasks. Traditional wiring is replaced by serial data buses transmitting an immense amount of data - such as control signals, feedback signals, statistical information, fault information, etc.

A general purpose computer system allows for the introduction of new functions, such as improved vehicle diagnostics, condition monitoring and more comprehensive passenger information, all of which boost the efficiency of rail transport systems and improve the quality of travel for the passengers.

More specifically, this approach offers new benefits, such as:

- many functions - both old and new - can be integrated into a given system for optimum cost effectiveness
- new functions can be added simply, with a minimum of expense for extra hardware
- redundancy can be incorporated simply and inexpensively
- high reliability, since the various functions share the hardware and thus minimize the total amount of hardware needed
- the use of data buses replaces a vast amount of traditional wiring, which saves cost, space and weight

ABB has been at the leading edge of this important railway engineering development right from the beginning. We have manufactured and delivered well over a thousand vehicles equipped with systems of this type, and we are geared up to continue along this path in the future.

TRACS – General purpose computer system

TRACS is a modular general purpose computer system developed by ABB. It is suitable for virtually any type of rail vehicle application. TRACS handles the control of the complete train set and each individual vehicle, including the drive system, and equipment such as auxiliary inverters, battery chargers and other auxiliaries. The system also includes functions such as vehicle diagnostics, vehicle testing, recording of events, and man-machine communication.

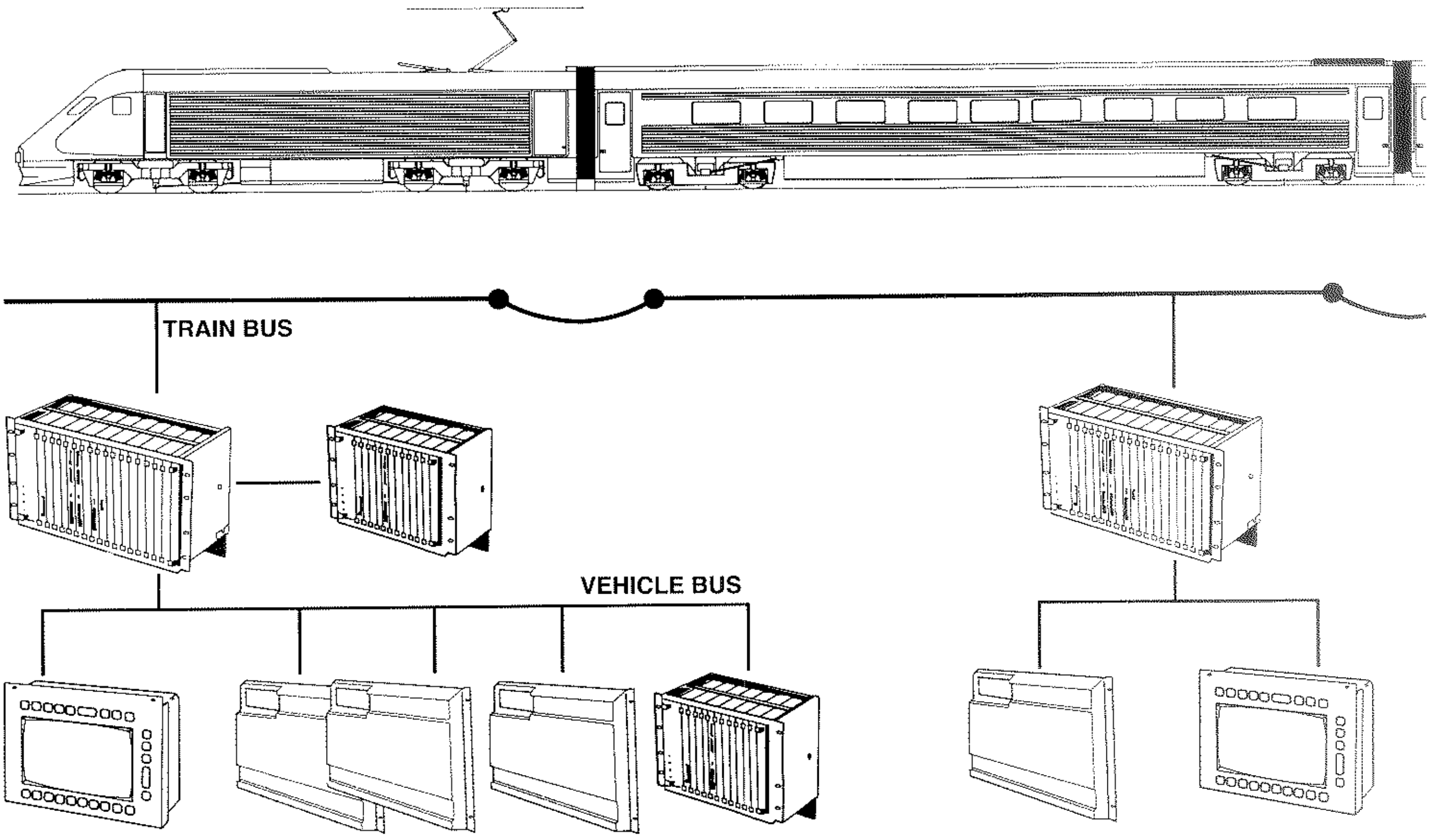
Using a standard range of modules, the computer hardware can easily be configured to suit a specific application. The software which performs all the application functions is easily programmed using a specially designed functional block/graphic programming language that enables the system to be programmed and used by personnel who have no prior computer experience.

TRACS is used for a wide variety of applications, such as:

- Train control
- Vehicle control
- AC and DC drive control
- Four-quadrant line inverter control
- Auxiliary inverter control
- Brake control
- Brake blending
- Slip/slide control
- Locked wheel protection
- Train communication network
- Advanced man-machine interfaces
- Vehicle diagnostics
- Vehicle testing

TRACS is currently in successful commercial service on numerous locomotives, commuter trains, high-speed trains and urban transit vehicles throughout the world.

TRACS
– System structure



FRAME COMPUTER:

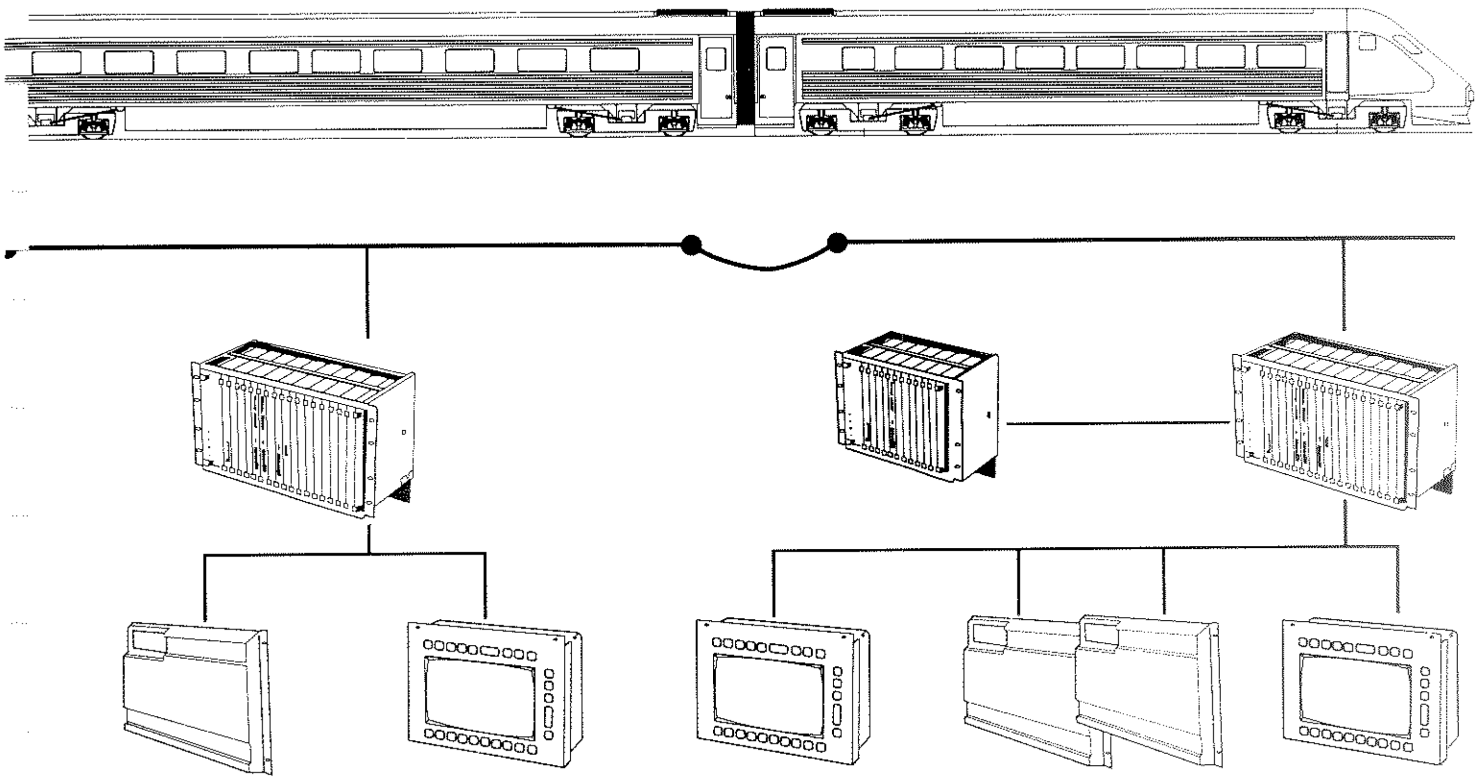
Frame-mounted equipment offers flexibility and makes it easy to expand the system by additional input/output channels and further processing capacity. This is the "main" computer of the vehicle to which both the train bus and vehicle bus are connected.

DISTRIBUTED CONTROL:

The distributed control unit handles the complete control of an inverter (motor, auxiliary or line inverter) and associated equipment. The unit is mounted directly together with the equipment it controls and uses fibre optics as interface to the inverters.

DISTRIBUTED I/O UNITS:

Distributed input/output (I/O) units enable the hardware to be mounted where it is used. The I/O units are connected directly to the vehicle bus, thus restricting the necessary vehicle wiring to the shielded twisted pair for the vehicle bus and the power supply lines to the unit.



DISPLAYS:

Small 2 x 40 character displays as well as large 10" flat panel displays are available for man-machine communication. In addition to providing diagnostic and operational information, these displays can also be used for tasks such as replacing traditional instrumentation and for passenger information.

TRAIN COMMUNICATION NETWORK:

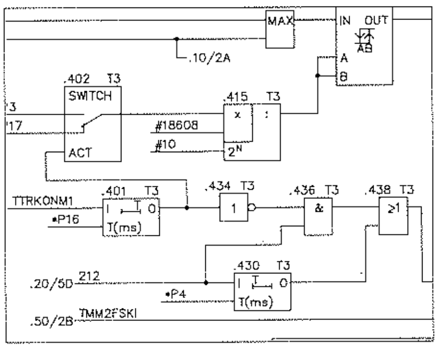
The train communication network interconnects all of the equipment in one vehicle (the vehicle bus) as well as equipment in different vehicles (the train bus). The train bus reconfigures itself automatically when the train configuration is changed. The buses use shielded twisted pairs and can be used with ordinary automatic couplers. Full redundancy can be provided.

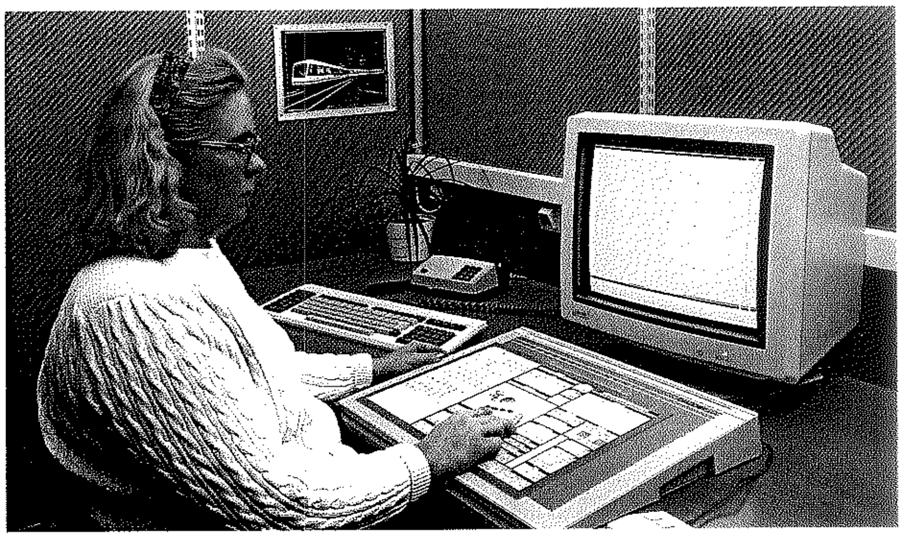
THIRD PARTY PRODUCTS:

Third party products, such as automatic train protection equipment and radio equipment, can easily be integrated into the system, either by direct connection to the vehicle bus or by dedicated point-to-point data links. A number of different interfaces, such as RS232, RS485 and 20 mA current loops are available for this purpose.

TRACS – Software

All train-related functions, such as door control, are implemented in software. This application software is written in a specially designed, functional block language based on the use of graphic symbols, each describing a function (PI controller, logical gates, etc). These graphic symbols are used to produce a block diagram which is the program as well as the basic document describing the function. All functional blocks have been written and tested once and for all, and are re-used in all projects. This approach leaves the detailed programming to the software experts, while the application engineers, engaged on the various vehicle projects, can concentrate on the train-related functions.

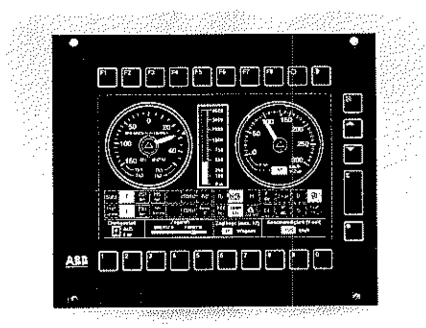




Man – machine interface

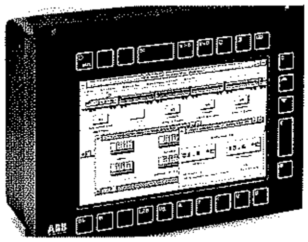
One important aspect of the computer system is to create an effective and user friendly man-machine interface between, for instance, the driver and the train. For this purpose TRACS allows more advanced man-machine interfaces to be employed, in addition to traditional switches, lamps, etc.. These range from small alphanumeric displays to large 10" flat panel displays.

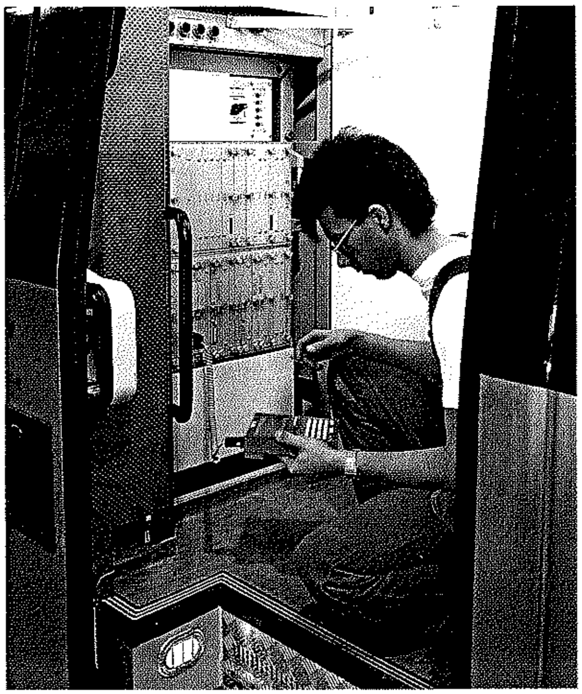
The displays are, for instance, used as driver interface, interfaces for maintenance personnel and for passenger information purposes.



TRACS – Diagnostics

TRACS includes a number of diagnostic functions, such as self test of the computer itself, fault detection and analysis on vehicle systems, as well as automatic and semi-automatic tests on the complete vehicle.



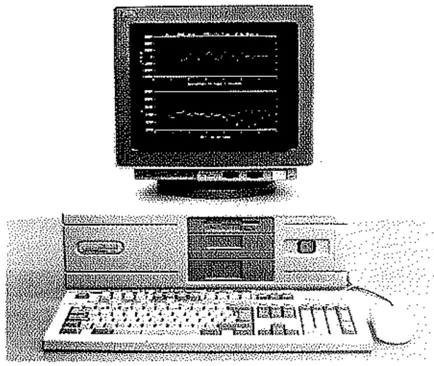


The fault detection and analysis system detects faults and automatically disconnects faulty parts of the vehicle. It also presents relevant fault information, help texts, etc., on the driver's display. Information on faults is stored, together with time and date, as well as other relevant data, such as speed, power/brake command, etc., in a fault data base.

This fault data base can be printed out by a printer or dumped to a PC for detailed fault analysis and for generating statistics.

Automatic vehicle tests allow the driver to detect possible faults before the vehicle goes into service. Additional, more comprehensive automatic and semi-automatic tests can be included to assist the maintenance personnel.

If the vehicle is equipped with radio data communication, the diagnostic system can be extended to workshops equipped with maintenance support systems. This allows for functions such as on-line supervision of vehicles in service, etc.



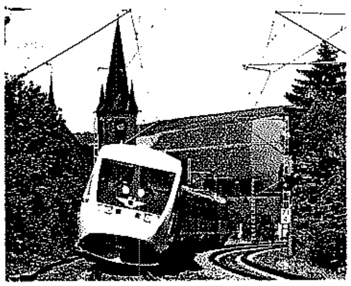
The most difficult faults to trace are those that occur sporadically, and TRACS therefore incorporates an event/transient recorder. The recorded data is stored in a nonvolatile type of memory which can be printed out or dumped to a PC for detailed analysis.

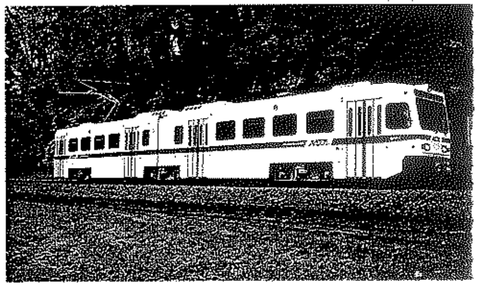
TRACS Technical data

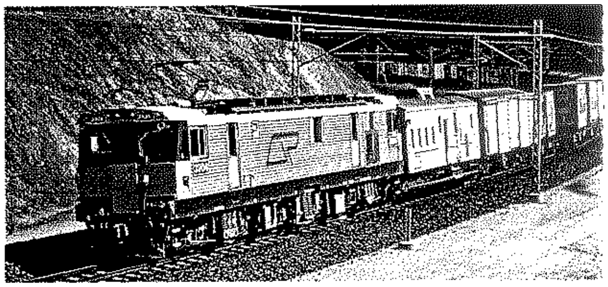
- Type tested according to IEC standards (IEC 571, IEC 77, etc)
- Operating temperature range (ambient): -40 to 70°C (-40 to 158°F)
- 16/32-bit processors, and 56-bit signal processors
- EPROM, Flash EPROM, SRAM
- Watchdogs, checksum, RAM test, I/O test, etc.
- 24, 36, 48 or 100/110 V vehicle battery
- Train communication network:
  - 153.6 kbit/s
  - Hamming distance 4
  - Twisted shielded pairs
  - Auto reconfiguration
  - Train bus max length 1000 m (3300 ft)
  - Vehicle bus max length 200 m (660 ft)
- ISO 9000 (ISO 9000-3)
- PC/MSDOS or UNIX software development environment
- Functional block language
- Multitasking real time operating system with cycle times down to 1 ms
- All software signals available as logical names

TRACS in brief

TRACS has been in commercial service for a number of years in many parts of the world. The applications include all types of vehicles, ranging from tramcars and light rail vehicles to multiple units, locomotives and tilting high-speed trains. The well-established and highly successful train communication network is used for replacing traditional train wiring and for new functions, such as diagnostics and passenger information. TRACS is regularly updated and expanded to keep it at the leading edge of development. In addition, "backward compatibility" has been a consistent feature of TRACS and enables users to expand their existing systems and maintain their viability for many years to come.







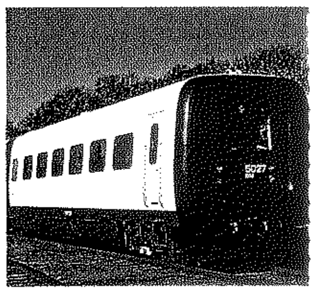


ABB offers a complete range of railway equipment.

The company manufactures service-proven electrical components, such as motors, inverters and computers, as well as mechanical products such as car bodies and bogies.

By combining these components, ABB can supply complete vehicles in which the electrical and mechanical equipment are fully integrated and optimized.

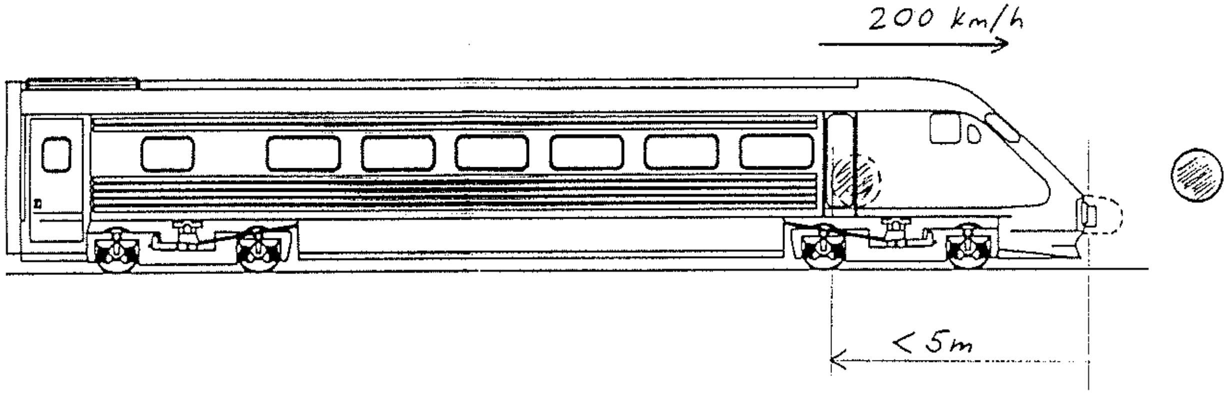
ABB also offers complete rail traffic systems, including power supply and signalling equipment, service, maintenance and financing.

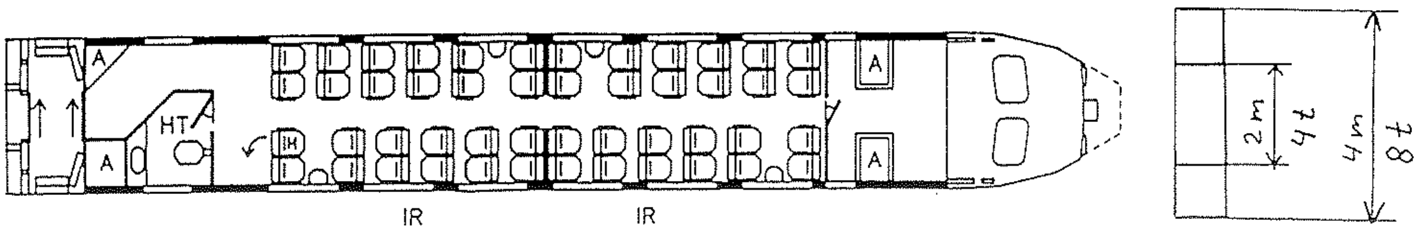
ABB
ASEA BROWN BOVERI

ABB Traction AB
S-721 73 Västerås,
SWEDEN
Telephone +46 21 32 20 00
Telefax +46 21 12 35 43

A12-0043 E Springfeldt&Co / Västerås Lito

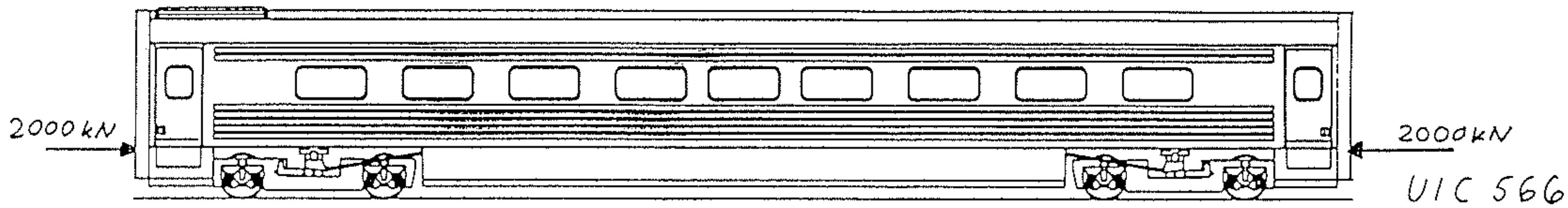
MANÖVERVAGN

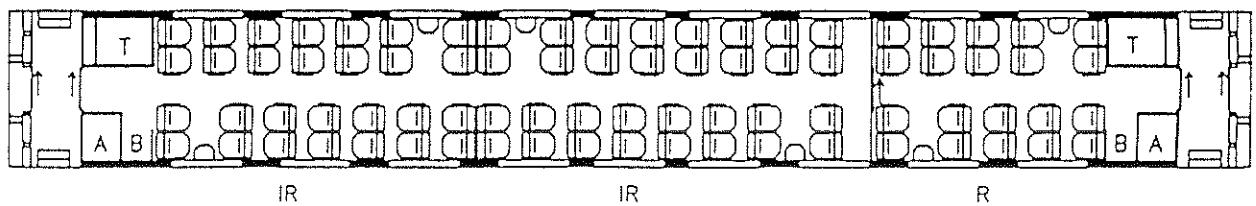




2 KLASS 48 PL

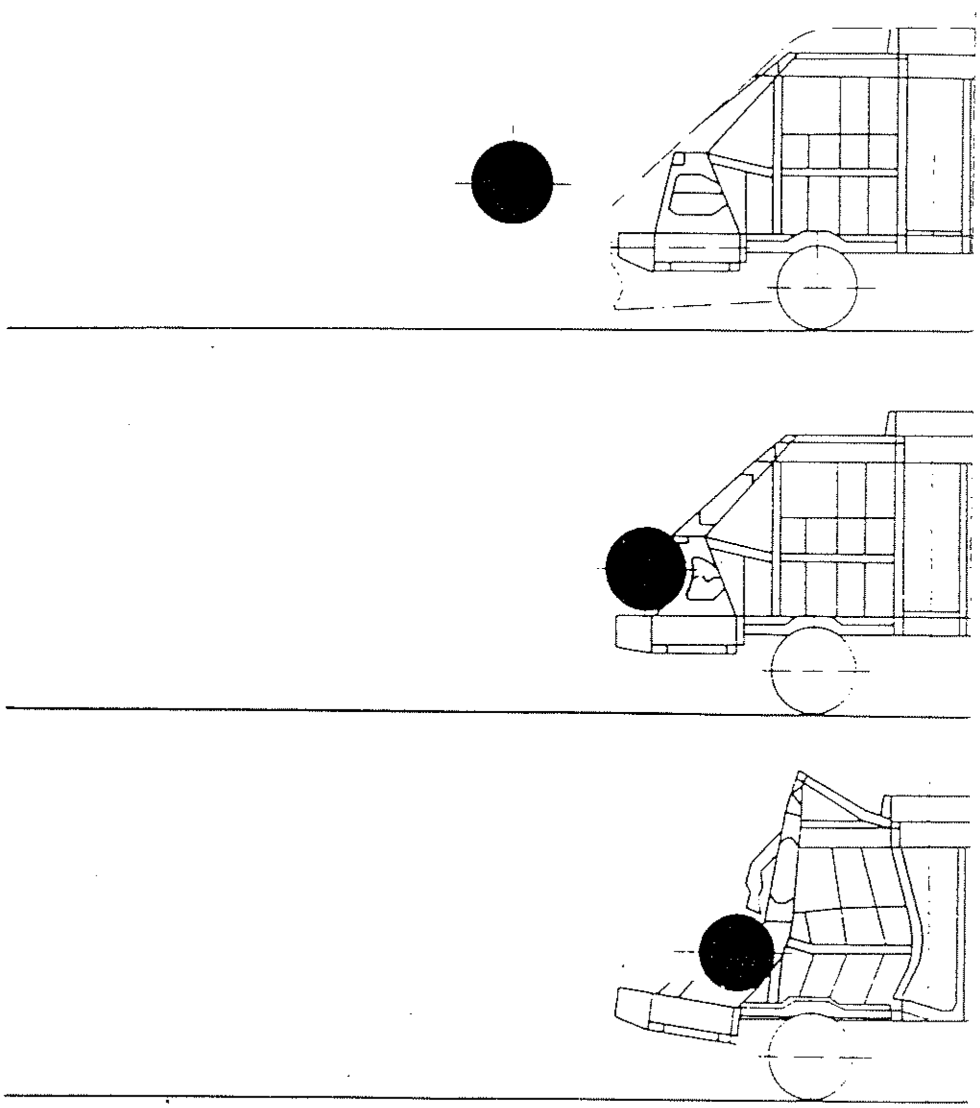
MELLANVAGN

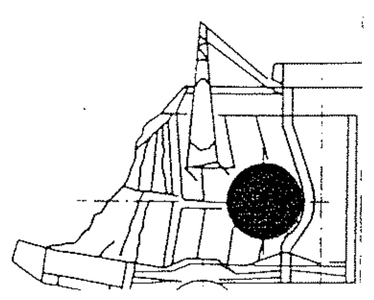




2 KLASS   80 PL

DEFORMATION SEQUENCE FOR THE FRONT OF THE X2 HIGH SPEED TRAIN DURING A COLLISION WITH A STEEL CYLINDER





DATA FOR THE CYLINDER

- Mass 10000 kg 400 kg
- Length 2 m

ABB
ASEA BROWN BOVERI

ABB TRACTION AB
S-721 73 VÄSTERÅS
SWEDEN

TELECOPIER +46 21 128803
TELEPHONE +46 21 322000
TELEX 40847 abbtrc s

Telecopier No. 0091 613 545-3856	**Date** 921214
Company Canadian Institute of Guided Ground Transport	**No. of pages incl. this page** 1
Attention Mr Gordon W. English	**Dept.** -
Copy to Åke Wennberg	**Dept.** TT
From Karin Håkansson	**Dept.** RTF
Reference Meeting in Västerås concerning X2000	

If not well received please advise sender.

Concerning deformation zones in passenger coaches for X2000, the vestibules are designed to act as deformation zones in case of a crash but no calculations to verify it have been done.

Best regards,

Karin Håkansson

ABB TRACTION plnvr5x2(turn) Mqt 1991-12-05-14.32

TSPC 1.10c1 X2 planspaar, drivenh plus 5 vagn

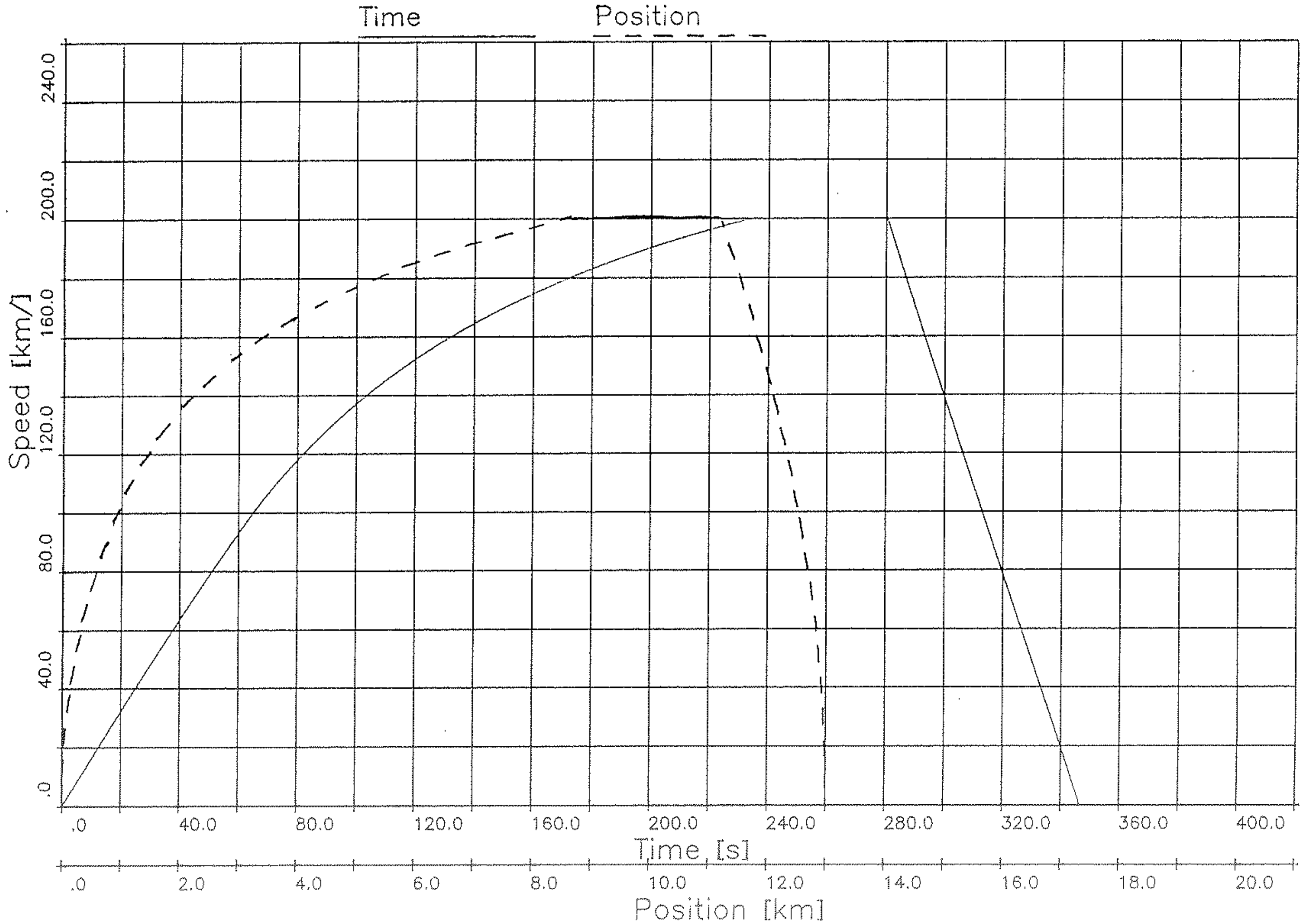
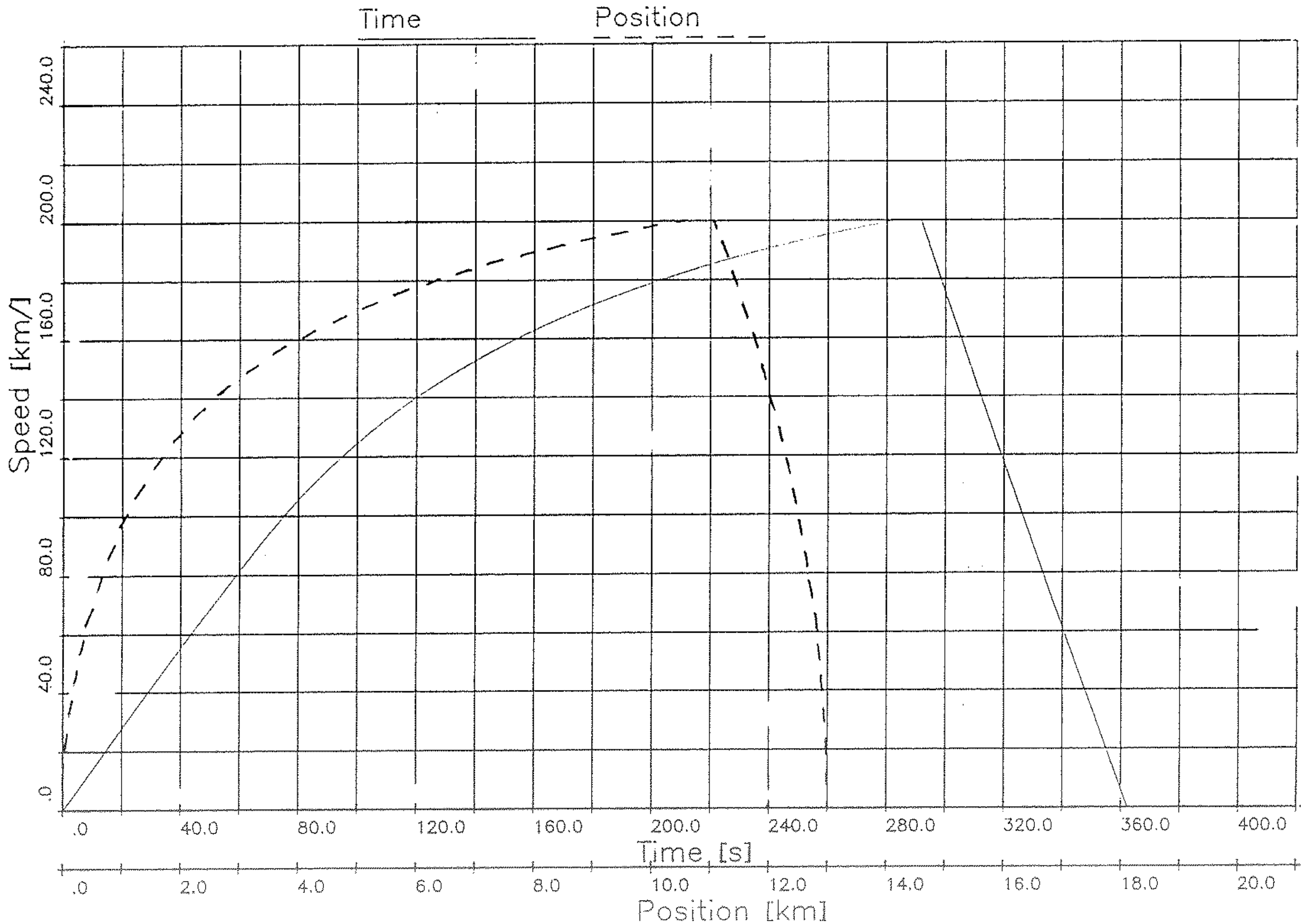


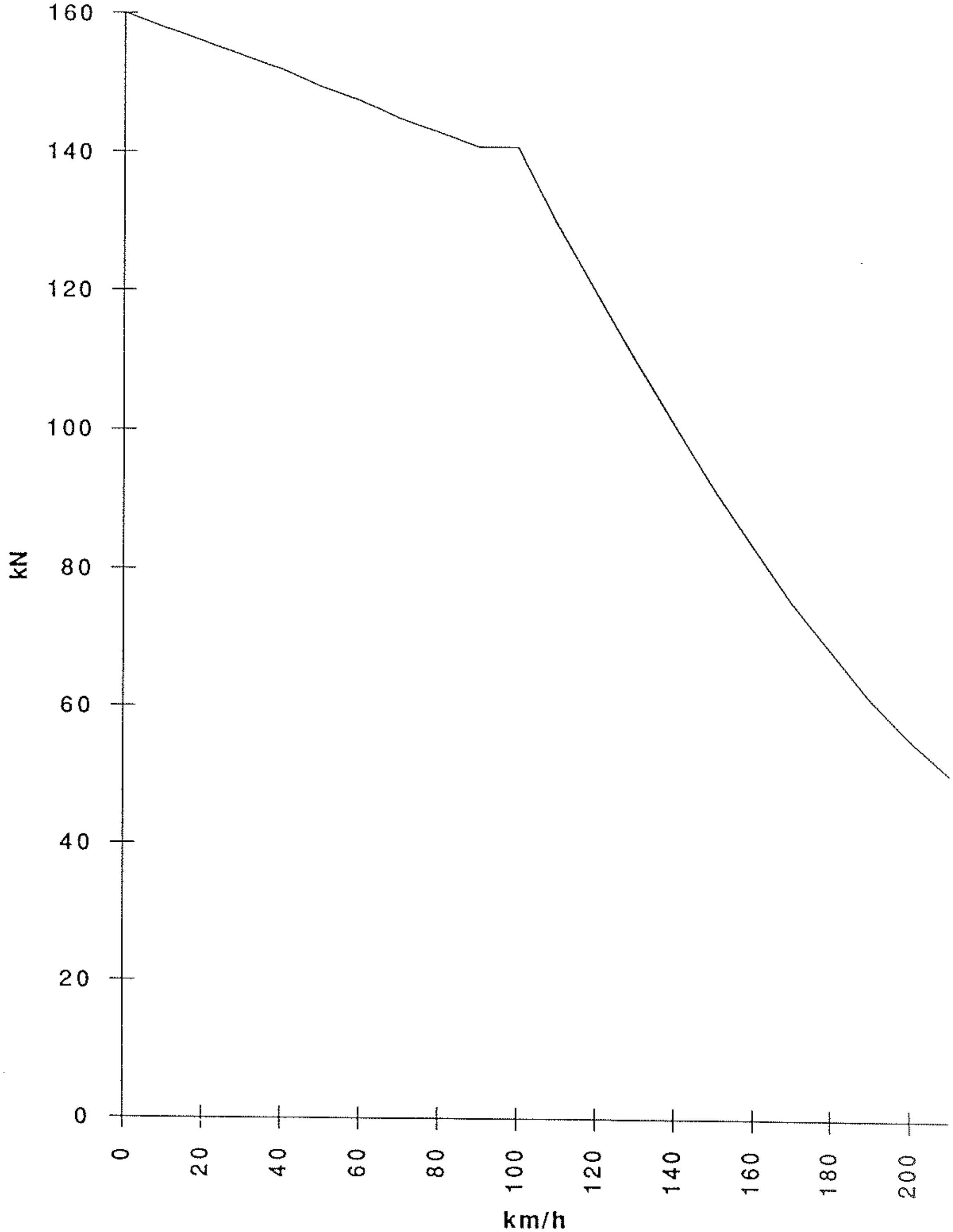
ABB TRACTION'planvrx2(turn) Mqt 1991-10-19-10.02

TSPC 1.10c1'X2 planspaar, drivenh plus 6 vagn



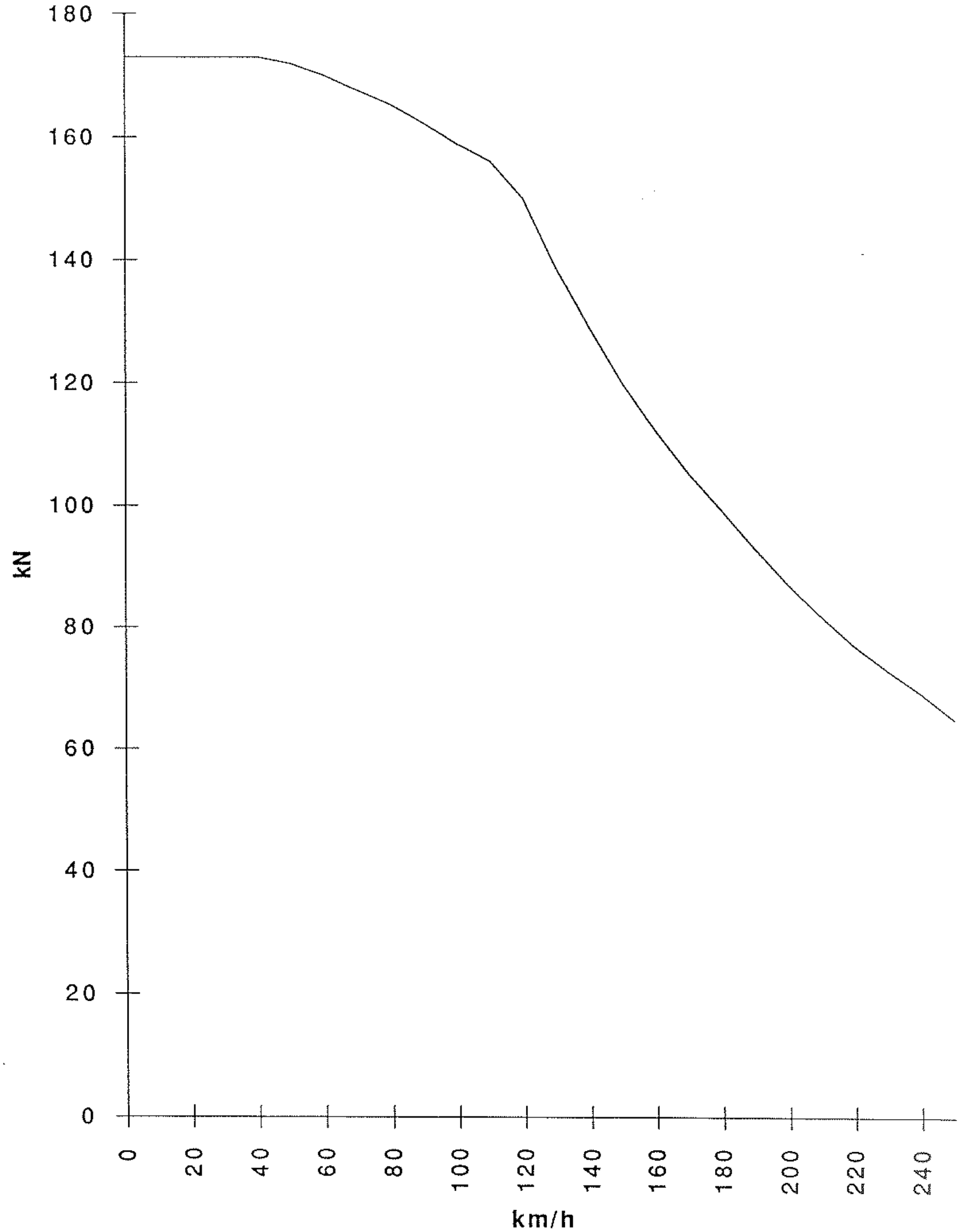
Diagr dragkraft X2/SJ 92-12-2

Tractive effort X2/SJ



Diagr dragkraft X2000-HP 92-12-2

Tractive effort X2000-HP



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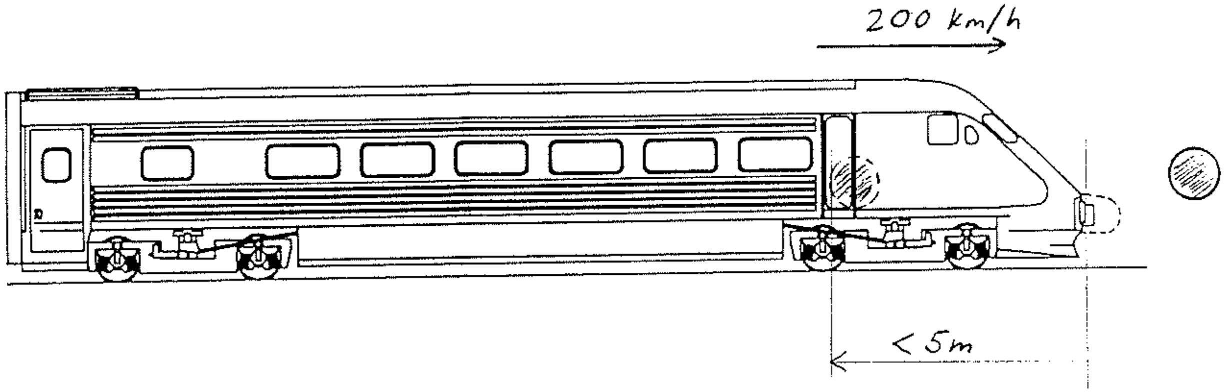

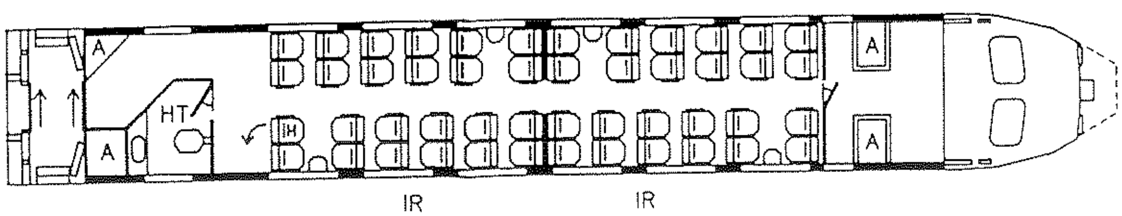

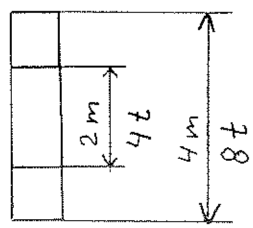

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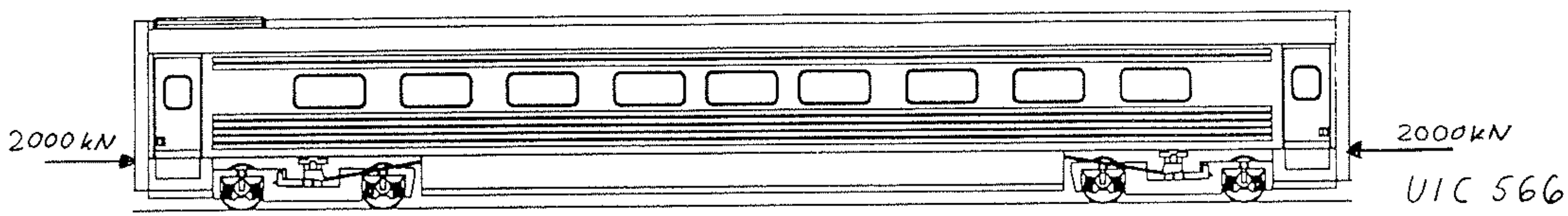

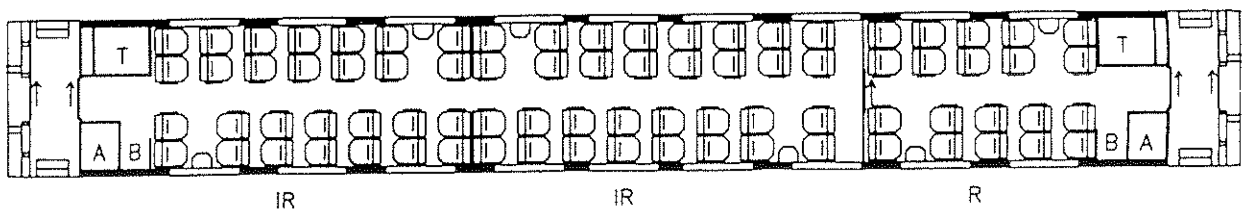

2 KLASS 80 PL

High Speed Train X2

Trainset description

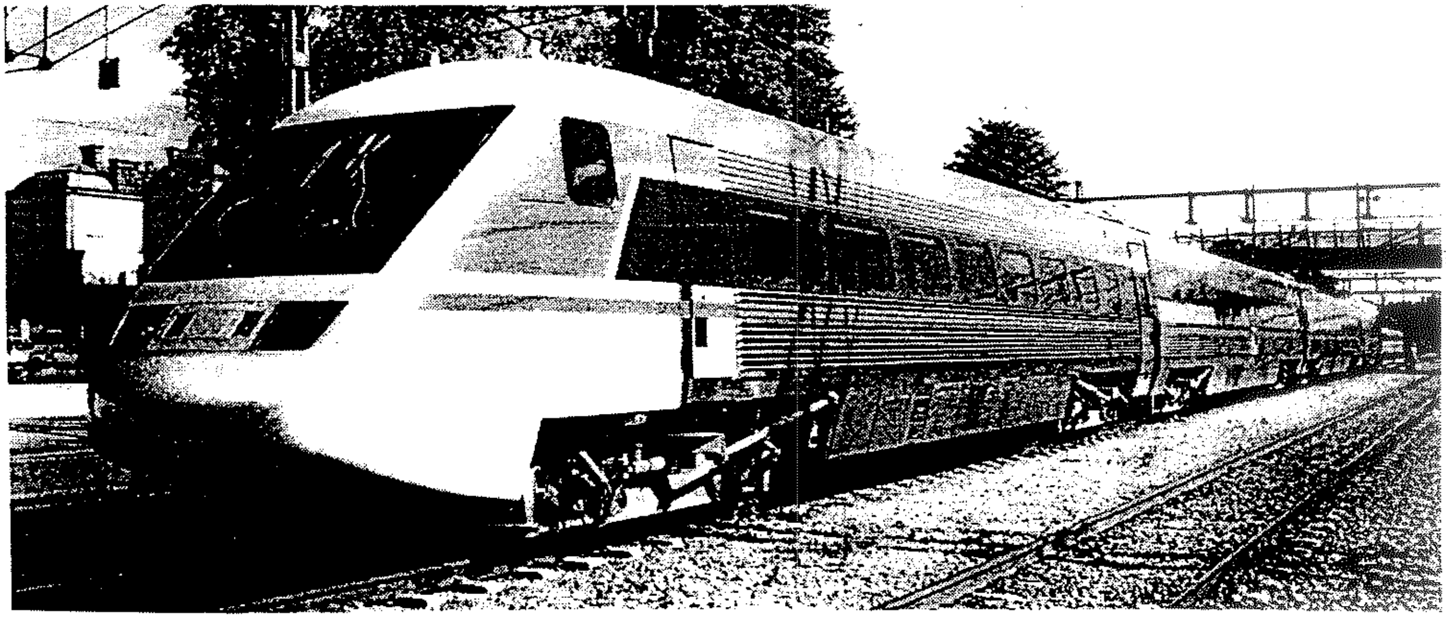

ABB Traction AB

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1. High speed train X2, general

After many years of development and tests, SJ has placed an order with ABB Traction for 20 exceptionally comfortable and modern high speed train sets with type designation X2. The high speed train is capable of travel at 200 km/h on existing rail tracks, between the three largest Swedish cities, Stockholm, Gothenburg and Malmö and between Stockholm and Sundsvall. This has been made possible by the advanced technology incorporated in the X2 train.

- smooth riding radial steering bogies
- asynchronous drive system
- active car body tilting

The savings in travel time in comparison with times currently available are as follows.

Line	**Current Travel time by train**	**Travel time by X2**	**Travel time reduction**
Stockholm - Gothenburg	4 hours	2 hours 55 mins	1 hour 5 mins
Stockholm - Malmö nonstop	6 hours 3 mins	4 hours 17 mins	1 hour 45 mins
Stockholm - Malmö incl. stops	6 hours 46 mins	4 hours 40 mins	2 hours 6 mins
Gothenburg - Malmö	3 hours 40 mins	2 hours 46 mins	54 mins

Table 1. Travel times

The active carbody tilting system in combination with radially steering bogies and functional and comfortable interior fittings has resulted in a high degree of comfort for the passengers and a good working environment for the train personnel. The aerodynamic shape of the train set gives low air resistance and a modern appearance and contributes to a low energy consumption. The carbodies are of stainless steel and are designed for optimum strength and rigidity which contribute to both comfort and safety in the event of an accident. A high degree of operational reliability and ease of maintenance have also been given high priority in the design of the X2 high speed train set.

A train set consists of six units, one power car with accomodation for express freight, two 1st class intermediate trailer cars, a buffet car, a 2nd class intermediate trailer and a driving trailer with 2nd class passenger seats. The driving trailer is designed to accommodate handicapped passengers and is provided with a wheel chair lift.

The arrangement of the train set is shown in Fig. 1 and the main data is presented in Table 2. A further intermediate car can be added to the set at the expense of slightly increased travel times. The train is also prepared for running with two power cars, one at each end. More intermediate cars can then be added to the train set. A number of train sets can be coupled in series by means of the automatic couplings at the ends.

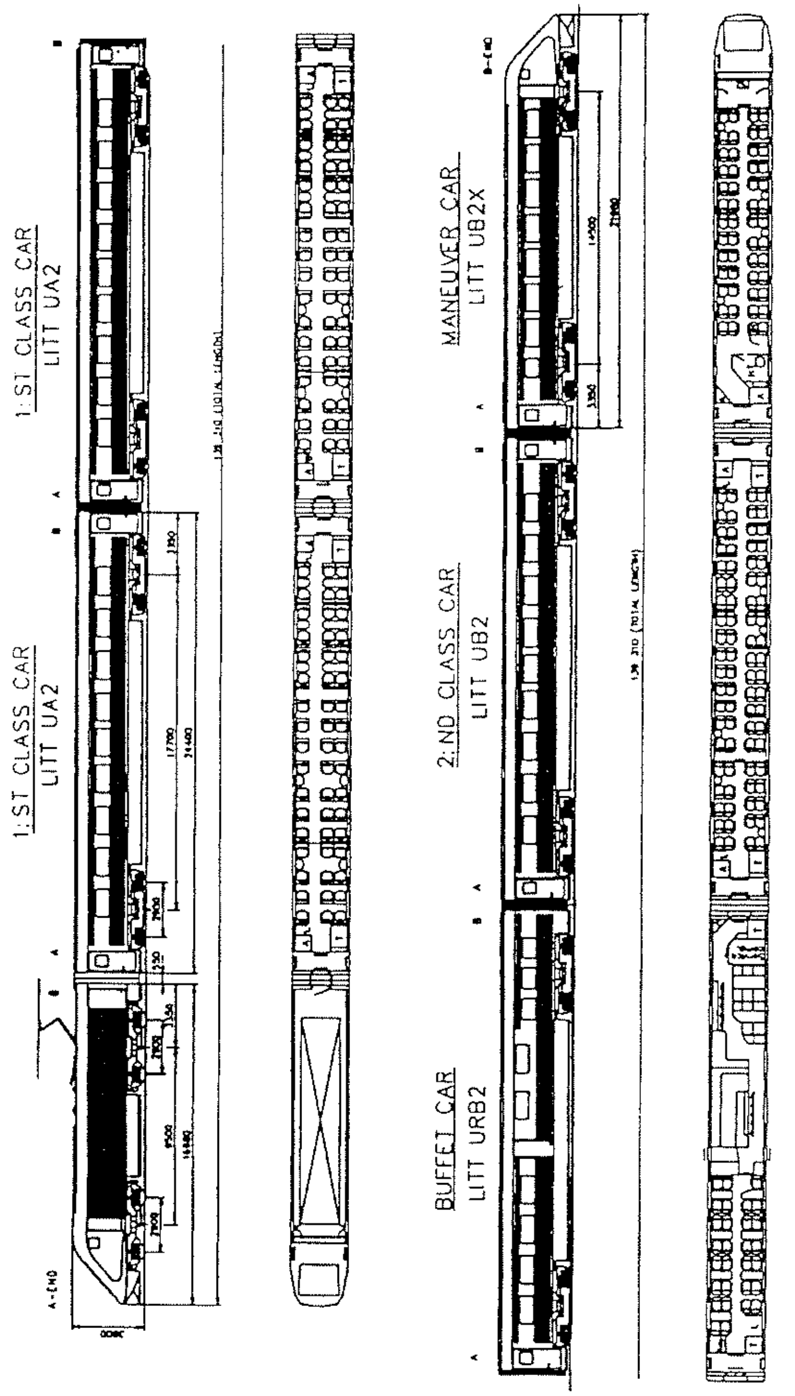


Figure 1. Arrangement of the first 10 high speed train sets to be delivered.

Number of seats

Car	UA2	UA2	URB2	UB2	UB2X
Non-smoker	39	39	29	60	50
Smoker	12	12	–	20	–
Handicap seats	–	–	–	–	2
Total seats	51	51	29	80	52

Train set configuration		1 power car, 5 car (incl. driving trailer)
Power supply		15 kV, 16 2/3 Hz.
Maximum speed		210 km/hour → 250 km/hour
Number of passenger seats		
1st class		102
2nd class		154
Buffert car		29 + 11
Track gauge		1435 mm
Length of train set		140 m
Total weight (train fully loaded)		343 tonnes
Drive system		Three-phase asynchronous motors GTO-thyristor convertors
Rated power		3260 kW
Maximum starting effort		160 kN → 180 kN
Wheel diameter	Power car	1100 mm,
	Trailer cars	880 mm
Carbody material		Stainless steel

Table 2. Main data

2. Power car, X2

2.1 General

The light weight X2 power car with asynchronous traction motors and convertor with modern GTO (Gate Turn Off) thyristor is the result of developments begun in the middle of the 70's in, for example, the Rz1 experimental locomotive.

The design of the X2 power car provides reliable and comfortable operation at speeds in excess of 200 km/hour and simple maintenance and service.

The power car accommodates a driver's compartment, space for express freight, and the extensive electrical equipment required for the operation of the train. The heaviest component, the main transformer, is installed under the floor, in the middle of the car, to lower the center of gravity.

The convertor equipment, vital parts of the control equipment and the compressed air equipment are located in the middle of the power car, accessible from passageways on both sides of the car.

The pantograph and other high voltage equipment are recessed in the power car roof.

The rounded front of the power car, the flush finish of the roof, car body, windows are doors and the enclosed undersides of the cars lower the air resistance and contribute to good aerodynamic characteristics and low energy consumption.

Automatic coupling devices at the front of the car permit the multiple coupling of two train sets. The layout of the power car is shown in Fig 2.

1 Traction module
2 Isolating switch
3 Auxiliary frequency converter
4 380 V framework
5 Microcomputer framework
6 Auxiliary transformer
7 33 Hz filter
8 DC link
9 Traction motor fan
10 Oil cooler
11 Oil pumps
12 Tool cupboard
13 Air framework
14 Compressor
15 Air dryer
16 Space for express goods
17 Main transformer
18 Line filter
19 Battery
20 ATC antenna
21 15 kV equipment

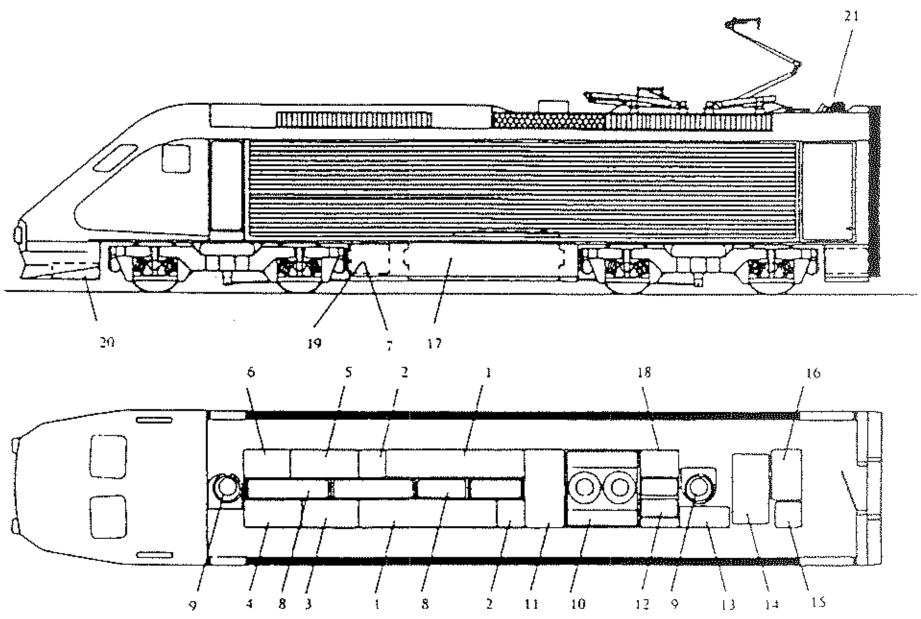


Figure 2. Power car layout

2.2 Electrical equipment

The design of the electrical traction equipment of the power car has been determined by the absolute requirement of SJ (Swedish State Railways) for short travel times. A modern traction system with asynchronous 3–phase motors has been selected. The convertors are quipped with modern GTO thyristors for high performance at attractive cost. The tractive effort curve for the X2 power car is shown in Fig 3.

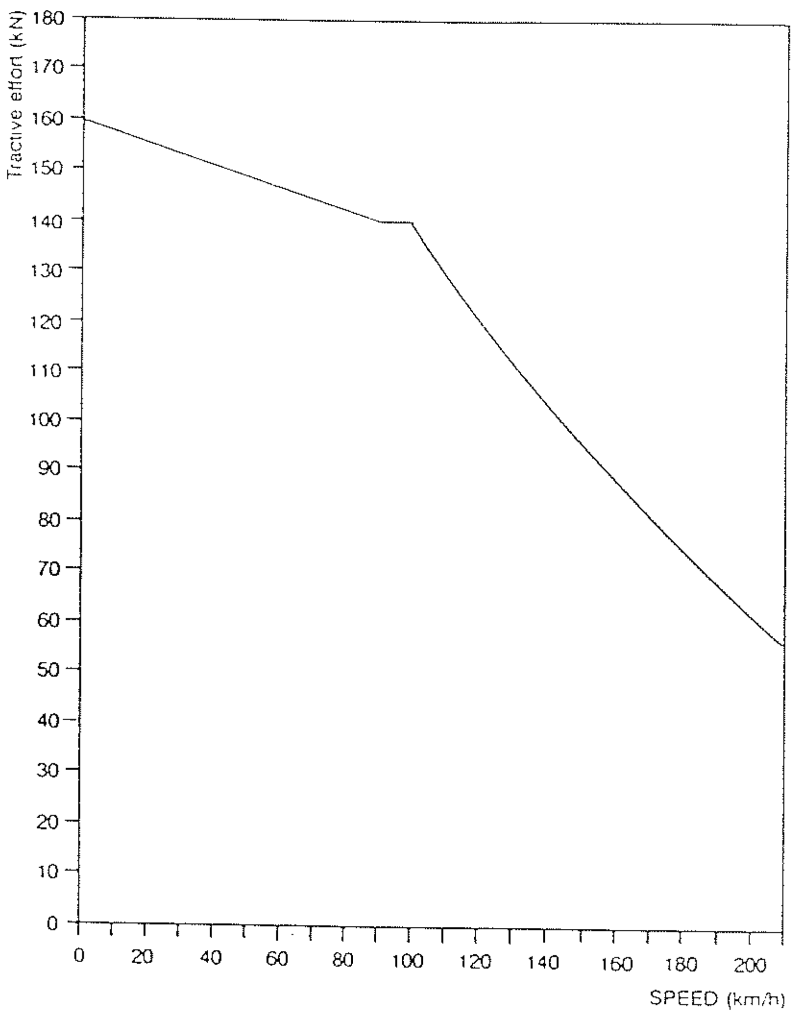


Figure 3. Tractive effort

The propulsion equipment has been divided into two identical traction modules to ensure a high degree of availability. Fig 4 shows, in principle, the design of the main circuits and of a traction module.

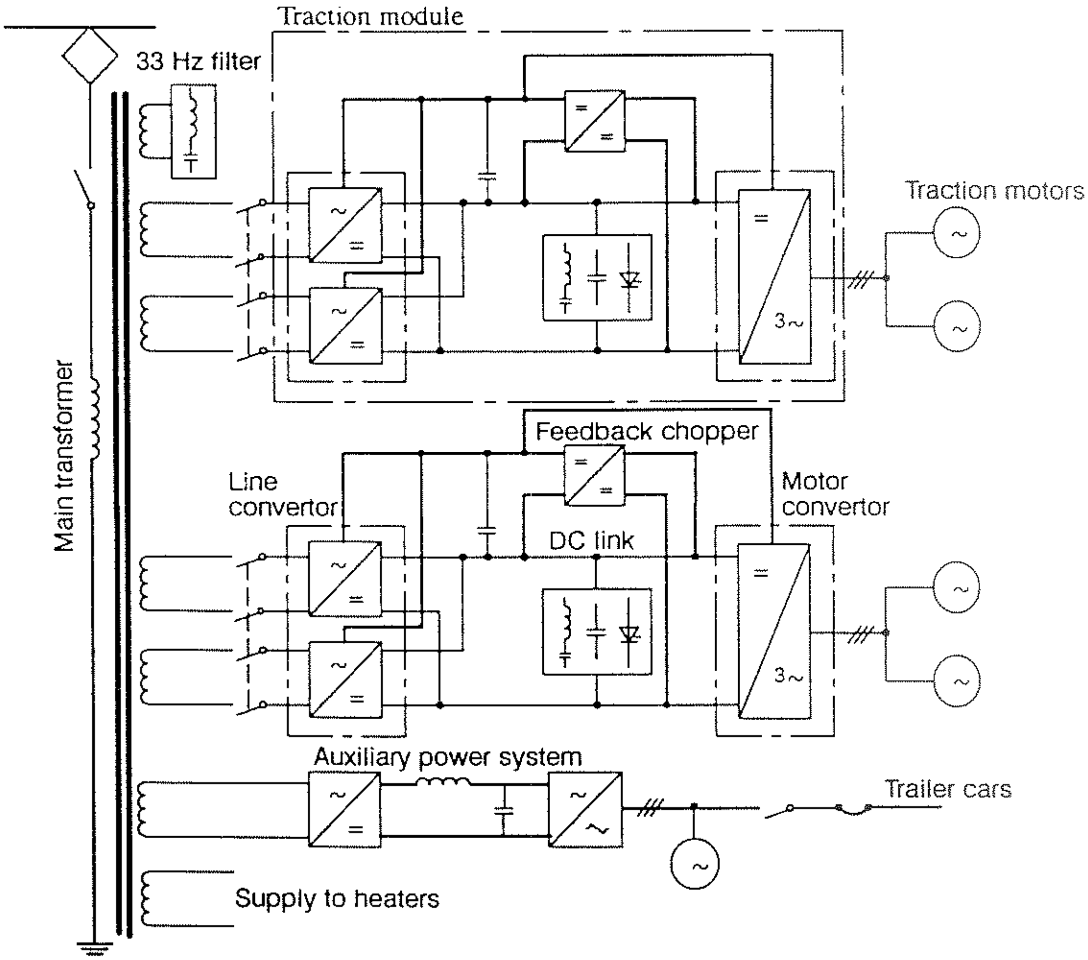


Figure 4. Design, in principle, of the main circuits

Each traction module consists of:

- two line convertors
- one d.c link
- one feedback chopper
- one traction motor convertor
- two traction motors mounted in the same bogie.

A line convertor consists of two GTO thyristor bridges which are self-commutating and work with a power factor close to 1 with negligible distortion of the sine form of the line current.

This results in the lowest possible current requirement from the overhead line and in a minimum of interference and losses in the power supply system. The line convertors have been designed for full feedback of electrical braking energy to the overhead line. The firing pulses are conducted to the thyristors via optical fiber cables that are insensitive to interference.

The d c link at 2400 V is common to two line convertors. It consists of capacitors, a 33 Hz filter and the necessary protective equipment. The feed back chopper returns the commutation energy from the convertors to the capacitor battery of the d c link which is mounted in the middle of the machine room of the X2 power car, between the two traction modules. From the top capacitor, the commutating energy is conducted further, via a thyristor, a reactor and a diode back to the d c link. The regeneration of the commutation energy increases the total efficiency of the drive system.

The traction motor converter converts direct current from the d c link to three-phase a c 0–1870 V, 0–120 Hz, to power two asynchronous motors coupled in parallel, each with a continous power rating of 815 kW. The GTO thyristors in the convertors are of the same type as those used in the line convertors. This simplifies maintenance and spare parts logistics. The frequency and the output voltage to the asynchronous traction motors are controlled in the convertors so that the maximum usable torque can be supplied at all train speeds, on order from the driver's power control and required speed selector.

The main transformer of the power car is specially adapted, with respect to voltage and inductance for convertor supply. The foil-winding method has been used for the convertor windings of the transformer. The transformer tank also accommodates reactors for the auxiliary power inverter and the 33 Hz filter that consequently does not require any separate cooling system.

2.3 Auxiliary power equipment

As shown by the circuit diagram, Fig 4 auxiliary power is drawn from a separate winding on the main transformer. The auxiliary power convertor converts 840 V, 16 2/3 Hz from the main transformer to standard voltage, 3 x 380 V. This is used to drive the cooling fans, the main compressor, pumps etc in the power car and also provides power to the comfort and service equipment in the trailer cars.

If the auxiliary power system is overloaded, the convertor reduces its output voltage and frequency.

A 1000 V, 16 2/3 Hz trainline runs the length of the trainset for supply to heaters and battery chargers. The 1000 V power trainline can be supplied from a separate winding on the main transformer or can be connected to fixed external train supply outlets.

2.4 Mechanical drive

The traction motors, which have a power rating of 815 kW, are built as four pole asynchronous motors with squirrel cage rotors and are adapted to convertor supply in the range 0–1870 V; 0–120 Hz. Because of the high inductance of the motor, it was possible to design the power car without the start reactor usually necessary.

The motors have forced double-sided cooling with radial air ducts in both stator and rotor. The robust motors have stators of ductile cast iron with varnished, glass fiber-covered copper wire windings. The coils ar insulted with dry mica tape and vacuum impregnated with silicone resin for resistance to dampness and high degree of thermal stability. The rotor winding is of aluminium rods and is dimensioned for considerable slip. This contributes to reduced sensitivity to any difference in wheel diameters with drives with two parallel-supplied motors in a bogie. Fig 5 is a photograph of a traction motor.

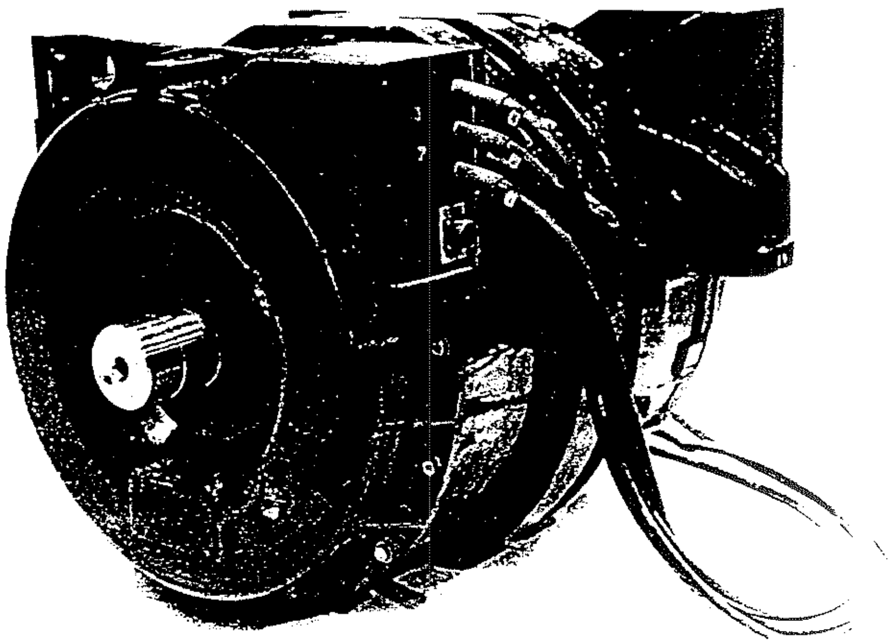


Figure 5. Traction motor

The mechanical drive system incorporates a fully suspended gearbox with quill tube and couplings to transfer the driving torque to the wheel of the power car. Fig 6 illustrates the configuration of the drive system.

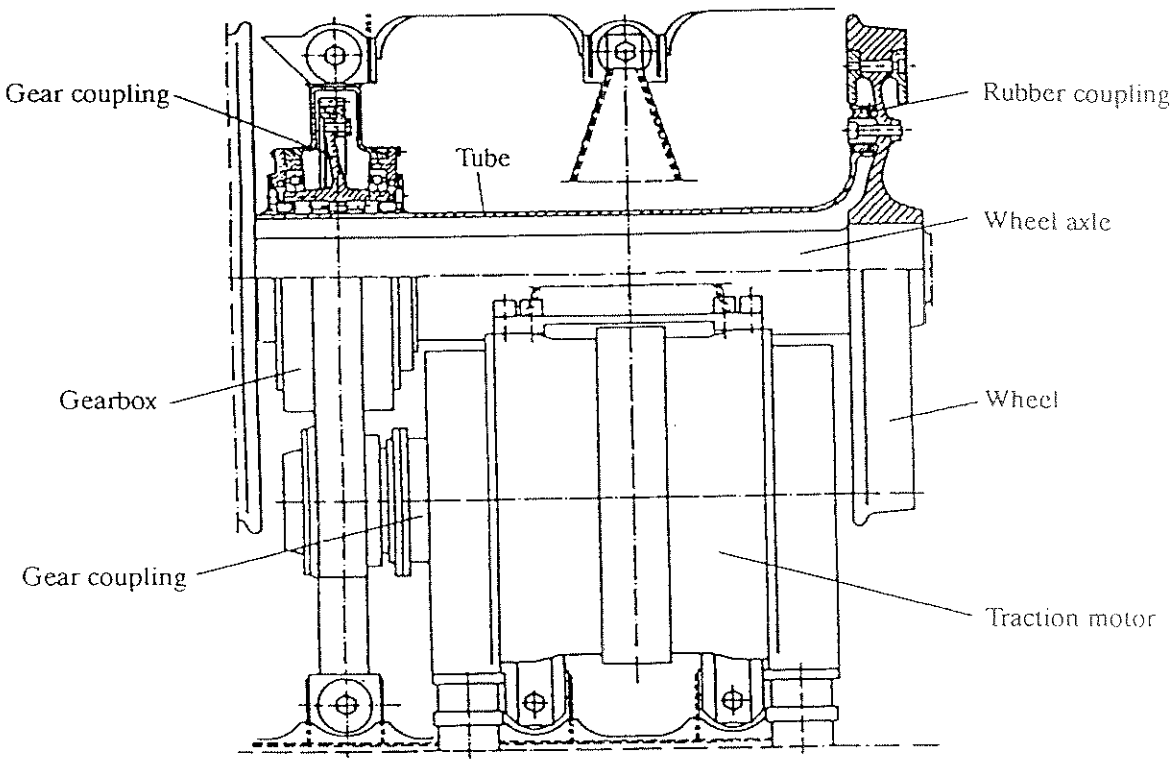


Figure 6. Mechanical drive equipment

The torque is transferred from the traction motor, through a double gear coupling to the gearbox, the output speed of which is adapted to the drive wheel diameter. From the gearing, the torque is transferred via a gear coupling to a quill tube which encloses the wheel axle. The tube transfers the torque further to rubber coupling elements mounted in one of the wheels of the pair. Both the motor and the gearbox are suspended in rubber elements on the bogie frame. This, together with the use of bored wheel axles reduces the unsprung mass to a minimum.

2.5 Power car bogie

The power car bogie is of the radially steering type with radially selfadjusting axles. The principle of the soft bogie is shown in Fig 7. The rubber element in the primary suspension of the bogie is specially adapted to the current static and dynamic forces between the wheel and the bogie frame so that the frictional forces which develop between wheel and rail steer the wheel pair through the curves in the track.

The secondary suspension consists of air springs which absorb the forces between the bogie and the carbody. The secondary springing is supplemented with an anti-rollbar which minimizes carbodies sway.

One of the important factors in obtaining riding comfort is the effective suppression of car motion on its suspension. The x2 bogies are therefore provided with a primary damping of the movement between wheel pairs and bogie and with lateral, vertical and yaw dampers in the secondary suspension.

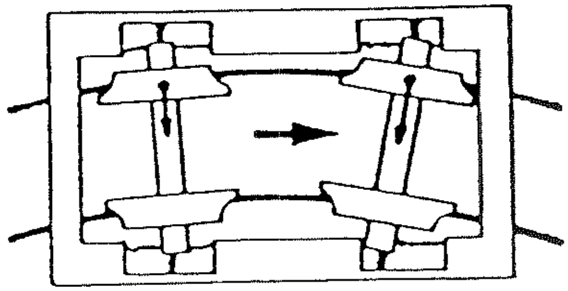


Figure 7. Principle of soft bogie

3. Trailer cars, UA2, URB2, UB2 and UB2X

3.1 General

The trailer cars of the train set have the same exterior design and aerodynamic characteristics as the power car. The appearance of the trailer cars is shown in Fig 8. The trailer carbodies are also of stainless steel and run on radially self-steering bogies which are equipped with an active tilting system.

The intermediate trailer cars and the driving trailer have, in principle, the same design. The driving trailer has been adapted for the convenience of handicapped passengers by widening the doorways and providing a lift for wheel chairs. Two places in the passenger compartment are reserved for wheel chairs. The driving trailer contains a compartment for the driver when this is the first car in the set. This compartment is equipped with the same controls and instruments as the driver's compartment in the power car. The "front" of the driving trailer has the same aerodynamic design and protective structure as the front of the power car. The bolster beams under the vestibules of the intermediate cars are designed to act as deformoration zones.

In designing the trailer cars, great efforts have been made to ensure the comfort of the passengers with a low noise level, effective ventilation, accurate temperature control, adjustable lighting and, not the least, a maximum of riding comfort.

The same construction is used for the 1st and 2nd class passenger cars. The passenger seats are fixed in longitudinal tracks to permit adjustment of seat spacing and flexibility when fitting out the car.

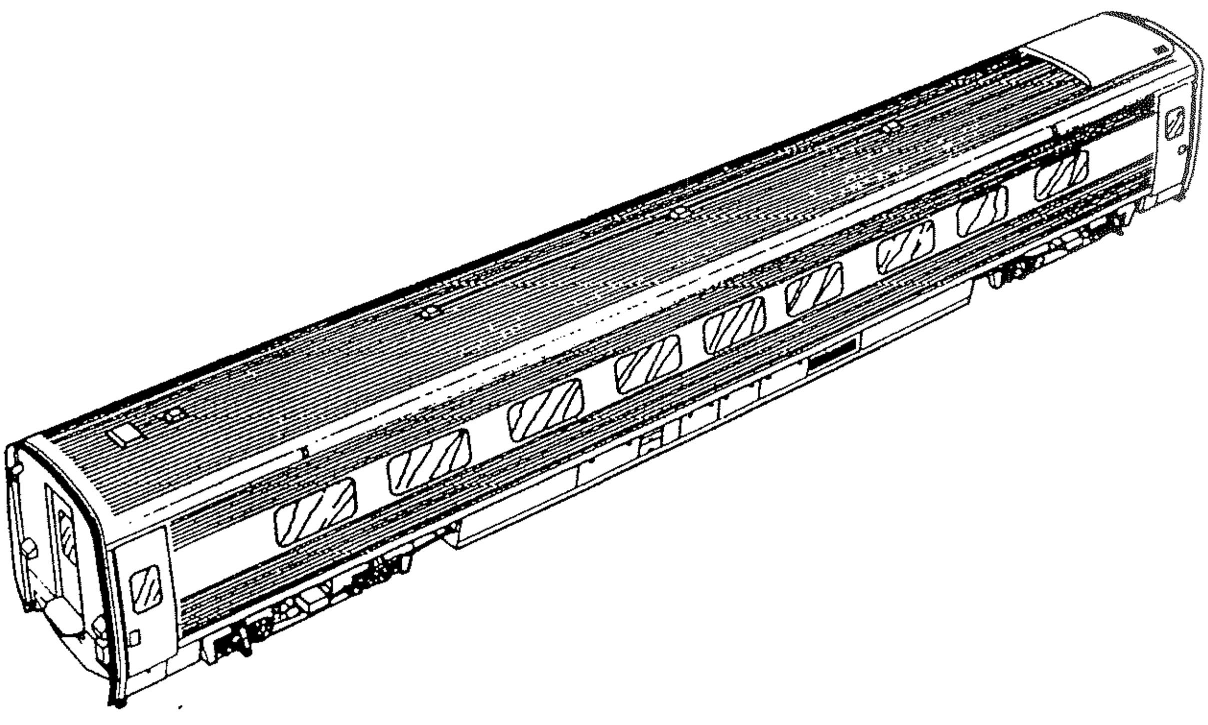


Figure 8. Trailer car extrior

3.2 Car interior

Walls

The partition walls in the passenger cars are finished with light-colored plastic laminate sheeting. The panels between the windows are clad with a suitable fabric.

Windows

The windows are double-glazed with a hardened outer safety glass pane with a light and heat-reflecting inner coating. The inner pane is of hardened glass laminated with a vibration-damping foil. The windows give a negligible distortion of natural external colors.

Ceiling

The ceiling coves are of lacquered sheet metal. The center panel, running the length of the car, contains fluorescent tube lamps which provide indirect lighting. Each passenger seat is provided with a reading lamp with a switch in the armrest.

Toilets

Toilets are located at each end of the passenger cars. The toilet system is of the completely sealed vacuum type. Fresh water and waste tanks and the vacuum pump are installed under the floor. A cooled drinking water fountain is located at the toilets.

Air conditioning

All of the passenger spaces and the driver's compartment are provided with air conditioning. The equipment for each car is installed in the roof space at the ends of the car with the compressor and condenser in the space under the floor. The air conditioning system is controlled by a local computer in each car.

Passenger information

The passengers are provided with relevant information via a public address system and a visual display. Microphones for the former are located in the driver's compartments, the staff compartment, the buffet counter and in one vestibule of each passenger car. The visual display is installed over the exits from the passenger compartments and contains symbols for toilet, telephone and the buffet and for indication of the name of the next station. The station name is coded in from the driver's compartment.

Music distribution system

The train is provided with a system which offers the passengers the choice of 3 radio/tape recorder channels. Contacts for earphones, selector and volume control are located at each passenger seat.

Communication equipment

The driver remains in contact with the SJ traffic radio network via an external radio connection from both the driver compartments. An internal telephone connection provides the driver with the means of contact with the other members of the train crew. A public telephone is located in the buffet car. Two cellular telephones are provided in the 1st class cars. The driver's compartments are equipped with a mobile telephone connected to the Nordic mobile telephone network. Terminals for rivate mobile telephones ar provided at 5 single seats in each 1st class car.

Planned conference compartments

It is possible, in the 1st class cars, to form 3 conference compartments with the help of glazed walls and draperies, each with 4 sets per compartment. There is access to a cellular telephone and 220 V 50 Hz power in each compartment for connection of PC's. The layout of a 1st class car with conference compartments is shown in Fig 9. An artist's impression of the interior of a conference compartment is shown in Fig 13 on the last page of this description. A conference compartment which has not been reserved can be made available for other passengers.

Handicap equipment

A wheelchair lift and extra wide doors for the passage of a 70 cm wide wheelchair are provided in the driving trailer which has space reserved for 2 wheelchairs and a large toilet. Some of the places in the driving trailer are equipped with specially adjustable seats. Seat numbers in relief are of assistance to blind passengers.

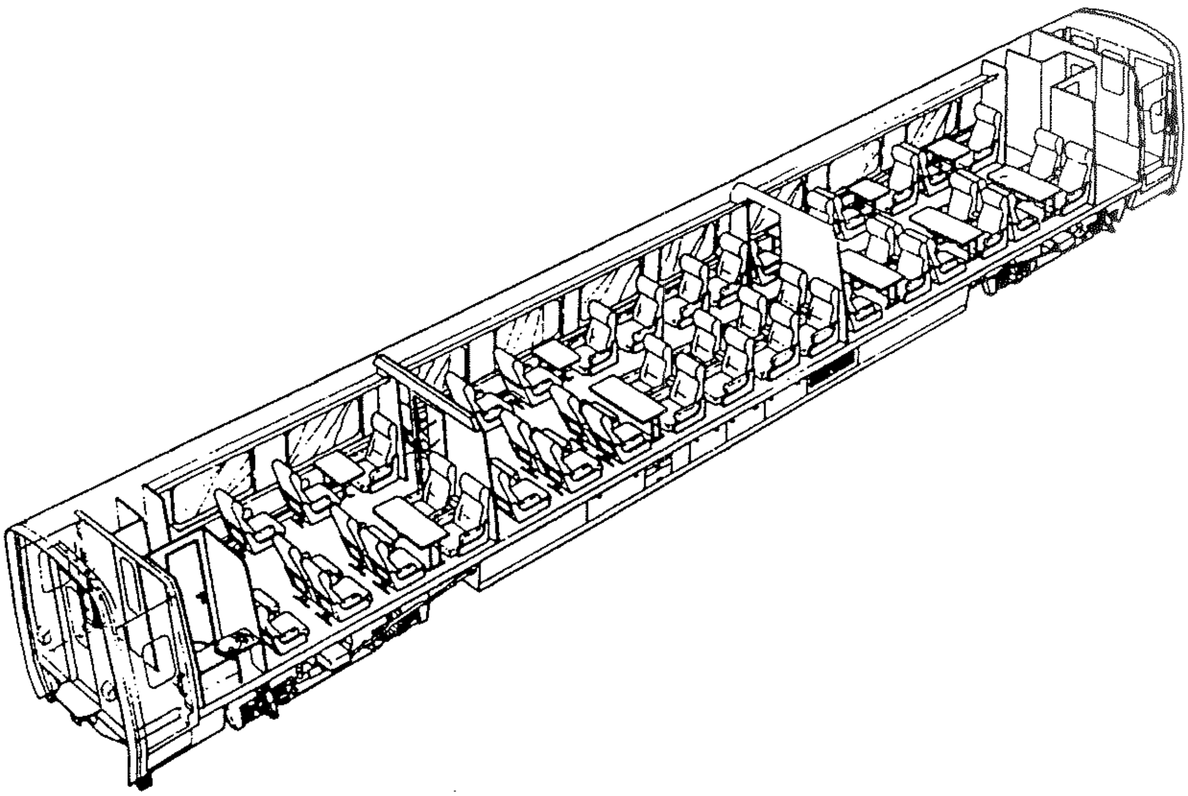


Figure 9. Layout of 1st class passenger car

3.3 Trailer car bogie

So-called radially selfsteering bogies are used in the X2 train. These are of a proven design which has been used in the X10 suburban trains in Stockholm, Malmö and Gothenburg.

In the X2 installation, the bogies have been provided with two bolster beams which, together with an hydraulic suspension system permit tilting of the carbodies when passing a curve. Fig 10 is a photograph of a trailer car bogie.

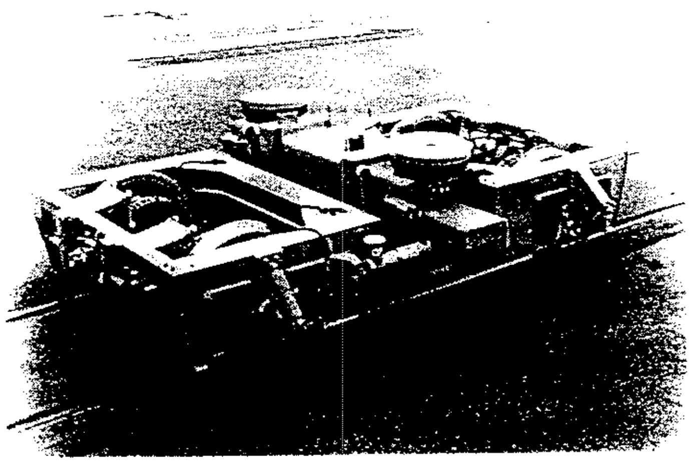


Figure 10. Bogie for trailer car

The lower bolster beam rests on the bogie frame via rubber sandwich elements which allow for rotation between these. The upper bolster beam is connected to the lower by four pendulum rods. Each end of the upper bolster beam can be lifted by an hydraulic cylinder, thereby tilting the carbody. The carbody is provided with secondary air spring suspension and is further stabilized with lateral, vertical and yaw dampers.

Each bogie has two pairs of monobloc 880 mm diameter wheels. Each wheel pair is equipped with compressed air-operated disc brakes. The braking forces are transferred from the wheel pair to the bogie frame via rubber elements in the primary suspension. The bogie frame is also provided with a magnetic track brake. The brake forces are transmitted further through a rubber-seated center pivot to the lower bolster beam which is connected to the carbody by traction rods.

3.4 Active car body tilting system

All of the trailer cars are provided with a carbody tilting system to ensure passenger comfort when the train passes curves at high speed. Fig 11 illustrates the principle of this system.

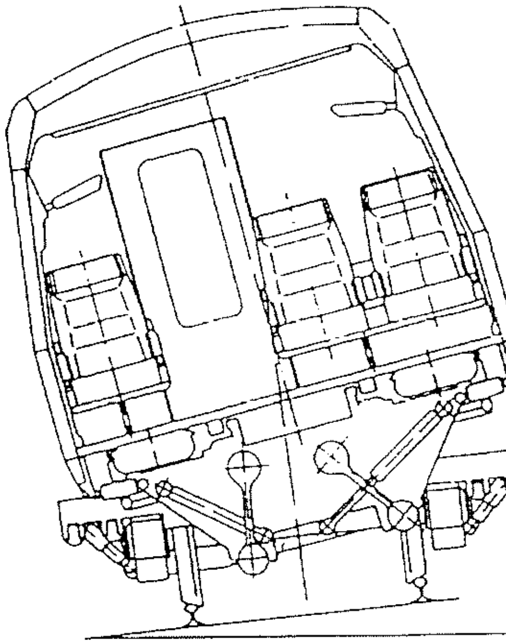


Figure 11. Carbody tilting

Extended testing in the X15 experimental project has demonstrated that a carbody tilt of 6,5 degrees is the optimum for passenger ride comfort at 9,5 degrees of cant deficiency. To achieve at 6,5 degreed carbody tilt, the angular displacement between carbody and bogie frame must be 8 degreed. Thus:

- Bogie frame - bolster beam	8 degrees
- Bolster beam - carbody	-0,5 degrees
- Bogie frame - track	-1 degrees
- Effective carbody tilt	6,5 degrees

This tilt eliminates the effects of approximately 70 % of the centrifugal forces developing at a curve. The speed of the X2 train can be increased by 30 % above that of a conventional train with no loss of passenger riding comfort. The carbody rotates around its center of gravity and the track forces are therefore not appreciably affected. The tilting of the cars is controlled by acceleration sensors installed in the first bogie in the train set. The signals from these sensors are processed in an advanced computerized system which in turn controls the hydraulic cylinders which tilt the car as required. The tilting of the car obtained is fed back to the control system for comparison with the value commanded. As a fault in the car tilting system could temporarily reduce passenger riding comfort the most important components in the system have been duplicated. Redundant system sections have been incorporated in the control system to minimize the consequences of any disturbance in its function.

4. Train braking system

The braking system of the X2 train includes and electric brake in the power car, compressed air–operated disc brakes on all of the wheels of the train, magnetic track brakes on the trailer cars and compressed air–operated block brakes on the wheels of the power car.

The electric brake in the power car and the disc brakes on the trailer cars are applied under normal circumstances. If the electric brake is inadequate for the power car braking, the disc brakes are automatically applied on the power car also. The position of the brake control lever determines the pressure in the brake pipe via the automatic brake valve. The brake pipe is continous through all of the cars of the train and a drop in the system air pressure results in increased braking effort. Each car is provided with a control valve unit which applies pressure to the brake cylinders corresponding to the decrease in pressure in the brake pipe.

Each control valve unit is provided with an electro–pneumatic unit which reduces the time taken in applying and releasing the brakes. The function of this, in principle, is to empty and fill the brake pipe with air when respectively applying and releasing the brakes. The ATC system can also apply the brakes via the automatic brake valve. The brakes are dimensioned for a maximum braking distance of 1750 meters from a speed of 200 km/h and 700 meters from 130 km/h.

For minor speed adjustments, the driver can deflect the speed controller backward. Only the electrical brake will then be operated on the power car without compensation for any brake action not obtained because the energy cannot be accepted by the overhead line.

If the emergency stop function is triggered by the driver, the conductor of a passenger or via the automatic train control system, all of the compressed air–operated block and disc brakes and the track brakes of the trailer cars are activated.

The disc brake system of the cars is supplemented with parking brakes. The block brakes of the power car can also serve as antiskid brakes when the train accelerates on a track with insufficient friction.

The compressed air brakes of the train are equipped with protection against brake locking to reduce the risk of wheel flats. This protection monitors the rotation of the axles and releases the brakes on the bogie concerned if any risk of brake locking develops. The design of the brake system ensures the maximum of operating safety.

5. Train computer system

Most of the train control functions are integrated in the train computer system.

The computer equipment executes orders from the driver and provides his with information regarding the function of the different train systems, it implements the necessary feedback control functions and communicates with the different systems, e g with the automatic train supervision system ATC. The layout of the computer system, in principle, is shown in Fig 12.

M = Power car computer
T = Traction computer
F = Driver compartment computer
B = Brake/compressed air computer
C = Car computer

D = Door opening computer
A = Air conditioning system computer
V = Visual display

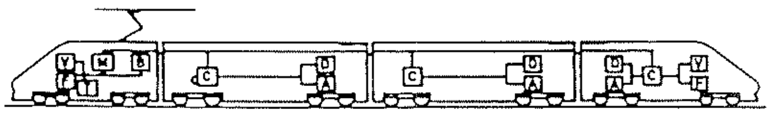


Figure 12. Computer equipment

The train computer system is based on the microcomputer system TRACS. TRACS has been specially developed for traction applications from the well-proven ABB MASTER computer system which is well known for its user-friendliness and simple programming. The computer system consists of a computer cabinet in the power car and a number of distributed computers in the trailer cars. The computers communicate via a 2-wire data bus.

The power car computer manages all of the functions necessary for the running and braking of the train set such as speed regulation, shunting control, limitation of the rate of change of power etc. It also calculates a required value for the tilting of the carbodies when the train set passes a curve. The main computer communicates via an ITDC communication link with the driver's computers and the car computers.

The driver's operations of the controls are transmitted as signals to the main computer via the driver's computer and signals for the driver's instruments and indicators are returned via the driver's computer. The main computer communicates with the compressed air system in a similar way via a decentralized single board computer mounted in the compressed air installation.

The main function of the car computers is to control the local carbody tilting and the anti-locking functions in accordance with references received from the main computer. They also communicate with their subordinate computers which control different brake functions, door opening functions and the air conditioning system.

The car computers also register up to 200 different signals from the car equipment.

The signal and indication system provides the driver with information about the status of the train set and the development of any malfunction. The system also issues appropriate instructions regarding action to be taken in any such situation.

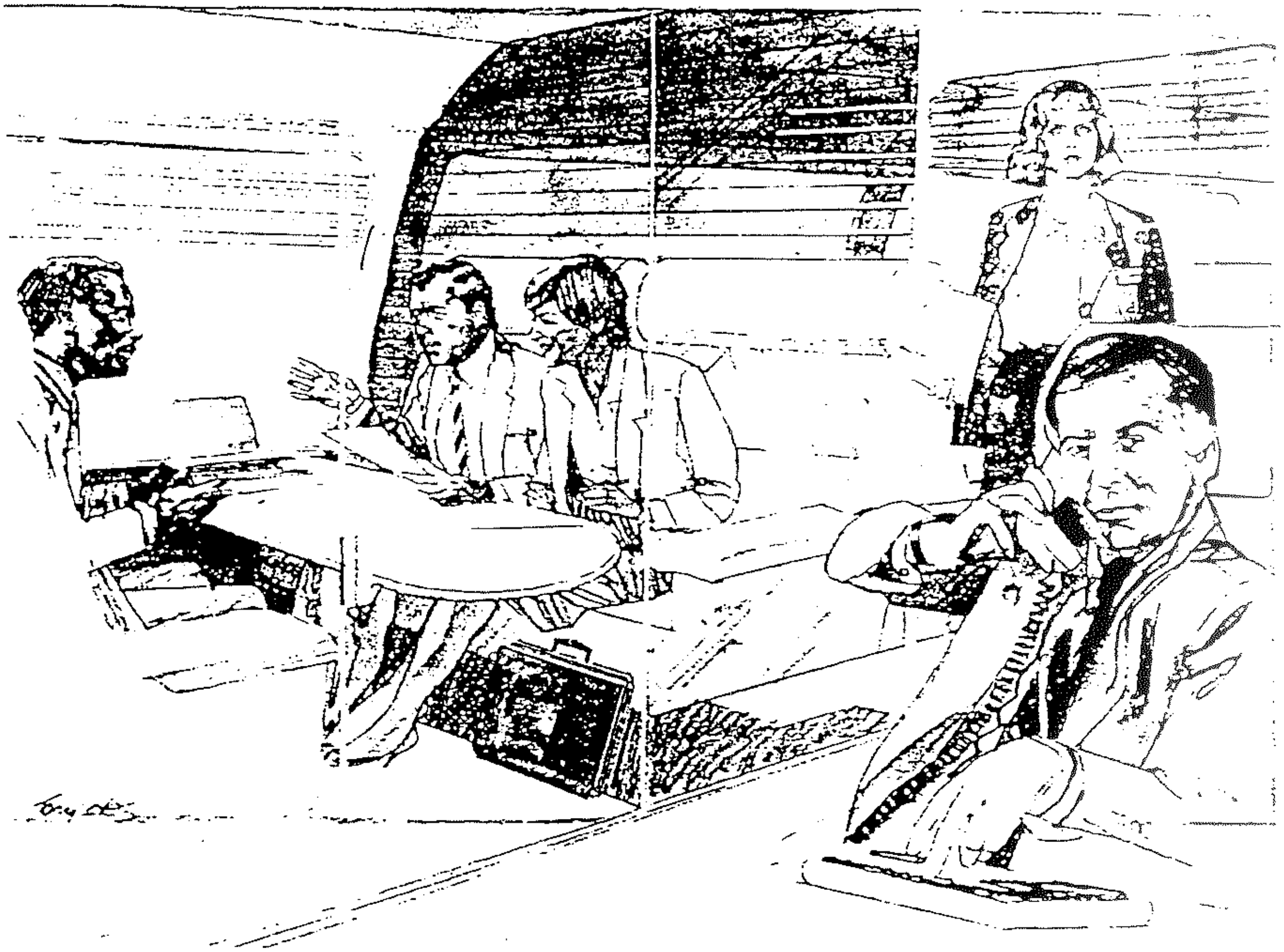


Figure 13. Interior of proposed conference compartment.

9

Market/Operations

SwedeRail AB

X 2000

Competitive Market Stockholm - Gothenburg (1989) before the introduction of the X2000.

(thousands)	Trips	of which business	Share	Change
Air	1.100	980	62%	+10-12%/year
Car	2.000	352	22%	+4-5%/year
Train	800	257	16%	decline

The air route is the ~~fourth~~ third in Europe in terms of travellers

ON-TIME PERFORMANCE

X 2000

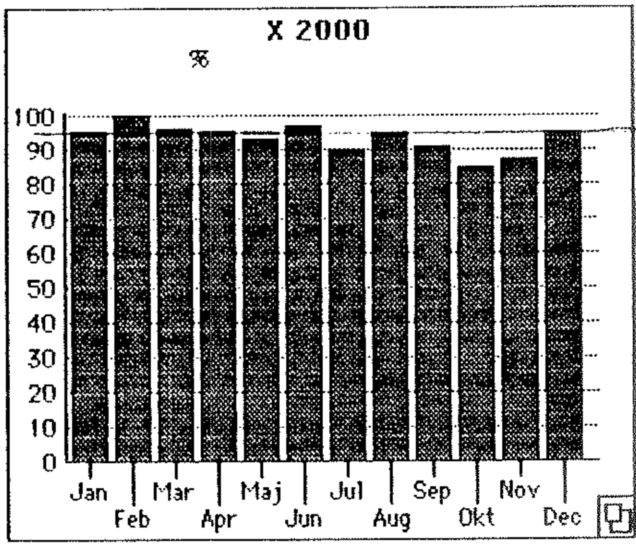
Vertikalt stapeldiagram

Skriv rubriker och värden.

1991

Rita diagram

X 2000	%	Enheter
Jan	95	
Feb	100	
Mar	96	
Apr	95	
Mai	93	
Jun	97	
Jul	89	
Aug	94	
Sep	91	
Okt	85	
Nov	87	
Dec	94	



krav 95%

☒ Använd till andra diagram

ON-TIME PERFORMANCE

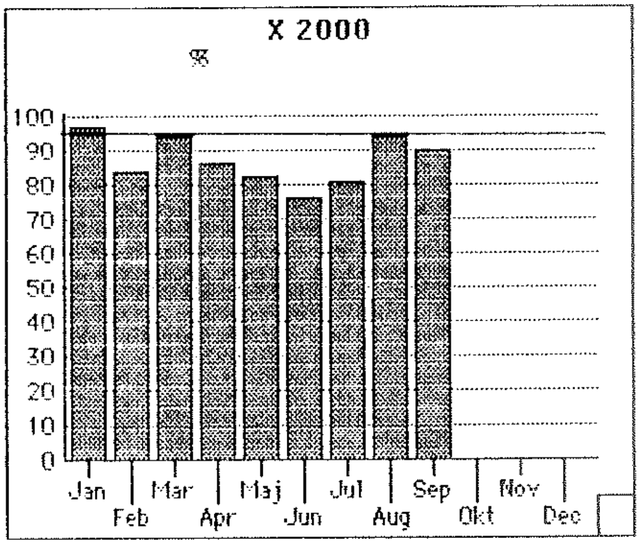
Vertikalt stapeldiagram

Skriv rubriker och värden. 1992

Rita diagram

X 2000 krav 95 %	%	Enheter
Jan	97	
Feb	84	
Mar	94	
Apr	86	
Maj	82	
Jun	76	
Jul	81	
Aug	94	
Sep	90	
Okt		
Nov		
Dec		

☒ Använd till andra diagram



10

Swedish R&D Projects (Infrastructure)

RECENT AND ON-GOING
SWEDISH NATIONAL RAIL ADMINISTRATION
R&D PROJECTS

AGENCY	STATUS	SUBJECT
Swedish Road and Traffic Research Institute	Complete	Risk analysis/evaluation in railway sector (Jointly funded with SJ and Railway Inspectorate
	Complete	Assessment of effectiveness of plastic foam insulation
	Complete	Development of Computer Program to calculate track and turnout geometry
	Active	Risk analysis of dangerous goods transport on road and on rail (Jointly funded by SJ and Swedish National Rescue Authority)
Lulet Technical University	Complete	Assessment of effects of different rail metallurgies on brittleness and fatigue life
	Active	Investigation of tunnel boring machine designs and cost-effectiveness under Swedish conditions
Royal Technical University	Active	Investigation of soil and rock mechanics in railway embankments and cuts
	Active	On-going invesigations in railway-related engineering problems
	Active	Development of dynamic track structure behaviour simulation program
Chalmers Technical University	Active	Investigation of track-train dynamic interactions
Swedish National Geotechnical Institute	Active	Investigation of Swedish and EEC design standards for bridges and other structures
	Active	Detection and warning system for landslides
	Active	Investigation of techniques for measurement and analysis of point and pore pressures