Tunneling in Móberg

VIRKIR

Orkustofnun
National Energy Authority

Tunneling in Móberg Formations

Study

Part II

Appendix 1—Photographs
Appendix 2—Drawings
Appendix 3—Documentation

EWI

Electro-Watt, Engineering Services Ltd.
Zurich, Switzerland

VIRKIR

Associated Engineering Consultants Ltd.
Reykjavik, Iceland

March 1972

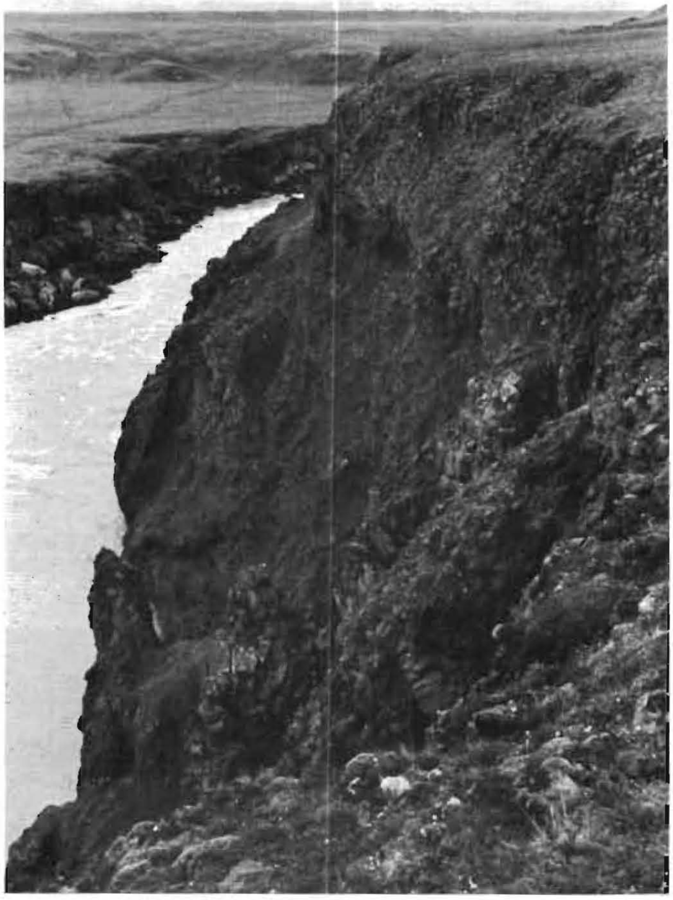
PHOTOGRAPHS

APPENDIX 1
LIST OF PHOTOGRAPHS

Photo No.	Film No.	Description	Date
1	8-17A	Right bank of the Tungnaa river at Sigalda showing the extension of the grouting test. This photograph shows the heterogenity of moberg formations: pillow lava, breccia and tuff. In the right-hand upper corner the site of drilling hole E-11 can be seen.	21.7.71
2	2-6A	Pillow lava in the left river bank, just downstream of the Tungnaa waterfalls at Sigalda. Practically vertical walls of solid and hard rock but including many cracks and voids between the pillows.	13.7.71
3	8-5A	Detail of the pillow lava at Sigalda shown on photograph No.4. The rock is strongly jointed but not loose, and is hard and solid. The individual particles are very hard and of size varying from about 3 to 40 cm thickness. The jointing surfaces tend in all directions and are both flat and curved. Lower right-hand corner, pillow lava can be seen grading into breccia with a sandy (yellow) matrix. In the upper half of the photograph, a basaltic vein (dyke) can be seen. Such veins and intrusions will only be rippable when thin.	21.7.71
4	8-19A	Mass of rounded pillows at Sigalda, between which voids can be seen.	21.7.71
5	9-10A	Tuff breccia at Sigalda, a compact and desne rock with basalt fragments. This formation can be compared with a well consolidated conglomerate or conglomeritic sandstone.	21.7.71
6	9-9A	A solid and nearly vertical wall of tuff and tuffbreccia at Sigalda. This face contains the rock shown in photograph No.5 and is found above the site of the grouting tests.	21.7.71

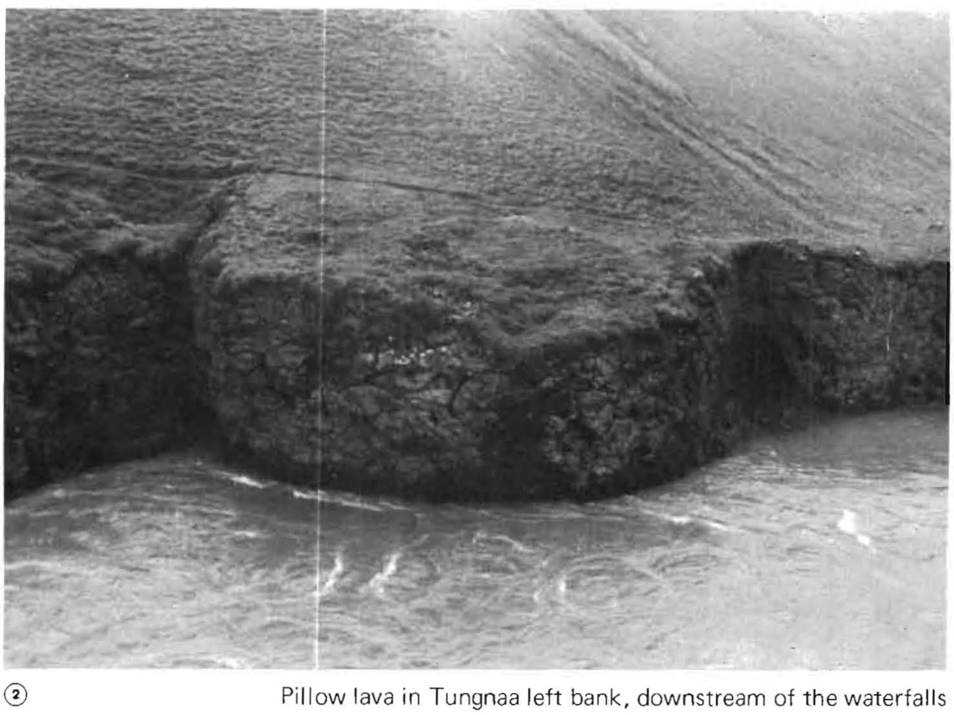
Photo No.	Film No.	Description	Date
7	9-3A	Breccia with pillow structures, the matrix being hard tuff with small pillow fragments. The Sigalda formation is solid and hard and the edges cannot be broken by kicking. Only in the zones where the pillows are not well embedded in the matrix is the rock loose.	21.7.71
8	9-6A	Tuff and tuffbreccia with eroded caves in vertical walls on the right river bank at the beginning of the Tungnaa Canyon at Sigalda. This formation seems to be rather resistant against erosion.	21.7.71
9	1-25A	Southern side of the trench of Sigalda ripping test No.2, showing breccia with fragments of pillow lava. The material has only little cementation and is easily broken out with a hammer. This breccia, which is similar to moraine, is cohesive and was stable with slopes of up to 60° or 70°. It can be easily ripped.	13.7.71
10	9-15A	Northern side of the ripped trench No.1 at Sigalda, showing details of the remaining wall of the brecciated pillow lava with a vein of basalt. This basalt intrusion is rippable as long as it is well fissured.	21.7.71
11	9-20A	Vatnsfall diversion canal, a view from control structure under construction. The canal cuts into the rather compact tuff of the crater wall formations, and the lower part of the control structure is situated in pillow breccia of the lava flow formations.	21.7.71
12	1-29A	Canal wall near the outlet structure, showing stony tuff of the well-consolidated crater wall formation. Overbreak occured due to cracks and sandy lenses at the base.	13.7.71
13	2-33A	Moberg landscape near Grettir looking north north-east towards the Skafta river near the Sveinstindur,1090 m.a.s.l. In this moberg topography it is proposed to drive tunnels for the Skafta diversion. To the left of the photograph is Graenifjallgardur.	14.7.71

Photo No.	Film No.	Description	Date
14	3-14A	Aerial view of the Skafta river near the future diversion dam south of Sveinstindur, looking southwest. The high peak on the right hand side is the Sveinstindur, and diversion tunnel would pass beneath the lower mountains on the left hand side. The Skafta flows from right to left.	15.7.71
15	K-22	Sigalda ripping test No.2 CATERPILLAR D-8 bulldozer with single shank ripper.	3.7.70
16	ZSCH 18-79	Drilling platform under a heavy rain of percolating water in very permeable and strongly jointed but stable dolomite. Diameter of the tunnel 5.70m, water temperature was 4^{o}. This photograph, which was taken in the Val S-charl headrace tunnel of the Engadine hydro-electric power plant in Switzerland, shows tunneling conditions under heavy water infiltrations such as may be expected in moberg below ground water level.	26.4.65



Terrace of grouting test, borehole E-11

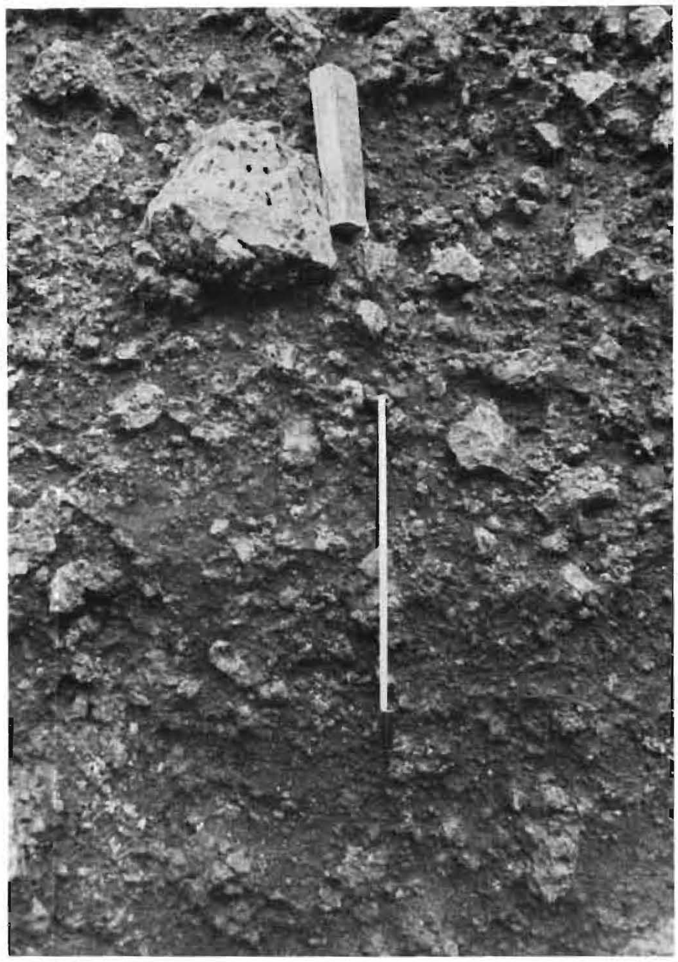
① Right bank of the Tungnaa river with pillow lava, breccia and tuff outcropping



② Pillow lava in Tungnaa left bank, downstream of the waterfalls

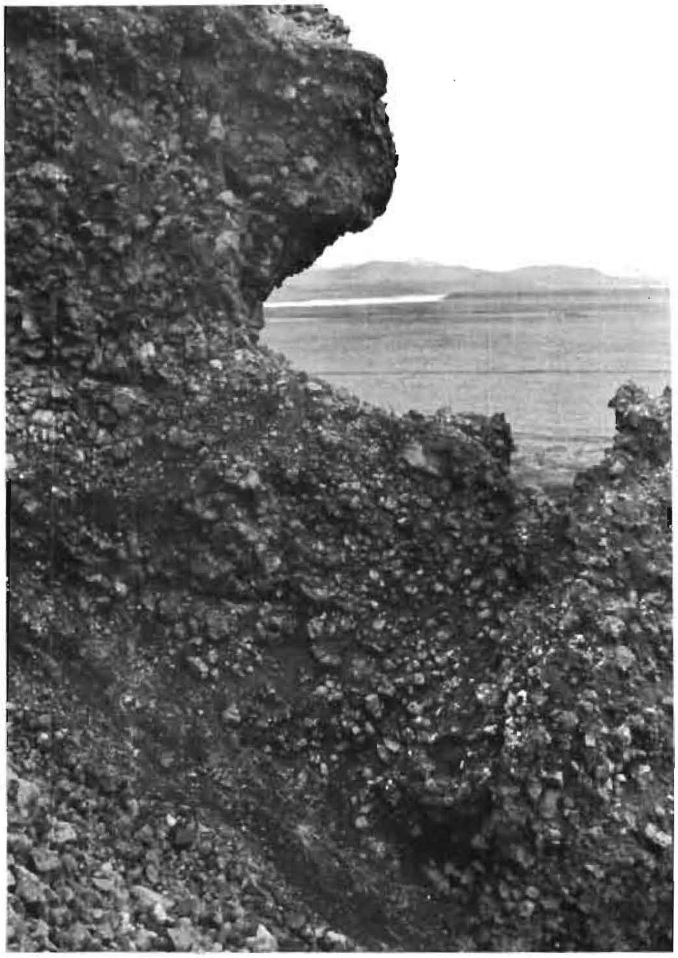
③ Strongly jointed, hard and solid pillow lava formation

④ Pillow lava



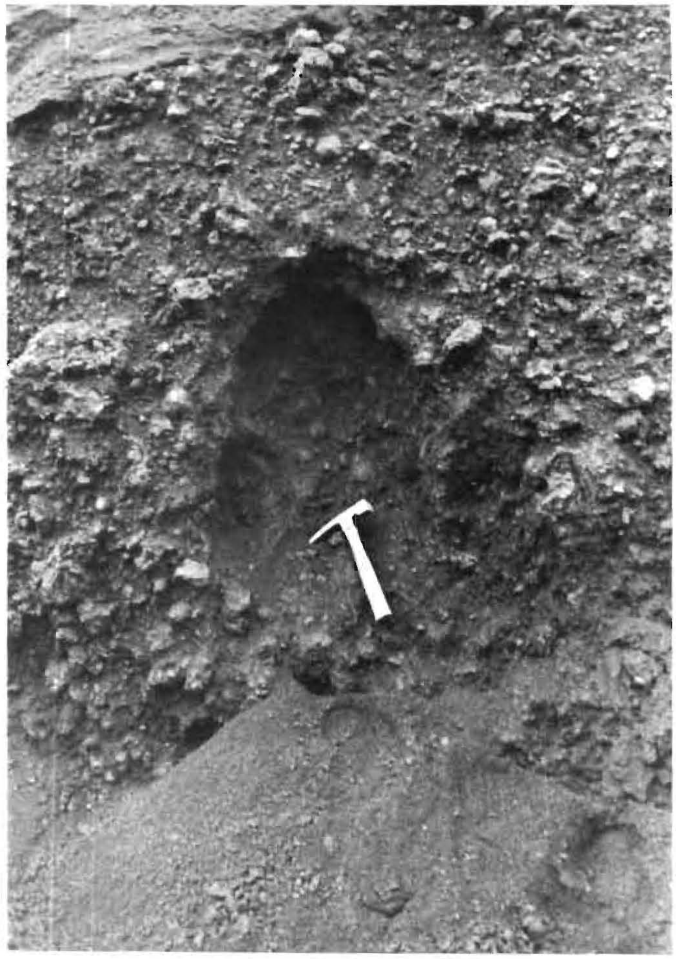
(5) Tuff breccia. The upper piece of wood is 20 cm long

(6) Tuff and tuff breccia



⑦ Breccia with pillow structure

⑧ Caves in the Tungnaa right bank, tuff and tuff breccia



⑨ Ripping Test II, breccia with fragments of pillow lava. The tillite cover is visible at the top of the photograph

⑩ Ripping Test I, brecciated pillow lava with a basalt vein

Vatnsfell tuff

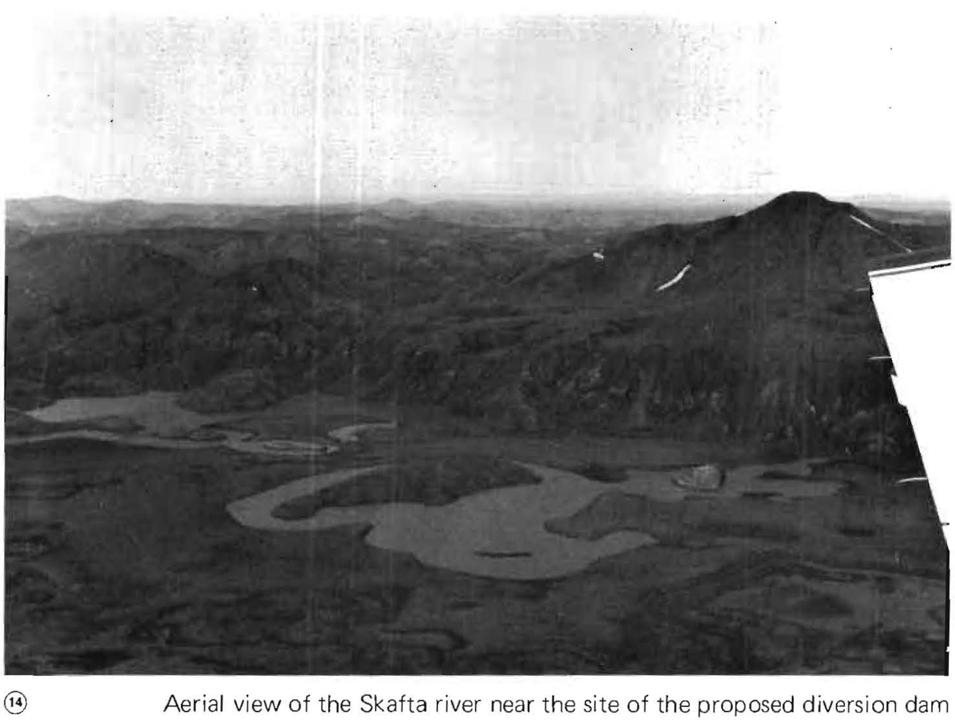
Pillow breccia

⑪
View upstream towards Vatnsfell control structure

Compact tuff

⑫
The canal wall near the outlet structure

⑬ Moberg landscape near Grettin, near the proposed Skafta diversion. Aerial view NNE towards the Skafta



⑭ Aerial view of the Skafta river near the site of the proposed diversion dam

⑮ Ripping Test II, Cat. D-8 with single shank ripper

⑯ Val S-charl headrace tunnel Engadine hydro plant, Switzerland. Heavy rain from very permeable dolomite, tunnel diameter is 5.70 m

DRAWINGS

A P P E N D I X   2

D R A W I N G S

AREAS AND NUMBERS OF PHOTOGRAPHS

A NR. 1,3,4,5,6

B NR. 7,8

C NR. 10

D 9,15 NR.

E NR. 2

LEGEND

- TRENCHES LH-(x)

- DRILLING HOLES E-(x) EXECUTED 1970

- DRILLING HOLES TK-5, TK-7 DEEPENED 1970

- DRILLING HOLES VI... AND TK-(x) EXECUTED BEFORE 1970

= RIPPING TESTS I and II

▭ AREA OF PHOTOGRAPHS OF THE MOBERG FORMATIONS

▲ AREA OF GROUTING TESTS IN MOBERG

0 100 200 400 600 800 1000 m

SEE DRAWG Nº 1263/108018/3-02

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NATIONAL ENERGY AUTHORITY

TUNNELLING IN MOBERG

SIGALDA PROJECT
GEOLOGICAL INVESTIGATIONS
AREAS OF PHOTOGRAPHS

ELECTRO-WATT ZURICH — CONSULTING ENGINEERS — VIRKIR REYKJAVIK

SCALE	DATE	DRAWING NUMBER	APPENDIX
1:20000	15.3.72	1301112851	2-01

IND.	DATE	CHE.
J		
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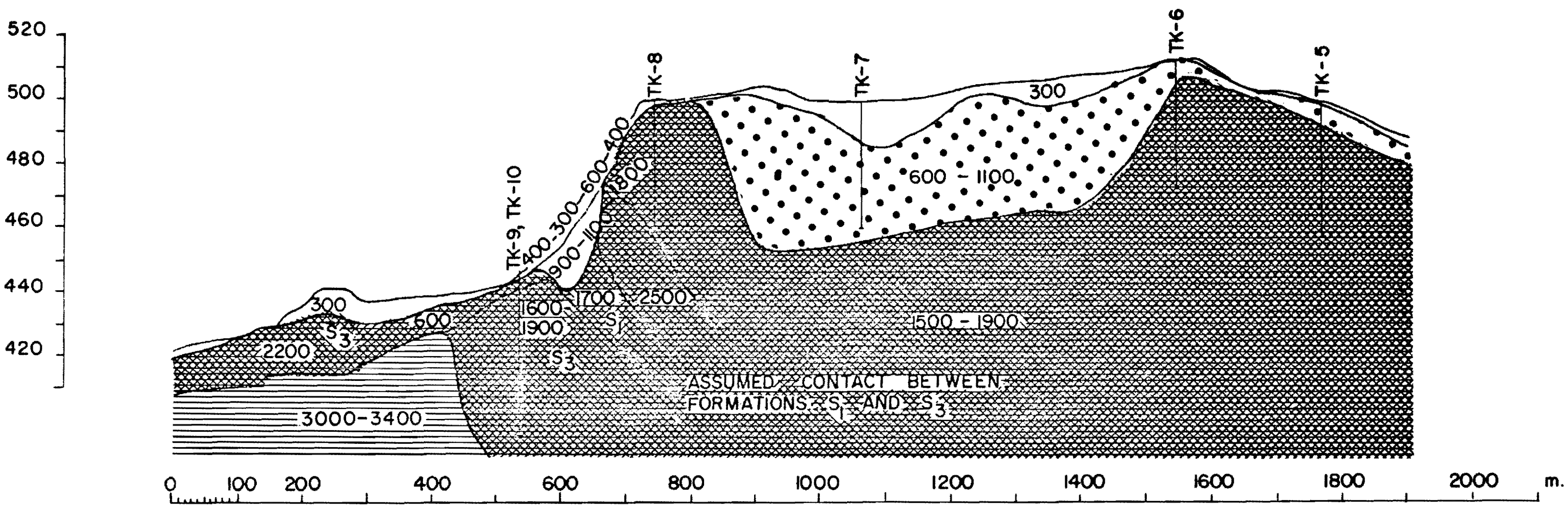
DRA.	RAG	
CHE.		
APP.	Met	

SECTION A – A ALONG ℄ OF WATERWAYS (APPROACH CANAL)



FOR LOCATION
OF GEOLOGIC SECTION
SEE APPENDIX 2-01

SEISMIC VELOCITY m per sec.		SEISMIC VELOCITY m per sec	
300-600	OVERBURDEN	3000-3400	BASALT INJECTIONS DOMINATING.
600-1100	BRECCIA DOMINATING. ALSO MOBERG IN GENERAL		DRILL HOLE LOCATED ALONG SECTION.
1500-2000 2000-2500	PILLOW LAVA DOMINATING. BASALT INJECTIONS INCREASING WITH INCREASING SEISMIC VELOCITY.		

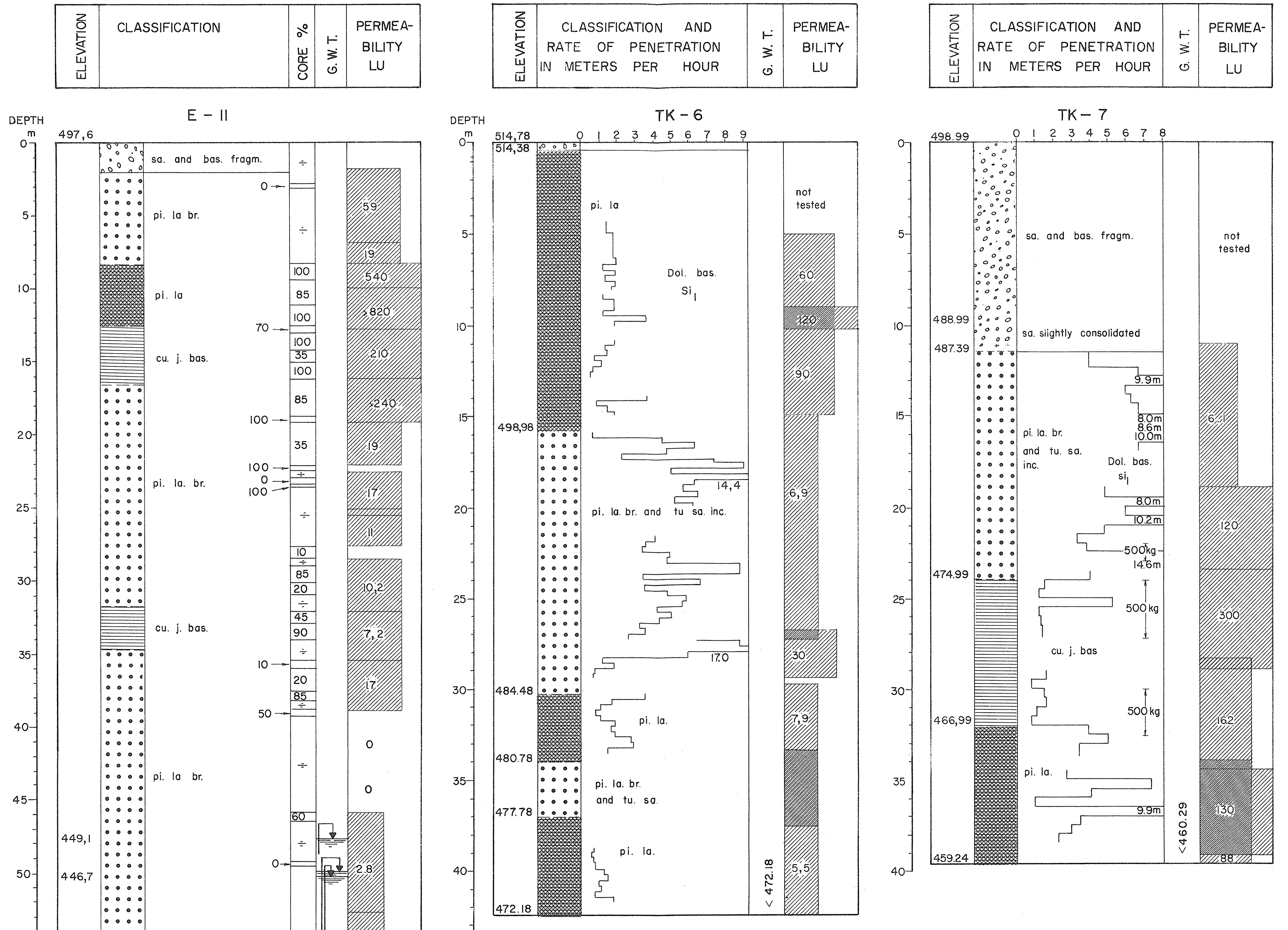
SIGALDA PROJECT
GEOLOGIC SECTION
LANDSVIRKJUN
Nr. R-25-M-36

MOBERG AT SIGALDA

A	B	C	D	E	F

ELECTRO-WATT CONSULTING ENGINEERS VIRKIR

DATE	15.3.72	APPX 2-02
DESIGN	RAG	DRAWING NUMBER
APPROVED	Met	1301112852



TK–7 were drilled with Craelius drilling equipment, TK-6 with Sullivan drilling equipment

Where penetration rate diagram is shown tricone rock bits have been used. Elsewhere core has been extracted.

YEAR OF DRILLING : 1968

LEGEND

- PILLOW LAVA
- PILLOW LAVA BRECCIA WITH TUFFACEOUS SAND INCOHERENT, ALSO MOBERG IN GENERAL.
- VEINS OF CUBE JOINTED BASALT
- MORAINE AND TALUS

ABBREVIATIONS

pi. la.	=	PILLOW LAVA
br.	=	BRECCIA
sa.	=	SAND
tu.	=	TUFFACEOUS
inc.	=	INCOHERENT
bas.	=	BASALT
fragm.	=	FRAGMENTS
cu. j.	=	CUBE JOINTING

NOTE ON PERMEABILITY AND GROUND WATER

GROUND WATER LEVELS ARE SHOWN BY ARROWS. BASES OF THE ARROWS AND THE HORIZONTAL BARS INDICATE THE HOLE DEPTH WHEN THE WATER LEVEL WAS MEASURED. IF NO CHANGE IN LEVEL WAS OBSERVED DURING DRILLING, THE ARROW REACHES THE BOTTOM OF THE HOLE.

1 LU = LUGEON UNIT = 1 ℓ/min / m in 76 mm ø HOLE AT PRESSURE 10 kg/cm^2

FIGURES FOR GROUND WATER LEVELS ARE SHOWN WITH SMALLER LETTERING ON GRAPHIC CORE LOGS

CORE: NUMBERS INDICATE % CORE RECOVERY
÷ CORE SAMPLING NOT ATTEMPTED

FOR LOCATION OF CORE LOGS SEE APPENDIX 2 - 01 AND 2 - 02

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TUNNELLING IN MOBERG

SIGALDA PROJECT
GRAPHIC CORE LOGS TK-6, TK-7, E-II
LANDSVIRKJUN Nr. R-24-M-26

ELECTRO-WATT CONSULTING ENGINEERS ZURICH — VIRKIR REYKJAVIK

SCALE	DATE	DRAWING NUMBER	APPENDIX
1:250	15.3.72	1301112853	2-03

DRA. RAG

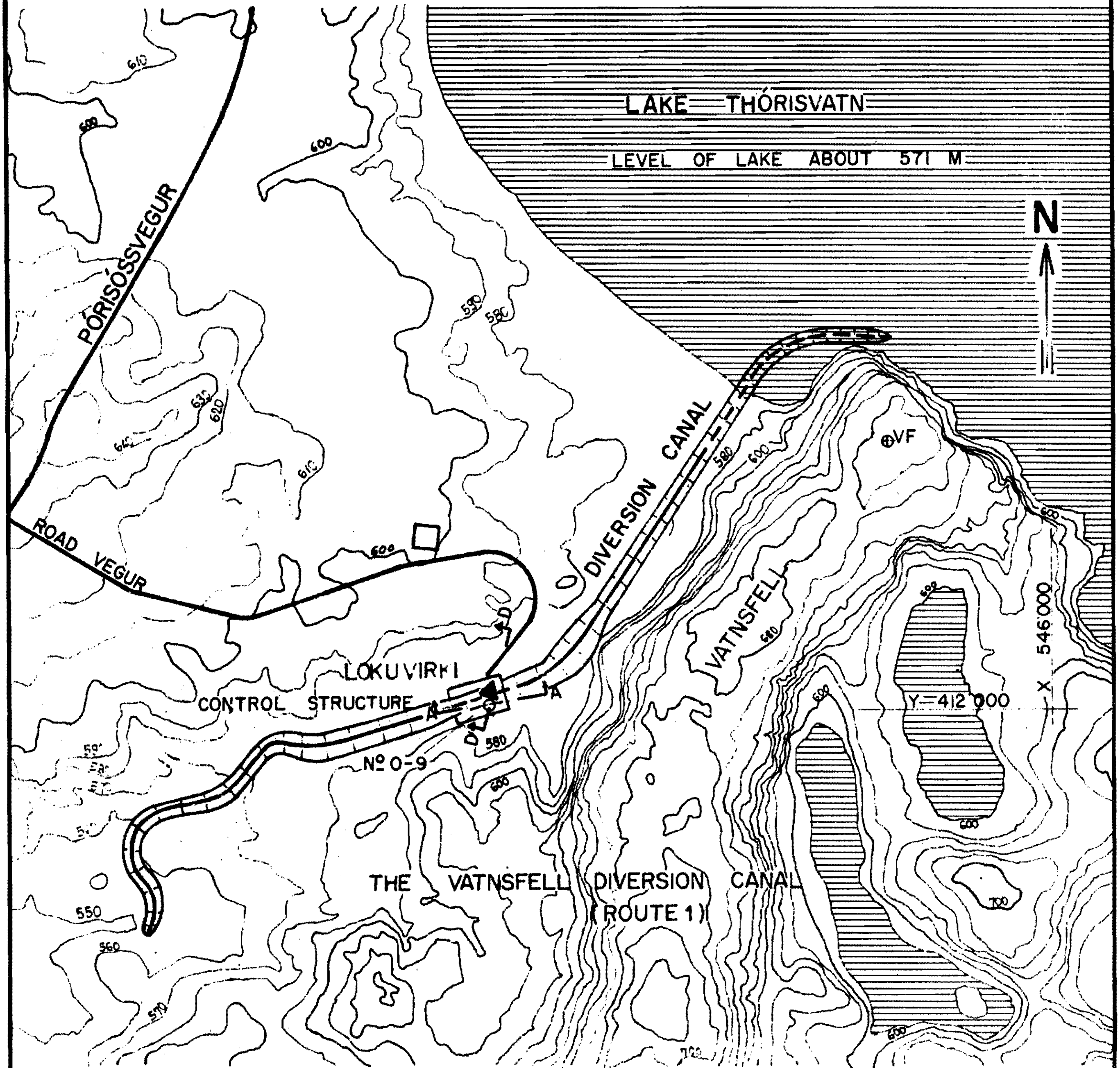
TUNNELLING IN MOBERG

THORISVATN PROJECT

SITUATION 1 : 2000

VATNSFELL DIVERSION CANAL

AREA OF PHOTOGRAPHS



LEGEND

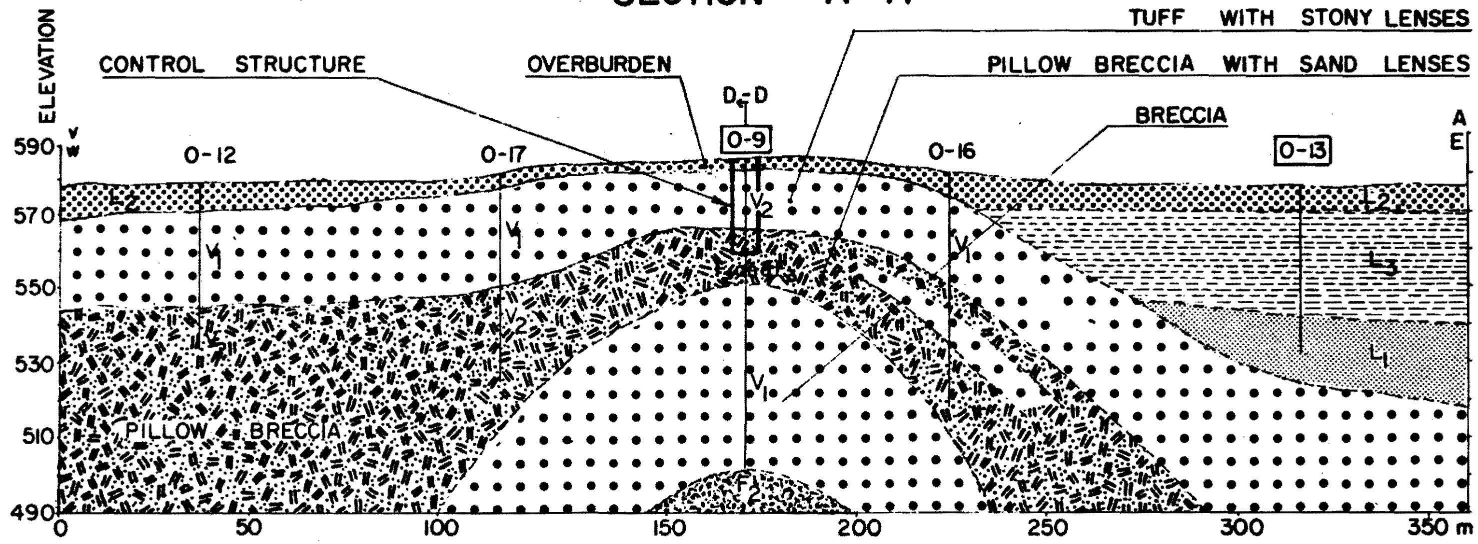
▲ CONTROL STRUCTURE

o CORE BOREHOLE

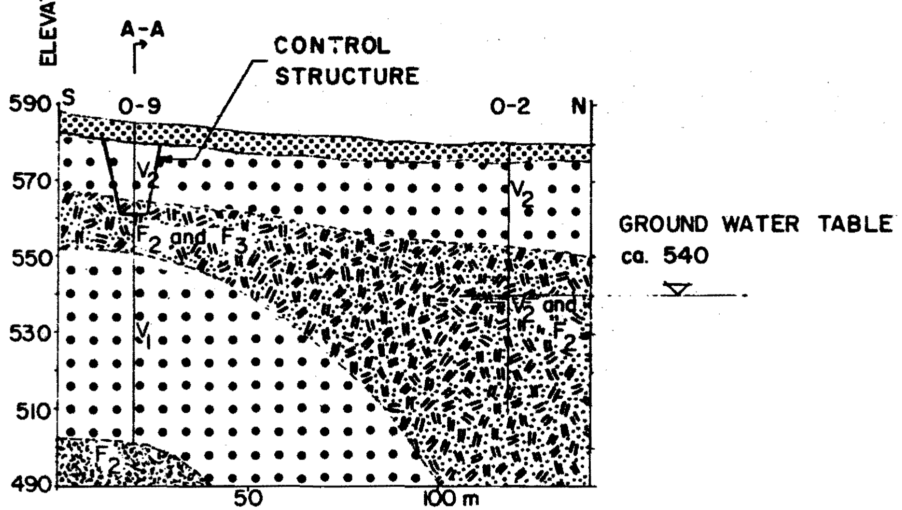
▭ AREA OF PHOTOGRAPHS NR. 11, 12

A	B	C	D	E	F	DATE	15.3.72	APPX 2-04
ELECTRO-WATT	CONSULTING ENGINEERS			VIRKIR		DESIGN	RAG	DRAWING NUMBER
						APPROVED	Mat	1301112854

SECTION A-A



SECTION D-D



FOR LOCATION OF SECTIONS
SEE APPENDIX 2-04

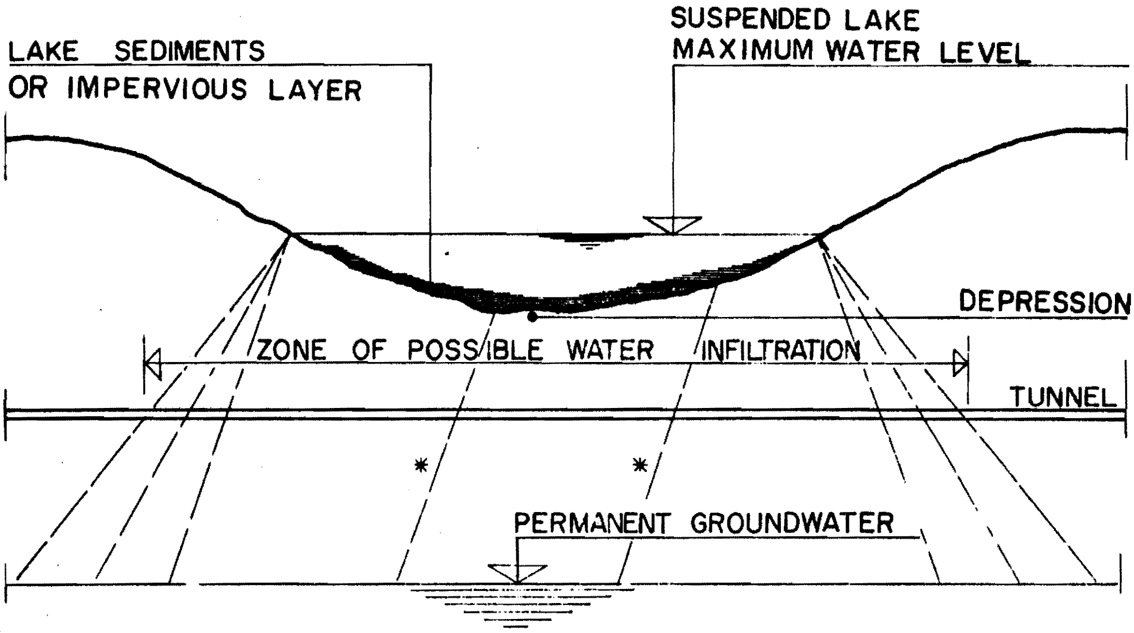
THORISVATN PROJECT
VATNSFELL DIVERSION CANAL
GEOLOGIC SECTIONS

A	B	C	D	E	F

ELECTRO-WATT CONSULTING ENGINEERS VIRKIR	DATE	15.3.72	APPX 2-05
	DESIGN	RAG	DRAWING NUMBER
	APPROVED	Mat	1301112855

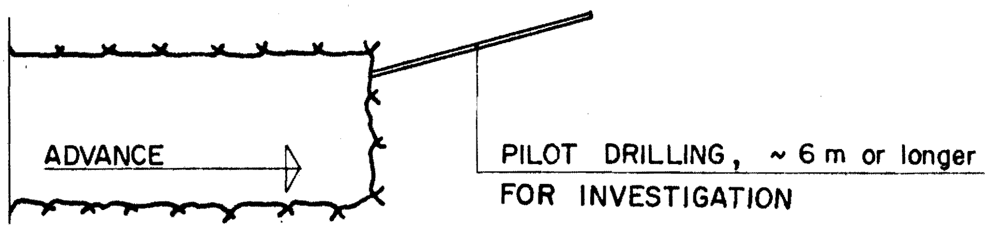
SCHEME OF GROUNDWATER

PERCHED GROUNDWATER

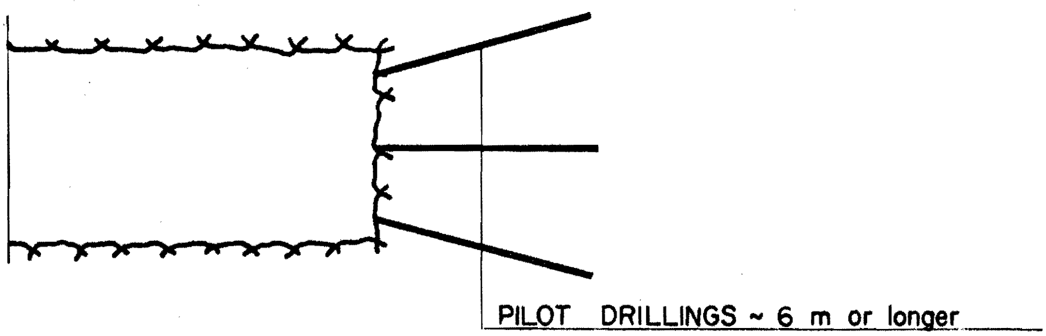


* WITH POSSIBLE LOCAL WATERWAYS ALONG FRACTURES AND INTER- CALATIONS OF PERVIOUS TUFFS AND BRECCIAS

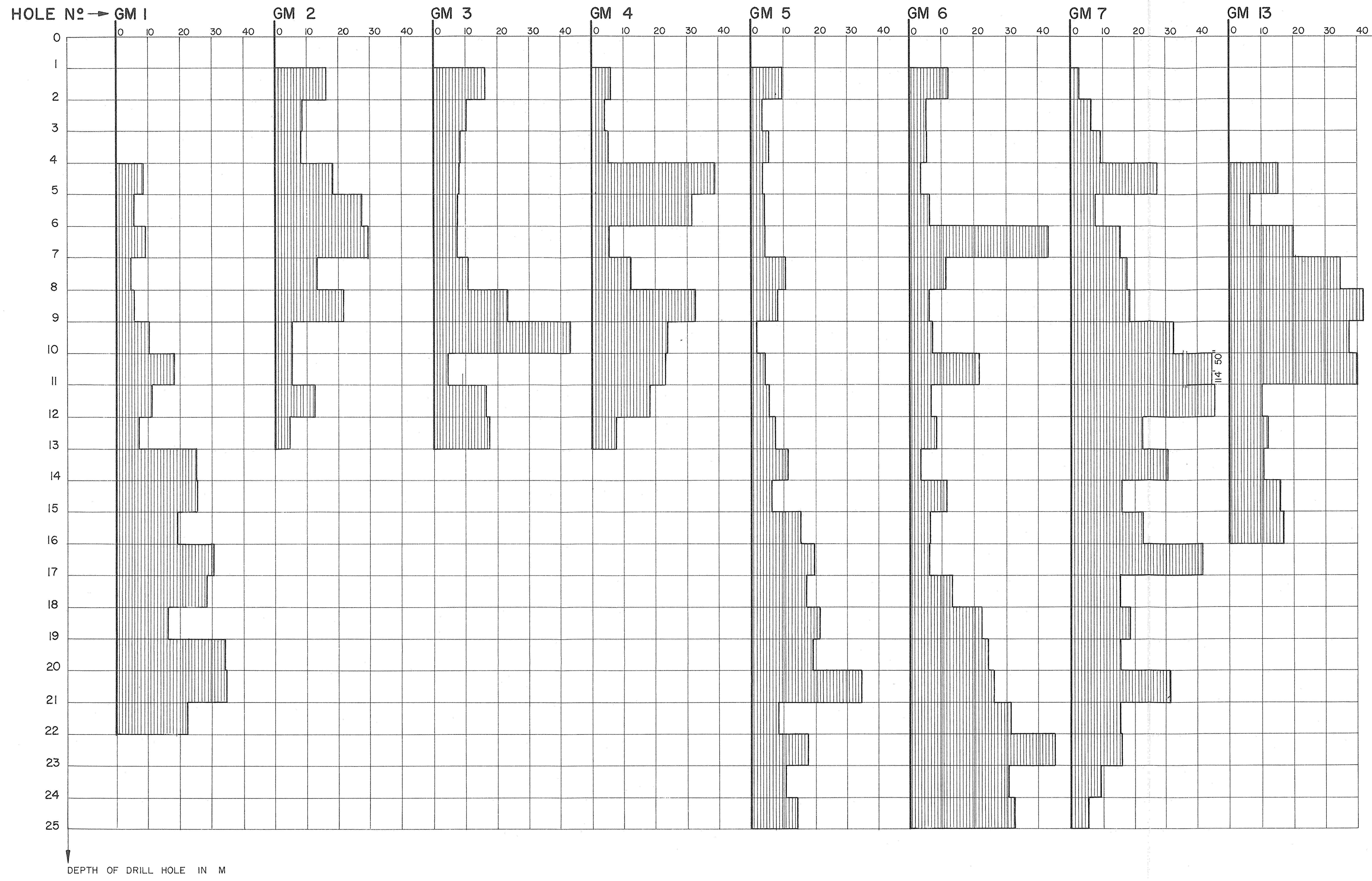
ELEVATION



PLAN VIEW



A	B	C	D	E	F	DATE	15.3.72	APPX 2-06
ELECTRO-WATT	CONSULTING ENGINEERS	VIRKIR				DESIGN	RAG	DRAWING NUMBER
						APPROVED	Met	1301112856



AVERAGE

DRILLING TIME 16 min/m ~ 3.75 m/hour

DRILLING WITH TRICONE BITS

See Report EWI – VIRKIR NOV. 1971

DRILLING TIMES WERE MEASURED FOR EACH METRE OF DEPTH. EVERY THREE METRES THE HOLE WAS GROUTED

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NATIONAL ENERGY AUTHORITY

TUNNELLING IN MOBERG

SIGALDA PROJECT
GROUTING TESTS IN MOBERG
DRILLING TIMES

ELECTRO-WATT CONSULTING ENGINEERS ZURICH — VIRKIR REYKJAVIK

SCALE	DATE	DRAWING NUMBER	APPENDIX
1:100	15.3.72	1301112857	2-07

IND.	DATE	CHE.
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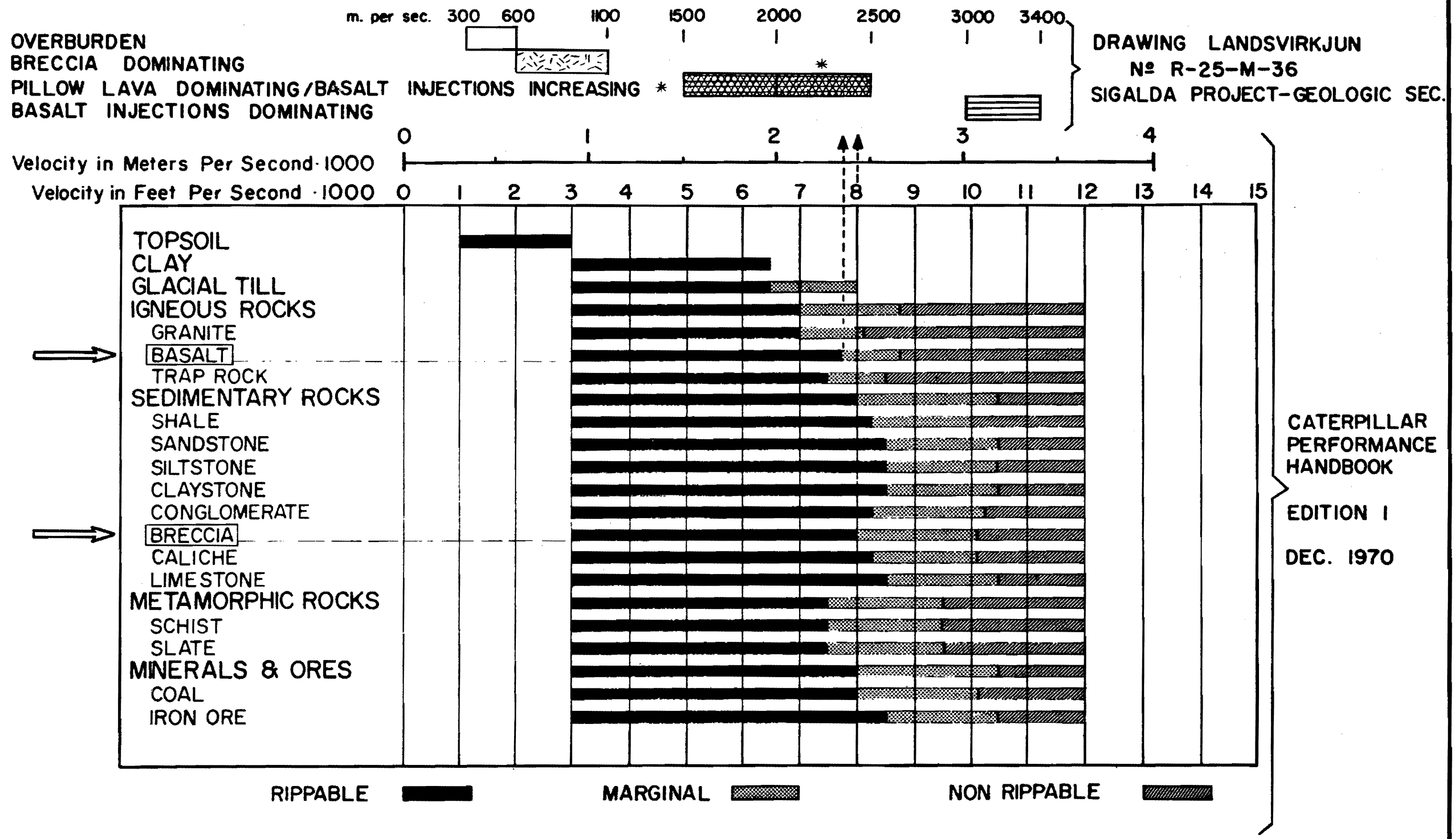
APP.	met	

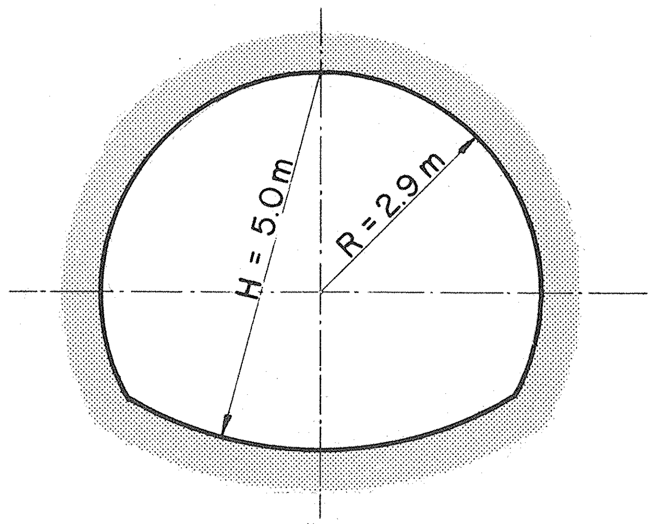


CATERPILLAR D9G (385 H.P.)-№ 9 SERIES D
MULTI AND SINGLE SHANK RIPPER
RIPPER PERFORMANCE AS RELATED TO
SEISMIC WAVE VELOCITIES

A	B	C	D	E	F

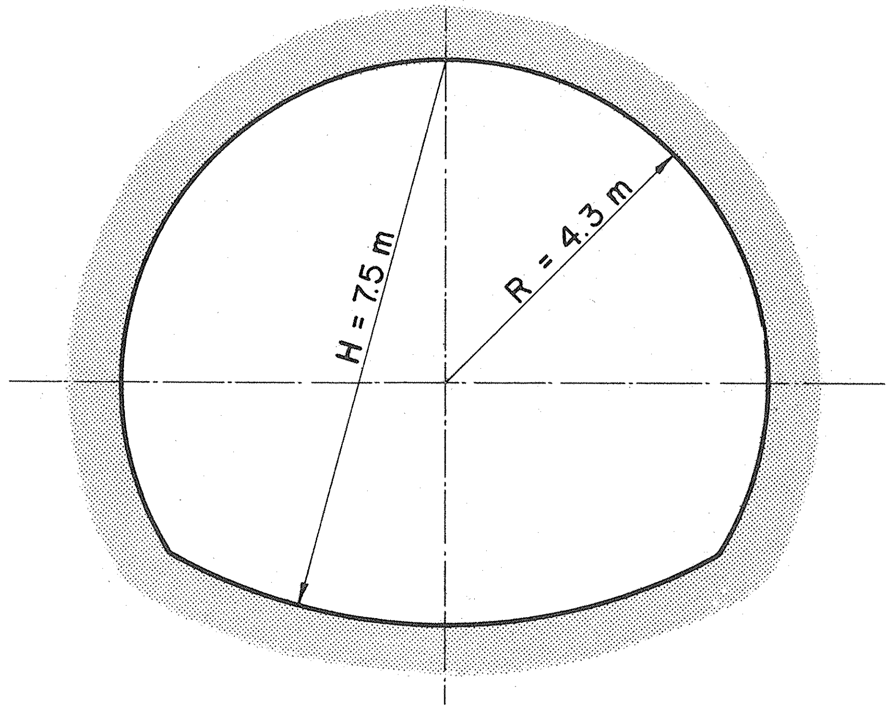
ELECTRO-WATT CONSULTING ENGINEERS **VIRKIR**

DATE	15.3.72	APPX 2-08
DESIGN	RAG	DRAWING NUMBER
APPROVED	Met	1301112858



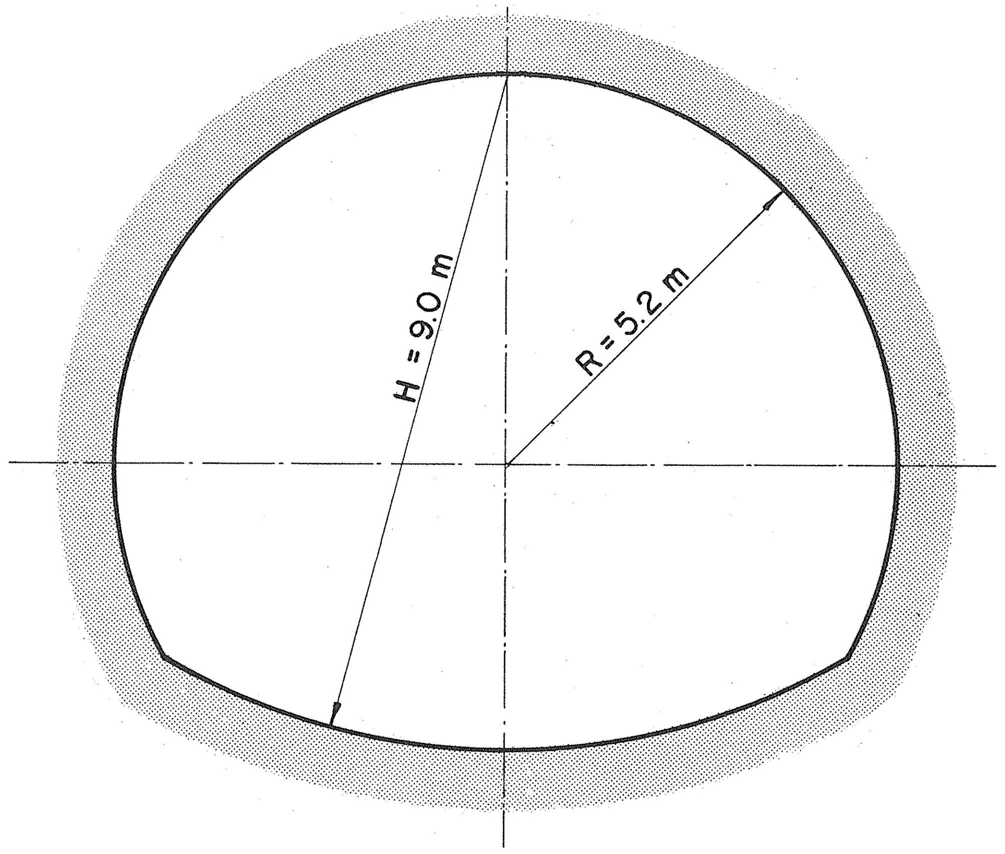
SECTION A
23.4 m²
H = 5.00 m

	Unit	I	II	III	IV
EXCAVATION TO PAY LINE INCL. DRAINAGE	m^3	28.2	30.3	31.5	29.7
CONCRETE P 300 TO PAY LINE	m^3	1.7	6.1	7.3	4.0
SHOTCRETE TO PAY LINE	m^3	2.9	–	–	–
GUNITE	m^3	–	0.6	0.6	0.6
ROCK SECURITY MATS	m^2	12.8	–	–	–
ANCHORS IF REQUIRED	m	–	–	–	–
SHEETS „BERNOLD" OR EQUIVALENT	m^2	–	12.7	12.7	12.7
STEEL REINFORCEMENT FOR INVERT	kg	34	40	46	53
MORTAR GROUTING	m^3	–	–	–	1.5



SECTION B
52.2 m²
H = 7.50 m

	Unit	I	II	III	IV
EXCAVATION TO PAY LINE INCL. DRAINAGE	m^3	59.7	64.0	66.7	64.7
CONCRETE P 300 TO PAY LINE	m^3	2.3	10.6	13.3	9.1
SHOTCRETE TO PAY LINE	m^3	4.9	–	–	–
GUNITE	m^3	–	0.9	0.9	0.9
ROCK SECURITY MATS	m^2	18.9	–	–	–
ANCHORS IF REQUIRED	m	–	–	–	–
SHEETS „BERNOLD" OR EQUIVALENT	m^2	–	18.8	18.8	18.8
STEEL REINFORCEMENT FOR INVERT	kg	49	66	75	86
MORTAR GROUTING	m^3	–	–	–	2.2



SECTION C
75.6 m²
H = 9.00 m

	Unit	I	II	III	IV
EXCAVATION TO PAY LINE INCL. DRAINAGE	m^3	84.6	90.8	99.9	91.7
CONCRETE P 300 TO PAY LINE	m^3	2.7	13.8	22.9	12.0
SHOTCRETE TO PAY LINE	m^3	6.0	–	–	–
GUNITE	m^3	–	1.1	1.1	1.1
ROCK SECURITY MATS	m^2	22.5	–	–	–
ANCHORS IF REQUIRED	m	–	–	–	–
SHEETS „BERNOLD" OR EQUIVALENT	m^2	–	22.4	22.4	22.4
STEEL REINFORCEMENT FOR INVERT	kg	60	92	106	136
MORTAR GROUTING	m^3	–	–	–	2.7

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TUNNELLING IN MOBERG

TUNNEL
TYPICAL CROSS-SECTIONS
SECTIONS A,B AND C

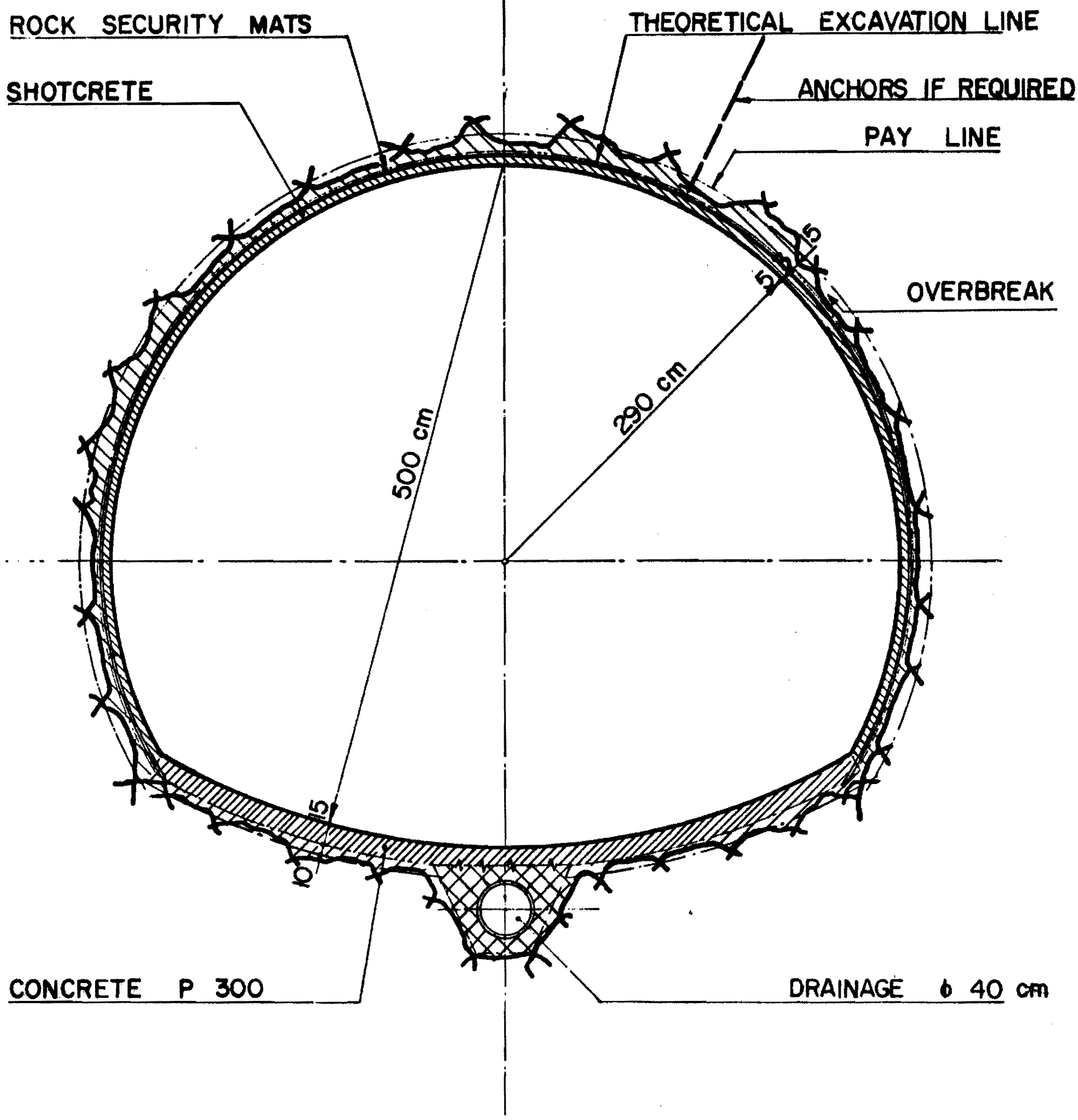
ELECTRO-WATT CONSULTING ENGINEERS ZURICH — VIRKIR REYKJAVIK

DRA. RAG — CHE. — APP. Mat

SCALE	DATE	DRAWING NUMBER	APPENDIX
1:100	15.3.72	13011112859	2-09

H = 5 m SECTION A I 1:50

$S = 23.4\ m^2$

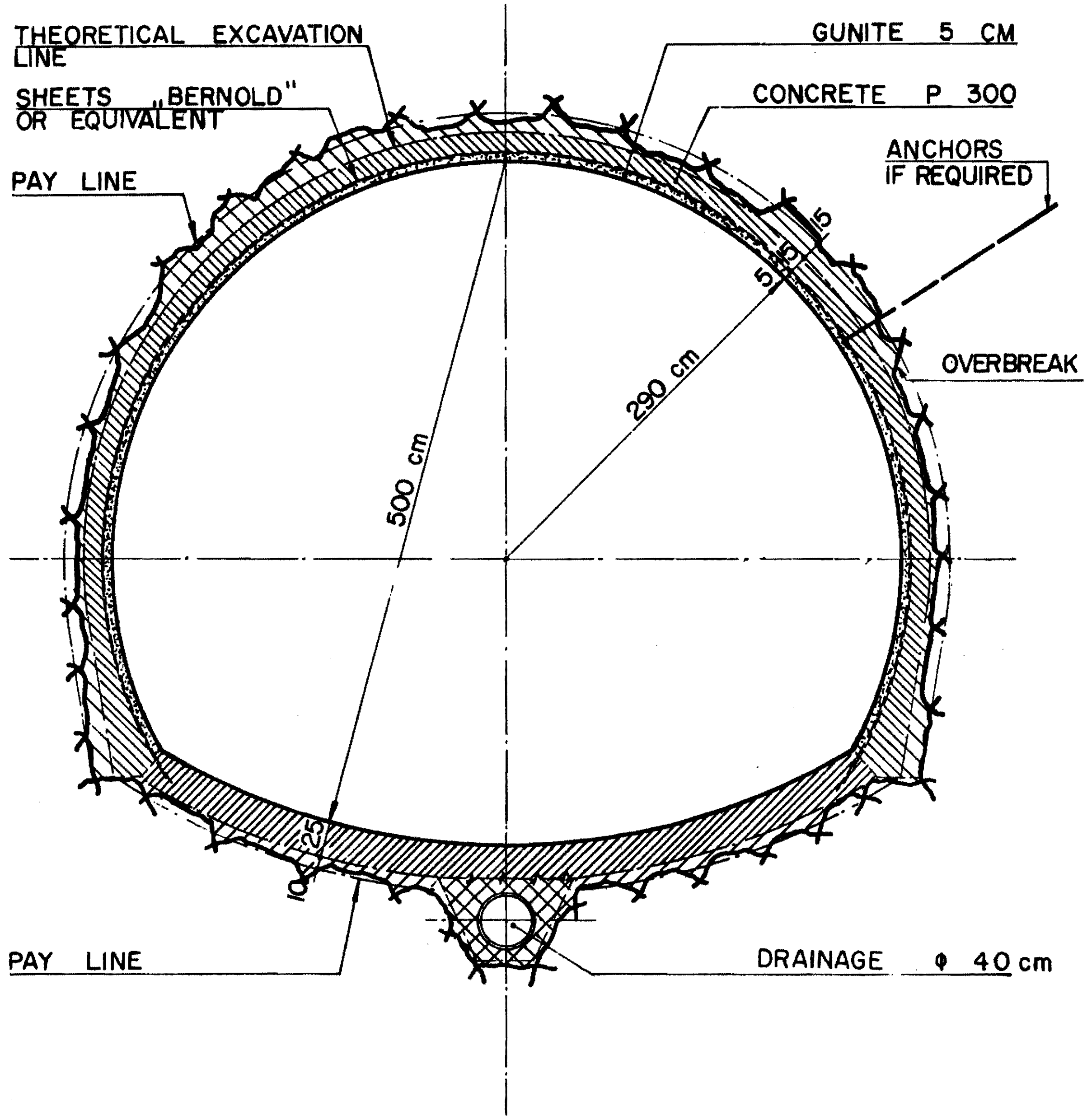


EXCAVATION TO PAY LINE	$28.2\ m^3$
CONCRETE P 300 TO PAY LINE	$1.7\ m^3$
SHOTCRETE TO PAY LINE	$2.9\ m^3$
GUNITE	– m^3
ROCK SECURITY MATS	$12.8\ m^2$
ANCHORS IF REQUIRED	– m^1
SHEETS „BERNOLD" OR EQUIVALENT	– m^2
STEEL REINFORCEMENT FOR INVERT	34 kg
MORTAR GROUTING	– m^3

A	B	C	D	E	F	DATE	15.3.72	APPX 2-10
ELECTRO-WATT	CONSULTING ENGINEERS				VIRKIR	DESIGN	RAG	DRAWING NUMBER
						APPROVED	Met	1301 1 1 2860

H = 5 m SECTION A II 1:50

S = 23.4 m^2

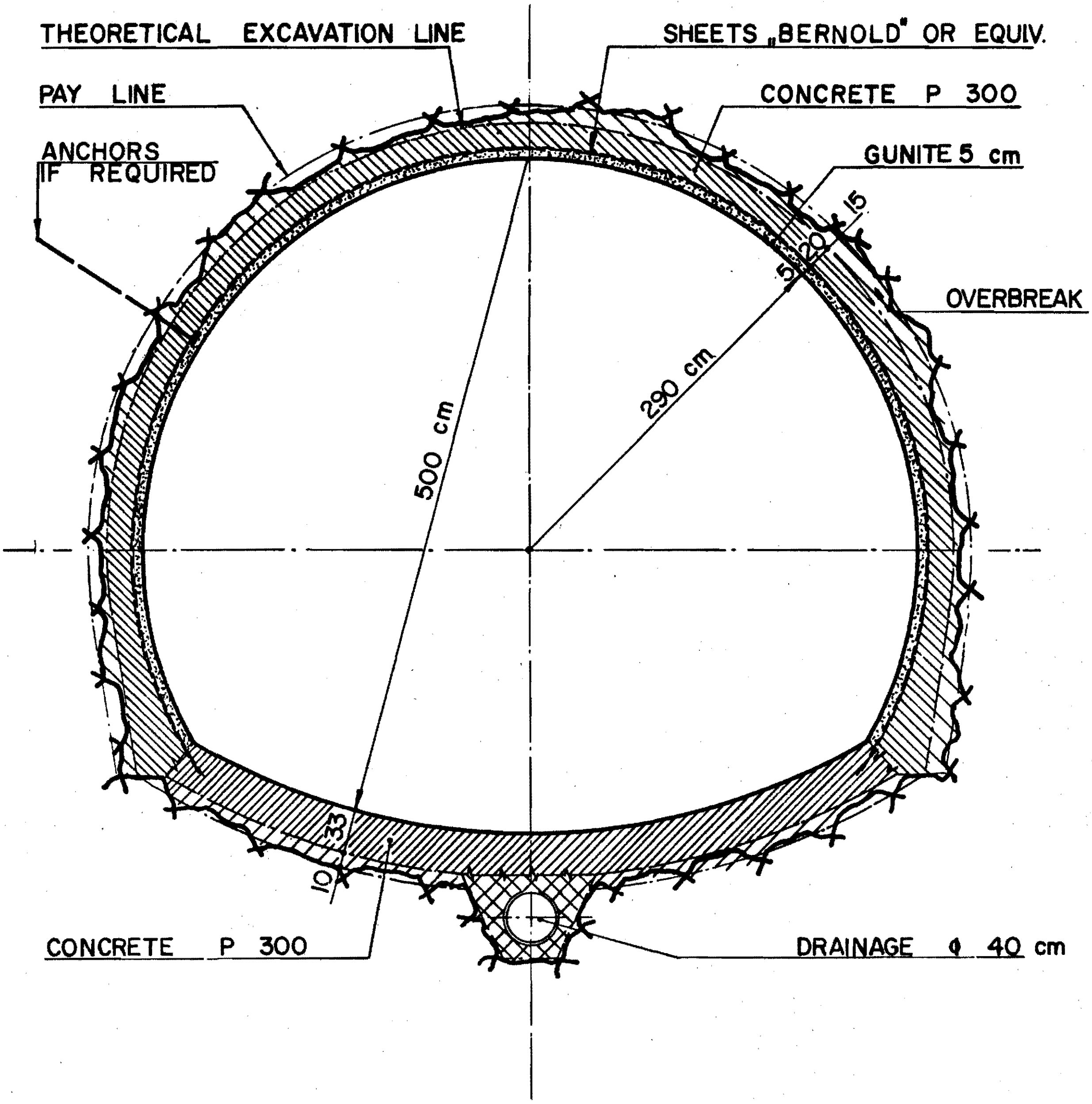


EXCAVATION TO PAY LINE	30.3 m^3
CONCRETE P 300 TO PAY LINE	6.1 m^3
SHOTCRETE TO PAY LINE	– m^3
GUNITE	0.6 m^3
ROCK SECURITY MATS	– m^2
ANCHORS IF REQUIRED	– m^l
SHEETS „BERNOLD" OR EQUIVALENT	12.7 m^2
STEEL REINFORCEMENT FOR INVERT	40 kg
MORTAR GROUTING	– m^3

A	B	C	D	E	F	DATE	15.3.72	APPX 2-11
ELECTRO-WATT	CONSULTING ENGINEERS		VIRKIR			DESIGN	RAG	DRAWING NUMBER
						APPROVED	Mat	1301 11 2861

H = 5 m SECTION A III 1:50

S = 23.4 m^2



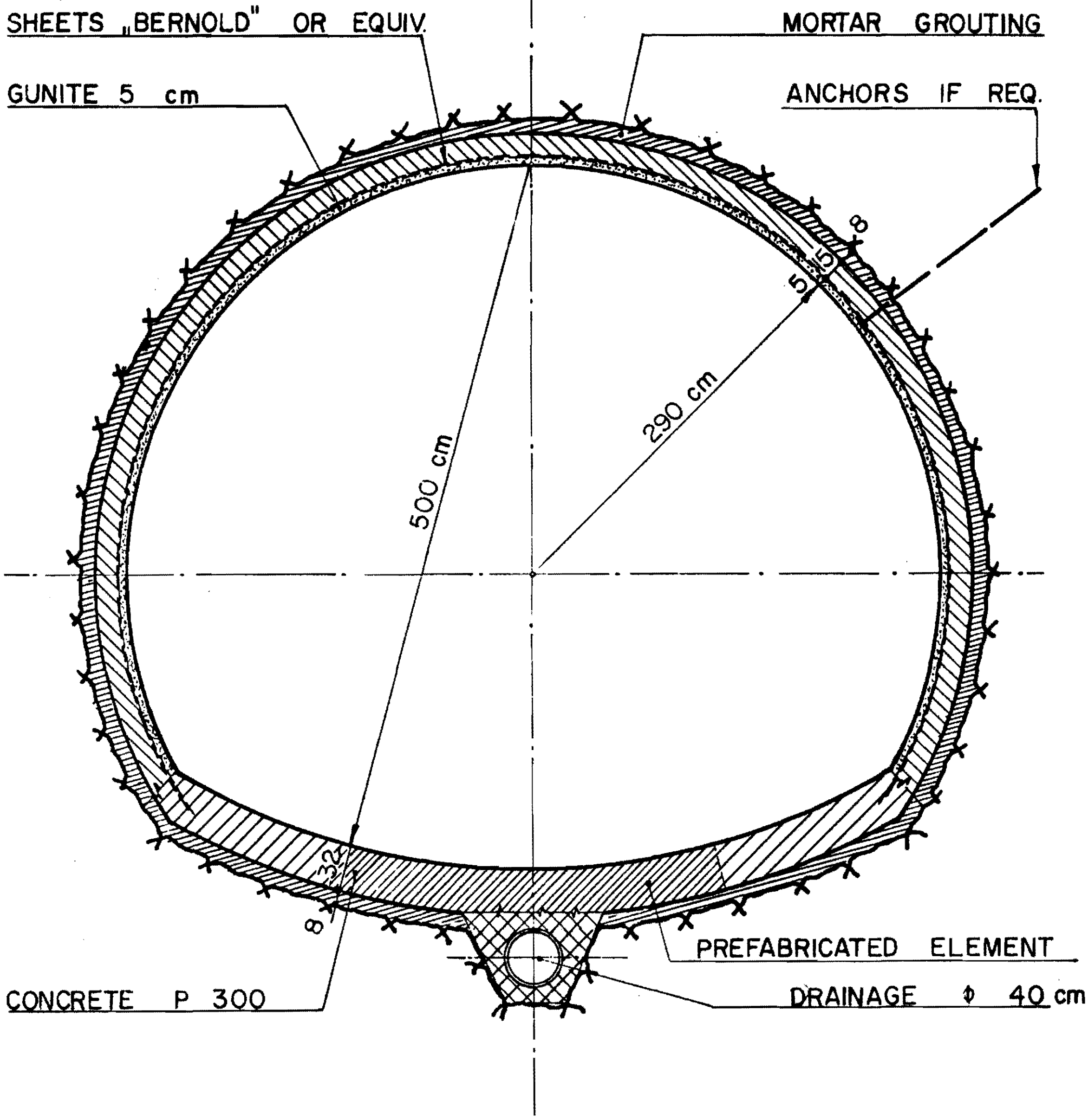
EXCAVATION TO PAY LINE	31.5 m^3
CONCRETE P 300 TO PAY LINE	7.3 m^3
SHOTCRETE TO PAY LINE	– m^3
GUNITE	0.6 m^3
ROCK SECURITY MATS	– m^2
ANCHORS IF REQUIRED	– m^1
SHEETS „BERNOLD" OR EQUIVALENT	12.7 m^2
STEEL REINFORCEMENT FOR INVERT	46 kg
MORTAR GROUTING	– m^3

A	B	C	D	E	F	DATE	15.3.72	APPX 2-12
ELECTRO-WATT	CONSULTING ENGINEERS			VIRKIR		DESIGN	RAG	DRAWING NUMBER
						APPROVED	Met	1301 112862

ADVANCE WITH STEEL POLING PLATES

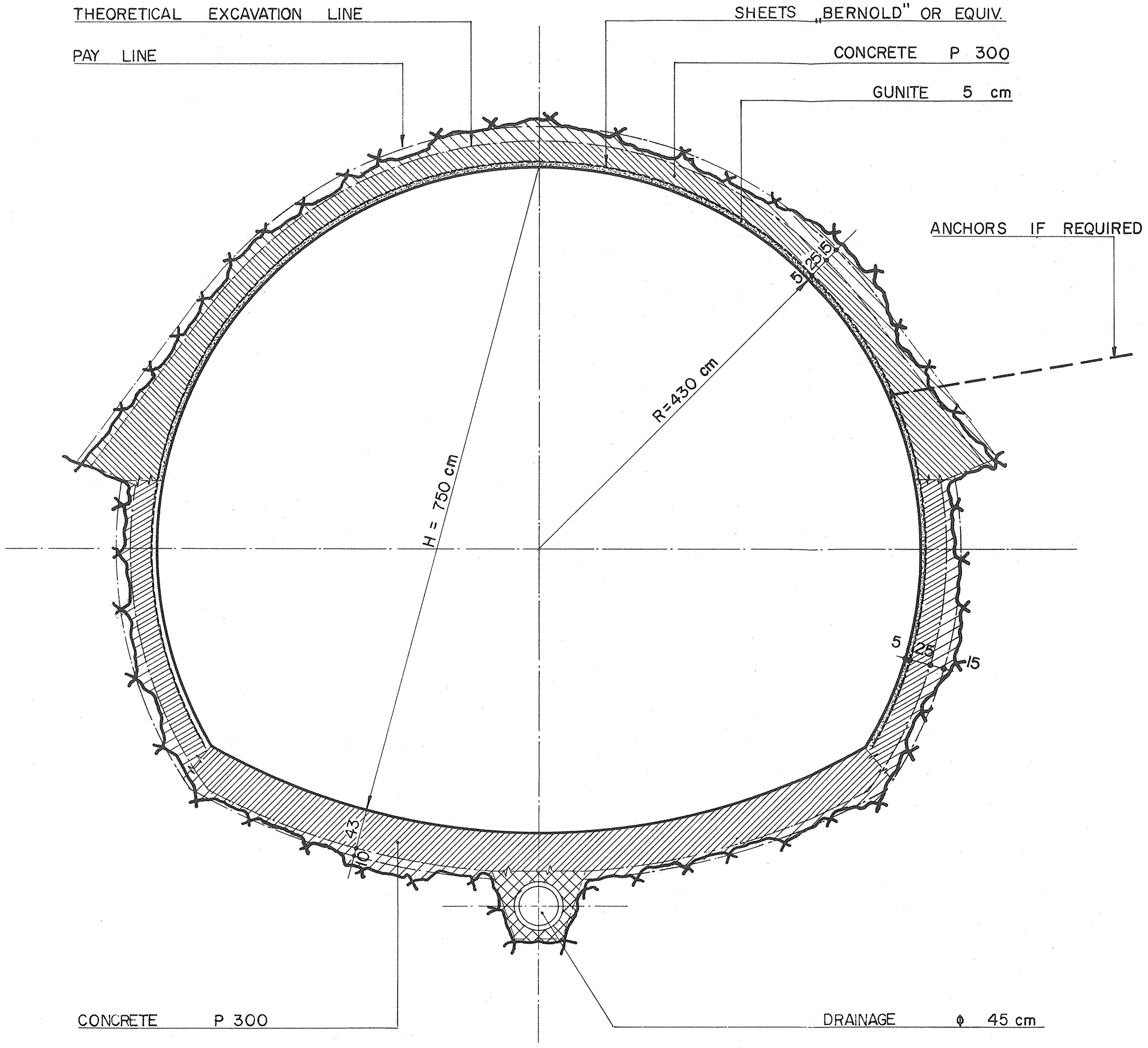
H = 5 m SECTION A IV 1:50

$S = 23.4\ m^2$



EXCAVATION TO PAY LINE	29.7 m^3
CONCRETE P 300 TO PAY LINE	4.0 m^3
SHOTCRETE TO PAY LINE	– m^3
GUNITE	0.6 m^3
ROCK SECURITY MATS	– m^2
ANCHORS IF REQUIRED	– m^l
SHEETS „BERNOLD" OR EQUIVALENT	12.7 m^2
STEEL REINFORCEMENT FOR INVERT	53 kg
MORTAR GROUTING	1.5 m^3

A B C D E F	DATE	15.3.72	APPX 2-13
ELECTRO-WATT CONSULTING ENGINEERS VIRKIR	DESIGN	RAG	DRAWING NUMBER
	APPROVED	Mut	1301 11 2863



SECTION B III $S = 52.2\ m^2$ $H = 7.5\ m$ 1 : 50

EXCAVATION TO PAY LINE INCL. DRAINAGE	66.7 m^3
CONCRETE P 300 TO PAY LINE	13.3 m^3
SHOTCRETE TO PAY LINE	– m^3
GUNITE	0.9 m^3
ROCK SECURITY MATS	– m^2
ANCHORS IF REQUIRED	– m^1
SHEETS „BERNOLD" OR EQUIVALENT	18.8 m^2
STEEL REINFORCEMENT FOR INVERT	75 kg
MORTAR GROUTING	– m^3

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NATIONAL ENERGY AUTHORITY

TUNNELLING IN MOBERG

SECTION B III
$S = 52.2\ m^2$
$H = 7.5\ m$

IND.	DATE	CHE.
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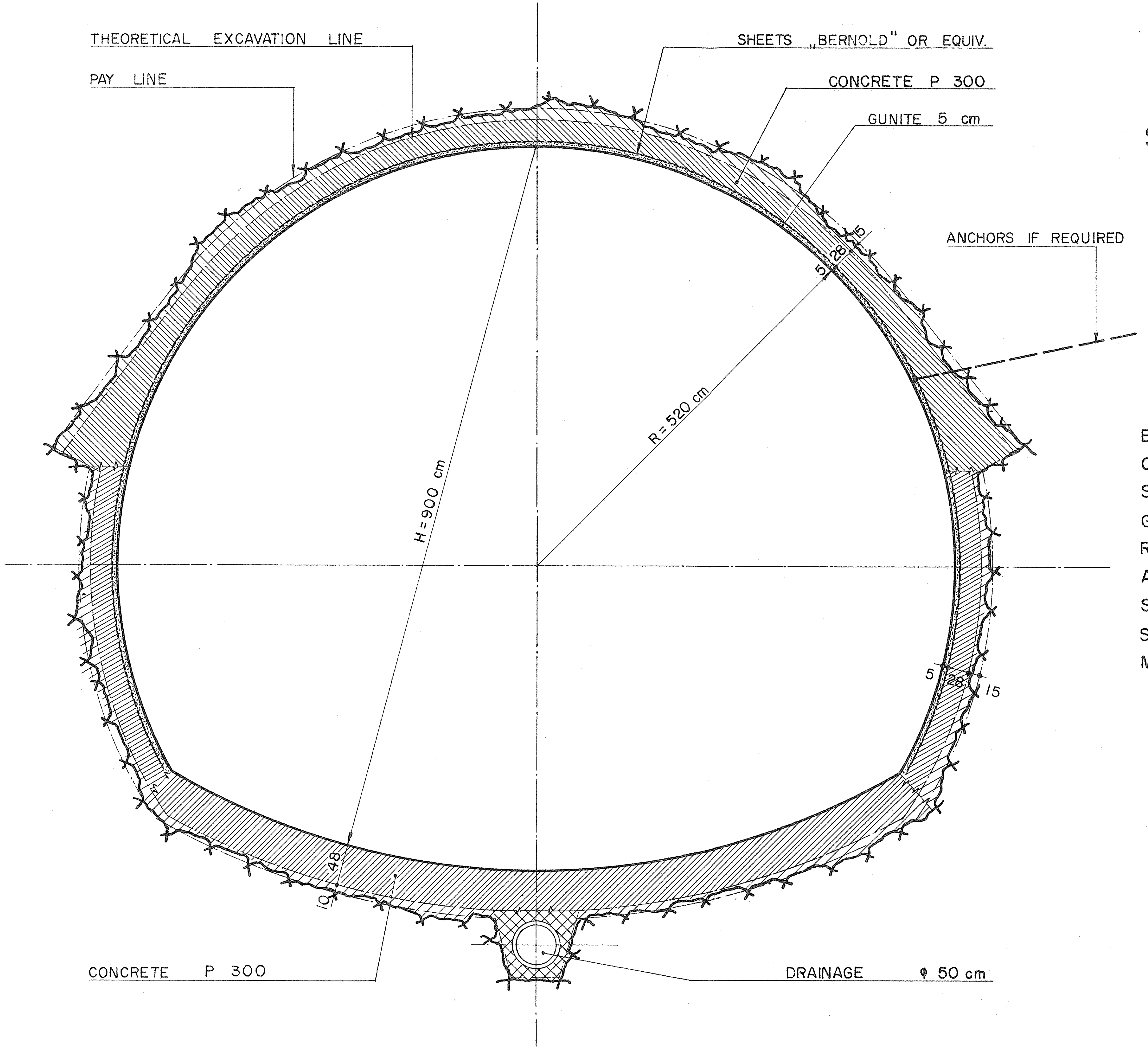
APP.	Mel	

ELECTRO-WATT CONSULTING ENGINEERS ZURICH — VIRKIR REYKJAVIK

SCALE	DATE	DRAWING NUMBER	APPENDIX
1:50	15.3.72	1301112864	2–14



# SECTION C III   S = 75.6 m^2 1 : 50
H = 9.0 m

EXCAVATION TO PAY LINE INCL. DRAINAGE	99.9	m^3
CONCRETE P 300 TO PAY LINE	22.9	m^3
SHOTCRETE TO PAY LINE	–	m^3
GUNITE	1.1	m^3
ROCK SECURITY MATS	–	m^2
ANCHORS IF REQUIRED	–	m
SHEETS „BERNOLD" OR EQUIVALENT	22.4	m^2
STEEL REINFORCEMENT FOR INVERT	106	kg
MORTAR GROUTING	–	m^3

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NATIONAL ENERGY AUTHORITY

TUNNELLING IN MOBERG

SECTION C III
S = 75.6 m^2
H = 9.0 m

ELECTRO-WATT CONSULTING ENGINEERS ZURICH — VIRKIR REYKJAVIK

IND.	DATE	CHE.
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DRA.	RAG
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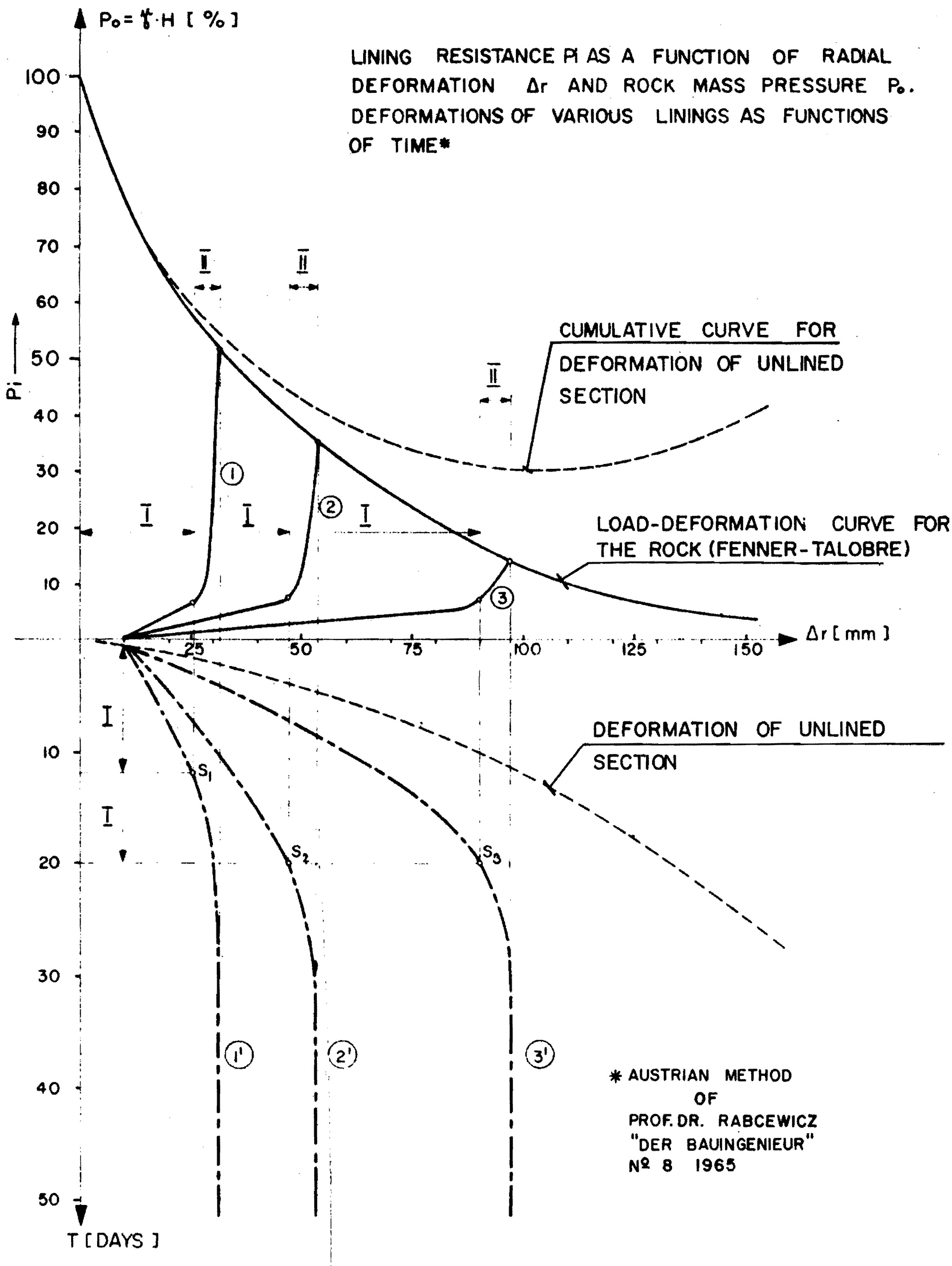
SCALE	DATE	DRAWING NUMBER	APPENDIX
1:50	15.3.72	1301112865	2–15



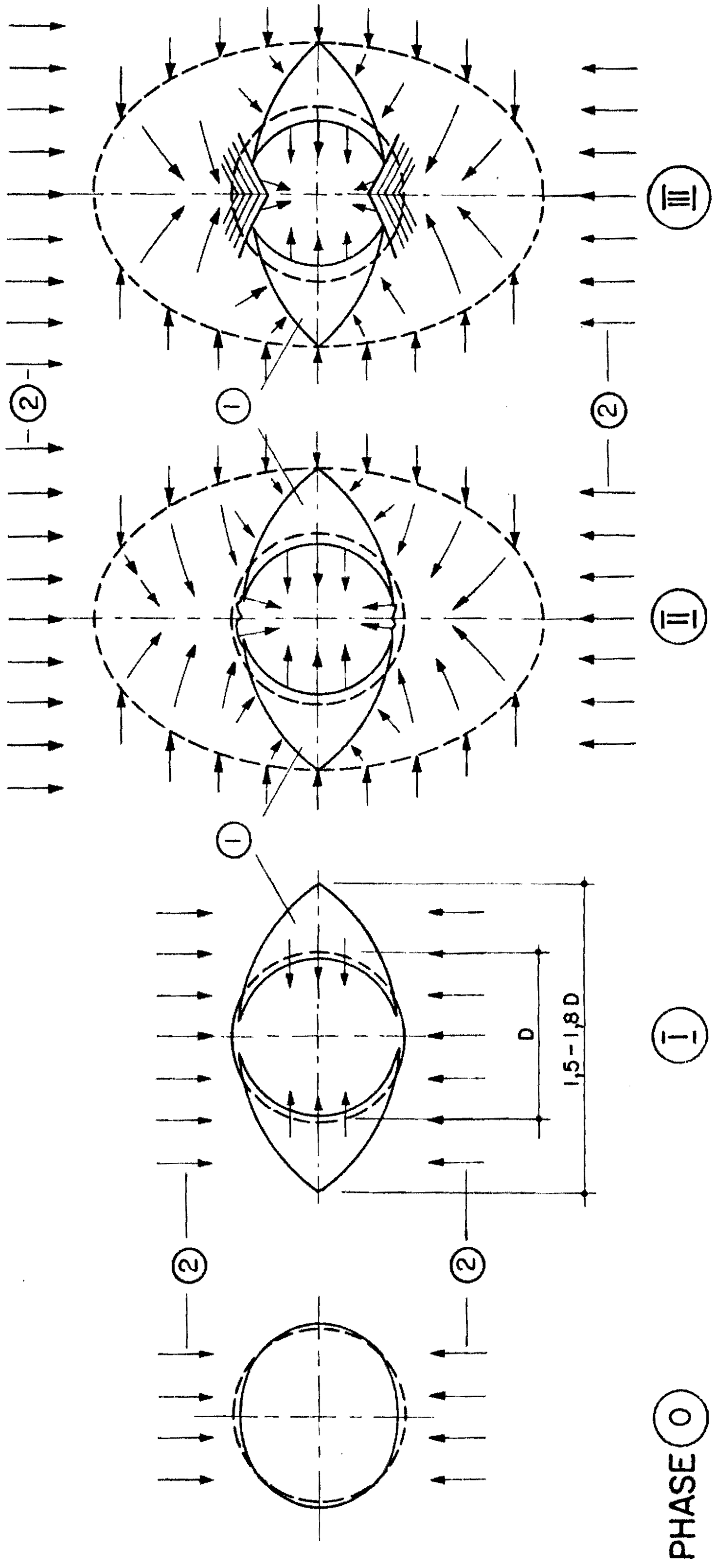
I VAULT ONLY LINED
II VAULT AND INVERT LINED
S_1 S_2 S_3 CONCRETING OF THE INVERT

LINING:
1 SLIGHTLY ELASTIC
2 ELASTIC
3 VERY ELASTIC

RELATION BETWEEN LINING RESISTANCE AND DEFORMATION

A	B	C	D	E	F	DATE	15.3.72	APPX 2-16
ELECTRO-WATT	CONSUSULTING ENGINEERS		VIRKIR			DESIGN	RAG	DRAWING NUMBER
						APPROVED	Mek	1301 112866

SCHEMATIC REPRESENTATION OF THE MECHANICAL PROCESS AND THE TIME SEQUENCE OF FAILURE AROUND A CAVITY BY ROCK PRESSURE. PHASES I, II AND III (ACC. RABCEWICZ), PHASE 0 SHOWS THE DEFORMATIONS BEFORE THE INITIAL FAILURE



① SHEARING WEDGES
② DIRECTION OF PRINCIPAL STRESS

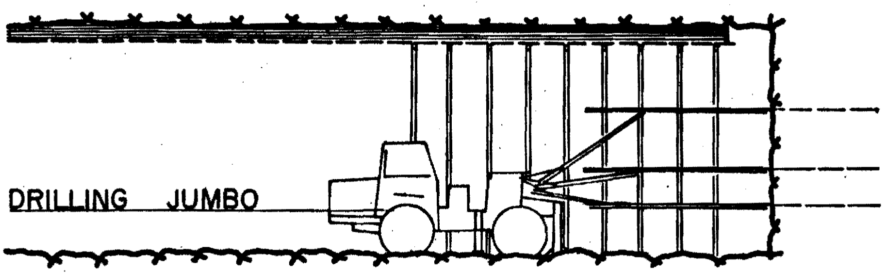
DOTTED LINE = ORIGINAL CROSS-SECTION
FULL LINE = DEFORMED CROSS-SECTION

SCHEMATIC REPRESENTATION OF THE FAILURE OF A TUNNEL SECTION

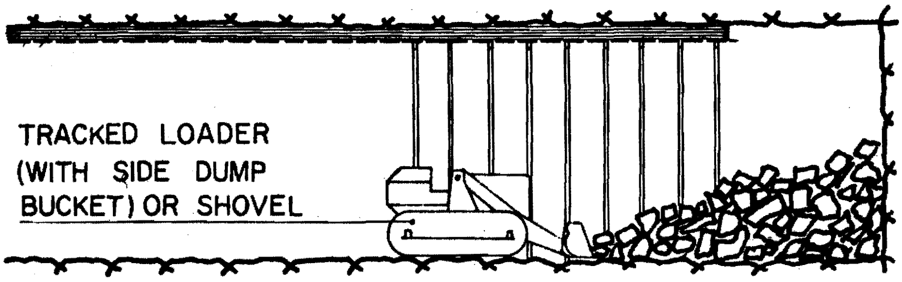
A	B	C	D	E	F	DATE	15. 3. 72	APPX 2-17
ELECTRO-WATT CONSULTING ENGINEERS					VIRKIR	DESIGN	RAG	DRAWING NUMBER
						APPROVED	Met	1301 112867

TUNNEL CONSTRUCTION METHOD

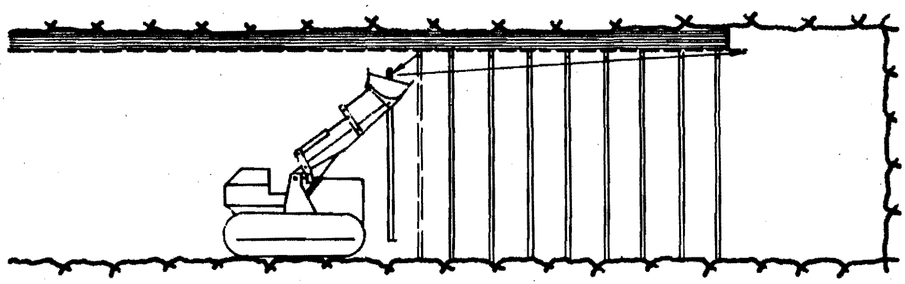
(1) DRILLING AND BLASTING



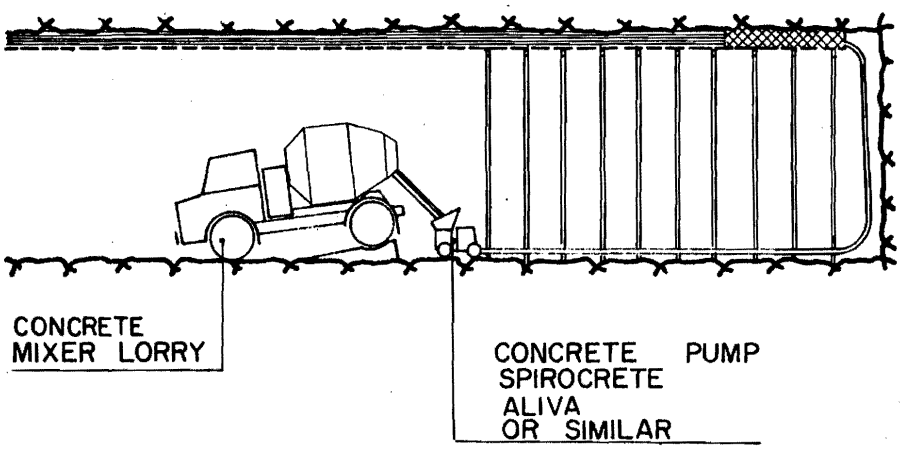
(2) MUCKING-OUT



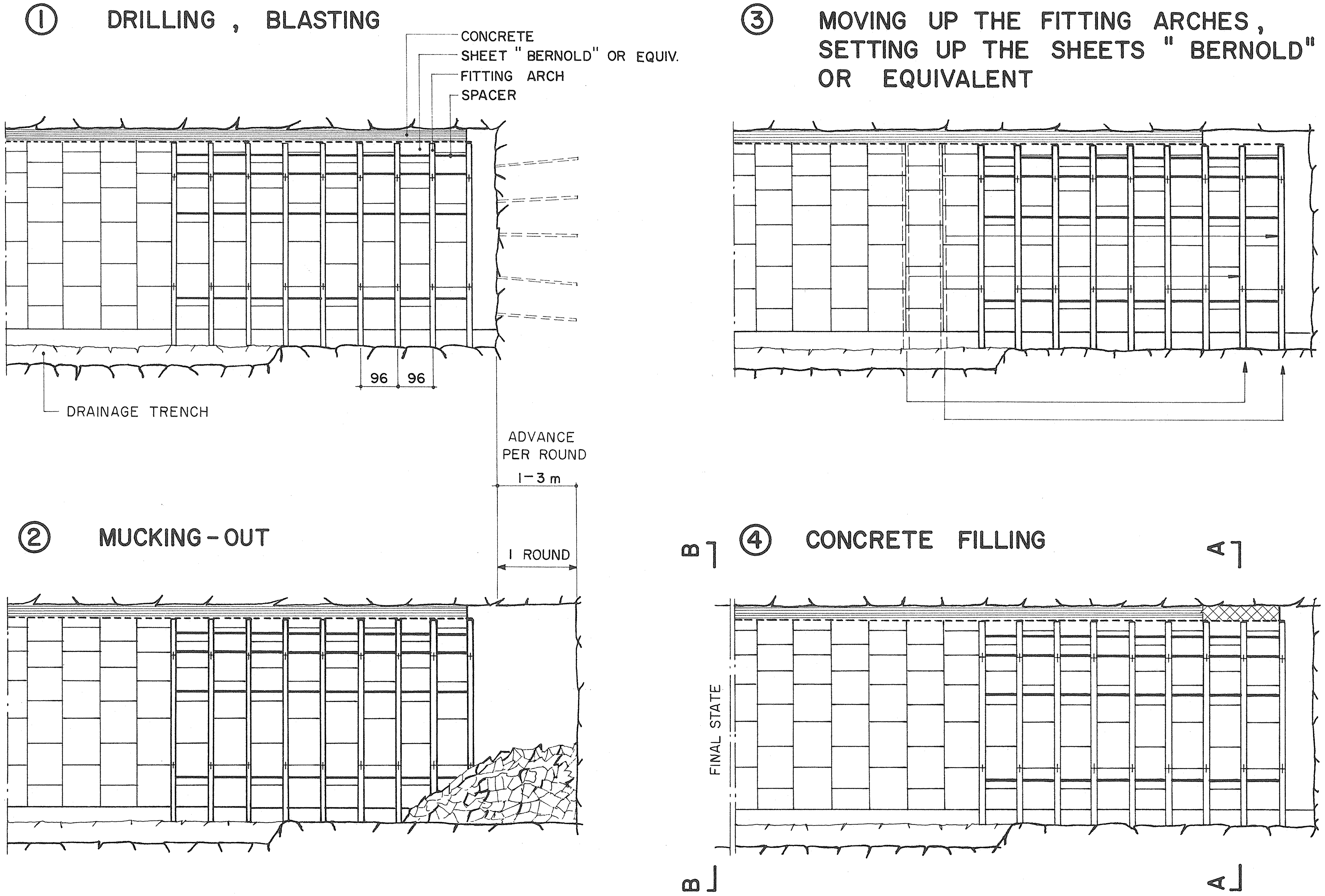
(3) ERECTION OF STEEL FRAMES AND BERNOLD SHEETS OR EQUIVALENT



(4) CONCRETING



A	B	C	D	E	F	DATE	15.3.72	APPX 2-18
ELECTRO-WATT	CONSULTING ENGINEERS				VIRKIR	DESIGN	RAG	DRAWING NUMBER
						APPROVED	Mat	1301112868



DAILY CYCLE
- EXCAVATION (DRILLING, BLASTING, MUCKING)
- ERECTION OF FITTING ARCHES
- ASSEMBLY OF SHEETS "BERNOLD" OR EQUIVALENT
- CONCRETE FILLING

COMMENTS

DRAINAGE TRENCH AND INVERT MUST BE CONCRETED SUCCESSIVELY IN ORDER TO GUARANTEE THE FULL SUPPORTING EFFECT OF THE LINING , THIS DEPENDS ON THE EFFECTIVE ADVANCE RATES.

E.G. DAILY CYCLES EXECUTED AS SHOWN IN FIGS ① TO ④ FOR THREE WEEKS

CONCRETING OF DRAINAGE TRENCH AND INVERT DURING THE FOURTH WEEK

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TUNNELLING IN MOBERG

BERNOLD TUNNELING SYSTEM

LONGITUDINAL SECTIONS

ELECTRO-WATT ZURICH — CONSULTING ENGINEERS — VIRKIR REYKJAVIK

SCALE	DATE	DRAWING NUMBER	APPENDIX
1:100	15.3.72	1301112869	2-19

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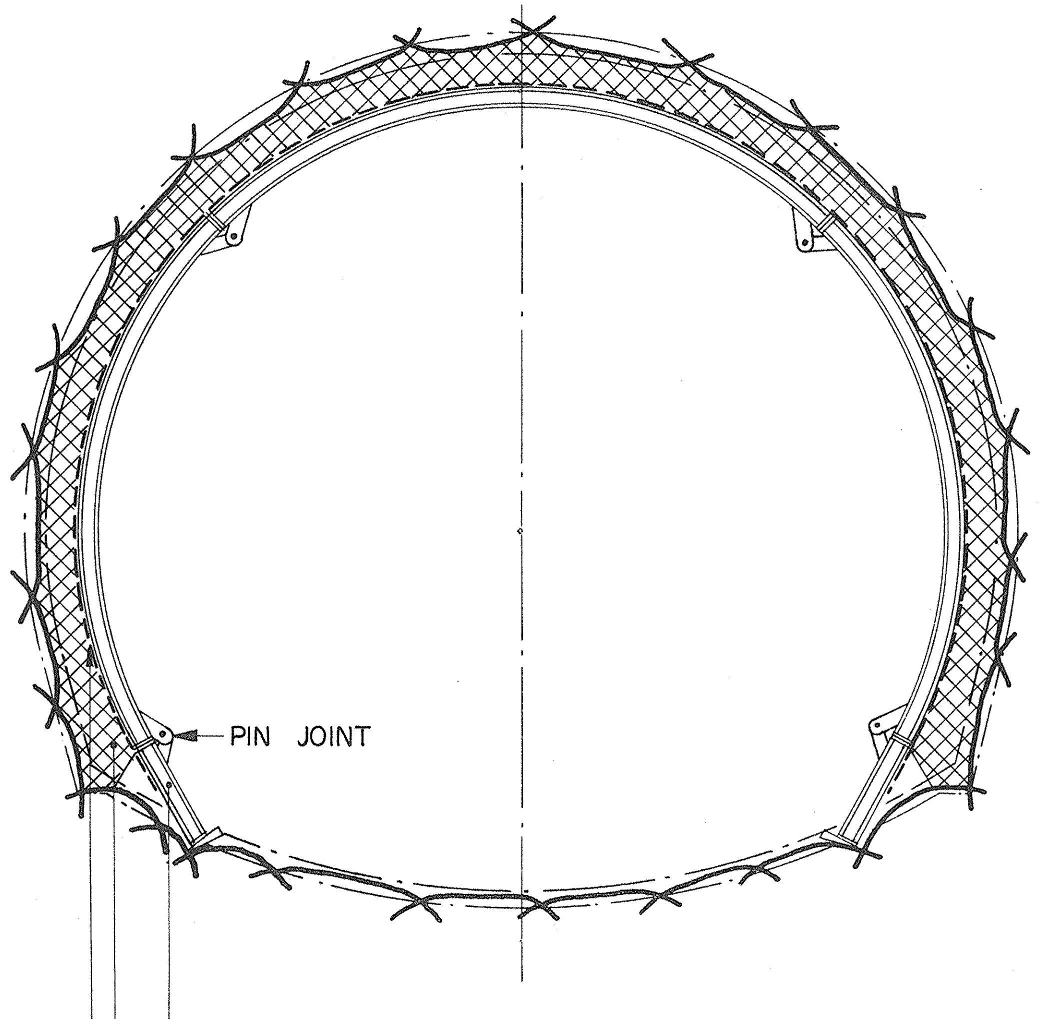
TUNNEL SECTION A III

SECTION A-A

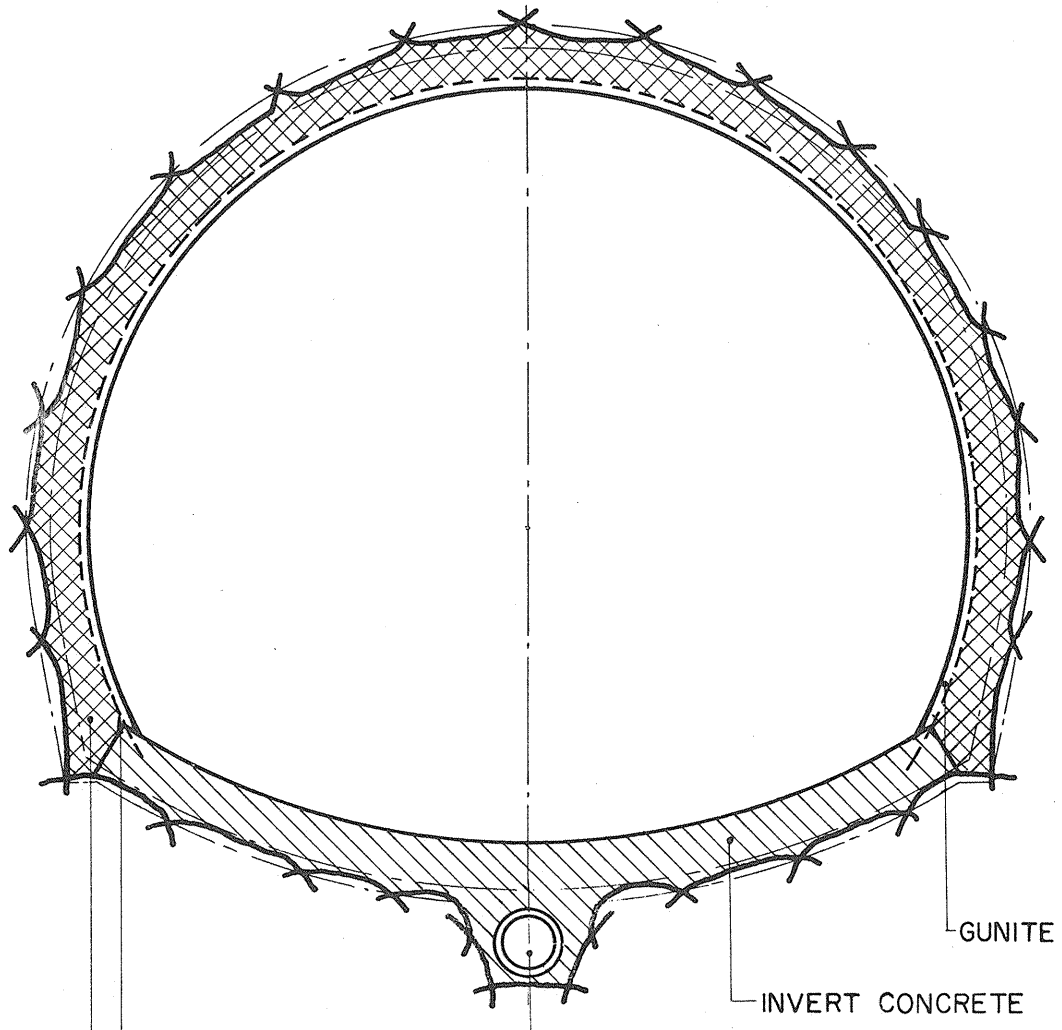
SCALE 1:50



TUNNEL SECTION A III

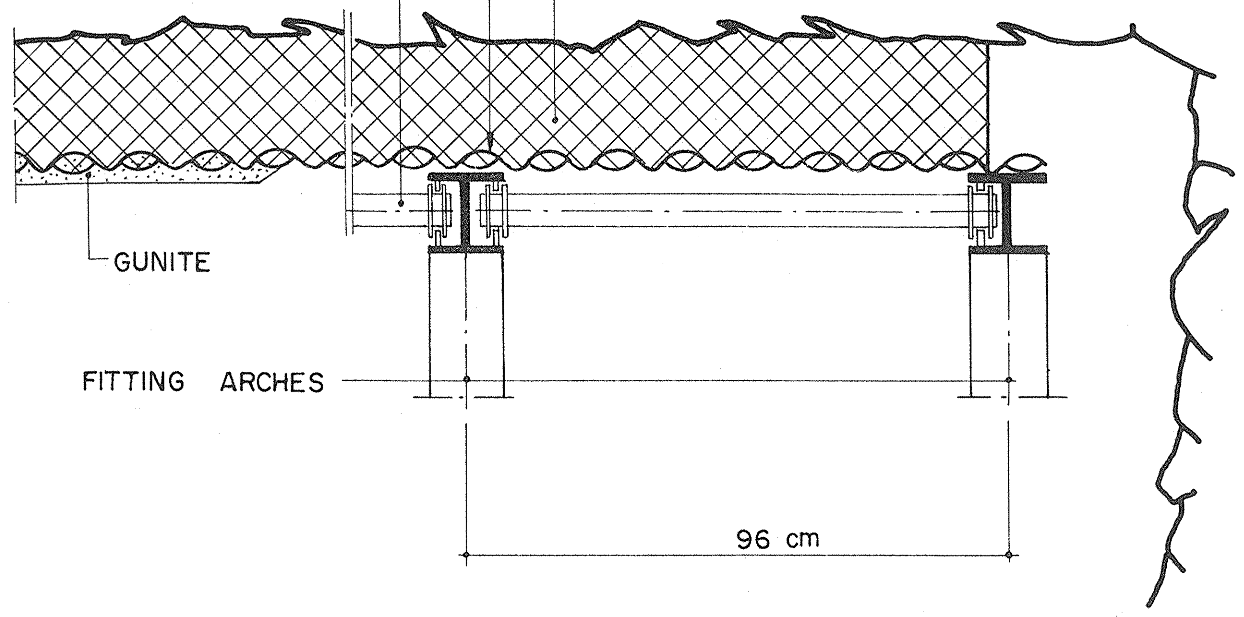
SECTION B-B

FINAL SECTION



DETAIL OF LONGITUDINAL SECTION

SCALE 1: 13,3



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NATIONAL ENERGY AUTHORITY

TUNNELLING IN MOBERG

BERNOLD TUNNELING SYSTEM
SECTIONS AND DETAILS

ELECTRO-WATT CONSULTING ENGINEERS ZURICH — VIRKIR REYKJAVIK

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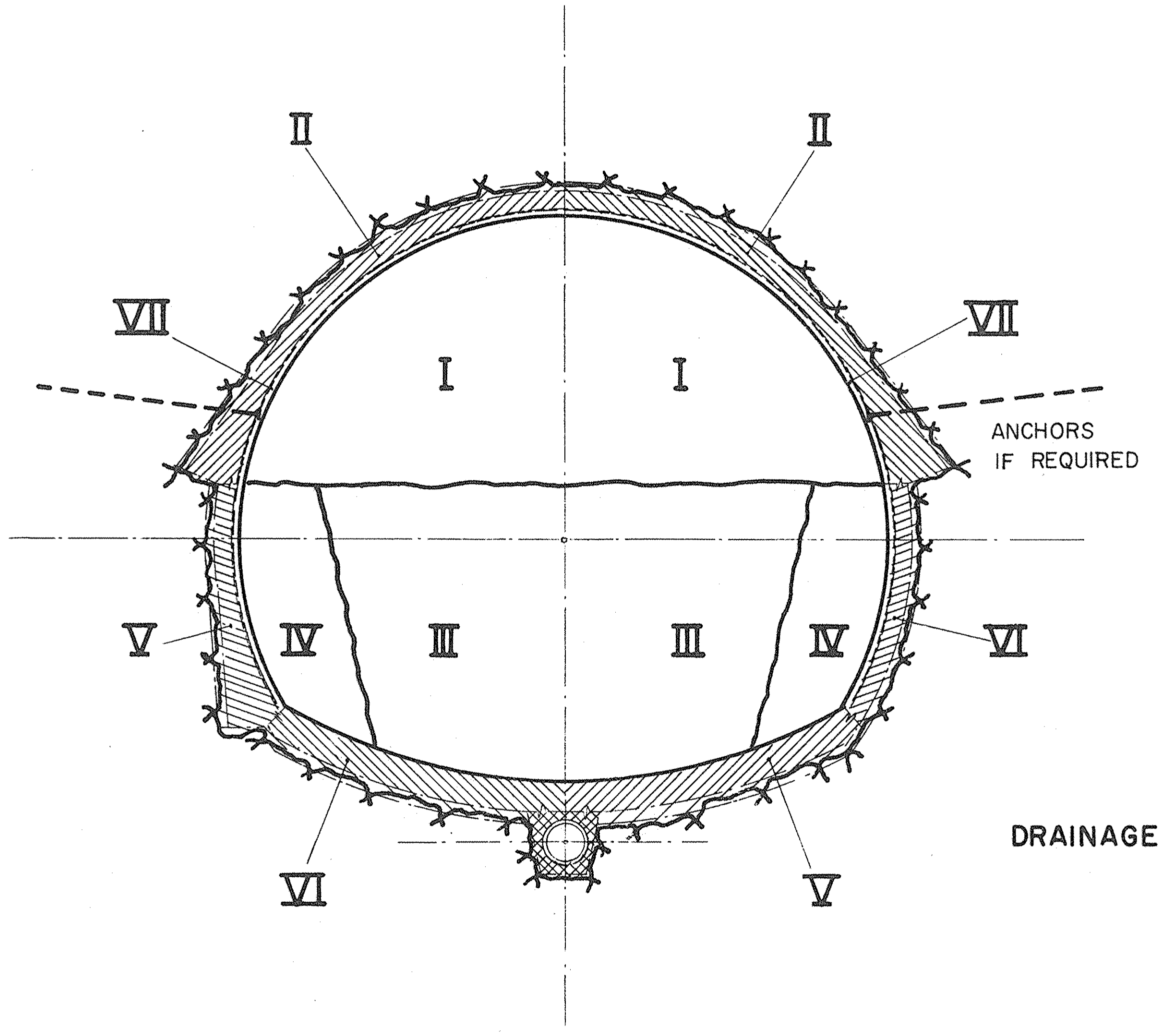
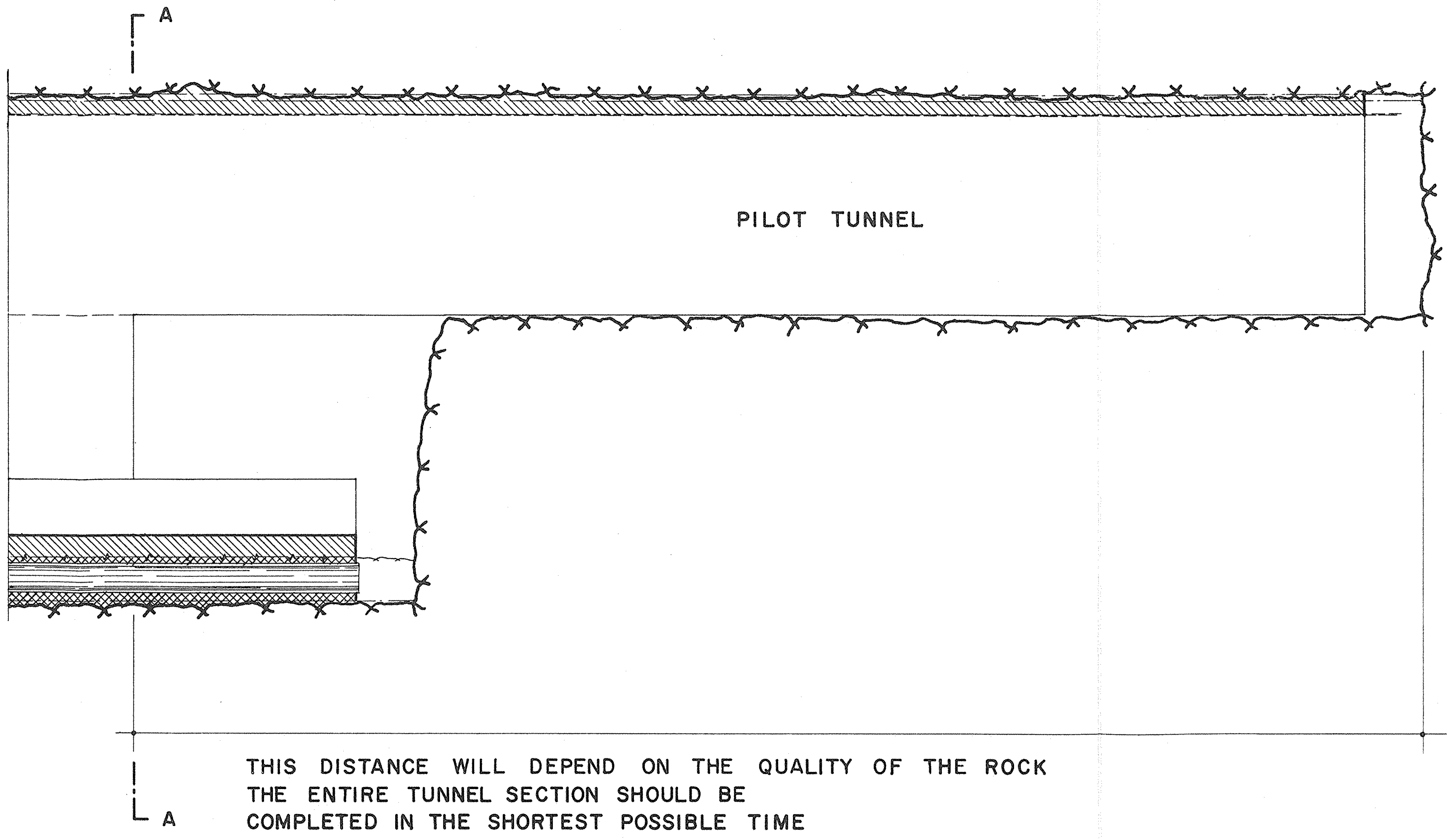
DRA. RAG
CHE.
APP. Met

SCALE	DATE	DRAWING NUMBER	APPENDIX
1: 50/133	15.3.72	1301112870	2-20

CROSS - SECTION
A - A
1:100



LONGITUDINAL SECTION



THE BELGIAN METHOD

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NATIONAL ENERGY AUTHORITY

TUNNELLING IN MOBERG

TUNNEL SECTION B
SEQUENCE OF
CONSTRUCTION STAGES

ELECTRO-WATT
CONSULTING ENGINEERS
ZURICH

VIRKIR
REYKJAVIK

IND.	DATE	CHE.
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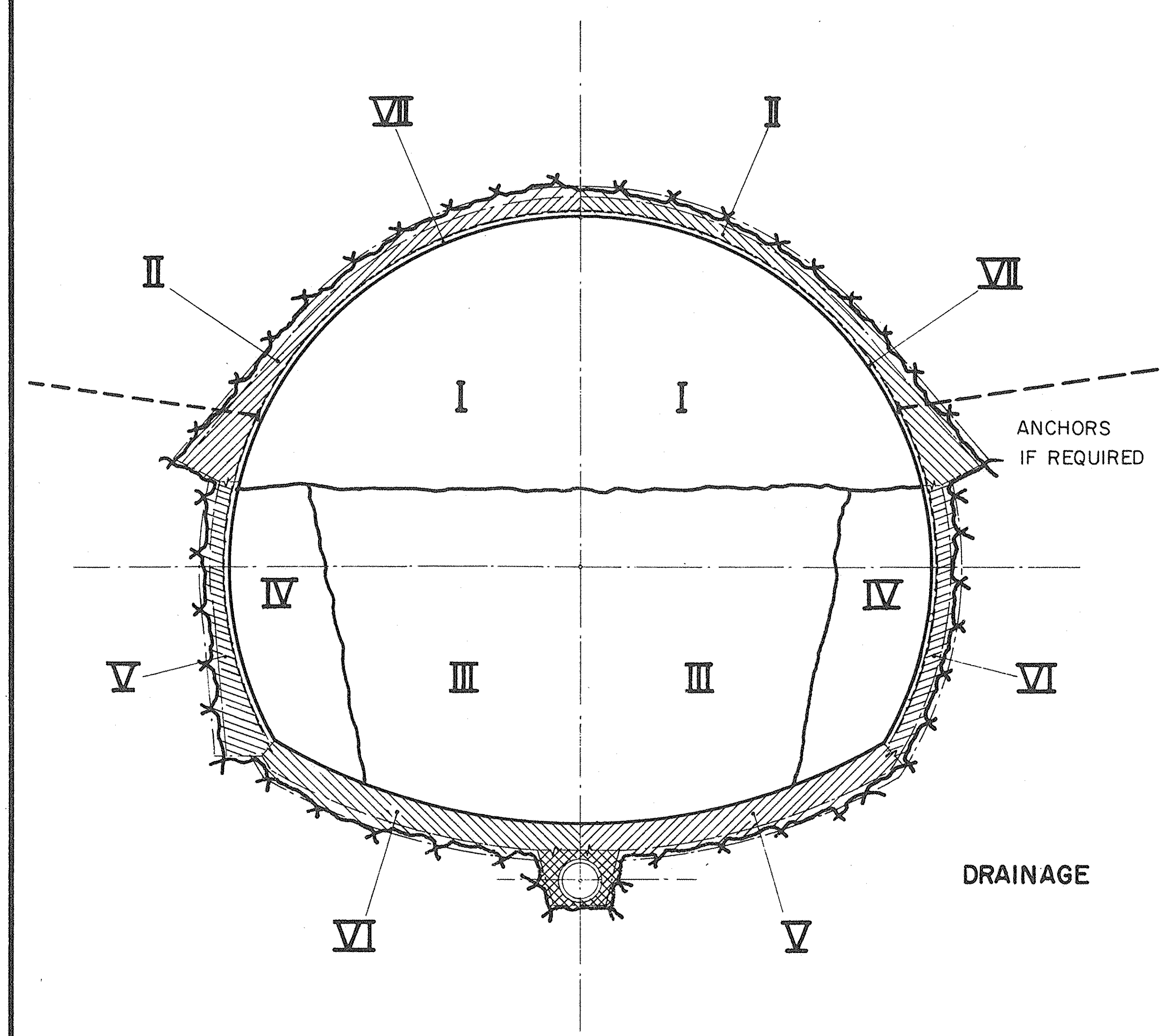
DRA.	RAG
CHE.	
APP.	Mat

SCALE	DATE	DRAWING NUMBER	APPENDIX
1:100	15.3.72	1301112871	2-21

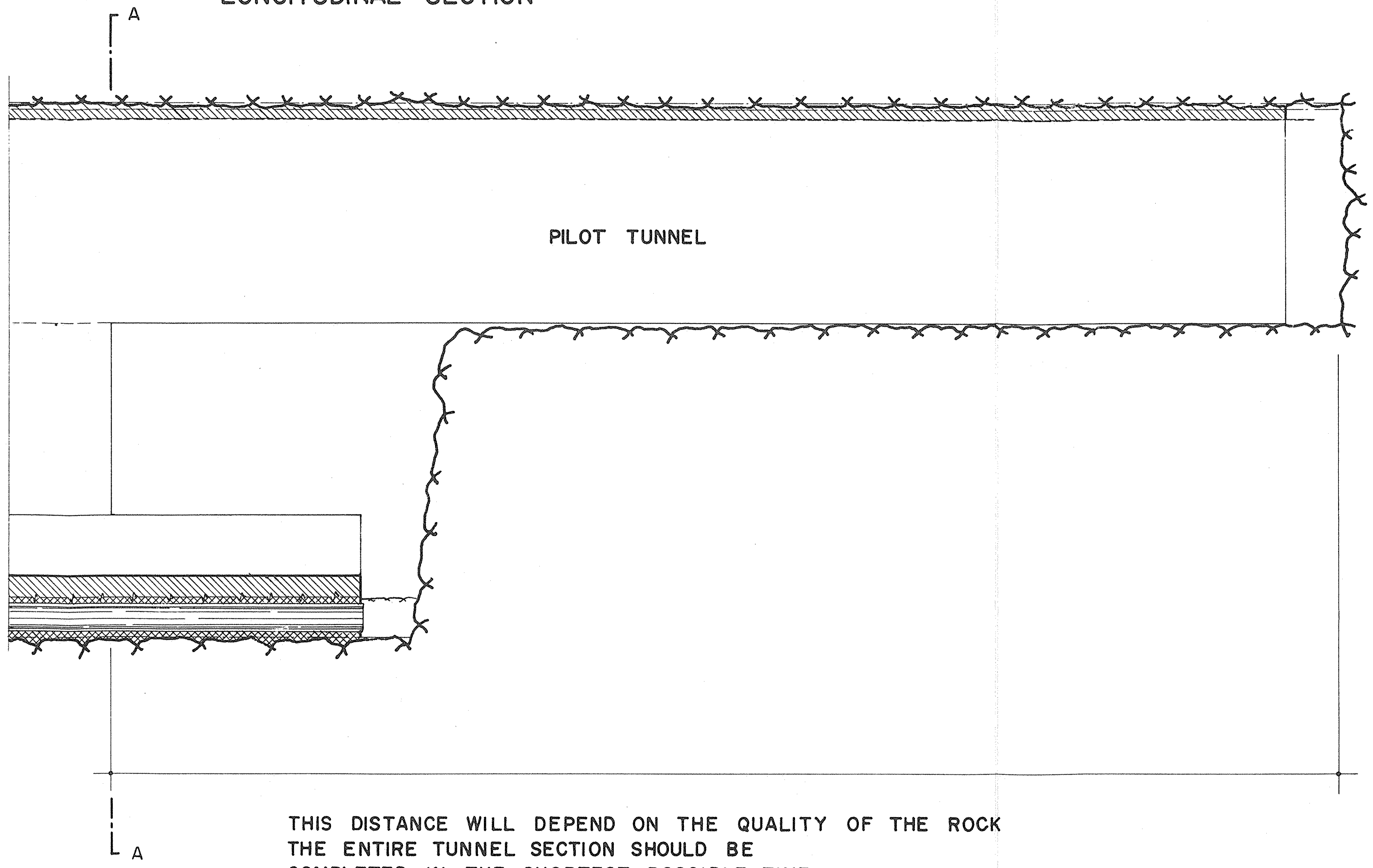
CROSS - SECTION
A - A
1:100



SEQUENCE OF STAGES IN FRIABLE ROCK

SEQUENCE OF STAGES IN STABLE ROCK

LONGITUDINAL SECTION



THIS DISTANCE WILL DEPEND ON THE QUALITY OF THE ROCK
THE ENTIRE TUNNEL SECTION SHOULD BE
COMPLETED IN THE SHORTEST POSSIBLE TIME

THE BELGIAN METHOD

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NATIONAL ENERGY AUTHORITY

TUNNELLING IN MOBERG

TUNNEL SECTION C
SEQUENCE OF
CONSTRUCTION STAGES

ELECTRO-WATT CONSULTING ENGINEERS ZURICH — VIRKIR REYKJAVIK

IND.	DATE	CHE.
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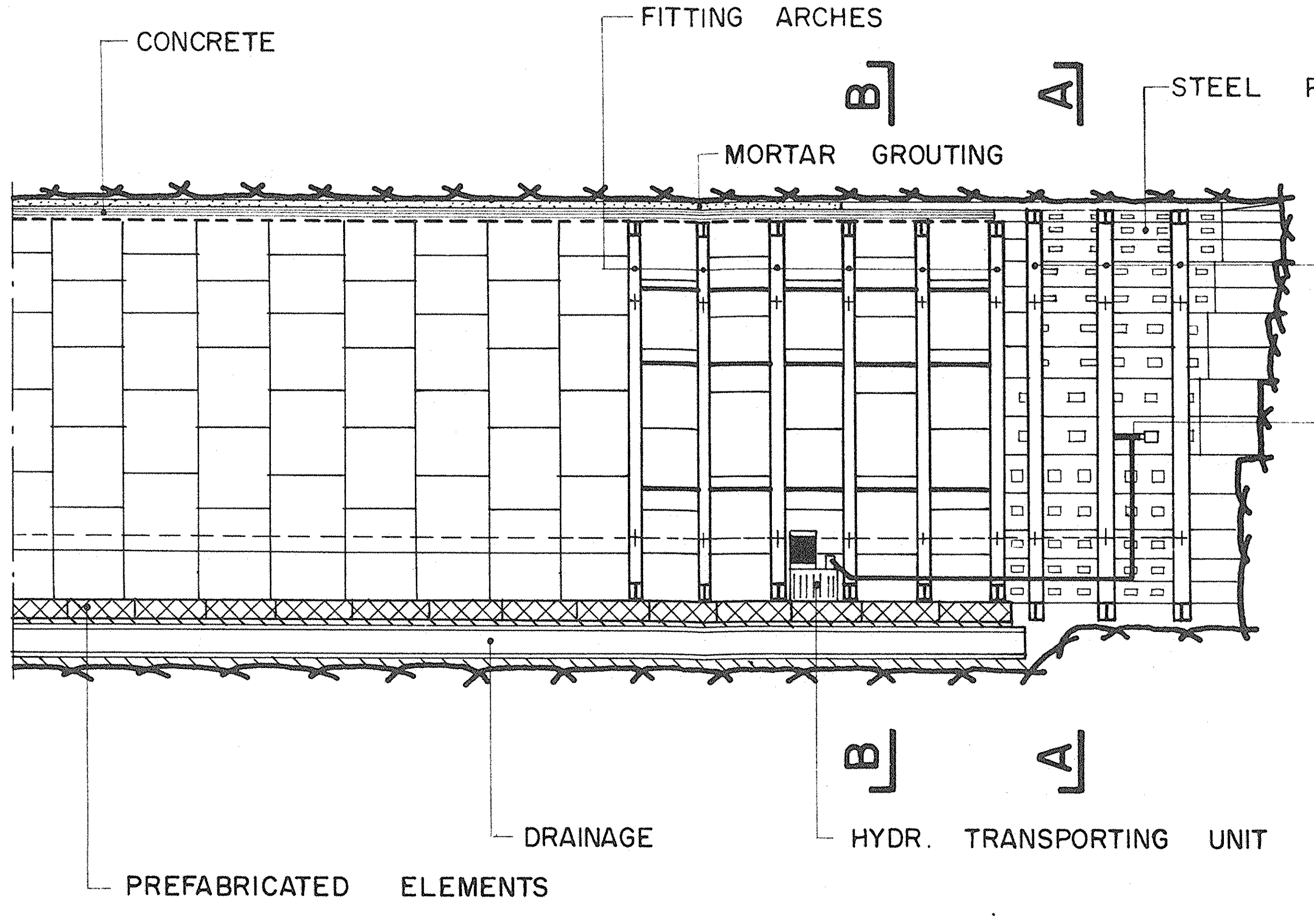
DRA. RAG
CHE.
APP. Met

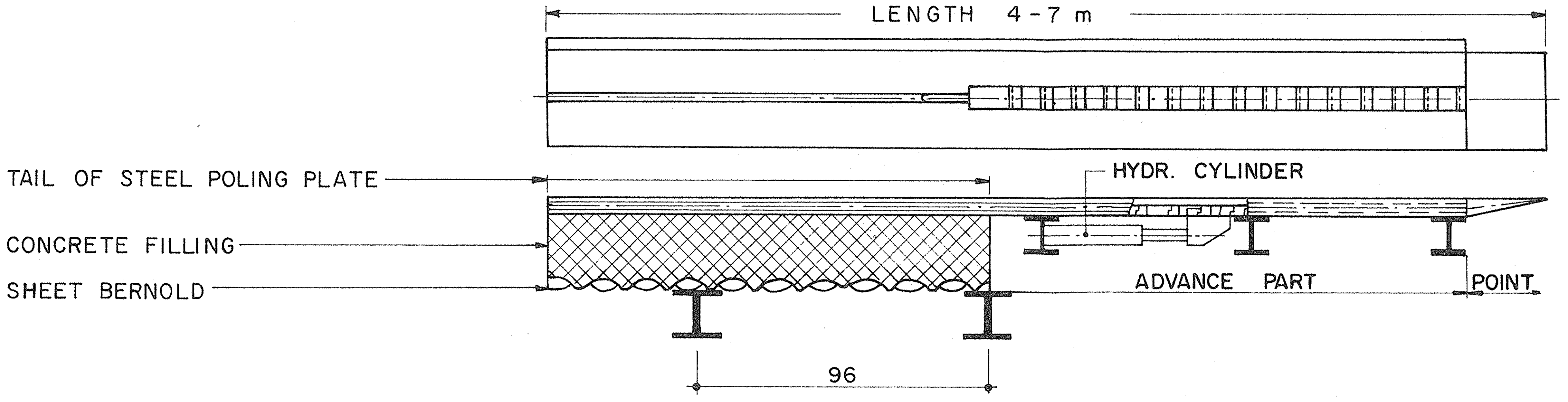
SCALE	DATE	DRAWING NUMBER	APPENDIX
1:100	15.3.72	1301112872	2-22

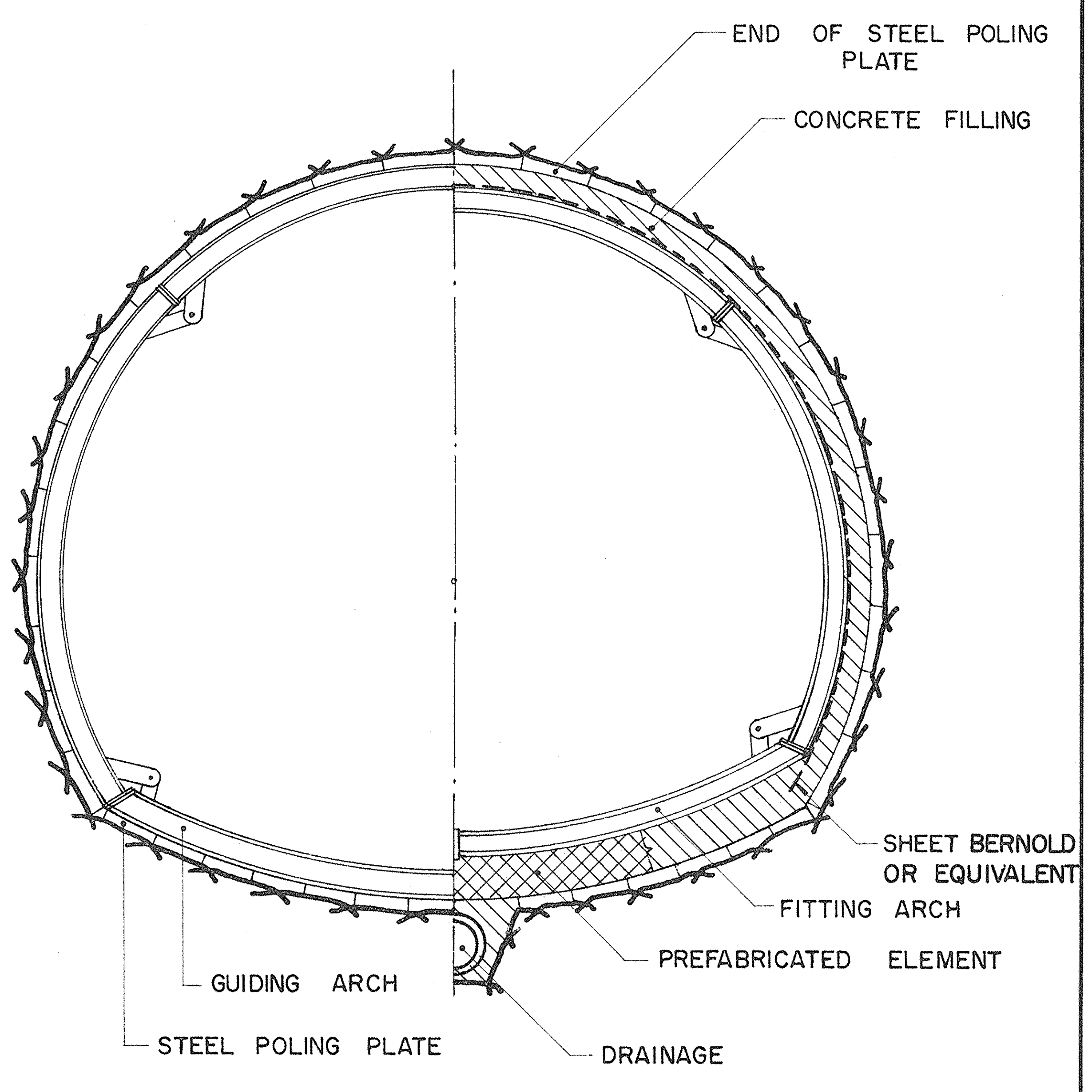
LONGITUDINAL SECTION

SCALE 1:100



STEEL POLING PLATE





SECTION A-A   SECTION B-B

SCALE 1:50

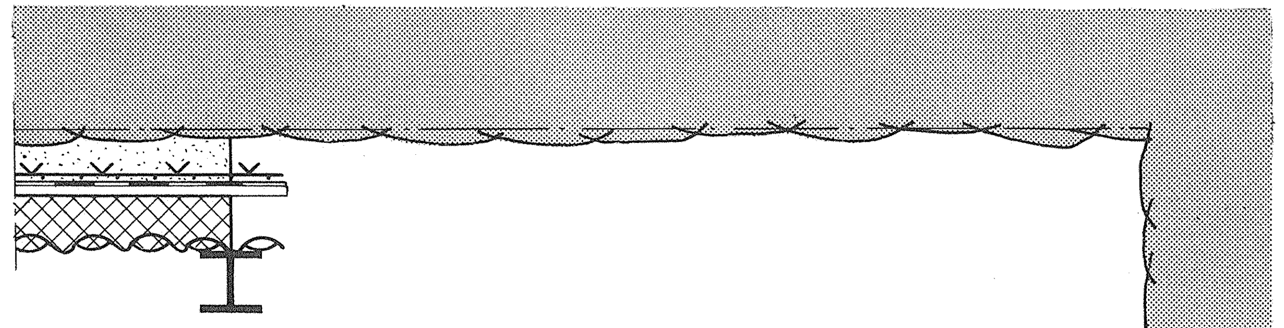
ORKUSTOFNUN NATIONAL ENERGY AUTHORITY		
TUNNELLING IN MOBERG		
TUNNEL SECTION A TUNNEL DRIVING WITH STEEL POLING PLATES		J H G F E D C B A IND. DATE CHE.
ELECTRO-WATT CONSULTING ENGINEERS ZURICH	VIRKIR REYKJAVIK	DRA. RAG CHE. APP. Met
SCALE 1:100/50	DATE 15.3.72	DRAWING NUMBER 1301 11 2873
APPENDIX 2-23		

METHODS OF DEALING WITH WATER

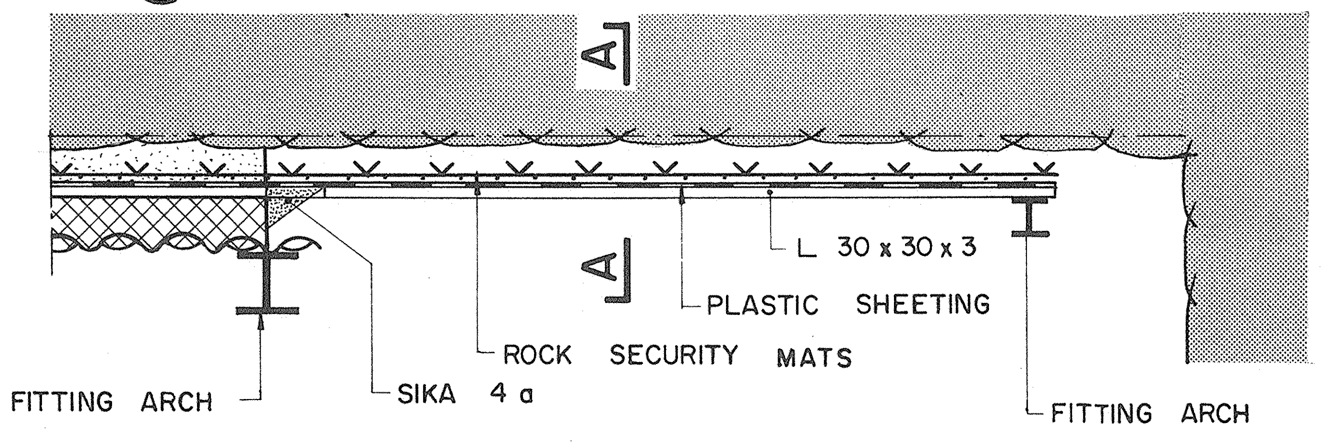
	TYPE OF LINING/SUPPORT			
	I	II	III	IV
	ROCK-SECURITY MATS AND SHOTCRETE	SHEETS BERNOLD OR EQUIVALENT WITH CONCRETE	SHEETS BERNOLD OR EQUIVALENT WITH CONCRETE	STEEL POLING PLATES SHEETS BERNOLD WITH CONCRETE
TYPE OF INFILTRATION	METHOD OF DEALING WITH WATER			
LOCAL	OBERHASLI PROCESS SPRIBAG DRAINAGE	OBERHASLI PROCESS SPRIBAG DRAINAGE	OBERHASLI PROCESS SPRIBAG DRAINAGE	PLASTIC SHEETING AND DRAINAGE HOLES
RAINY ZONES	OBERHASLI PROCESS SPRIBAG DRAINAGE METHOD I	SURFACING WITH PLASTIC SHEETING METHOD II	SURFACING WITH PLASTIC SHEETING METHOD III	PLASTIC SHEETING AND DRAINAGE HOLES METHOD IV

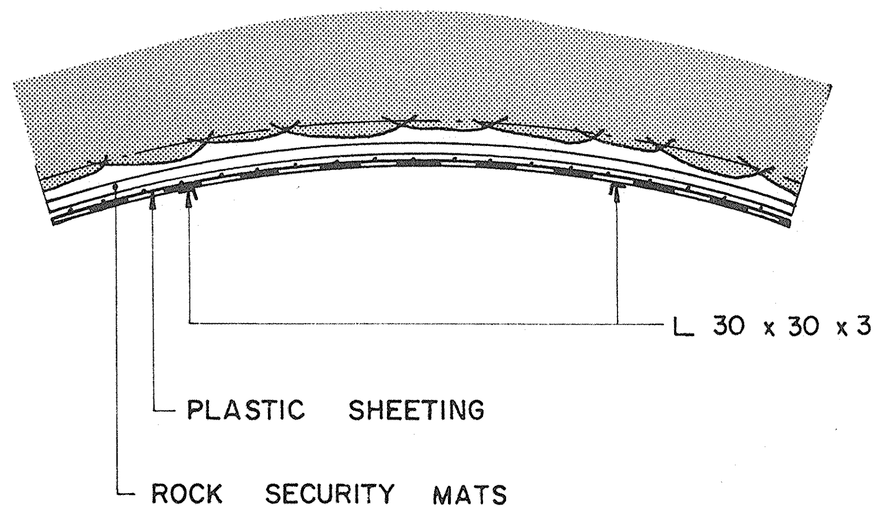
A	B	C	D	E	F	DATE	15.3.72	APPX 2-24
ELECTRO-WATT CONSULTING ENGINEERS VIRKIR						DESIGN	RAG	DRAWING NUMBER
						APPROVED	Mlet	1301112874

① SITUATION AFTER EXCAVATION



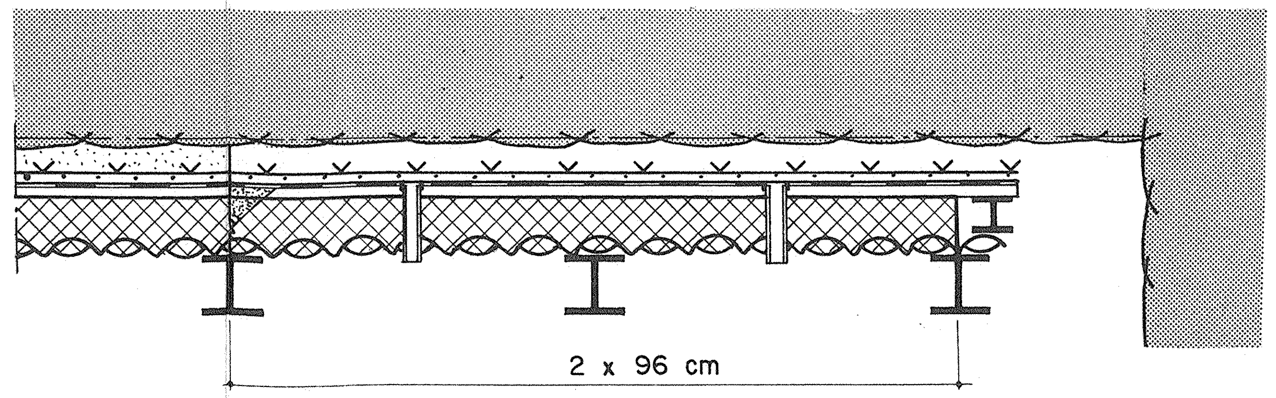
② PLASTIC SHEETING PLACED



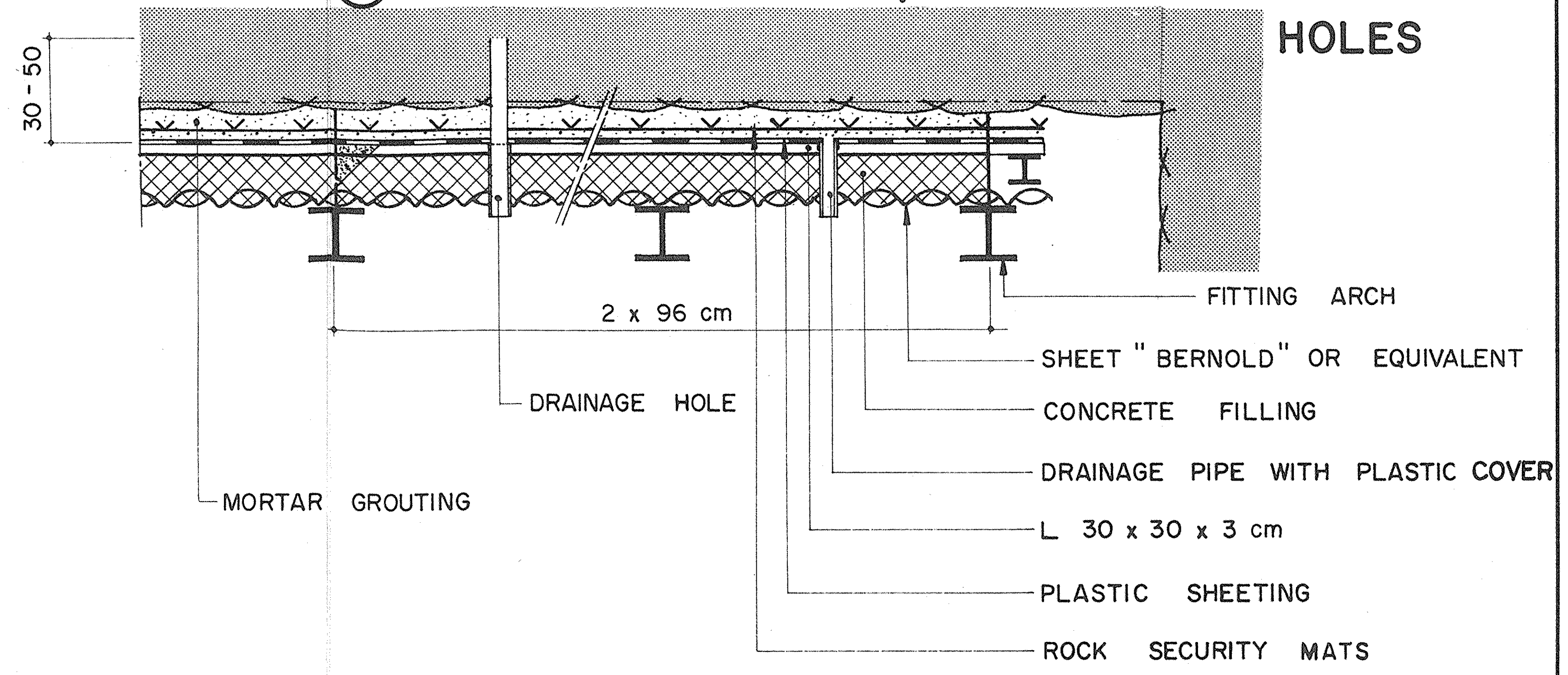


SECTION A-A

③ CONCRETE FILLING



④ MORTAR GROUTING, DRILLING OF DRAINAGE HOLES



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NATIONAL ENERGY AUTHORITY

TUNNELLING IN MOBERG

DEALING WITH WATER
METHOD II - DETAILS

IND.	DATE	CHE.
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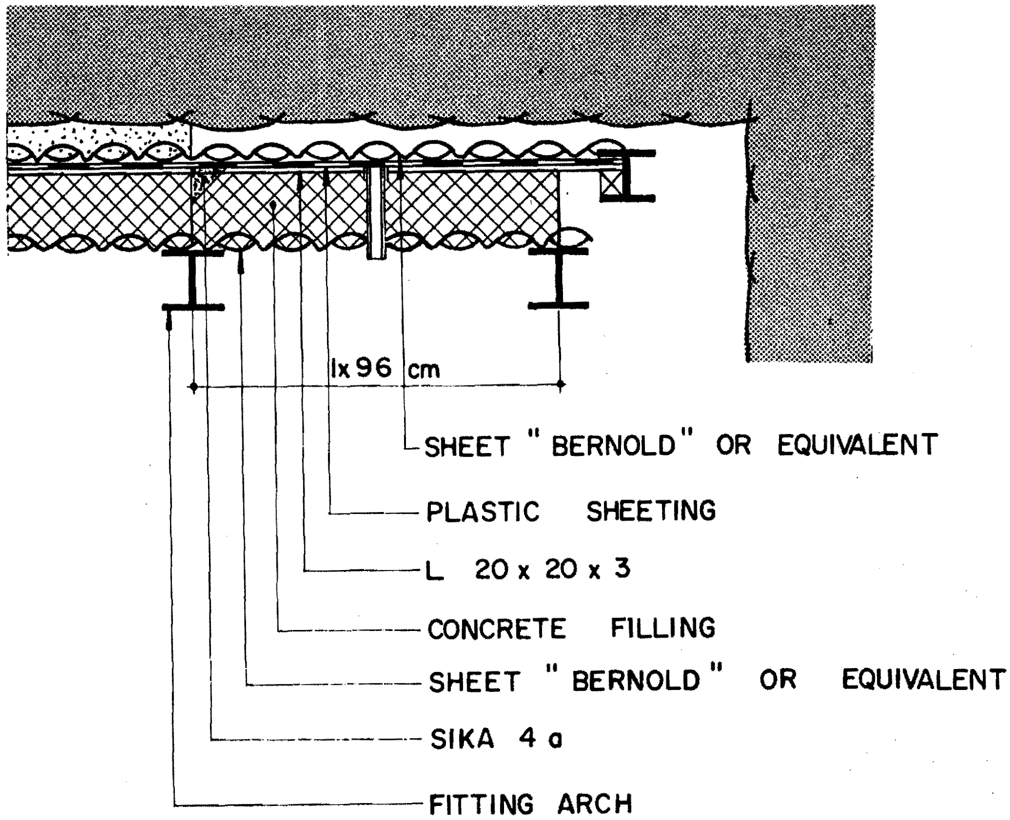
ELECTRO-WATT CONSULTING ENGINEERS ZURICH — VIRKIR REYKJAVIK

DRA. RAG
CHE.
APP. Met

SCALE	DATE	DRAWING NUMBER	APPENDIX
1:20	15.3.72	1301112875	2-25

DETAIL OF LONGITUDINAL SECTION

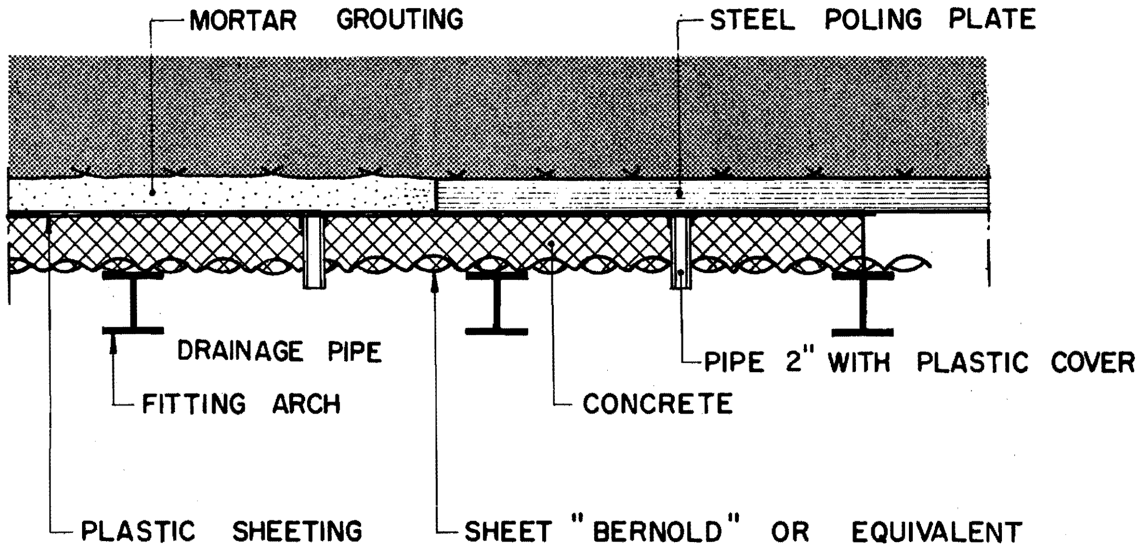


DUE TO THE ROCK QUALITY THIS SECTION NEEDS A SECOND LAYER OF SHEETS " BERNOLD" OR EQUIVALENT

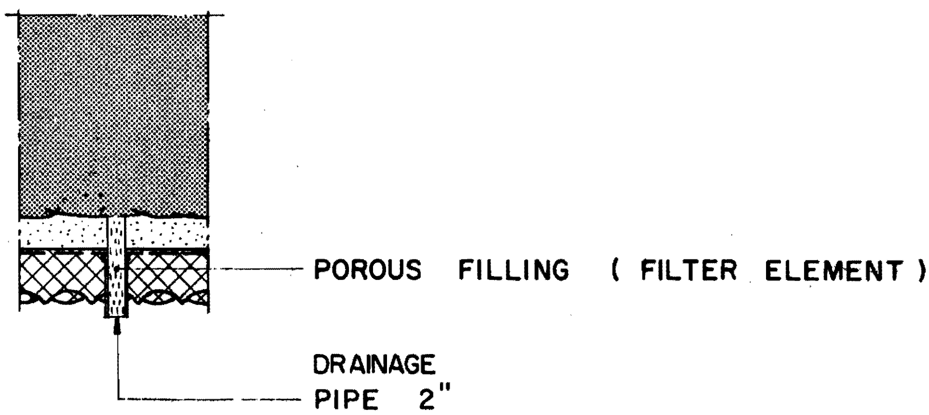
DEALING WITH WATER , METHOD III

A	B	C	D	E	F	DATE	15.3.72	APPX 2-26
ELECTRO-WATT CONSULTING ENGINEERS VIRKIR						DESIGN	RAG	DRAWING NUMBER
						APPROVED	Met	1301112876

DETAIL OF LONGITUDINAL SECTION



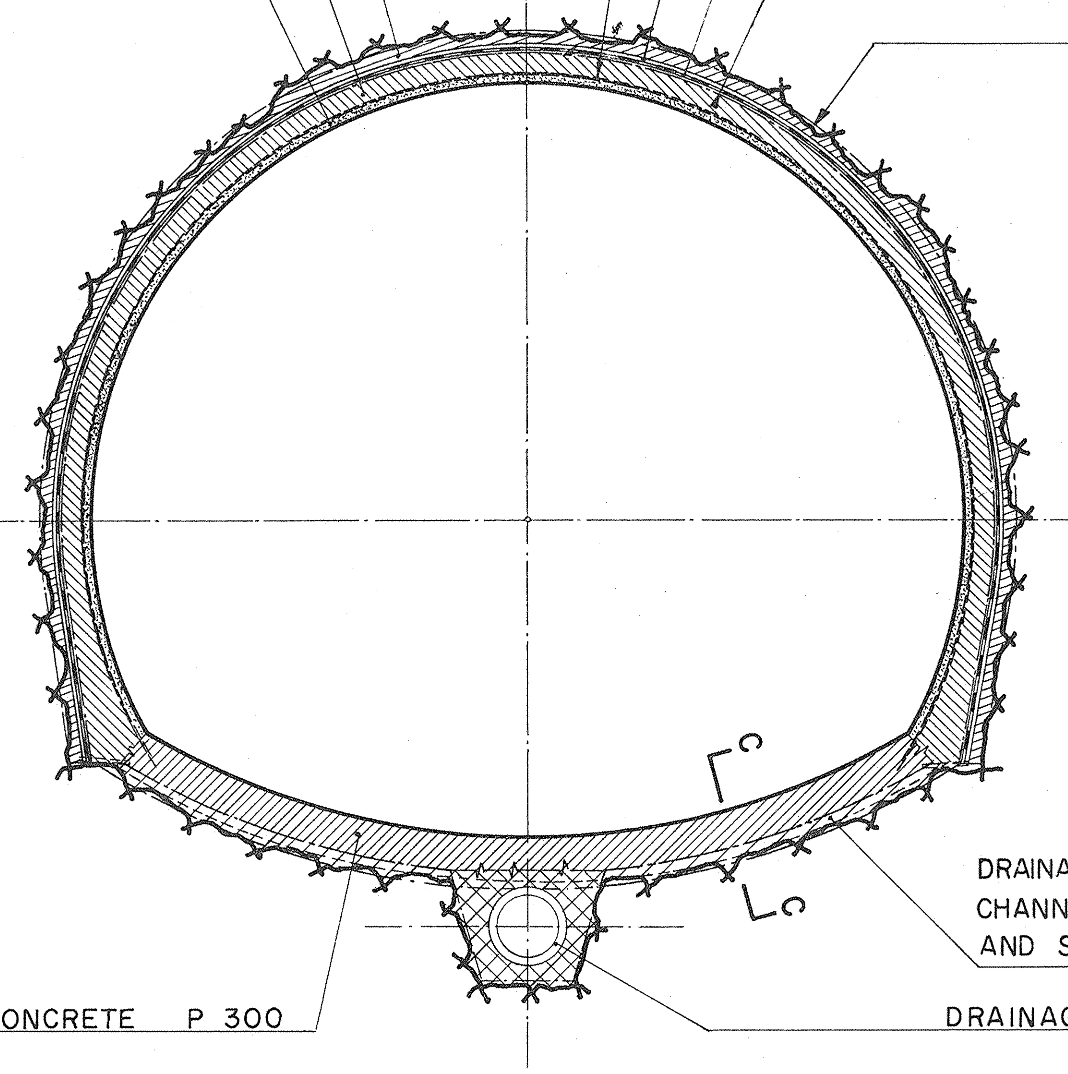
DETAIL OF A DRAINAGE HOLE



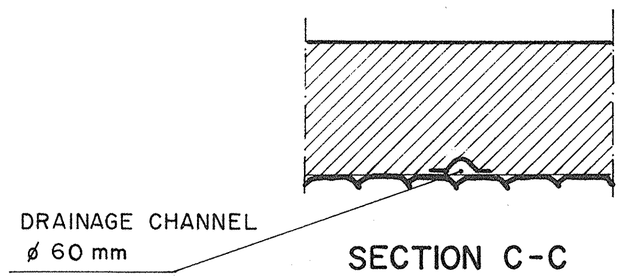
DEALING WITH WATER, METHOD IV

A	B	C	D	E	F	DATE	15.3.72	APPX 2-27
ELECTRO-WATT CONSULTING ENGINEERS VIRKIR						DESIGN	RAG	DRAWING NUMBER
						APPROVED	Met	1301112877

SECTION A
1:50



		SECTION A, 23.4 m^2			SECTION B, 52.2 m^2			SECTION C, 75.6 m^2		
		II	III	IV	II	III	IIV	II	III	IV
EXCAVATION TO PAY LINE INCLUDING DRAINAGE	m^3	30.3	31.5	29.7	64.0	66.7	64.7	90.8	99.9	91.7
ROCK SECURITY MATS	m^2	13.3	–	–	19.6	–	–	23.2	–	–
SHEETS „BERNOLD" OR EQUIVALENT	m^2	12.7	26.2	12.7	18.8	39.0	18.8	22.4	46.0	22.4
PLASTIC SHEETING	m^2	13.3	13.5	12.9	19.6	20.2	19.4	23.2	23.6	20.6
CONCRETE P 300	m^3	4.1	5.2	4.0	7.7	10.3	9.1	10.3	19.4	12.0
MORTAR GROUTING	m^3	2.0	2.1	1.5	2.9	3.0	2.2	3.5	3.5	2.7
STEEL REINFORCEMENT FOR INVERT	kg	40	46	53	66	75	86	92	106	136
GUNITE	m^3	0.6	0.6	0.6	0.9	0.9	0.9	1.1	1.1	1.1



SECTION C-C
1:20

ORKUSTOFNUN
NATIONAL ENERGY AUTHORITY

TUNNELLING IN MOBERG

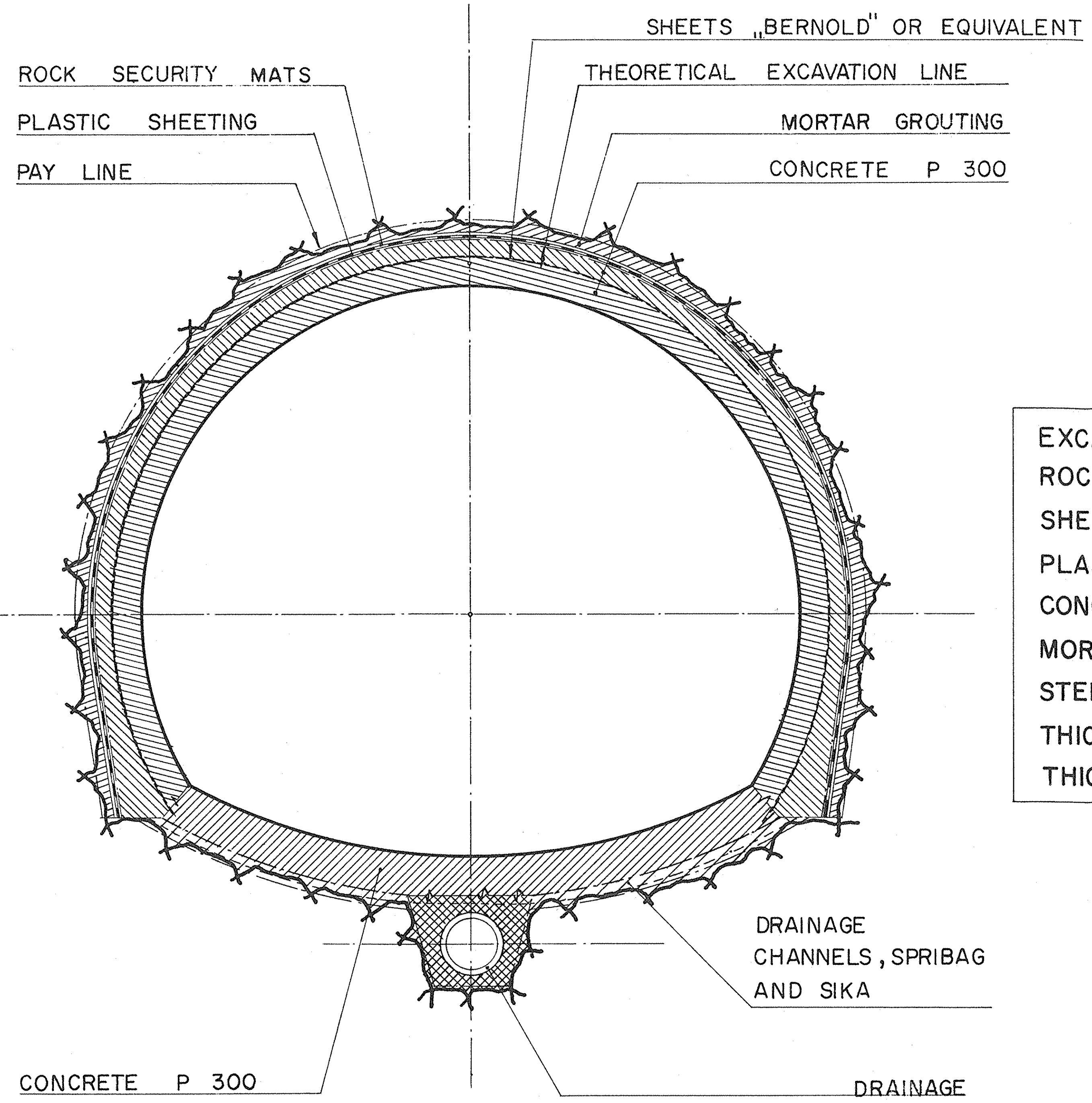
TUNNEL CROSS SECTION
AS MODIFIED FOR
DEALING WITH WATER

ELECTRO-WATT VIRKIR
CONSULTING ENGINEERS
ZURICH REYKJAVIK

SCALE	DATE	DRAWING NUMBER	APPENDIX
1:50	15.3.72	1301112878	2-28

DRA. RAG
CHE.
APP. Mat

SECTION
1:50



		SECTION A 23.4 m^2			SECTION B 52.2 m^2			SECTION C 75.6 m^2		
		II	III	IV	II	III	IV	II	III	IV
EXCAVATION TO PAY LINE INCLUDING DRAINAGE	m^3	30.3	31.5	29.7	64.0	66.7	64.7	90.8	99.9	91.7
ROCK SECURITY MATS	m^2	13.3	–	–	19.6	–	–	23.2	–	–
SHEETS BERNOLD OR EQUIVALENT	m^2	–	26.2	12.7	–	39.0	18.8	–	46.0	22.4
PLASTIC SHEETING	m^2	13.3	13.5	–	19.6	20.2	–	23.2	23.6	–
CONCRETE P 300	m^3	7.8	8.9	7.7	15.8	17.6	16.4	20.6	29.7	22.3
MORTAR GROUTING	m^3	2.0	2.1	1.5	2.9	3.0	2.2	3.5	3.5	2.7
STEEL REINFORCEMENT FOR INVERT AND SEC. LINING	kg	140	150	150	230	240	270	310	340	360
THICKNESS OF LINING, OUTER / INNER	cm	15/25	20/25	23/25	18/30	25/30	30/30	20/35	28/35	33/35
THICKNESS OF INVERT	cm	35	43	50	50	63	72	60	73	81

ORKUSTOFNUN
NATIONAL ENERGY AUTHORITY

TUNNELLING IN MOBERG

TUNNEL CROSS SECTION
MODIFIED FOR DEALING WITH WATER
AND INCLUDING A SECOND LINING
AGAINST WATER PRESSURE

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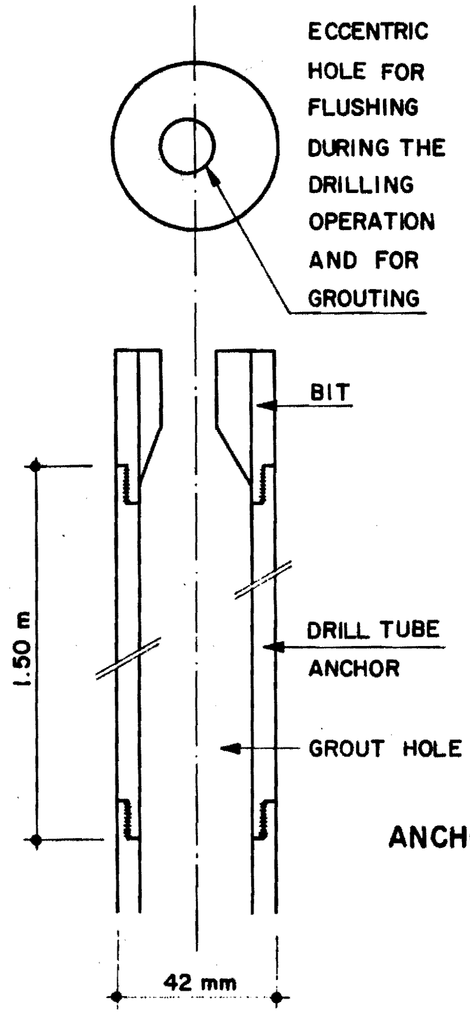
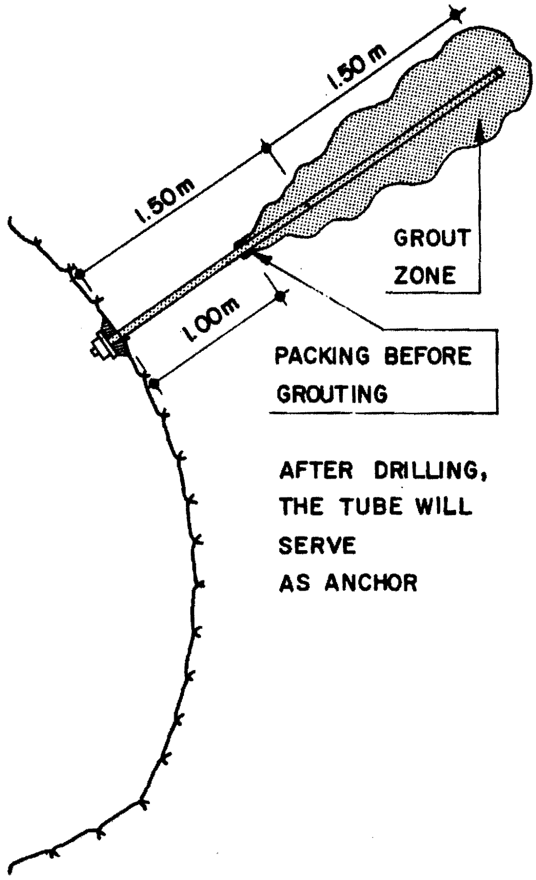
ELECTRO-WATT ZURICH — VIRKIR REYKJAVIK
CONSULTING ENGINEERS

DRA. RAG
CHE.
APP. Mah

SCALE	DATE	DRAWING NUMBER	APPENDIX
1:50	15.3.72	1301112879	2-29

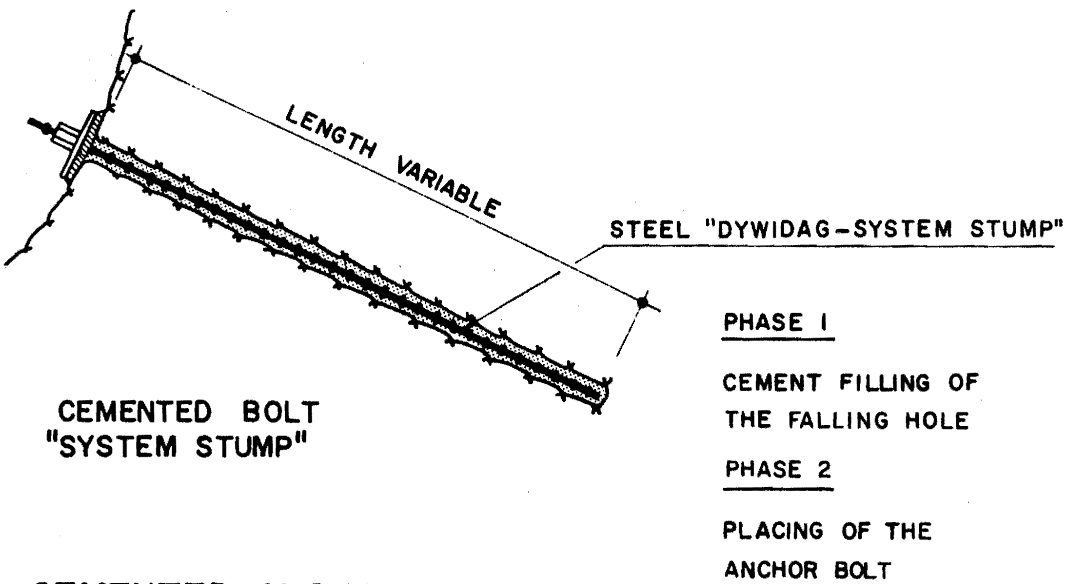


DETAIL OF TUBE ANCHOR



ANCHOR FOR BAD GROUND AND RISING HOLES

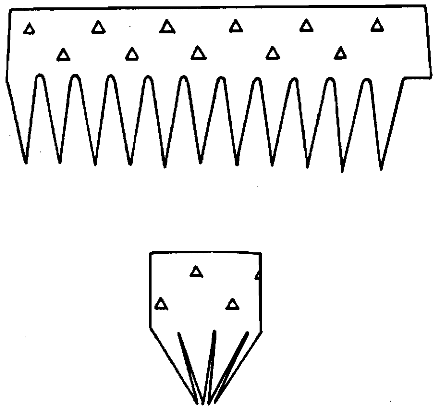
CEMENTED TUBE ANCHOR
SYSTEM "STUMP"



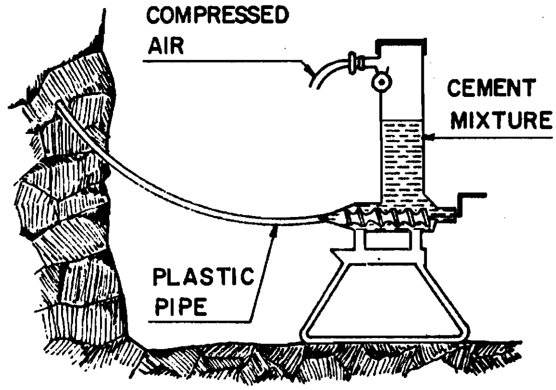
CEMENTED BOLT
"SYSTEM STUMP"

CEMENTED ANCHORS

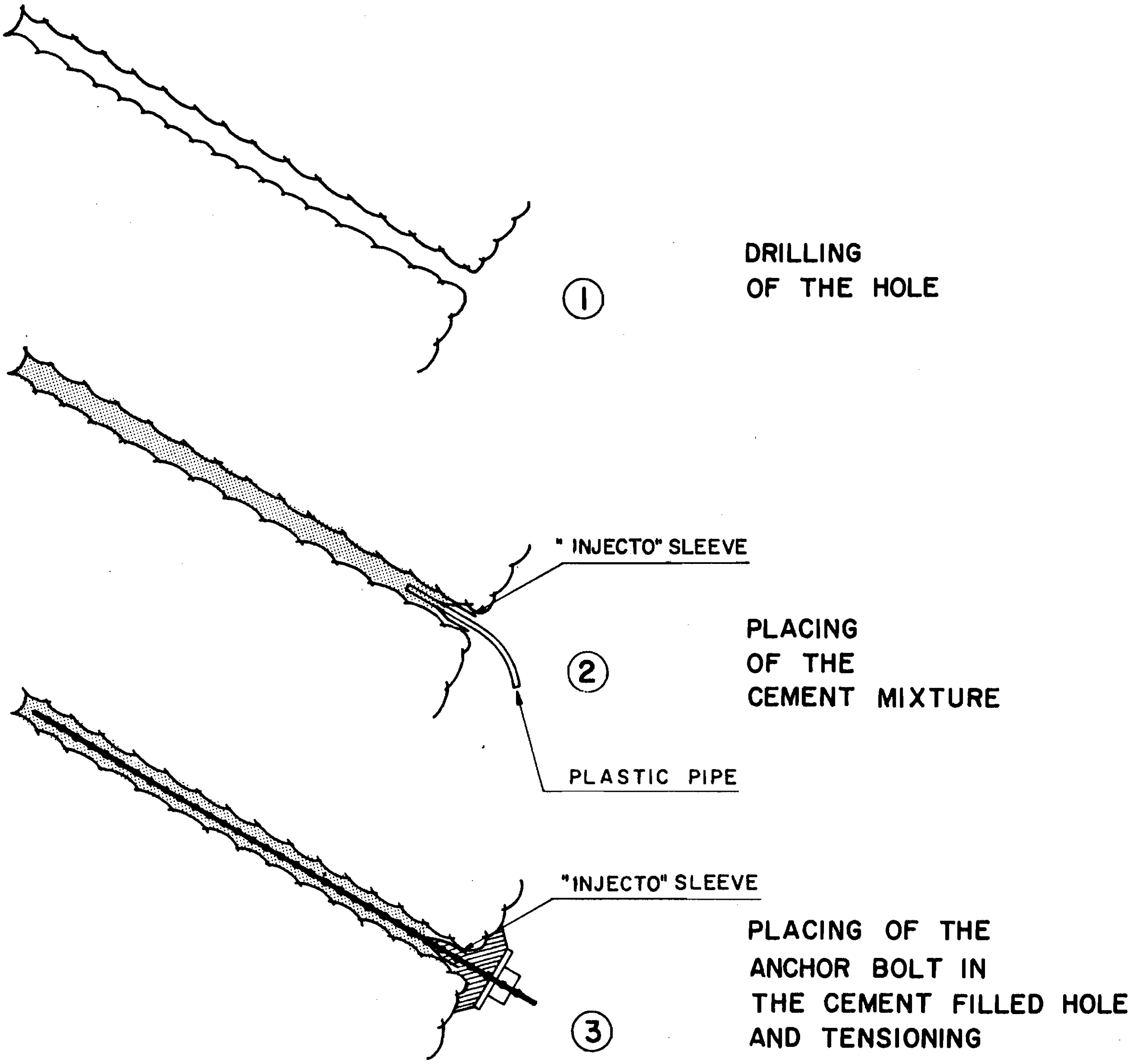
A	B	C	D	E	F	DATE	15.3.72	APPX 2-30
ELECTRO-WATT CONSULTING ENGINEERS VIRKIR						DESIGN	RAG	DRAWING NUMBER
						APPROVED	Met	1301 11 2880



"INJECTO" SLEEVE



SN CEMENT GUN
ATLAS COPCO



"INJECTO" BOLT SYSTEM ATLAS COPCO

A	B	C	D	E	F	DATE	15.3.72	APPX 2-31
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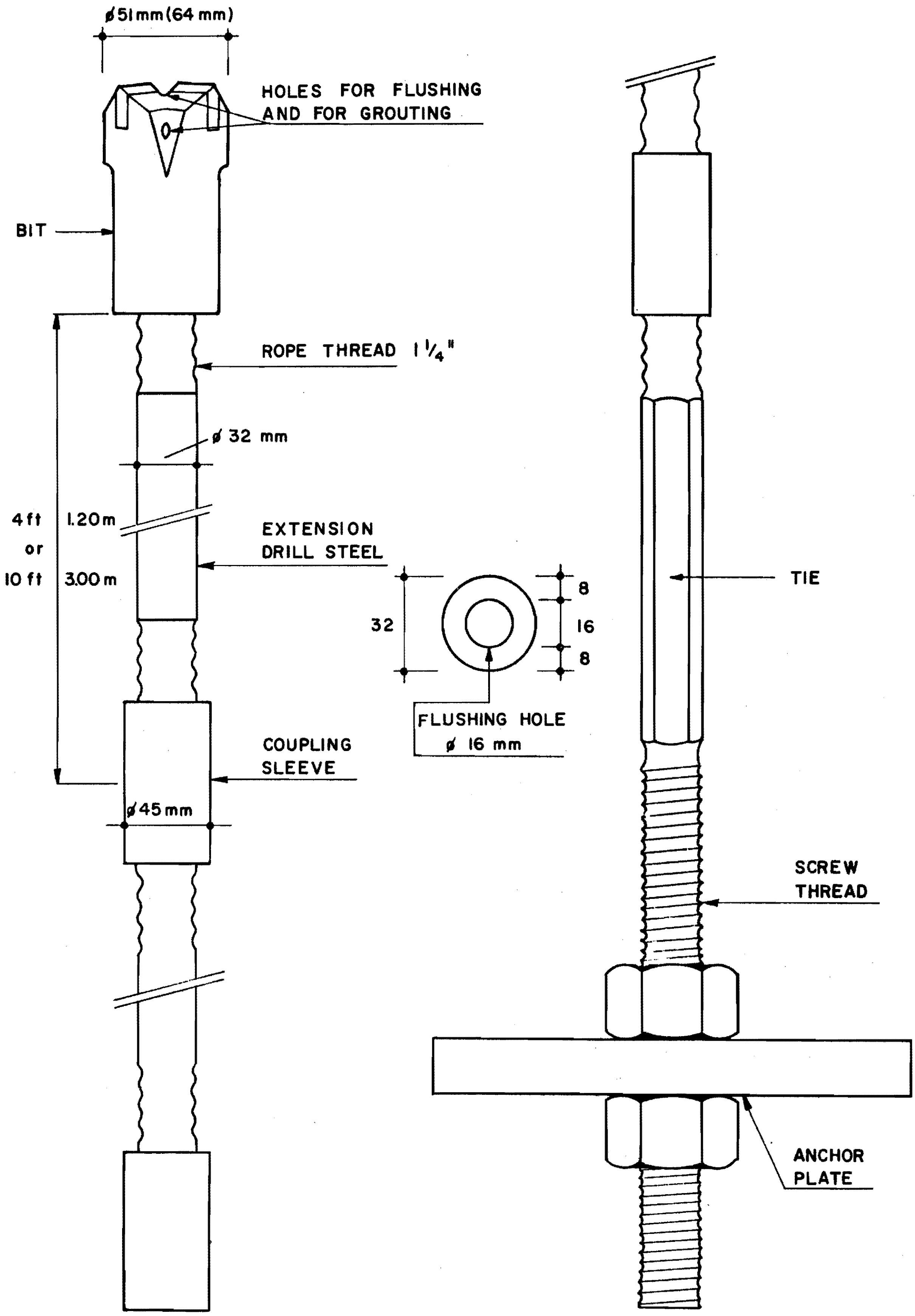
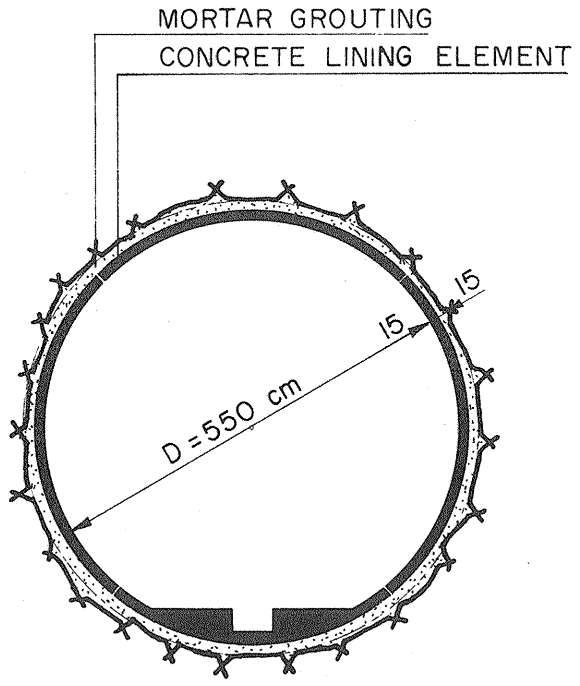


INSITU ANCHOR – SYSTEM SANDVIK

A	B	C	D	E	F	DATE	15.3.72	APPX 2-32
ELECTRO-WATT CONSULTING ENGINEERS VIRKIR						DESIGN	RAG	DRAWING NUMBER
						APPROVED	Met	1301 112882

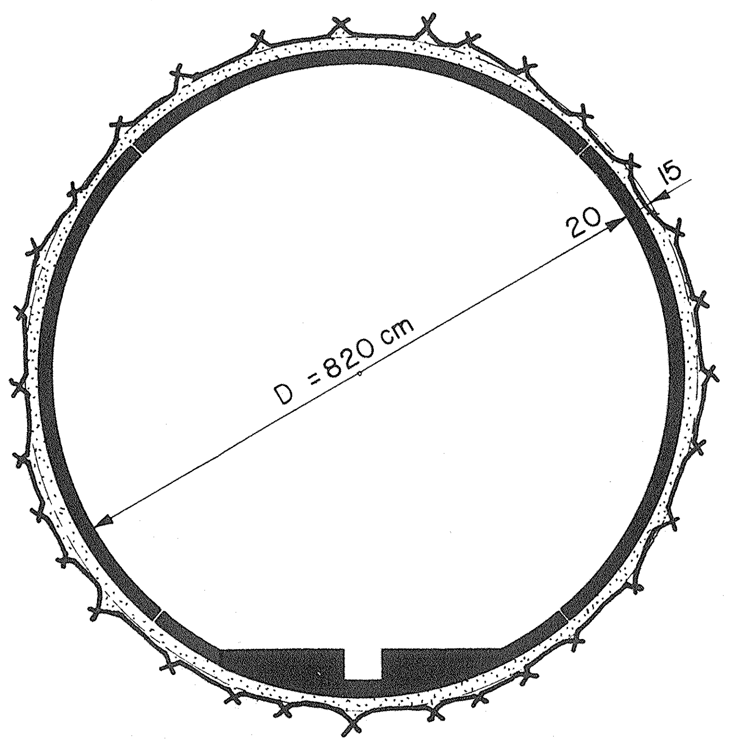
SECTION (A)

S = 23.2 m²



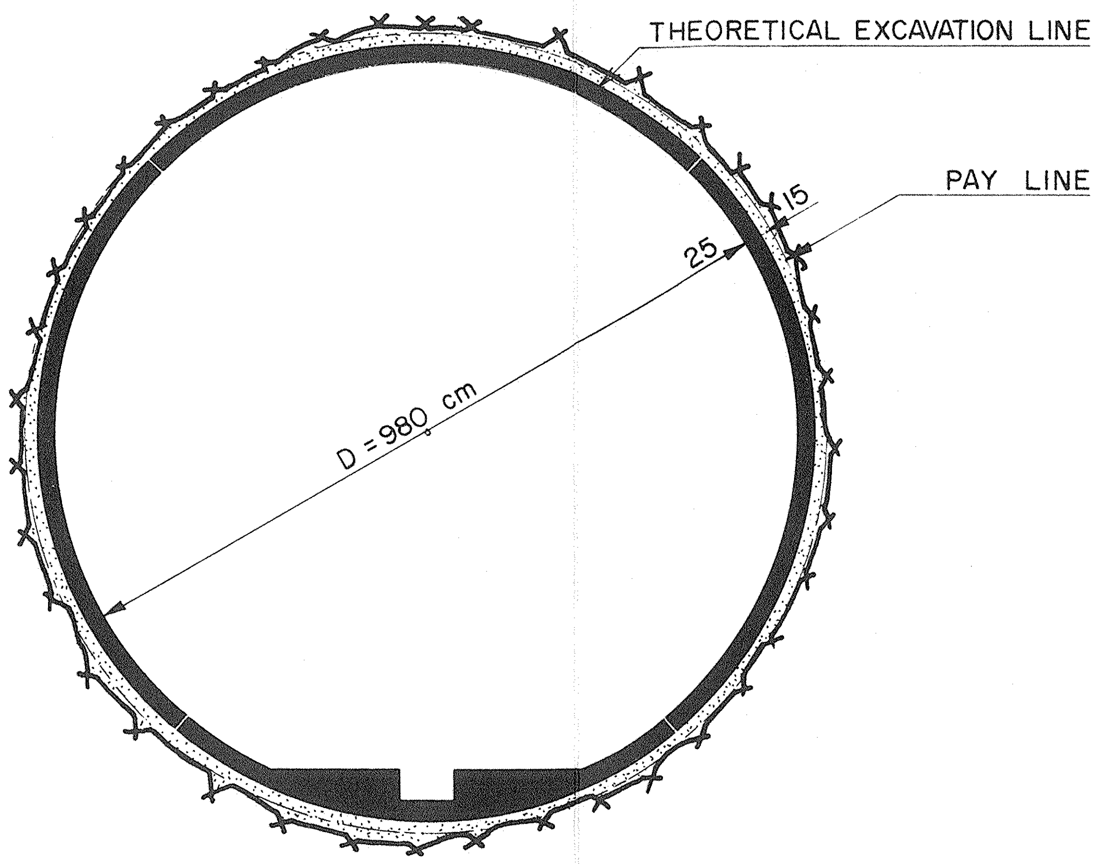
SECTION (B)

S = 51.9 m²

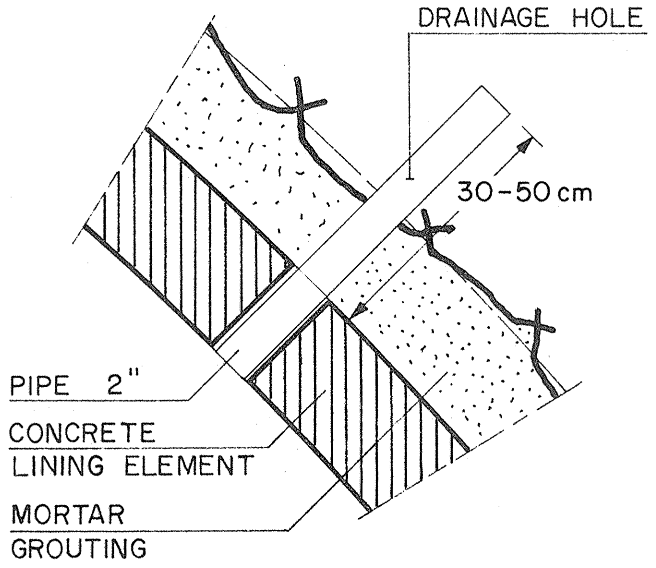


SECTION (C)

S = 74.4 m²



DETAIL OF A DRAINAGE HOLE



NOTE:

- DRILLING OF DRAINAGE HOLE APPROX. ONE DAY AFTER MORTAR GROUTING
- WHEN DRILLING OF DRAINAGE HOLE IN THE ROCK IS NOT POSSIBLE, THE METHOD SHOWN ON APPENDIX 2-27 MUST BE EMPLOYED.

EXCAVATION TO PAY LINE	29.2 m³	EXCAVATION TO PAY LINE	62.2 m³	EXCAVATION TO PAY LINE	88.2 m³
CONCRETE ELEMENT	2.7 m³	CONCRETE ELEMENT	5.3 m³	CONCRETE ELEMENT	7.9 m³
MORTAR GROUTING	2.8 m³	MORTAR GROUTING	4.1 m³	MORTAR GROUTING	4.9 m³

IF IT IS NOT POSSIBLE TO LOWER THE GROUNDWATER LEVEL, A SECOND LINING WILL BE NECESSARY FOR A WATER HEAD OF 50 m, IN THIS CASE THE FOLLOWING ADDITIONAL QUANTITIES WILL BE NECESSARY:

CONCRETE P 300	4,1 m³	CONCRETE P 300	7.4 m³	CONCRETE P 300	10.4 m³
STEEL REINFORCEMENT	130 kg/m'	STEEL REINFORCEMENT	195 kg/m'	STEEL REINFORCEMENT	265 kg/m'

ORKUSTOFNUN
NATIONAL ENERGY AUTHORITY

TUNNELLING IN MOBERG

CIRCULAR TUNNEL SECTIONS
SECTIONS A, B and C

ELECTRO-WATT ZURICH — VIRKIR REYKJAVIK
CONSULTING ENGINEERS

IND.	DATE	CHE.
J		
H		
G		
F		
E		
D		
C		
B		
A		

DRA. RAG
CHE.
APP. Met

SCALE	DATE	DRAWING NUMBER	APPENDIX
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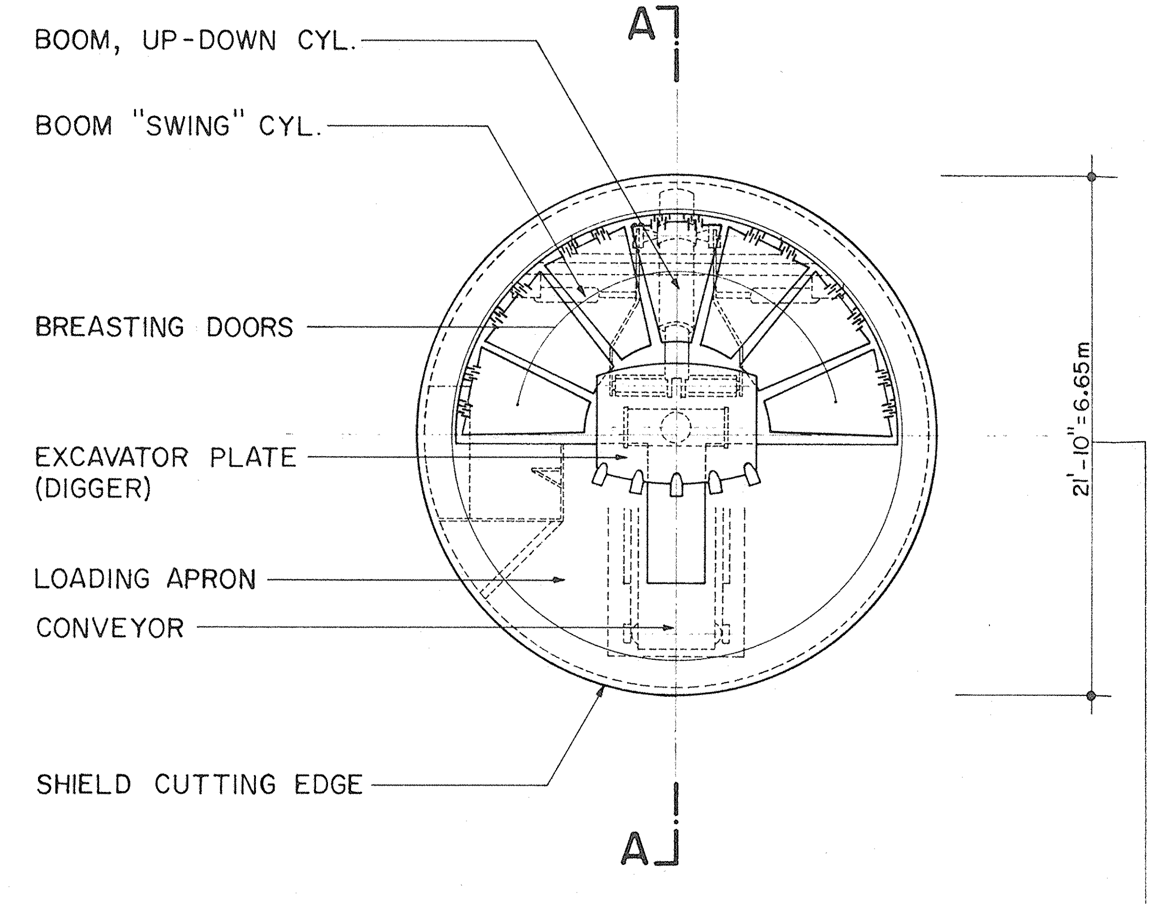
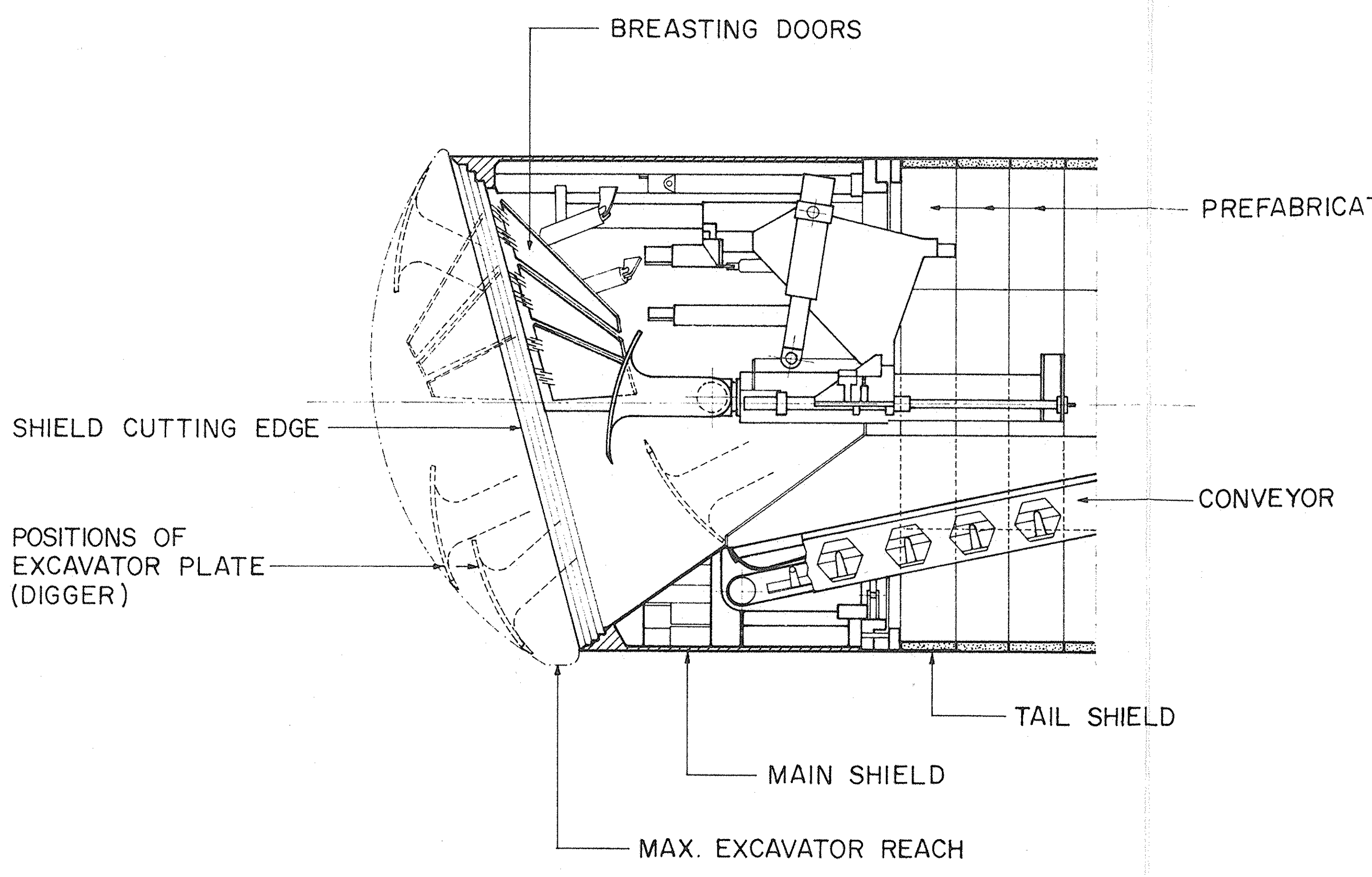
FRONT VIEW
~1:100



SECTION A-A
~1:100



DIAMETER 21'-10"=6.65m (34.6 m^2)
ROBBINS SOFT GROUND TUNNEL MACHINE MODEL 220S
FOR SAN FERNANDO WATER TUNNEL, LOS ANGELES USA

ORKUSTOFNUN
NATIONAL ENERGY AUTHORITY

TUNNELLING IN MOBERG

RIPPING TYPE TUNNELING MACHINE
ROBBINS MODEL 220

ELECTRO-WATT CONSULTING ENGINEERS ZURICH — VIRKIR REYKJAVIK

IND.	DATE	CHE.
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SCALE	DATE	DRAWING NUMBER	APPENDIX
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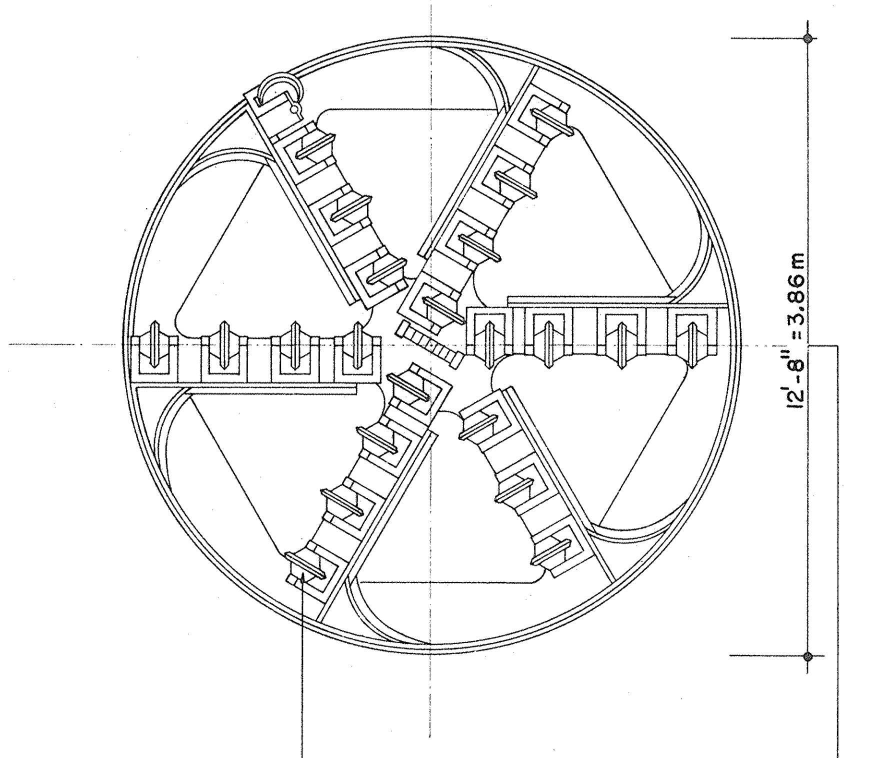
FRONT VIEW
~1:47



SIDE VIEW
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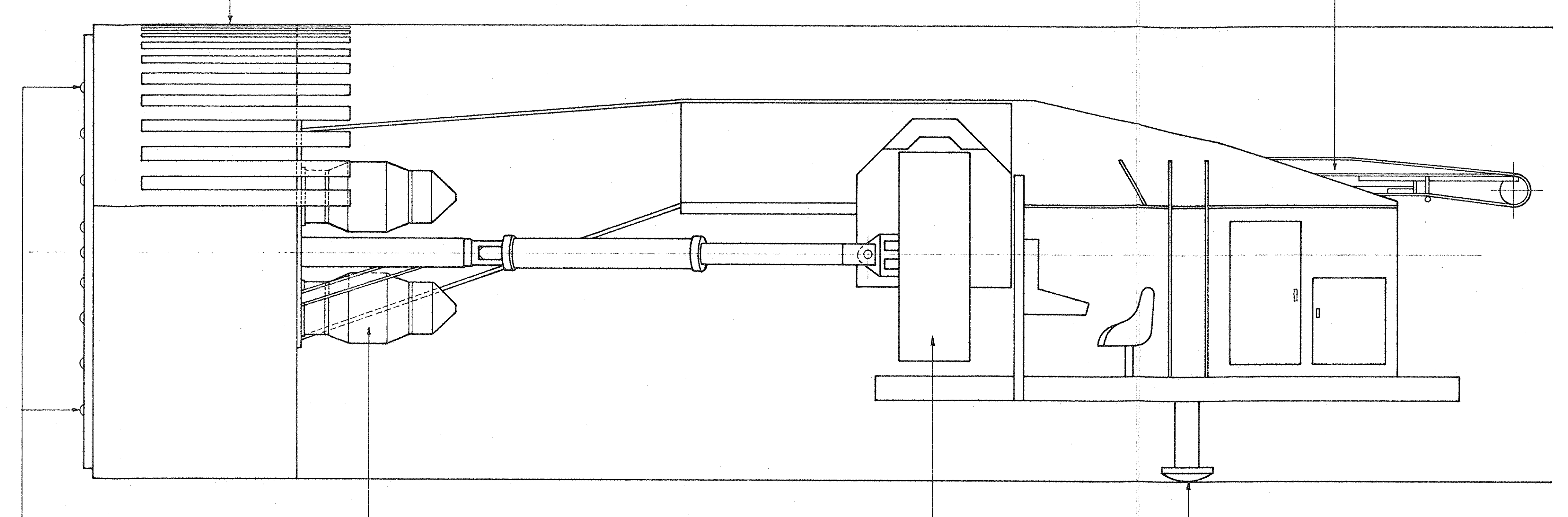

DIAMETER 12'-8" = 3.86m (11.7m^2)
ROBBINS TUNNEL MACHINE MODEL 110
(MELBOURNE-METROPOLITAN BOARD OF WORKS MACHINE)

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NATIONAL ENERGY AUTHORITY

TUNNELLING IN MOBERG

TUNNELING MACHINE
WITH ROTATING CUTTER HEAD
ROBBINS MODEL 110

ELECTRO-WATT VIRKIR
CONSULTING ENGINEERS
ZURICH REYKJAVIK

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APP.	Met

SCALE	DATE	DRAWING NUMBER	APPENDIX
~1:47	15.3.72	112885	2-35

DOCUMENTATION

APPENDIX 3
DOCUMENTATION

Concrete lining in tunnel constructions according to the Bernold System - A technical brochure giving details of the erection and back-filling of Bernold sheets, as well as of particular applications and static characteristics of the system.

Information sheet giving dimensions and weights of Bernold steel rock security mats (in German).

New Swiss tunnel lining system - a reprint from Neue Zürcher Zeitung, 21st June 1971, describing the use of the Bernold system in tunnel on the N9 Motorway in Switzerland.

Brochure giving details of Spirocrete equipment for the wet spraying of concrete in connection with the use of Bernold sheets and mats.

Information sheet giving details of Aliva mortar and concrete spraying machines.

Information sheet giving details of Spribag gunite and shotcrete machines (in German).

Information sheet giving details of Spribag plastic drainage guttering for the Oberhasli method (in German).

Information sheet on Guniplast plastic sheeting (in French).

Brochure giving full details of the Atlas Copco Boomer 131 bore-jumbo and its equipment.

Information sheet on Sandvik Coromant 'Retrac' drill bits

Brochure on Joy RPD Rotary Percussion Drills

A descriptive note on the Atlas Copco Overburden drilling method.

Brochure on Krupp jack-hammers for use on bore jumbos where blasting is not possible.

Drawings and dimensions of the Secoma 225 jumbo (in French).

Brochure on the Cat.955L Tracked loader.

Information sheet on the Eimco 105 Tracked loader (in Spanish).

Information sheet on the RH 20 Roadheader.

Information sheet on Paurat tunneling machines.

Descriptive brochures on the 'Perfo' method of rock bolting (in German).

Information sheet on Reed Tunneling cutters.

AUTOROUTE DU LÉMAN

Société générale pour l'Industrie Lausanne

C. Zschokke – H. R. Schmalz SA

TUNNEL-TUNNELLING

SYSTEM BERNOLD

Contents

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(2) Sattler, K.: Neuartige Tunnelmodellversuche – Ergebnisse und Folgerungen (Felsmechanik und Ing. Geologie Suppl. IV, 1968);

(3) Thürlimann, B.: Plastische Berechnungsmethoden;

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(5) Kastner, H.: Statik des Tunnel- und Stollenbaus (Springer-Verlag 1962);

(6) Felsmechanik & Ing. Geologie Suppl. I 1964, Beiträge: F. Pacher, L. v. Rabcewicz;

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1970 Edition

Concrete Lining in Tunnel Constructions according to the Bernold System

Jean Bernold, Civil Engineer

I. Introduction

An ideal instance of tunnel construction would be to simultaneously excavate the profile and put up the final concrete lining. This can be realized in modern gallery- and tunnel construction by means of new technical equipment.

Although excavating and concreting cannot be carried out in one single process, the time gap between those two operations has been so thoroughly reduced that they can be finished while rock pressures still equal zero or at least are very low.

In any kind of rock (with the exception of boggy rock in which water pressure is decisive) a certain space can remain open for some time without requiring propping, i. e. rock pressure does not occur and the fresh lining is not stressed. The slackening zones around the cavity are forming gradually and advancing towards the inner part of the mountain. Quick lining with closely fitting concrete prevents or interrupts those movements. It may therefore be said that rock pressure increases from zero on with the progress of the excavation (Wiedermann 1948).

Kastner (1962) also writes about the subject: It takes some time for the pressure to develop, i. e. as a rule the plastic deformations of the rock only start some time after the slackening caused by the excavation. If a concrete lining of adequate thickness could be produced within this time range, we should be able to work faster than with any other known construction method.

Experience has taught us that Wiedermann's and Kastner's opinion on rock pressure is correct and that we can rely upon a minimum temporary stability in any kind of rock, except boggy rock.

Although in the course of the last 15 years steel linings have successfully supplanted the traditional timber linings, new experiments have been made during the last years, trying to introduce a more economical method of tunnel lining, the ring-construction-method. This method which uses embedded steel arches or lattice girders, wire-mats and sprayed mortar, has afforded good practical results (Schwaikheimer tunnel and Autostrada tunnels). However, it did not prove economical enough to supplant steel linings.

It is the Bernold System, concrete lining in tunnel constructions with boarding and reinforcing metal sheets, all patents for wich are in the author's possession, which has first succeeded in replacing conventional building methods as described above.

II. The Boarding and Reinforcing Metal Sheet according to the Bernold System

1. Technical Data

a) Sizes

Standard size 1200 x 1080 mm
Sheet thickness 1, 2, 3, to 5 mm

The sheets are bent to fit the tunnel radius exactly and are locked by means of connection-rods, which guarantee a quick assembly.

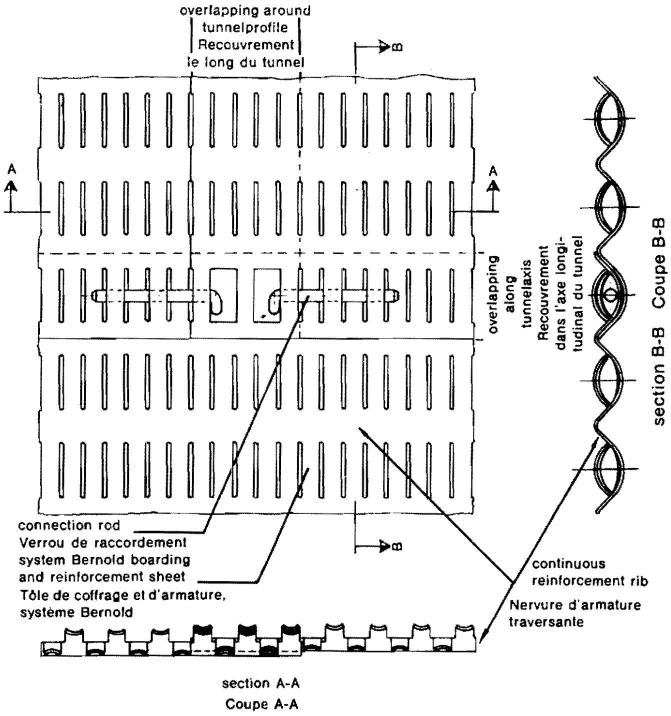


Fig. 1
Bernold System boarding and reinforcement sheet
Tôle de coffrage et d'armature, système Bernold

b) Weights

Table 1

Sheet thickness	1 mm	2 mm	3 mm	5 mm
1 standard sheet (1.08 x 1.20 = 1.296 m2)	10.5 kg	21.0 kg	31.4 kg	52.4 kg
Total weight incl. connection rod per m2 app.	11.0 kg	21.0 kg	31.0 kg	52.0 kg

The exact weight per running meter and per m^2 can be determined as soon as the cross section of the tunnel is known.

c) Cross sections of reinforcements

The following (Fe-) steel cross sections may be considered as concrete-reinforcement.

Table 2

Sheet thickness	1 mm	2 mm	3 mm	5 mm
Steel cross section of one reinforcement rib	0.57 cm^2	1.09 cm^2	1.62 cm^2	2.7 cm^2
Diameter of a steel rod with the same cross section	8.5 mm	11.8 mm	14.4 mm	18.5 mm
Distance between ribs	12 cm	12 cm	12 cm	12 cm
Fe (iron) per meter with an overlap of 12 cm	5.3 cm^2	10.2 cm^2	15.2 cm^2	25.2 cm^2

2. Use of the Sheet as Boarding

Their special shape makes the Bernold sheets suitable for boarding. On the one hand the perforated and deformed sheets are rigid enough to resist the boarding pressure, on the other hand tight enough to prevent leakage of a concrete of stiff-plastic consistency. For the concrete filling in method, which has been most frequently used up to now, the concrete should have a grain of 0—30 mm, 250 — 300 kg of cement and a water/cement ratio of 0.4 to 0.5. After filling, the concrete is vibrated with a dip-vibrator in order to obtain a good bond of rock, concrete and sheet. By means of appropriate additives it is possible to produce a concrete that is absolutely waterproof.

In the spraying-mortar-through-method the sheet also acts as perforated boarding.

Besides the sheet has proved an excellent support for sprayed concrete. This is especially advantageous when the Bernold sheets are being used for mechanically excavated tunnels.

3. Use of the Sheet as Reinforcement

The cross section of the longitudinal, V-shaped ribs in the sheet may be considered as reinforcement (compare with table 2). The EMPA (Eidgenössische Material- und Versuchsanstalt) in Zurich has made several tests on this matter.
The EMPA test-reports nrs. 59 392, 60 410 and 67 839 have given full confirmation regarding the suitability of the Bernold sheets as reinforcement. Owing to the larger surface and the good locking, the bond between concrete and sheet is much better than with rod-irons.
In spite of maximum strain occurring in rock that is very friable or under stress, there are no visible cracks or other damages of any kind to be found in any of the jobs done with the concrete lining according to the Bernold System. Measurements show a maximum crown deflection of 1/300 of the span. These deformations are small and even desirable for the convenient rearrangement of loads.

III. Rock Pressure

Load is at the base of the calculation of rock pressure. The pressures which arise in a mountain cannot be accurately calculated and one must therefore rely upon estimates, as the vibrations caused by the excavation and blastings destroy the balance of the rock and it is no longer homogeneous.
In order to determine the method to be used we have classified rocks as follows:

I.	Slightly friable rock	(Shearing strength larger than tangential tensions in the range of the excavation zone).
II.	Friable rock	
III.	Very friable rock	Shearing strength smaller than the tangential tensions in the range of the excavation zone).
IV.	Rock under stress	

Experience and measurements show that the following values for temporary stabilty can be safely reckoned with:

I.	Slightly friable rock	24—48 hours
II.	Friable rock	8—18 hours
III.	Very friable rock	4—12 hours
IV.	Rock under stress	0— 2 hours

As the length of excavation is determined by the quality of the rock, the span from the last concrete vault to the drilling front will be such that the above temporary stabilities may be observed.

IV. The Bernold System and it's Application

1. The general principle

The concrete lining construction according to the Bernold System consists of a concrete lining which fits the rock and being well vibrated clings to the excavation profile **without hollows.** It thus prevents further destruction of the rock through alien influences such as air and water and it diverts the loads from the less resisting rocks to the stronger rock formations. It secures the excavation zone in a very little time and in accordance with rock pressure and construction method.
The boarding and reinforcement sheets, which are supported by the fitting arches prevent the concrete lining from cracking during blasting processes as often happens with sprayed-concrete-securing for instance.
This method of putting up a concrete lining in one single working process on the job site itself with absorption of rock pressures by the homogeneous structure of rock/concrete boarding, reinforcement and fitting arches and with-

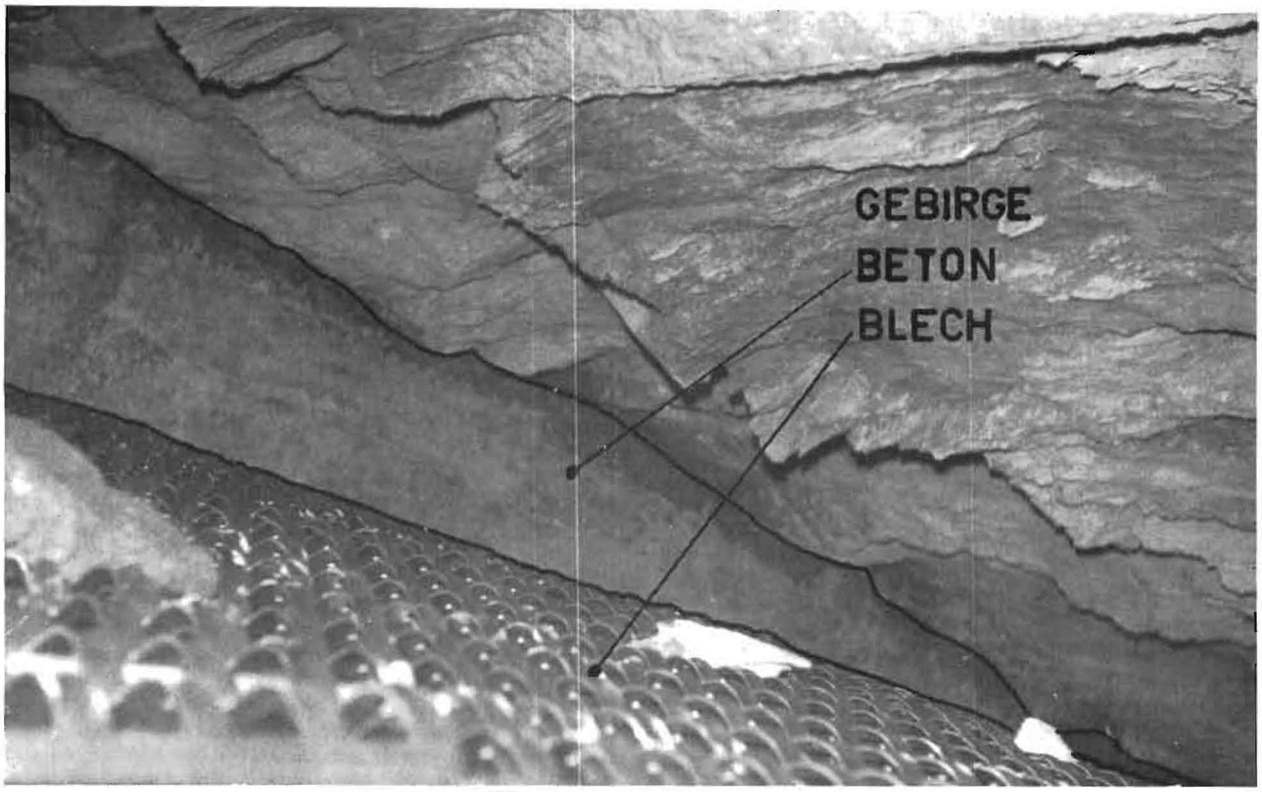


Fig. 2 ROCK - CONCRETE - SHEET / ROCHE - BETON - TOLE

out causing the slightest interruption in the excavation process, has made a successful entry in tunneling in the course of two years only.
During this period the method has been tested as to technical, statical and economical qualities on 42 buildings sites in Switzerland, Germany, France, Italy, Norway, Austria and Algeria.

vantages and possibilities of this new tunneling system, building sites may be visited all over Europe.
In Austria, Germany, Switzerland and France the first highway tunnels and army buildings have already been tendered for submission and inquiries from various countries have come in for large projects in which millions could be saved with the Bernold System.

The method has been used for the construction of:

— Road- and highway-tunnels
— Large underground shelters and fortresses
— Galleries for power plants
— Sewage galleries for clarifying plants
— Vertical and inclined shafts
— Galleries for river diverting (Energie Atomique Française)
— Tunnels for pipe-lines (Algeria)
— Stream cuts and subways
  and more recently in coal and oremining for:
— Shaft constructions
— Galleries in direction of the rock
— Pit-eyes and cross-cuts

The Bernold System has proved satisfactory in every respect.

Tunneling experts are especially taken with the simple way it can be operated and the large scale of possibilities for application as regards handling techniques and statics.
In technical negotiations it always appears that there is a tendency to rate the method as a complicated one, owing to the special shape of the boarding and reinforcement sheets. We therefore ask potential clients to visit a building site and see for themselves. This makes negotiations much more to the point.
Owing to the fact that engineers working for contractors and as building supervisors have recognized the essential ad-

2. Tunnel- and Shaft-Constructions

For securing friable and very friable rock in the excavation zone we generally use

the concrete filling method

on which a well known tunneling engineer writes:
"With this sheet-concrete-rock-bond we for the first time get a lining, which can be set up immediately after excavation and the putting up of which does not take more time than that of the traditional steel lining. A final and hollowless lining can therefore be built in immediately without causing any loss of time or changes in the course of operations. Besides, owing to the fitting arches, the immediate bearing capacity afforded by the Bernold System is at least as good as that of the steel lining covered with sprayed concrete."

The concrete filling method implies the use of

Fitting arches

the number of which is determined by the daily excavation capacity, since the fitting arches should remain on their place for approx. 36 hours. Then they can be moved on to the drilling front. In blasting excavation the average amounts to 12—18 arches. These are already bent to profile when delivered and provided with hinged joints. Owing to these joints it is possible to move the arches without taking them apart on a caterpillar or tyre vehicle. This takes about 20 to 30 minutes. The fitting arches have been statically conceived in such a way as to absorb the rock pressure until the concrete lining has reached it's full bearing capacity without getting deformed or damaged by the constant blasting to which the fitting arch approx. 0.5—1.0 m behind the drilling front is exposed.

The boarding and reinforcement sheets are delivered bent to profile as well. They are linked by means of overlaps and locked together by 2 connection-rods per m^2. The sheets are shaped according to a unit-composed system. They can therefore overlap in tangential and axial direction of the tunnel at will and be reinforced, should rock pressure make it necessary, without any alterations. An assembly drawing will be set up if the tunnel profile has different radii and the sheets identified accordingly. They allow for compact stacking and are easy to transport.

3. Building Process

As soon as the blasting and loading work have been finished 1—3 fitting arches will be moved depending on the rocks pressure. As a rule the distance between the arches is either 0.96 or 1.92 m. The fitting arches are joined by spacing iron rods which absorb tension and pressure.

The sheets are put up one by one on both sides of the shaft, operations starting from the floor, installed on the fitting arches, overlapped and locked. Simultaneously the concrete is filled between rock and sheet by means of a concrete pump.

The filled in concrete will then be vibrated until it flows fully through the ribs. We thus obtain a rigid bond of rock/concrete and sheet with a good bearing capacity.

We use a normal filling concrete of stiff-plastic consistency with a grain of 0—30 mm, 250—300 kg of cement and a water/cement ratio of 0.4—0.5.

The concrete's resistance to pressure is without exception very high in this process.

Up to an angle of 100—120° approx. the concrete is filled in from above and vibrated. The filling in between the top sheets and the crown takes place from the front.

In this part the whole space is filled with pumped concrete and then carefully vibrated. However it can only be fully vibrated after a second filling. If there should still be hollows in the top, the concrete must be shot in under pressure.

In order to prevent the concrete from flowing out between the rock and the sheet in the direction of the drilling front, a front boarding of expanded metal will have to be put up. The front boarding remains in it's place until the next concrete ring is started. When putting up the front boarding, one should be careful to leave the last rib of the sheet free to be locked with the following sheet. If the work is done with reasonable care, the locking should be granted.

The distance to be kept between the drilling front and the building in of the lining depends upon the rock stability and must, for safety's sake, be determined by the engineer in charge. When there is a danger of rock fall, the rock should be secured by means of a thin layer of sprayed concrete or by means of hydraulic props, if it is very strongly fissured.

When the loading can take place very briefly after the excavation and a front protection has to be put up, fore rails shall be used. An additional roof part of the fitting arches (as a rule 60—70° of the tunnel development) will be put on these and brought to a distance of approx. 0.50 m from the tunnel front.

The boarding and reinforcement sheets will then be placed downwards from the crown, on both sides and locked with the steel ring that had been built in during a prior concreting stage.

Under the protection of this safety device the hollow between the sheet and the rock will then be filled up from both sides with pumped or sprayed concrete.

When the loading is finished with, the side parts of the arch will be put up and the sheets placed from above, whereafter the concrete filling method may be used.

As soon as the concreting work has been finished, the next section may be cleared by drilling, blasting and loading and the last fitting arch can be taken down after having been in place for 24—36 hours and put up for the building in of the next concrete ring.

4. Concrete Filling Method:

These two pictures show in practice the ideal case of the building in of a concrete lining directly behind the excavation or the drilling front.

In one instance the building site is located in Rhine slate with strong rock fall in the other instance in friable Grison slate with temporary stabilities of 6—12 hours. The concrete lining is at only 0.5 m of the drilling front.

On these building sites conventional methods were used until the summer 1968, embedded arches, wire-matting and sprayed concrete in one case and steel arches, lining plates and filling up with concrete of the surplus excavation in the other case.

Fig. 3

Fig. 4

Fig. 5

Fig. 5 shows the transition to the Bernold System with 3 mm metal sheets. It is perfectly visible that with the Bernold System the sheets alone remain in the construction, contrarily to the traditional steel construction, where steel arches and lining plates remain in the construction. During the last years the hollows behind lining plates had to be filled up with concrete as well, because of the strong distortions in the steel arches resulting from missing bond. These steel arches had to be replaced.

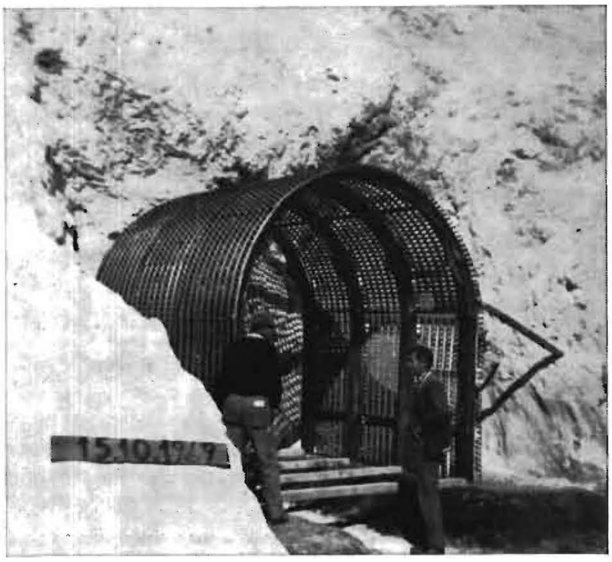


Fig. 6

Fig. 7

For the construction of the flight-shaft for the Gotthard road tunnel Bernold Sheets were used even for (6) the preliminary cut.

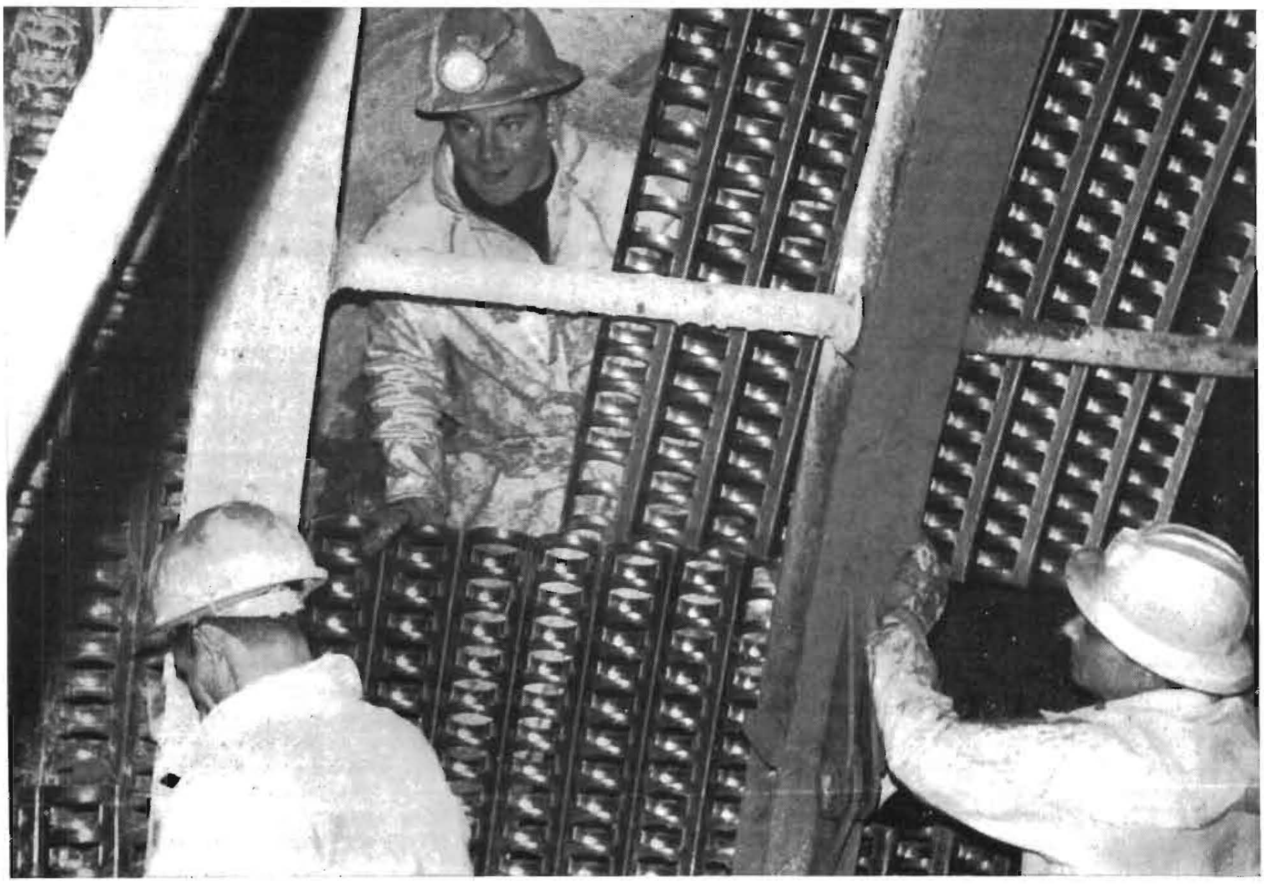
In this contact zone in the trias with partial water irruptions enormous difficulties had to be overcome. (7)

The sheets are placed on the fitting arches from the floor upwards and locked (fig. 8).

In the case of the Chauderon highway tunnel, excavations of 2—3 m are made in the very friable molass with 12—15 m layers of marl and the concrete lining is brought in immediately (fig. 9).

Concrete of a stiff-plastic consistency (water/cement ratio 0.4—0.5) is pumped into the hollows between rock and sheet after the putting up of 1—2 sheets (fig. 10 and 11).

Fig. 8



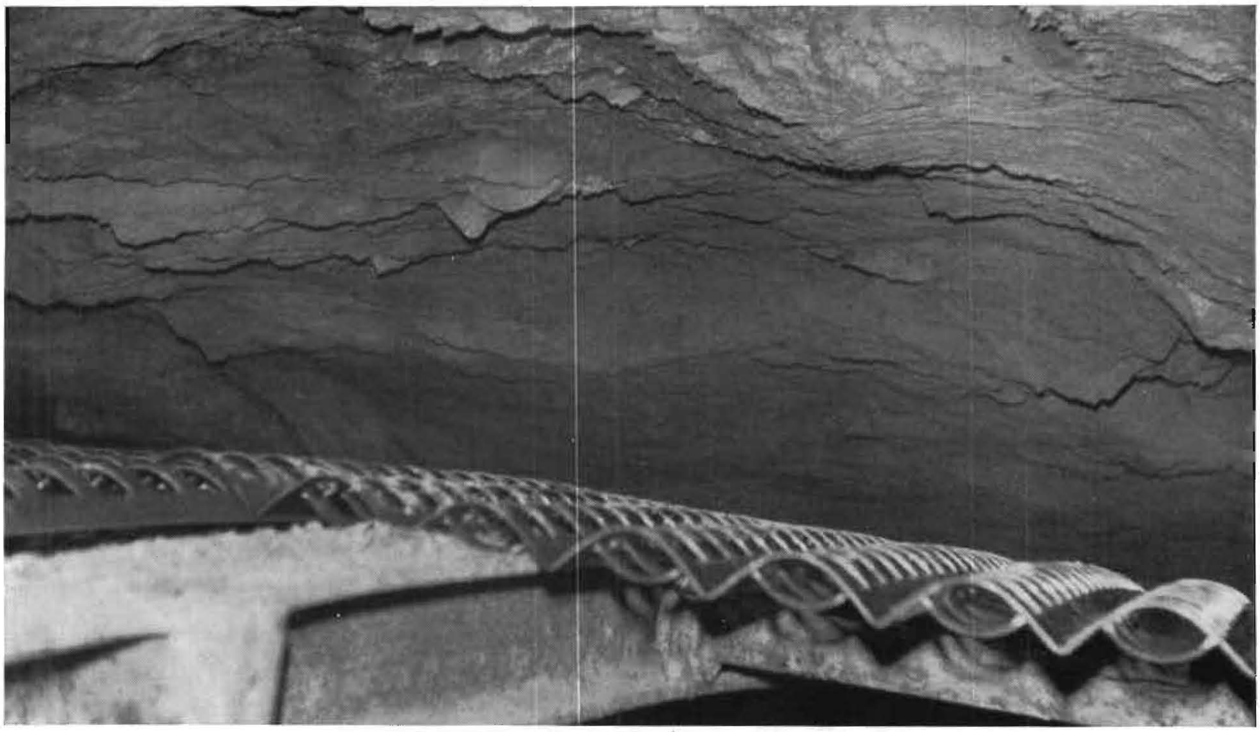


Fig. 9

Fig. 10

Fig. 11

The concrete that is between the rock and the sheet should be vibrated in such a way as to make it flow through the longitudinal ribs, as shown in fig. 12. Provided the consistency of the concrete is as required the actual loss of concrete for a theoretical concrete thickness of 20 cm amounts to 3%. It is logical that the loss in the crown should be larger than on the sides, however experience has taught us that the man who operates the vibrator soon finds out his own method to keep it as low as possible.

When the thickness of the concrete or the surplus excavation are larger this percent loss is consequently reduced.

It is essential that dip-vibrators should be used. Boarding-vibrators having proved only just sufficient for concrete linings with a thickness of less than 15 cm.

In order to prevent the concrete from flowing out towards the drilling front a simple front boarding of expanded metal and iron rods is put up (fig. 13).

If the work is done with reasonable care, a thorough bond of concrete and sheet can be granted for.

Fig. 12

Fig. 13

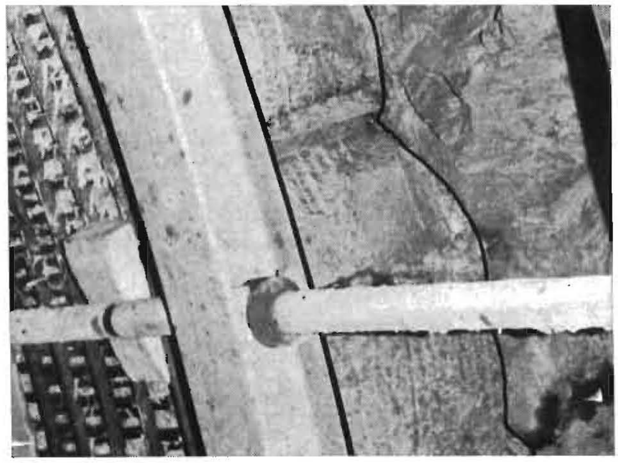


Fig. 14

Fig. 16

When putting up the front boarding one should be careful to leave one rib of the sheet free (fig. 14) to ensure it's locking with the next steel ring.

Fig. 14 shows that with the Bernold System even the bond in the crown of the vault is no special problem. On various building sites using the Bernold System, injection is left out because it is no longer necessary. If there still are hollows of a certain size the work has not been properly done.

With the Bernold System even a blasting excavation is certain to produce a tunnel true to profile and it grants the possibility of building it economically as a one-lining-vault, a thing economically impossible with sprayed concrete.

Fig. 15

The following pictures give a view of a highway tunnel, that was lined partly with sprayed concrete (15) and partly with the Bernold System (fig. 16).

5. Sprayed mortar on the concrete lining

The following process depends on what finish should be given the tunnel. If an isolation is to be placed on the outer concrete lining, the sheets must be sprayed with a layer of 2—3 cm of sprayed mortar. If not, the second lining vault can be put up at a certain distance.

If the system is to be the final structure in a vault, the Bernold sheets should be covered by a layer of profile-gunite of 4—5 cm thickness. The sheet is perfectly suited to the gunite (fig. 17 and 18).

Fig. 17

Fig. 18

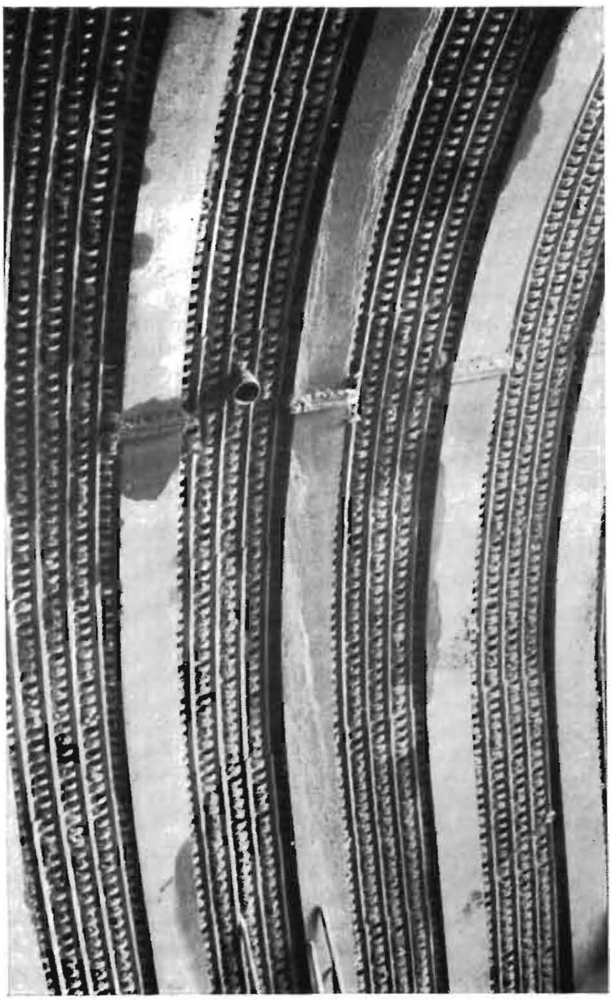
Fig. 20

The sheets are put up and the system is applied with rock anchors (in this case prestressed VSL anchors).

6. Various possibilities of application in tunneling

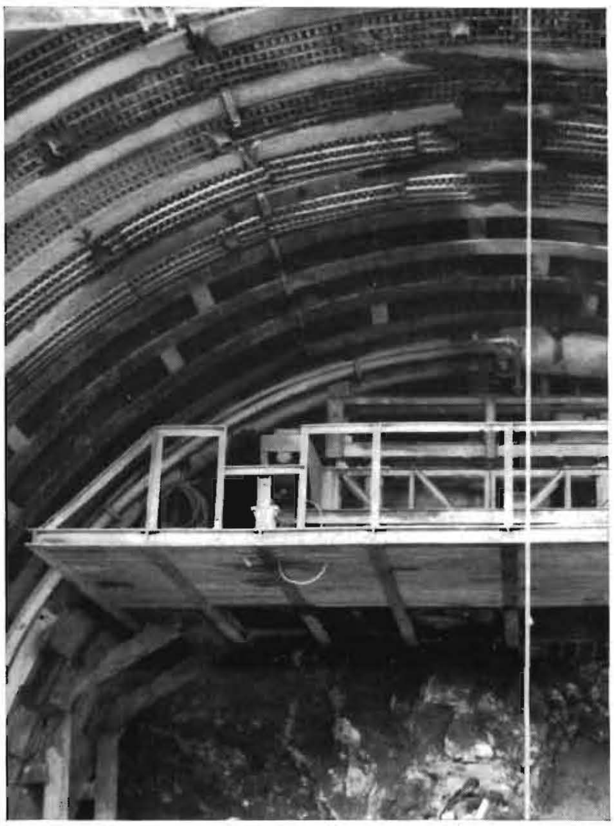
The sheets can even be put up without fitting arches as shown in the following examples.

Fig. 19



Application of 1 or 2 mm sheets as boarding between steel arches during the construction of Glion Highway Tunnel.

Fig. 21



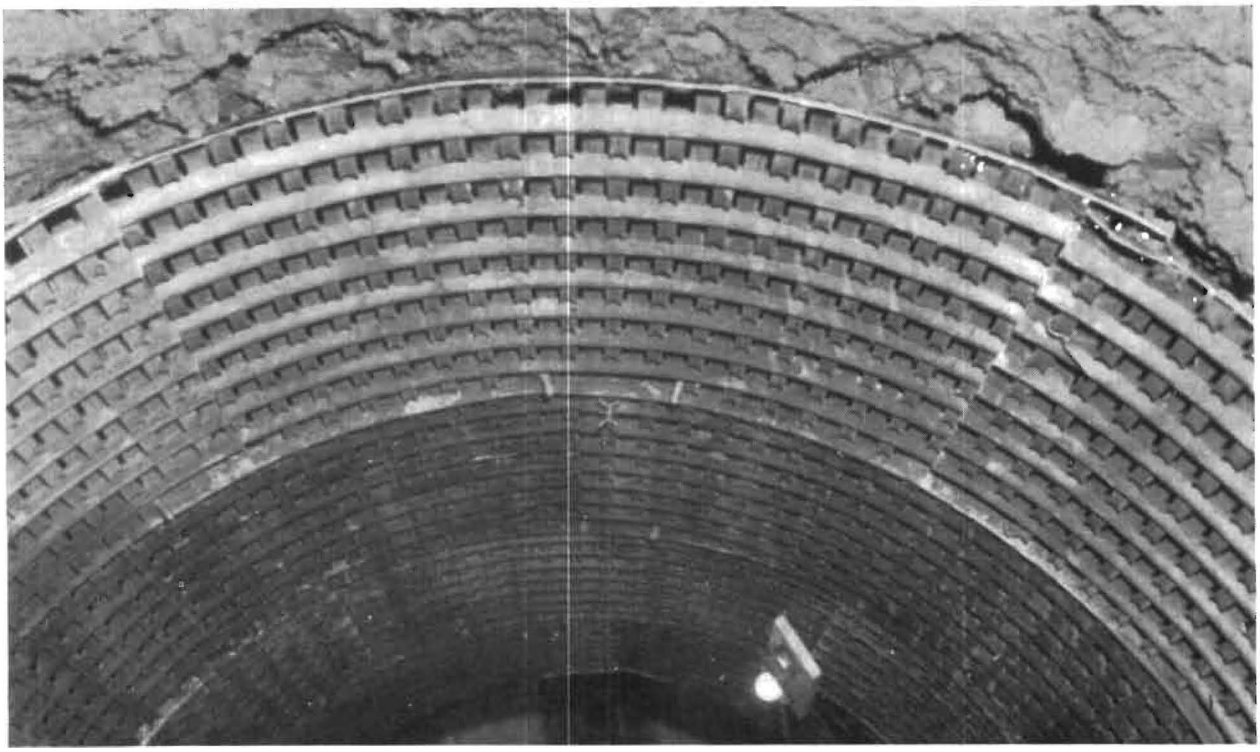


Fig. 22

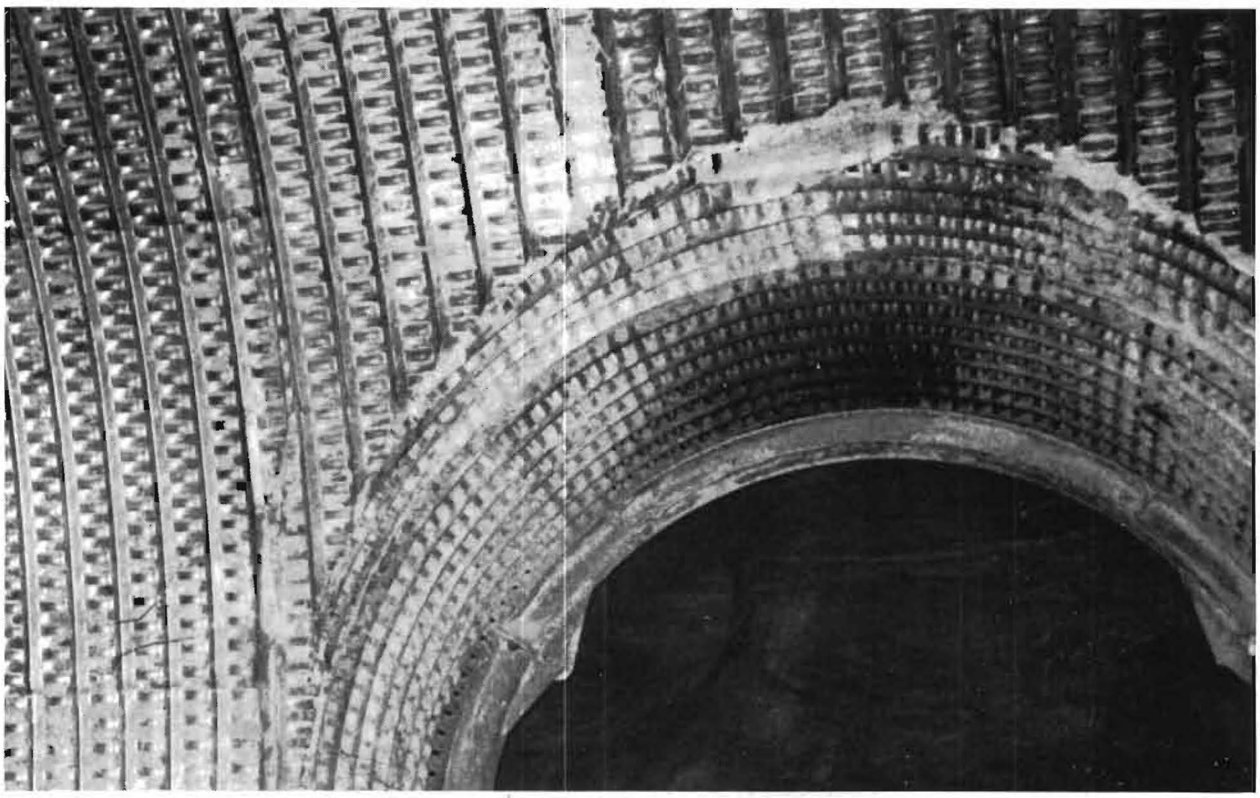


Fig. 23

Ring construction in the sewage gallery Bietigheim, by Baresel, Stuttgart, without fitting arches and without concrete or gunite in sand and clay. Diameter of gallery 2.00 m.

With some practice it is possible to build clean branchings and crossings as is done by Wagener, Essen, who builds underground galleries for the army somewhere in Germany.

7. Securing of the rock behind the tunnel excavation machine

The Bernold System holds a special position in tunnel excavation. During the Stini Kolloquium 1969 in Salzburg, Austria, Dr. ing. Naber, manager of the Bodensee-Water Supply, Stuttgart, Germany, held an extensive talk on mechanical tunnel-excavation.
During the discussion Dr. ing. Nathau of the «Technische Universität» Clausthal-Zellerfeld said among other things:

"In addition to the already known securing methods with steel rings, anchors and sprayed concrete, we should like to introduce a new method that has been applied for the first time in the Oker-Grane-Gallery in the Harz. This gallery is being constructed by the associated Wix & Liesenhoff Gebr. Abt. KG and Deilmann-Haniel with Demag excavating-machine and the zones in the Wissenbacher slate and Kahlenberg sandstone in which there is danger of rock fall are secured by means of Bernolds sheets (fig. 1). These specially shaped and perforated norm sheets with an approximate size of 1m² have been developed for the simultaneous boarding and reinforcement of steel-concrete-structures (1). In this case they have proved, even without the use of concrete, to be a securing that can be put up quickly, is reliable and economical. They have further advantages such as the slight sheet thickness of 4 cm and the possibility of creating a safety vault of homogeneous aspect that fits the rock closely, is sufficiently stable (fig. 2) and can absorb tension and pressure in all directions. It has not yet been decided which type of final lining should be used for this gallery. We should like to point out, that this provisional lining can be transformed into a thin-walled steel/concrete bond lining by means of the wet concrete spraying method (2). In this way the zones requiring a lining of greater bearing capacity can be provided by degrees with a lining that excludes the loss of building elements and can be integrated organically in the other excavation processes from the very first securing of the rock to the final lining."

This article is concerned with the use of sheets in mechanical excavation with or without the use of sprayed concrete. When the excavation is done with tunneling machines in cross sections of 30 m² and more, the sheets cannot be put up without auxiliary tools. For such large spans the light fitting arches must not be moved until the concrete is sprayed on.
There is another way of building a statical steel/concrete lining (fig. 28).
A movable boarding structure is erected on a working vehicle. The length may vary from 2—6 m depending on the excavation capacity and the rock stability. This steel structure may be lifted and lowered mechanically and matches a tunnel development of 160°. The sheets which are bent exactly to profile are put up on the boarding structure in low position on that side of the vehicle, which is away from the drilling front and then brought to the drilling front and to their proper place.
Then the boarding structure is mechanically lifted and pressed against the excavated rock.

Fig. 24 Locking of the sheets

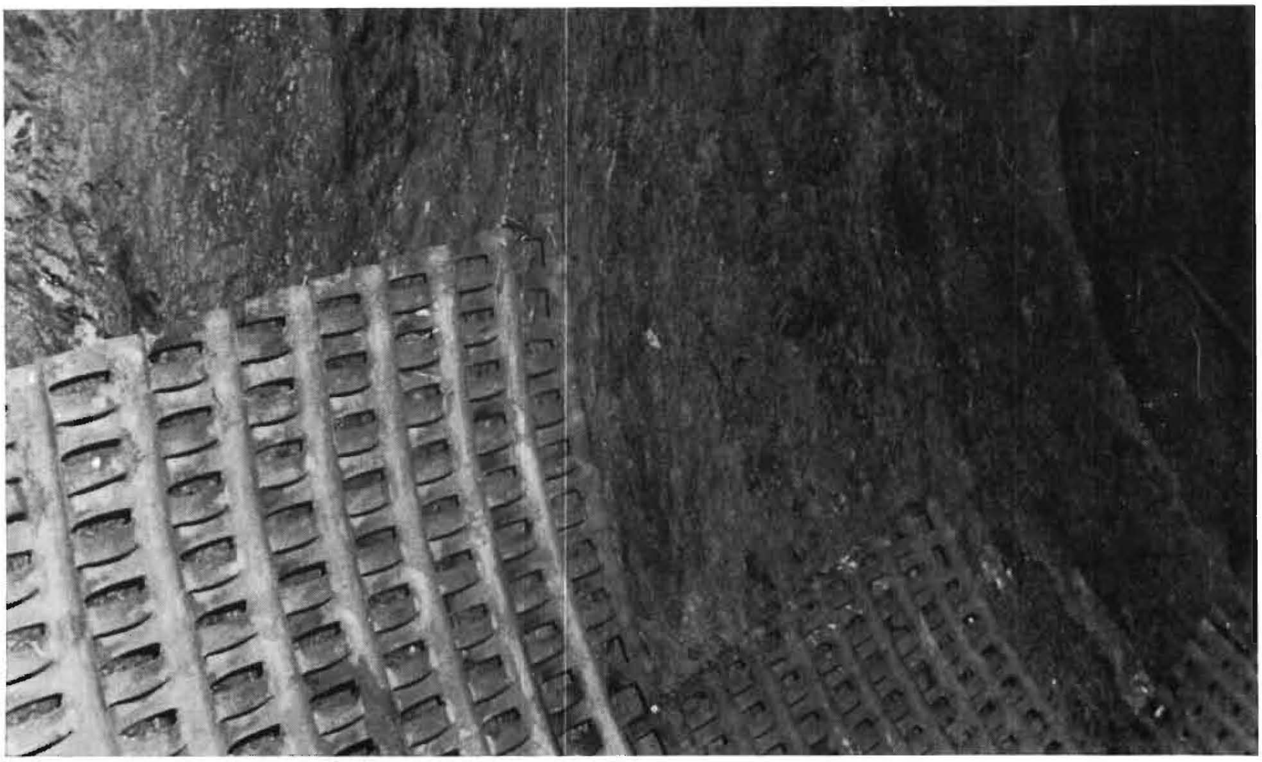


Fig. 25 The sheets are staggered

We now have two possibilities for fastening the sheets. Either by means of rock anchors and bolts. When this is done the boarding structure may be **lowered** and driven back and concrete is sprayed on. Or, the other possibility is to leave the boarding structure until sprayed concrete or gunite with a thickness of 4—6 cm has been sprayed on and bond is achieved. The boarding structure may then be lowered and driven back. After a few hours another 4—6 cm of concrete are sprayed on and the hollows caused by the boarding structure filled up.

Fig. 26 Securing of the roof section by means of the Bernold sheets

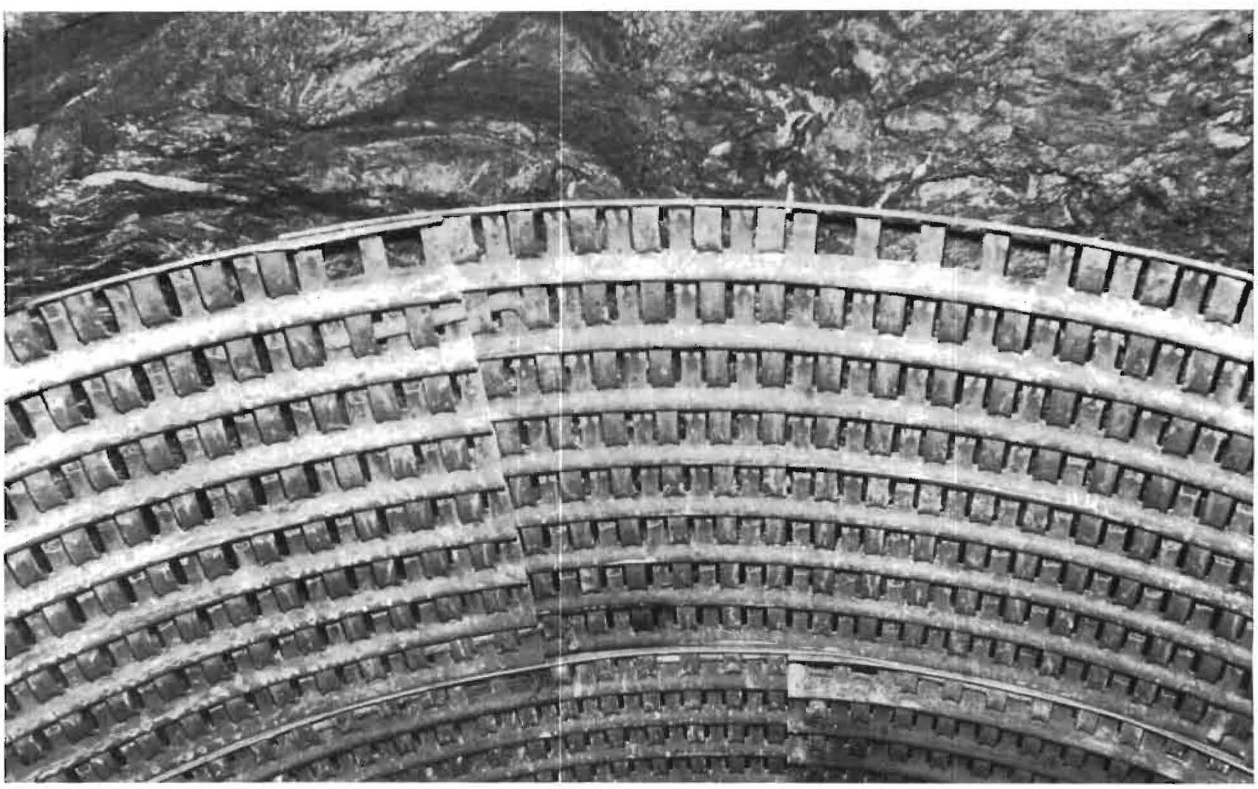
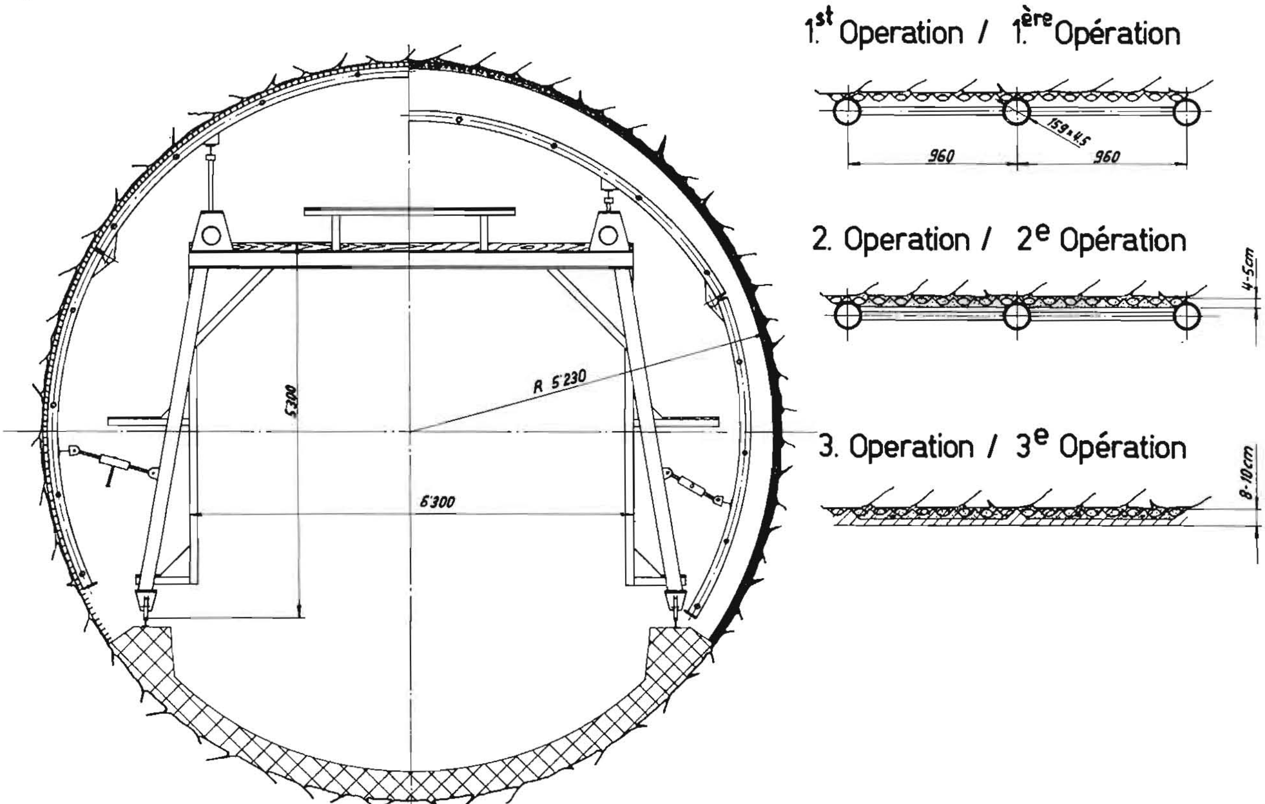


Fig. 27 Securing of the ring in the Oker-Grane-Gallery

With this method we also have the possibility of fastening an appropriate isolating foil directly on the rock surface and to integrate this auxiliary vault in the statics. There we have another opportunity for making tunneling with mechanical excavation even more economical.

Fig. 28



8. Shaft-Construction with the Bernold System

For the driving of inclined or vertical shafts, either by blasting or with the excavating machine, the sheets are used with or without concrete.
The method was applied for the first time in autumn 1968 in Rhine slate for driving a 12 m shaft underground (fig. 29). The shaft was excavated first and then the sheets were put up from the bottom to the top and concrete was filled in.

Fig. 29

Some weeks later work started on the 35 m Gose-shaft on the Oker-Grane building site. This shaft of a Φ 2.10 m was driven from the top. As soon as an excavating stretch had been completed, the Bernold sheets were put up and concreted with the concrete filling method (fig. 30).

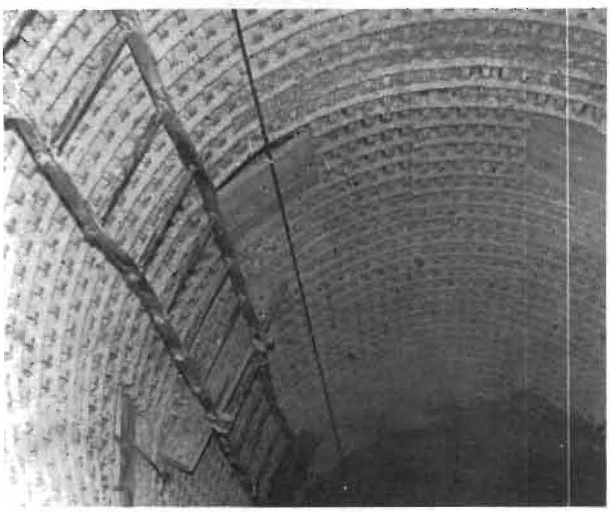


Fig. 30

The first use of Bernold lining in **mining**

Mining firms began to show interest in the new method. In summer 1969 Preussag in Bad Grund started with two shafts 50 and 58 m deep and with a Φ of 1.4 m and 2.00 m. These shafts are being mechanically excavated and the Bernold lining is being put up directly behind the excavating machine (fig. 31).

Fig. 31

Shaft construction with excavating machine, Preussag, Bad Grund.

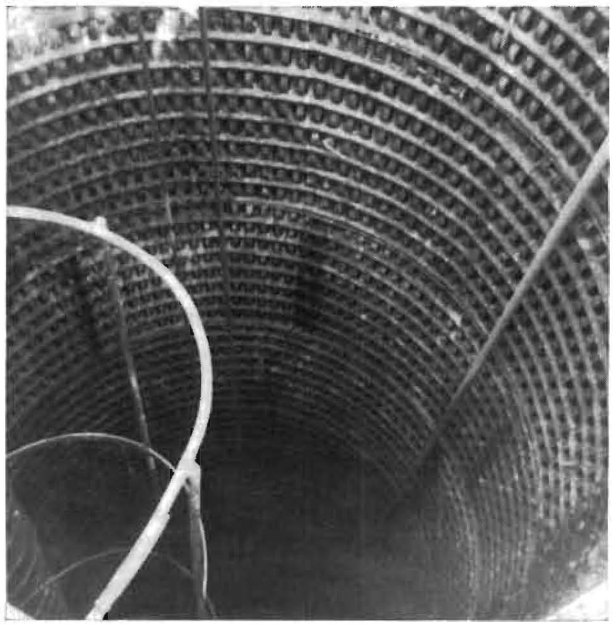


Fig. 32

Some time ago a vertical shaft with a diameter of 3.0 m has been lined with Bernold sheets in Lucerne.

In Germany the construction of a large number of shafts with various diameters is under way.

Why are Bernold sheets used for shaft-construction?

An engineer for shaft-construction answers this question as follows:

"The Bernold lining is especially suited for shaft-construction because it can be adapted to the rock stability. I need not conform to certain fixed sizes because the sheets can overlap in axial and tangential directions at will. All sheets whether their thickness be 2 or 5 mm have the same shape and identical connection-parts may be used for them."

Another engineer for shaft-construction declares:

"So far the Bernold lining is the most economical method for securing excavated shafts.
The costs for excavating with an excavating machine are approximately the same as with the traditional methods, while the lining according to the Bernold System affords definitive advantages."

9. Repair work in existing galleries

A large number of galleries, which had been constructed in solid rock some decades ago, must now be lined, since slackening zones have formed in the course of time, which are a potential danger for all users. In this respect the Bernold boarding and reinforcement sheets have stood the test as a lining true to profile and of good bearing capacity, that is most economical.

10. Application of the Bernold System in Rock under Stress

The question frequently arises whether the system can be used in rock under stress with no temporary stability, in sand, clay or moraines.

As was already stated in the account of 1967 this question can be answered by yes, with the one difference that we are now in possession of experimental data and have been able to develop essential technical improvements.

In mining the question of safety and of the securing methods to be used always comes first before cutting through rock under stress. The method of driving under lances has been developed to make work under protection of a steel lining possible. This construction has been developed and improved for more than 20 years and can cope with any kind of difficulty occurring in rocks (except boggy rocks), provided that geological conditions, rock pressure and unhomogeneous conditions be known to the planners.

Rock securing with hydraulic driving under lances

(Drawing 35)

3 guiding arches are statically adapted to the rock pressure to be expected. For loads of more than 25 tons/m² a circular profile is generally chosen.

The guiding arches are put up true to profile, locked with each other and anchored.

Then the top lance which is provided with guiding rails on both sides is fastened and the other lances are put up left and right.

To support the lance ends a concrete ring with a length of 2 m and exactly fitted to the profile of the tunnel can be preconcreted.

Every lance is fitted with a guiding rail (A) which acts as hinge joint to assure the polygonal adaptation to the radius of the tunnel. This guiding rail prevents deviations of more than 5 cm from the axis of the tunnel. Deviations of ± 5 cm can easily be corrected. It is essential that the guiding arches should be installed with accurateness.

Lances (B) have sharpened points in direction of the drilling front and are fitted with advancing catches on a length of 2.0—2.5 m, which are necessary for advancing the lances with the lifting cylinder.

The end of the lance which is generally 2—4 m long, is polished as it acts both as support of the rock between guiding arch 3 and fitting arch 1 and as outer boarding for the concrete ring. In accordance with the thickness of the concrete vault, the radius of fitting arches (1—3) is smaller, however their size is chosen in such a way as to enable them to absorb rock pressures which might arise. As a rule concrete rings with a length of 1.0—3.0 m are concreted according to the working rhythm of the lances.

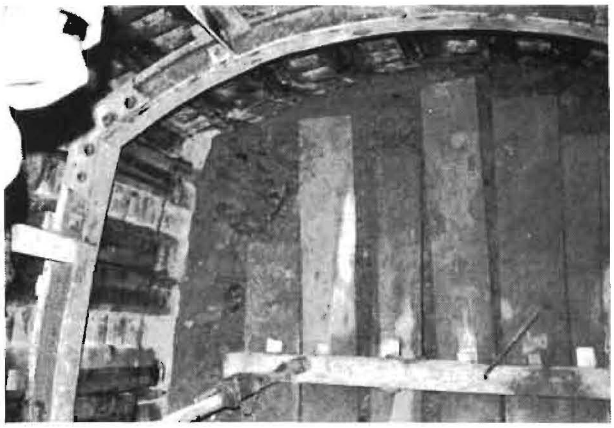


Fig. 33

The hydraulic driving lances have been installed, after the difficulties at the beginning, which stemmed from the strong rock pressure, had been overcome. The normal working rhythm had been reached after an introductory 4 days.

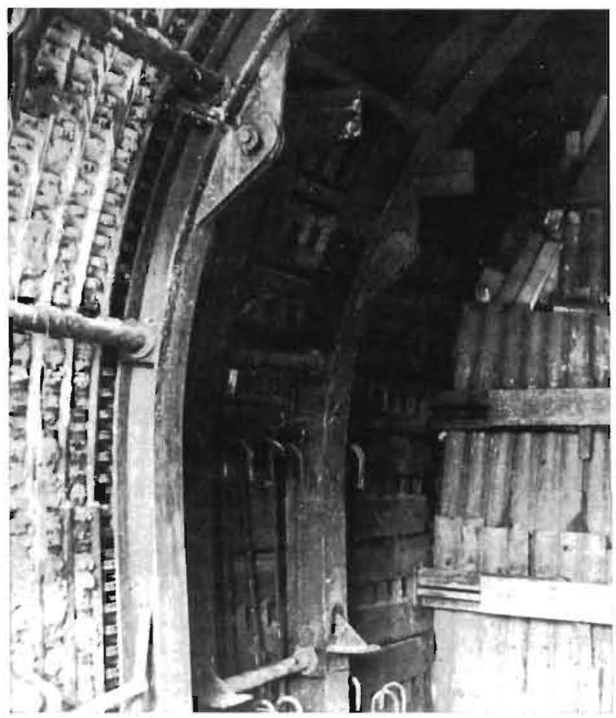


Fig. 34

For the front securing a device was created that consists of cross pieces of adjustable width (A), which can be fastened to the lances by a catch and remain there.

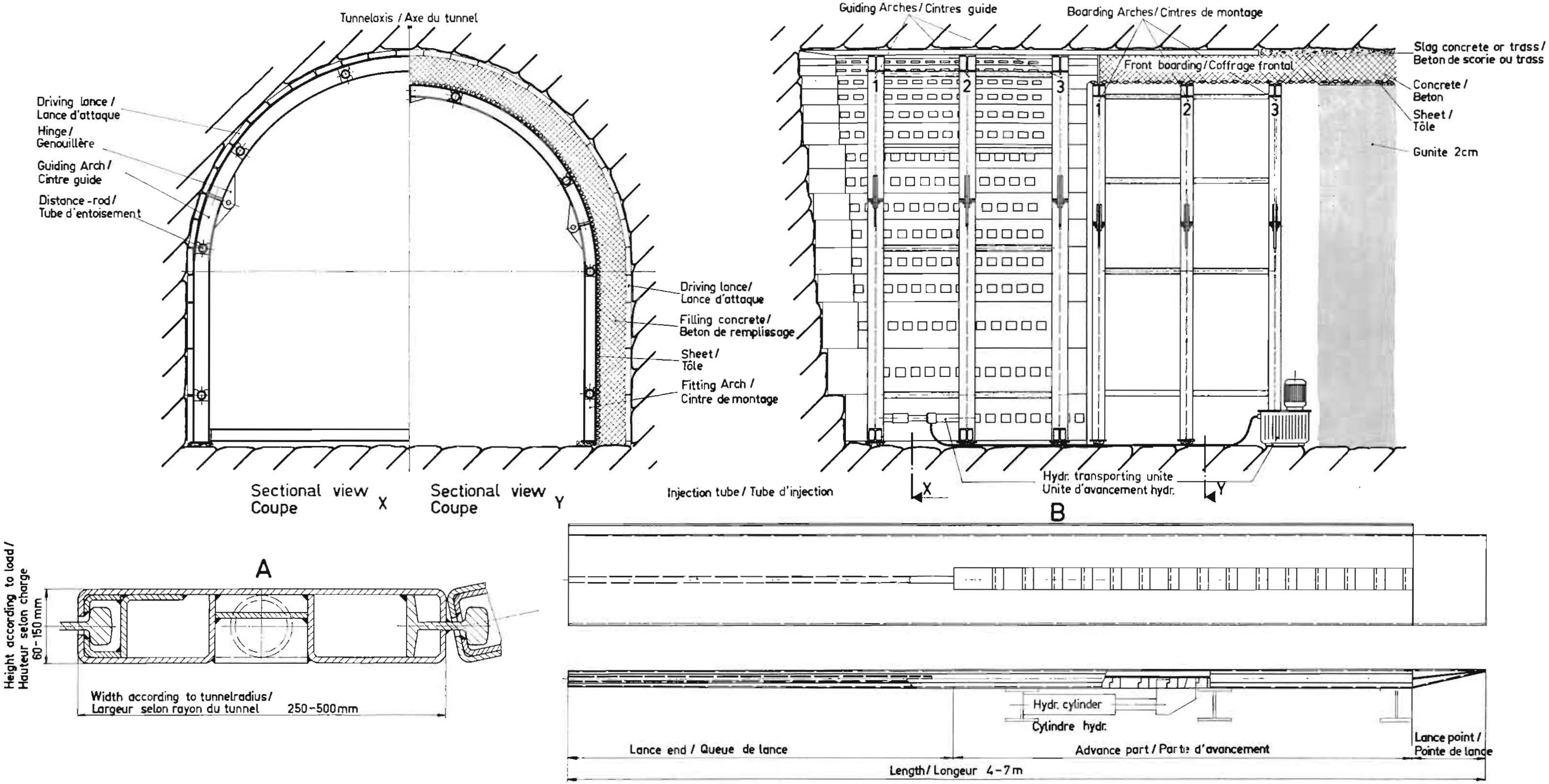
As the excavation is done by steps from the crown to the bottom, the cross piece can be driven ahead with the lances on both sides and then the liner plates (B) be put in to secure the rock.

The following description of the working process will help to elucidate further points:

When the guiding arches and lances have been set up, the lifting cylinders are put into place and the driving starts. As the material is being taken down at the points of the lances, these must be pushed on together.

When the lances have passed guiding arch 1 by 1—1.20 m, the Bernold sheets can be put up and locked on the fitting arches 1 and 2. The front boarding will then be fastened and the concrete pumped in between lance end and sheet and vibrated.

The lances may not be driven forward during concreting. Only when the whole concrete ring has been finished, may the driving operation start in the crown. Simultaneously with the excavation, the hollow space which develops between the rock and the lance end, is pressed out with lag concrete or trass by means of a special device, in order to avoid settlings of the soil.



Tunnelaxis / Axe du tunnel
Driving lance / Lance d'attaque
Hinge / Genouillère
Guiding Arch / Cintre guide
Distance-rod / Tube d'entoisement
Driving lance / Lance d'attaque
Filling concrete / Beton de remplissage
Sheet / Tôle
Fitting Arch / Cintre de montage
Sectional view Coupe X
Sectional view Coupe Y
Guiding Arches / Cintres guide
Boarding Arches / Cintres de montage
Front boarding / Coffrage frontal
Slag concrete or trass / Beton de scorie ou trass
Concrete / Beton
Sheet / Tôle
Gunite 2cm
Injection tube / Tube d'injection
Hydr. transporting unite
Unite d'avancement hydr.
X
Y
B
A
Height according to load / Hauteur selon charge
60-150 mm
Width according to tunnelradius / Largeur selon rayon du tunnel 250-500mm
Hydr. cylinder
Cylindre hydr.
Lance end / Queue de lance
Advance part / Partie d'avancement
Lance point / Pointe de lance
Length / Longeur 4-7m

Drawing 35

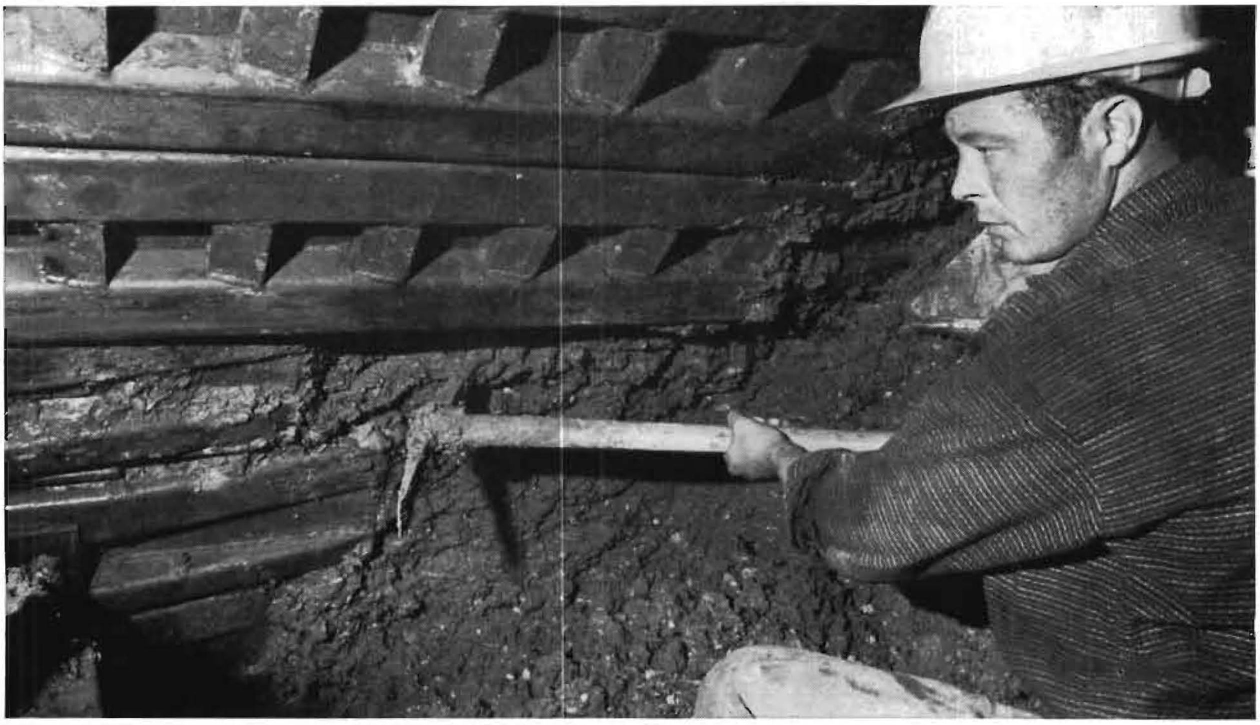


Fig. 36

While the lances are driven forward, the material should be taken down as shown on the picture. If the work is to be interrupted for some time no more than the points of the lances should be pushed into the ground. The lances should never be driven more than 1.20 m ahead of guiding arch 1.

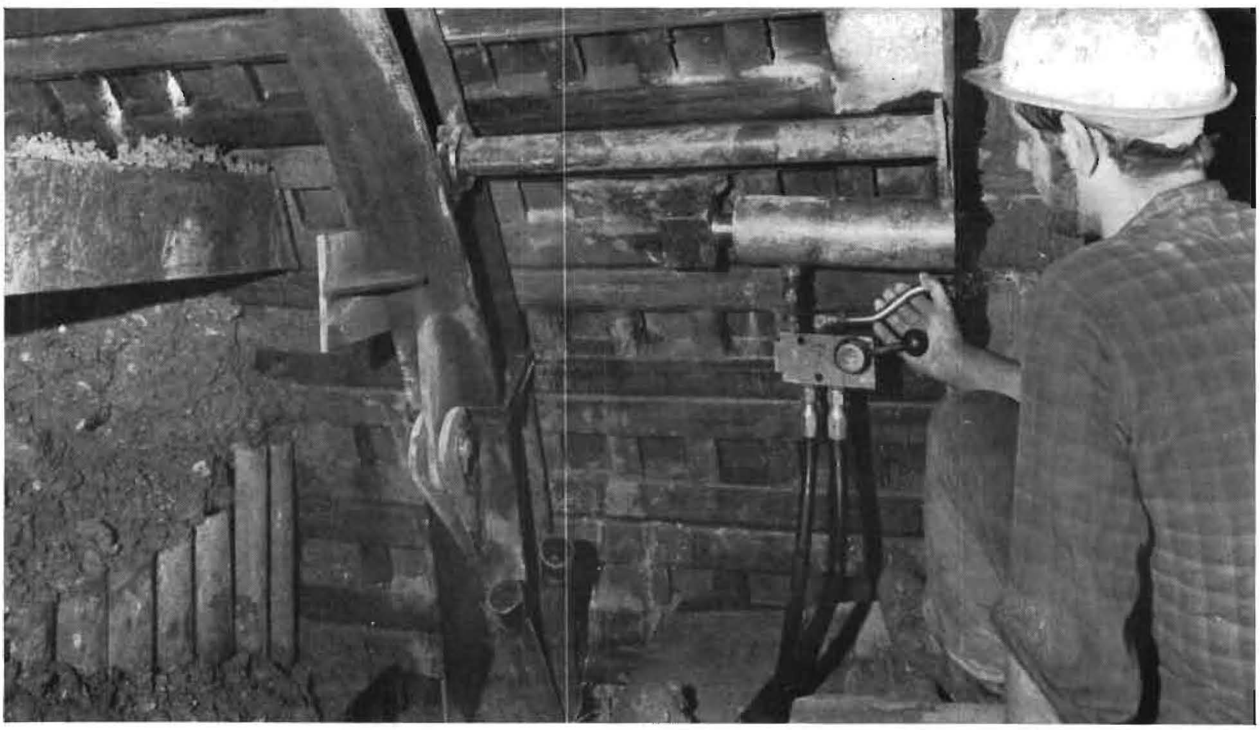


Fig. 37

Driving ahead of the lances by means of a hydraulic cylinder with a pressure of 20—30 atmospheres between guiding arches 1 and 2. As for any systematical work it takes some practice to carry out this operation properly. 2—3 driving cylinders are needed depending on the size of the tunnel cross section.

In the crown, the lances have already been driven so far ahead, that no more than the polished lance ends appear near guiding arch 2, while the lances on the sides still must be driven ahead.

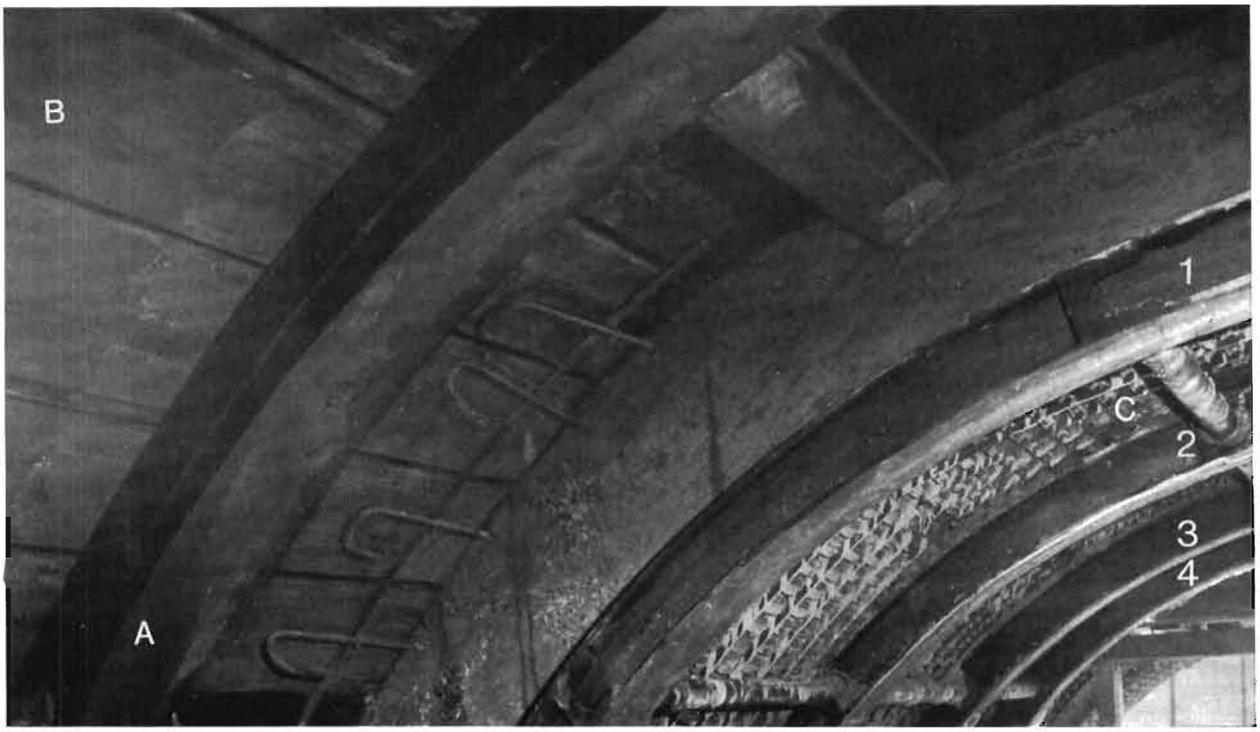
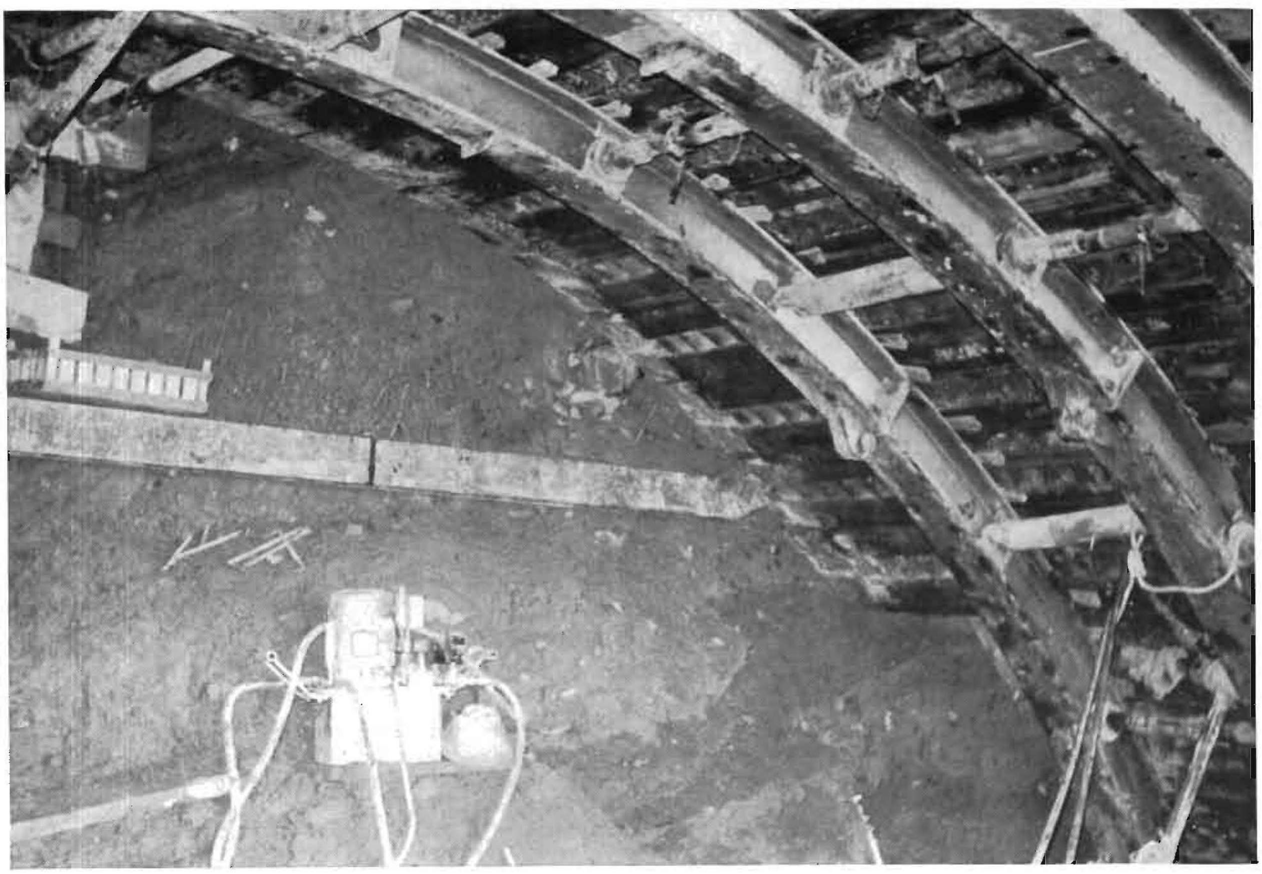


Fig. 38

In the foreground you may see guiding arch 3 (A) and lance end (B) resting on the concrete ring. In the background appear fitting arches (1—4) with the Bernold sheets (C) which have been put up and concreted. Follows the moving of guiding arch 3 to the drilling front and the advancing of fitting arch 4. Then the putting up of the sheets and the front boarding may start as well as the concreting of the next ring. In hydrous rock the longitudinal locks of the lances should be made waterproof before concreting. Depending on tunnel cross section and material, the daily excavation capacity of this system ranges from 2.0 to 3.0 m. This capacity can be doubled when there is a cover of 30 m and more, but it may also be reduced to 1.0 m and less in the case of a permanent front securing as shown in pictures 34 and 35.

Fig. 39 Highway Tunnel Flonzaley Conrad Zschokke S.A. — H. R. Schmalz AG.



V. Mining

Special features of mining

For many years a fundamental improvement of lining operations by mechanization was striven for in mining. Since a mechanization of the construction of curved sections seems hardly possible, the only successful attempts were achieved with concrete lining so far.

First trials have shown that the lining of drifts and mining tunnels with the concrete lining system and Bernold boarding and reinforcement sheets has a great future ahead. These lining operations can be fully mechanized. The fitting arches which can be reused at any time, can be moved simply by hydraulic devices. The putting up of Bernold sheets is as simple as could be. The concrete is brought in by means of the concrete filling method. This process can easily by mechanized and it is merely a question of organization to facilitate the transport of concrete. The high strength which is achieved by this method is especially significative in mining. Thin walled concrete linings, which are true to profile, have a bearing capacity three times as big as that of the traditional drift lining, which costs as much. For these reasons they will have conquered mining very soon.

In those cases however, in which mining tunnels are to be but short-lived and a destruction of the drifts is put up with, conventional lining techniques will not be dislodged so quickly.

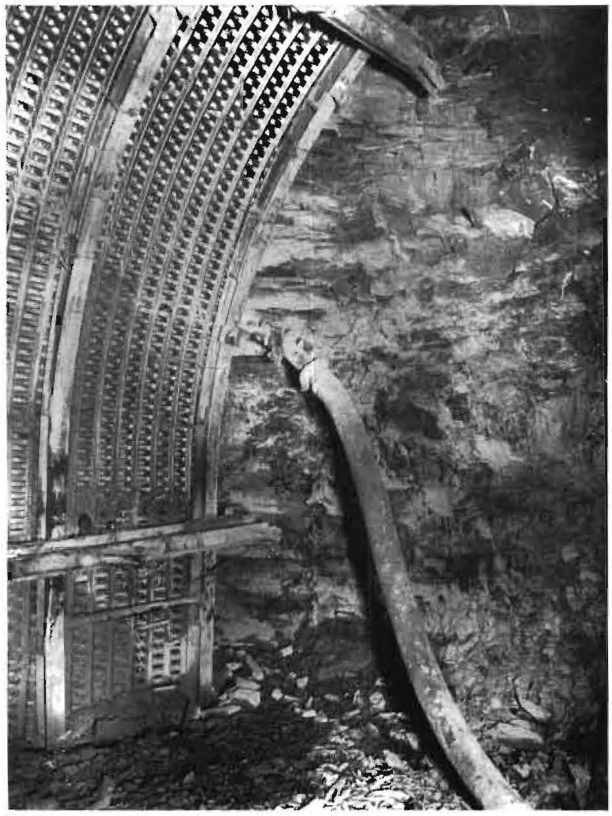


Fig. 40

Fig. 41 Eschweiler Bergbau-Verein, Grube Emil Mayrisch

VI. The Mortar Spraying Through Method

For the mortar spraying through method the arches are installed in the same way as for the concrete filling method, but the boarding and reinforcement sheets are put up and locked on the whole development of the tunnel.
The nozzle of the wet concrete spraying machine is designed in such a way as to horizontally fit the outer rib of the sheet (fig. 42 and 43), whereafter the concrete penetrates through the sheet with a pressure of 6 atmospheres into the empty space between the rock and the sheet.
State of the sheet directly after the spraying through, before the levelling coat has been applied.
The filling of the hollows between the rock and the sheet depends to a large exent on the routine of the man who holds the spraying nozzle. Experience has shown, that one can count on all hollows being filled but that the hollows in the crown should be filled from the front as well if they are more than 20 cm thick.
The spraying through method should only be used for concrete linings, which have no big statical strain to resist and the theoretical concrete thickness of which does not exceed 10—25 cm. It can also be used for local securing, the sheet being fastened with rock anchors and the hollows filled in with the spraying through method.
One instance of application which has already proved quite successful is the spraying through method in connection with mechanical excavation. The Bernold sheet acting as front protection is anchored to the rock directly behind the excavating machine or provided with distance blocks, put up and gunited, in order to obtain a direct bond with the rock and a statical vault.
With this latter method the rock is secured directly behind the dust-shield and there are no steel profiles to obstruct the way back. Contrarily to liner plates no pressing out with cement/mortar is required as the sprayed concrete or gunite fills possible hollows.

Fig. 42

Fig. 43

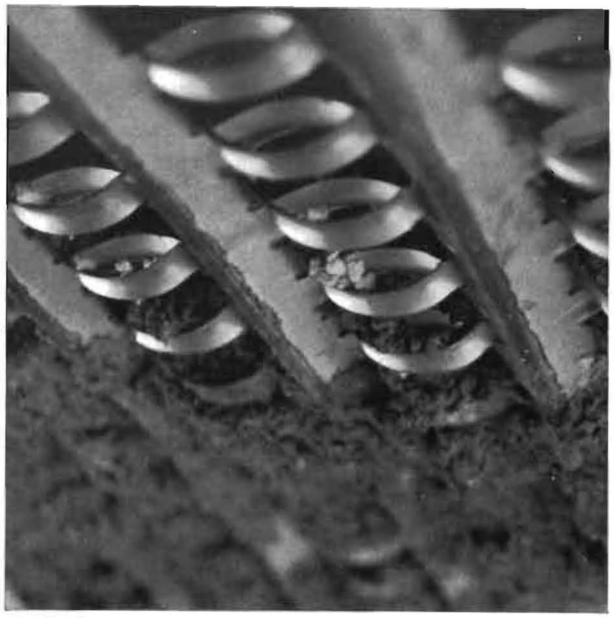
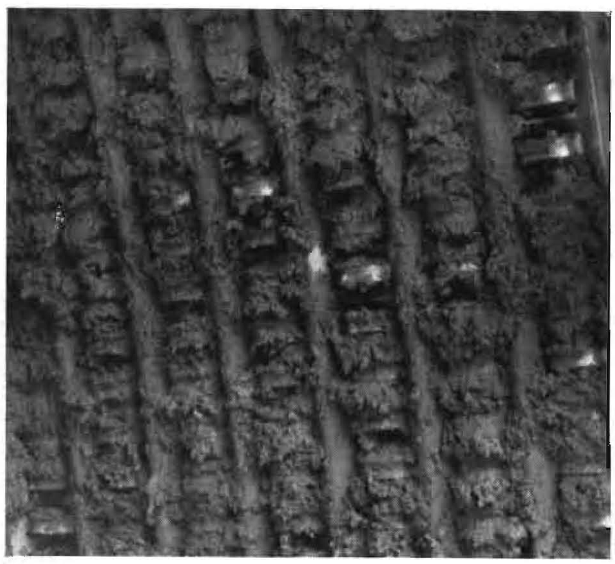


Fig. 44

Fig. 45
Installation Process
View from within before the spraying



VII. The Bernold System in the Construction of Underground stream passages and Subways

As a rule the wet-spraying system is used for these constructions after a sole of poor concrete has been put in to match the slope.
Then the boarding and reinforcement sheets are put up (fig. 46 and 47), which operation requires only very little time.

The economy of this procedure for the construction of underground stream passages depends on the diameter, which ranges from 1.50 to 4.0 m for a thickness of the concrete wall of 8—20 cm.

Fig. 47 Assembling process

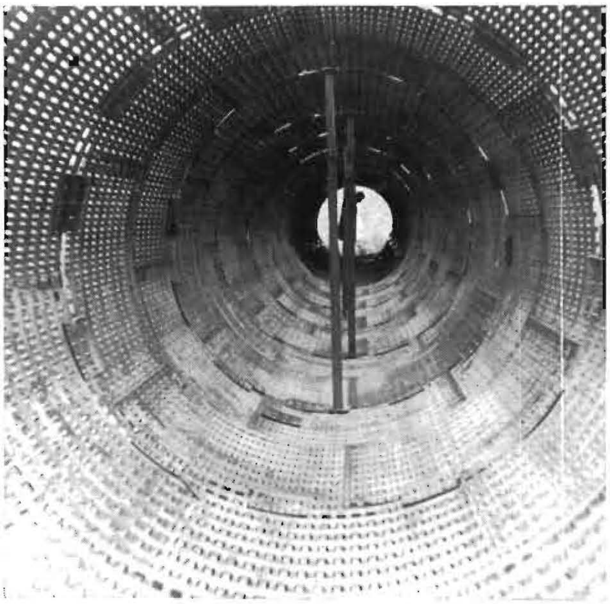


Fig. 46 View on the inside before spraying

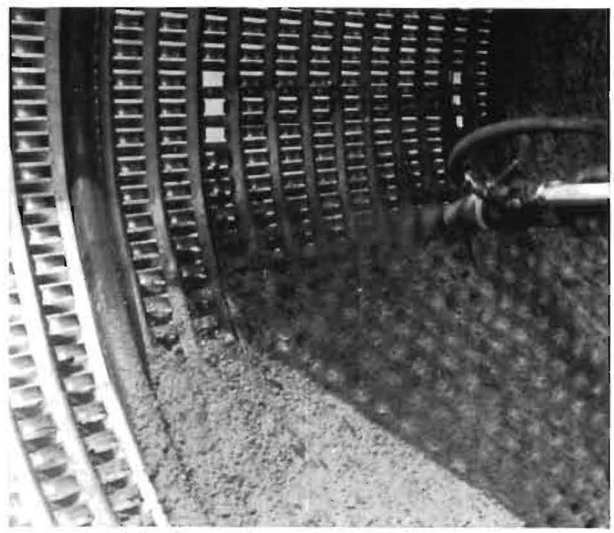


Fig. 48

Construction of the concrete lining with the wet-spraying method and the use of spraying concrete PC 350—400 with a grain of 0—8 or 0—15 mm.

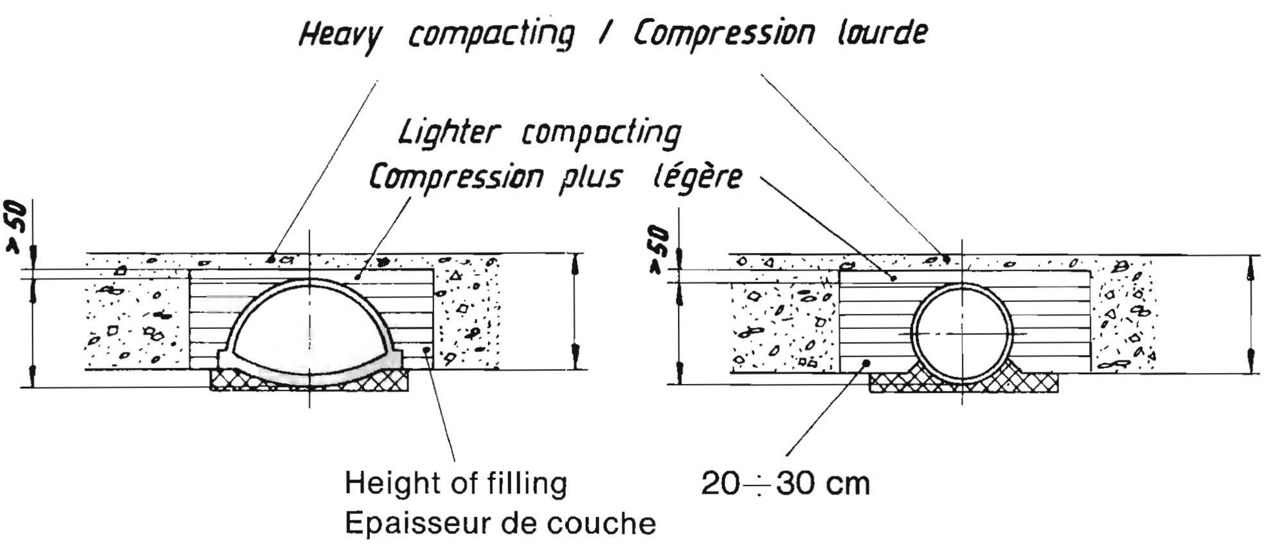


Fig. 49 The following drawings inform about sections, shapes of profile and capacity of bearing.

Fig. 50 Underground stream passage under Swiss Highway N 3

VIII. Statics

(Modern knowledge of tunneling statics
and the Bernold System)

It is not in the scope of this article to give directions about the calculation and dimensioning of tunnel linings. But we should like to point out the close relationship between modern tunneling statics and the Bernold System.

1. Essential points for the static calculation of underground buildings

A static calculation ought to enable the economical and safe dimensioning of supporting structures with an intended safety degree. Owing to the knowledge of the laws of equilibrium and of the deformation qualities of building materials, techniques of calculation have been developed during the past decades, which allow the building of daring structures. Thus bridges with a span of up to 1300 m and skyscrapers and towers of a height of 500 m have been planned and built.
To make such calculations possible the dimensions of the supporting structure, the loads and their repartition, the quality and stability of the building materials and the disposition of the supporting parts must be known. The result naturally depends on the accuracy of these values.
This now is the special difficulty in tunneling. The above mentioned values are but estimates and affect the reliability of the results so much, that the economy and therefore the aim of the whole calculation become doubtful.

The close correlations between the thickness of the concrete vault, the deformation qualities of the rock and the size and direction of the load make it impossible even with the use of computers to set up a reliable calculation according to the theory of elasticity. For tunneling other ways had to be sought and found, to make economical building possible.

The experience made with tunnel buildings, that had not been correctly dimensioned and the corresponding load tests, were the reason for developing new calculation methods, which result in the following conclusions, diverging in part from the elasticity theory:

- Thin walled tunnel linings (thickness of wall approx. 1/15 to 1/25 of the radius) are better suited for the safe absorption of rock pressures.
- The determinating cause of rupture manifestly is shearing rupture.
- Bending ruptures are possible only if hollows have remained unfilled behind the lining.
- Thick walled tunnel linings (thickness of wall approx. 1/5 to 1/8 of the radius) can only absorb comparatively small loads without suffering damage: bending ruptures and other results of destruction soon show.

We therefore know, that for the construction and calculation of tunnel linings:

- Building methods must be used, by which a slim final concrete lining may be built in as quickly as possible.
- It is decisive, that the lining should fit the rock without leaving hollows, adequate care is essential.
- It is very important, that a profile should be chosen that matches the rock quality. A circle is the ideal profile. The sole may be slightly flatter, straight parts ought to be avoided or limited to stable rock-conditions.
- The statical calculation can be limited to a shearing rupture test with triple security, according to the theory of semi-stiff construction.
- Nowadays differing methods are appropriate only for uneconomical thick-walled tunnel linings.
- Bending ruptures are hardly to be expected in thin walled tunnel linings, since large normal forces reduce possible bending-tensile stresses.
- An additional inner reinforcement has the task of absorbing bending-tensile stresses resulting from local disorder in the rock.

These claims which are uncontested by modern tunnel engineers, are all fulfilled by the Bernold System. The final concrete vault is erected immediately after excavation with a minimum thickness of 15 cm. The gradual filling in of concrete behind the perforated sheets can be optically controlled at any time. The fitting arches, which are reusable, guarantee a lining true to profile and an undisturbed working process.
Owing to it's compression the concrete is of a very good and homogeneous quality. The inner reinforcement is achieved by the simultaneous use of boarding and reinforcement sheets in one element and one single working process.

2. The bearing capacity of thin concrete linings

Some figures to illustrate what was said in the above chapter:

Example: Circular tunnel with a radius of 5 m, wall thickness 25 cm, compressive strength of concrete cubes larger than 300 kp/cm². In such linings bending ruptures occur only at a load of 95 to/m². A triple safety therefore makes an approx. 32 to/m² admissible.
When checking the ring pressure, we get a concrete compressive strain of 63 kp/cm² under a load of 32 to/m². As compared with the cylinder compressive strength of concrete, the safety is larger almost by four times. Many tests for such calculations have been carried out or are still under way (lit. 2).
The question of the slenderness limit, i. e. the moment when shearing rupture is determinating or in other words when the concrete lining does not absorb load movements any more without being damaged, can be answered as follows:
It is commonly known, that rock pressure does not occur suddenly, develops slowly. The first loads arise in vertical direction and occasion a slight crown deflection and as a result a movement of the side walls towards the mountain. Thus side forces are roused so that finally the line of pressure lies in the range of the lining. The slenderness depends on the size of the movement necessary to cause these side forces. For elastic rocks such as slate, clay, marl, sand and moraine the ratio wall thickness/radius should be approx. 1/25. For more stable rocks the limit is 1/15.
Other interesting methods of calculation are the well known bearing stress procedures. With the hypothesis of so called bending mechanisms, loads for thin walled tunnel linings can be calculated, which lie far higher than shear breaking loads and confirm the calculation method for semi-stiff constructions.
There is a constant development of new calculation methods: for known rock conditions they are being refined as much as is economically interesting and technically practicable. At the end however the tunneling engineer will always have to consider new and unknown inhomogeneities which make an exaggerated calculatory work for underground operations questionable.

3. The adequate shearing reinforcement in connection with Bernold sheets

Since dimensioning in tunnel construction should be determinated as said before by the causes of breaking to be expected, and we know that shear breaking is responsible for it, a strengthening of the concrete vault with a shearing reinforcement may be required in various cases. The shear stirrups increase the dowelling action of the Bernold sheets, prevent detaching caused by radial deflection forces under high tensile stresses and absorb the tensile forces under shearing stress that leads to shearing cracks.

4. Fundamental principles for dimensioning

The fundamental principles for dimensioning are based upon the following test reports of the EMPA:

1. EMPA-report nr. 69 953/3	Tension tests on single ribs
2. EMPA-report nr. 59 392	Plate-bending tests with single Bernold sheets
3. EMPA-report nr. 67 839	Plate-bending tests with overlapped Bernold sheets
4. EMPA-report nr. 60 410/2	Breaking tests with simply and doubly reinforced semi-circular arches.

Besides the expertise of the Institute for Statics of Prof. Dr. Ing. H. Duddeck we also call upon our own calculations and experience with finished constructions.

Evaluation of the tests

a) Tensile strength of the sheets and measuring of bendings

The basic material has a tensile strength of 3500—4200 kg/cm^2, the yield point at 2700—3200 kg/cm^2 (EMPA-report nr. 60 410/2, annex 21).

By the perforating and cold deformating of the basic material into Bernold sheets we naturally get a compacting of the material with a loss of plasticizing capacity. The resulting reinforcement rib has a variable jointly carrying breadth.

I. e. under tensile stress the working line of the rib features a slightly higher E-module of approx. 2.3—2.6 10^6 kg/cm^2 if the tension is related to the minimum cross section.

In the minimum cross section the tension is higher than in the range of the rib, the flow range will therefore be reached sooner there. This means, that the flow range of the rib as a whole is higher and the elongations accordingly smaller.

The nominal yield point was between

3680 and 3810 kg/cm^2

The tensile strength amounted to

3820—4070 kg/^{2}

The ductile yield amounted to 8.6—9.6‰ for 3 mm-sheets and 12.5—14.3‰ for 2 mm-sheets. In concreted ribs higher elongations at rupture of approximately 30% were measured. An exact study is under way in order to allow a better judgement on the rotational capacity of plastic moments.

b) Necessary lengths of overlapping

EMPA-test nr. 67 839 deals with the sheet-overlappings.

Under bending stress alone the breaking load was only 10% less with an overlap of 9 cm (= 3 ribs) than at an overlap of 15 cm (= 5 ribs).

At breaking point steel tension amounted to

= 3000 kg/cm^2 (in the range of the overlap).

It depends on the condition of the building site, whether this value should be fixed somewhat lower.

It is to be expected that 2 mm-sheets will have stronger steel tensions in the overlap. As long as no further tests on this point exist, the above mentioned value may be used.

c) Shear dimensioning

As a rule shearing forces in tunnel linings are small. The bond between Bernold sheet and concrete is very good. A test has been made in which the shearing tensile stress was of a good 20 kg/cm^2 although the quality of concrete was low: 170 kg/cm^2. Since we know of no further tests and we want to give a value that is on the safe side,

$$\tau_{Br} \left(\text{kp/cm}^2\right) = 0{,}75 \sqrt{\beta_w} \quad \left(\text{kp/cm}^2\right)$$

should be the basic formula for dimensioning (as for steel concrete plates).

If shearing stirrups are ordered, this value may be doubled, providing that the shearing forces are absorbed by stirrups.

d) Radial forces with tensile stress

Although up to now no damages have shown in finished constructions, an evidence of radial forces should be kept for the dimensioning of bent steel concrete parts. If there are no stirrups, detaching may occur through radial forces from.

= 45 Mp/m^2 on.

Radial forces of such strength are rare and should be absorbed by stirrups, especially in the range of overlaps.

e) Widths of cracks

Concrete, that has been reinforced with Bernold sheets, is well secured against cracks. Tests have shown, that the ratio between the load under which the admissible width of cracks of 0.2 mm occurs and the breaking load ranges from 0.70 to 0.84. I. e., that under service loads no visible cracks need be expected.

A special calculation of crack-safety is therefore superfluous.

Summary

The tests, that have been made so far, are quite sufficient to justify the full use of boarding and reinforcement sheets according to the Bernold System, with due regard to the fundamental principles of dimensioning as described above. All the experiences made in finished constructions confirm this fact. Until today no damages of any kind could be found. However the favourable experiences gathered, are not simply a result of the fact that Bernold sheets act as reinforcers but are also based on the immediate, hollowfree concreting of the final lining after excavation, whereby an extremely favourable effect on the developement of rock pressure and the consolidation of the rock is achieved.

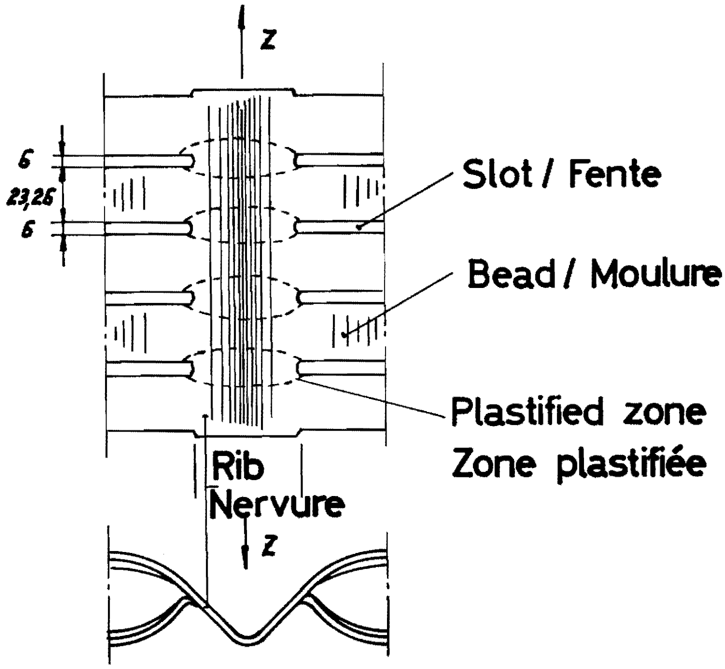
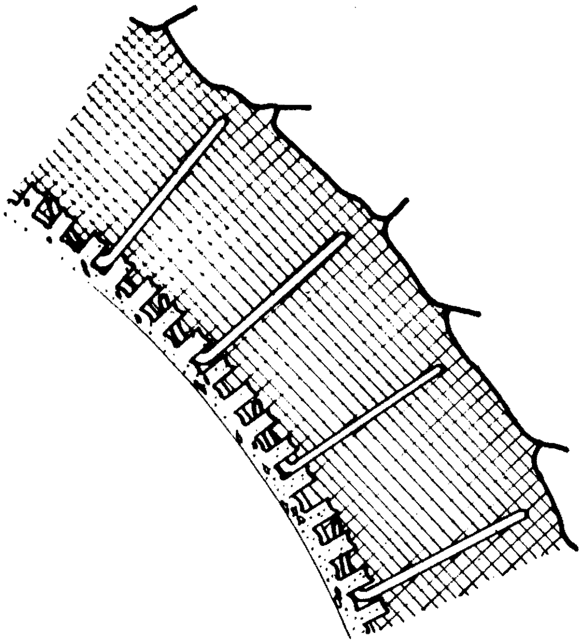
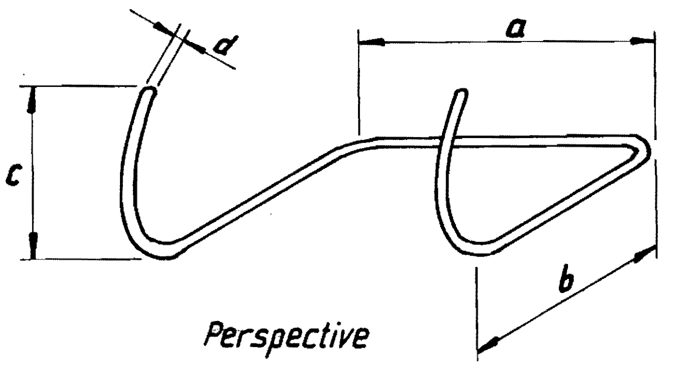


Fig. 51





Shearing stirrups to transfer shearing forces and absorb radial forces in zones under very high stress.

Etrier pour transmettre le cisaillement et absorber les forces radiales dans des zones fortement sollicitées.

Fig. 52

IX. Economical Advantages of the Bernold System

To make a success, a new building system must not only be advantageous from a technical point of view but also from an economical one.
Questions to this effect were asked in the article of 1967. In the meantime the necessary figures have been collected and evaluated. To sum up we can say, that the indications, which had then been given on possible cost reductions have proved true and to some extent even exceeded all expectations.

We would like to specially point out that:

Because they use the system, a large amount of tunneling sites abandon sprayed concrete, the compressive strength of which, as has been proved, lies far under that of filling concrete, which is filled in between sheet and concrete and vibrated. Post-calculations have shown, that the costs for sprayed concrete are 50—80% higher than those for filling-concrete PC 300.
In other cases the contractor renounces to steel or to be more exact to centering arcs. This means a reduction in weight of 50%.
If one calculates the actual weight of the built in centering arcs, the weight is of 150% as compared to the 100% of the Bernold sheets. These figures only comprise the actual delivery, without higher installations costs.

Special attention was given to the **installation costs,** since an identical base of calculation cannot be adopted on every building site or in every case.
The following indications are average values for a modern, well equipped and well organized building site, which have been compiled from the figures and experience gained on several building sites, on which the Bernold System was used for the construction of galleries and tunnels.

Work per m³ of lining

Average tunnel developement 15.0 m	Worker minutes
1. Transport tunnel entry — place of use	2.1
2. Moving and placing of a fitting arch	12.4
3. Putting up and locking of sheets of 1, 2, 3 mm	22.0
4. Putting up of the front boarding	14.3
5. Installation and operation of the concrete conveying machine and equipment Filling in and vibrating of the concrete	21.6

Average time: 72.4 worker minutes per m³

The total building costs including all supplements amount to a total of sfr. 80.— to 120.— per m², when the concrete lining has a thickness of 20 cm.

Comparison of offers

A graphic chart of the comparison of offers shows how economical the Bernold System is, when several methods are genuinely competing. It is interesting that everyone of the 5 contractors has calculated an average reduction of 1.1 million with the Bernold lining as compared to the traditional steel linings, that means approximately 11% of the total building costs — but approx. 38% of the lining costs. Experience has shown that the economical advantages of the Bernold System even increase with the degree of difficulty in the excavation.

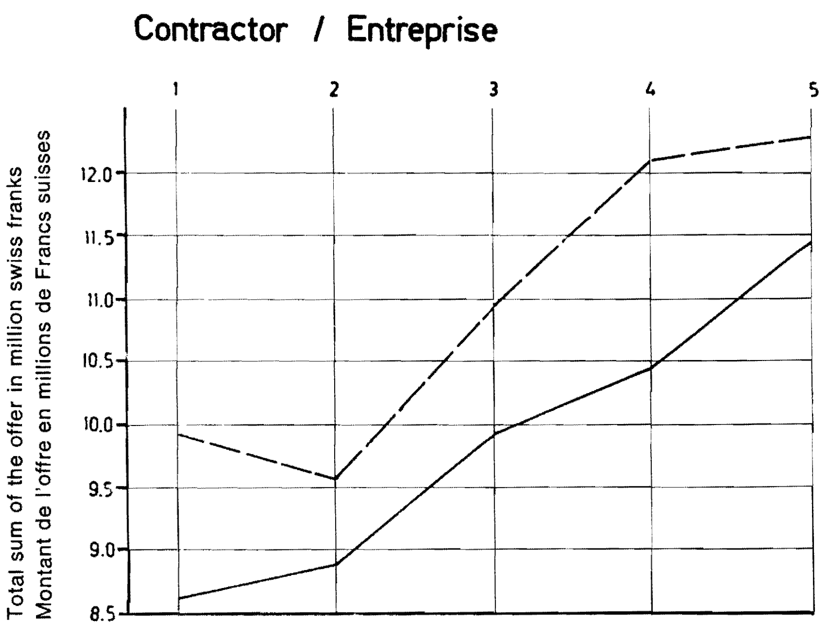


Fig. 53

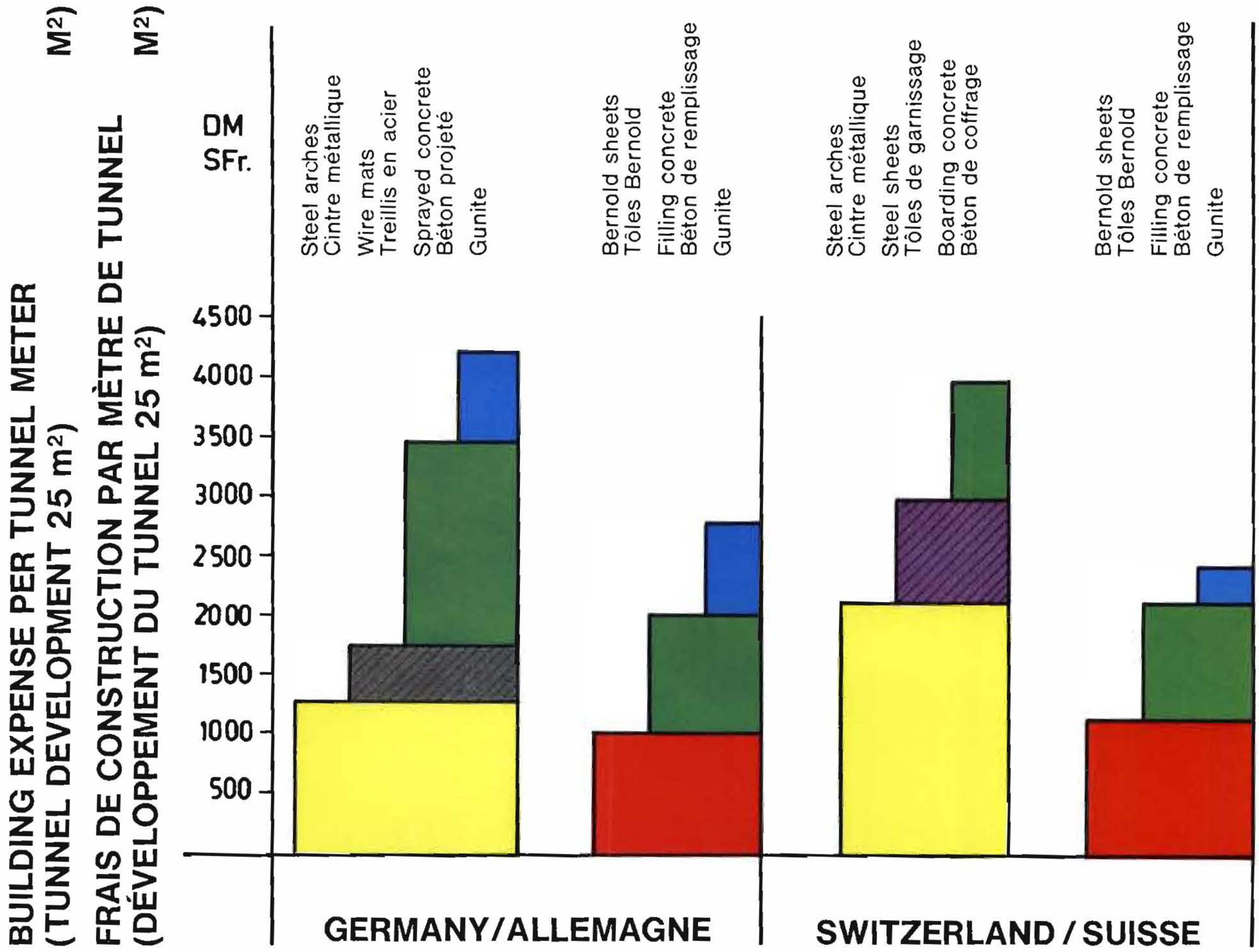


Fig. 54

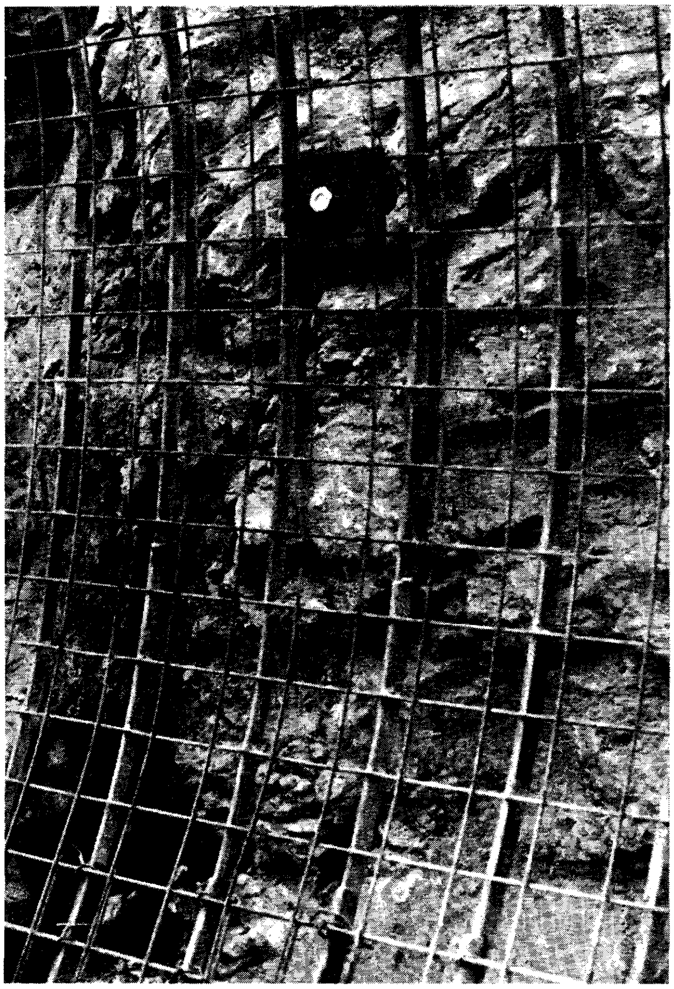
A graph of the actual and total building expenses for two underground buildings in Switzerland and in Germany, which were built under similar rock pressure and working conditions, clearly show the economical advantages of the Bernold System for modern tunnel- and gallery-construction.

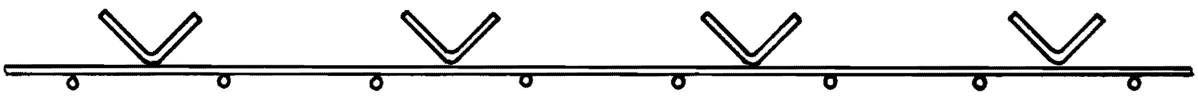
We should like to close with a few lines from the expertise by Prof. Dr. Ing. H. Duddeck, Institut für Statik, Technische Universität Braunschweig:

"THE BERNOLD SHEETS ARE WELL SUITED FOR THE REINFORCEMENT OF CONSTRUCTIONS, WHICH ARE MAINLY UNDER COMPRESSIVE STRESS.
THIS IS TRUE FOR THIN WALLED LININGS OF TUNNELS AND GALLERIES.
AS TENSILE REINFORCEMENT FOR BENDING STRESS ONLY, THE SHEETS MAY BE EFFICIENTLY USED WITH LARGER OVERLAPS OR REINFORCING IRONS TO STRENGTHEN THE JOINTS.
THE BERNOLD SHEETS ARE NOT ONLY ADVANTAGEOUS FOR THE WORK AT THE DRILLING FRONT (PROTECTION FROM ROCK FALL, SIMPLICITY OF INSTALLATION, COMBINATION OF BOARDING AND REINFORCEMENT IN ONE STRUCTURAL ELEMENT), BUT THEY ALSO MAKE POSSIBLE THE USE OF CONSOLIDATED LOCAL CONCRETE, (BETTER QUALITY AND SMALLER DIFFERENCES IN SOLIDITY THAN WITH SPRAYED CONCRETE).
TESTS AND CALCULATIONS HAVE PROVED THAT CONCRETE LININGS, WHICH ARE REINFORCED WITH BERNOLD SHEETS, ARE PERFECTLY SUITED FROM A STATICAL POINT OF VIEW FOR TUNNELS AND GALLERIES UNDER ALMOST ANY KIND OF STRESS."

Buchdruck + Offset AG Bad Ragaz

Typenliste für Bernold-Felssicherungsmatten insbesondere zur Verwendung beim maschinellen Tunnelvortrieb





Typ	Rundstahl Durchmesser	Maschen-weite	Gewicht pro m²
(Winkeleisen 40 × 40 × 2,5 mm)			
BF – 4	ϕ 4 mm	100 × 100	8,25 kg
BF – 5	ϕ 5 mm	100 × 100	9,36 kg
BF – 6	ϕ 6 mm	100 × 100	10,70 kg
BF – 7	ϕ 7 mm	100 × 100	12,30 kg

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New Swiss Tunnel Lining System

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About three years ago Jean Bernold, Engineer of Walenstadt/Switzerland developed a new tunnel lining system which he patented and then placed on the market. Experience has shown that this system has advantages over other systems now in common use. A detailed description of the process is given here, together with a number of illustrations which refer to the driving of the Flonzaley and Chauderon tunnels on the new Autoroute du Léman, N 9, in the canton of Vaud.

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dated Monday 21st June 1971, No. 282.

THE PRINCIPLE

In the concrete shell method of construction a rock which has a limited period of stability is underpinned within the shortest possible time by means of a concrete arch. To do this, single concrete rings are installed one at a time at the same rate as the excavation stages and immediately following the advance into the tunnel. What is novel consists in the fact that specially shaped perforated steel sheets are used which are joined together to form a shuttering and reinforcing casing. These cold-shaped sheets with V-shaped ribs are supported temporarily on assembly arches while the concrete hardens and then serve as permanent reinforcement in the concrete. Because of their special shape they are sufficiently rigid to resist the shuttering pressure and in addition they are sufficiently resistant to prevent a concrete of stiff plastic consistency from running through during the vibratory operation. Standard sheets of more or less square size can be bent accurately to the radius of the tunnel so that a rapid and simple method of assembly is assured. The Bernold system fulfils two different functions at the same time, nameley that of the steel supporting frame and that of the permanent rock lining. The consolidation of the concrete placed between the sheets and rock face both protects the face from the effects of air and moisture movement and prevents the rock from further fragmentation. The rock, the concrete and the steel linings act as a homogeneous structure which distributes the loads of those parts of the rock which are not so capable of carrying a load onto layers of rock which have a greater load-bearing capacity. The danger zone which is immediately behind the advance in the tunnel is eliminated in a short time. The possibility of application of this highly promising principle is not necessarily restricted to tunnel construction.

FIELD OF APPLICATION

In tunnel construction the Bernold system can be used wherever one has to deal with rock which for the most part varies from slightly crumbly to very crumbly. The condition necessary to ensure the economic application of the process, however, is that this system does not possess merely the character of a temporary support but that it becomes part of the permanent structure and can take

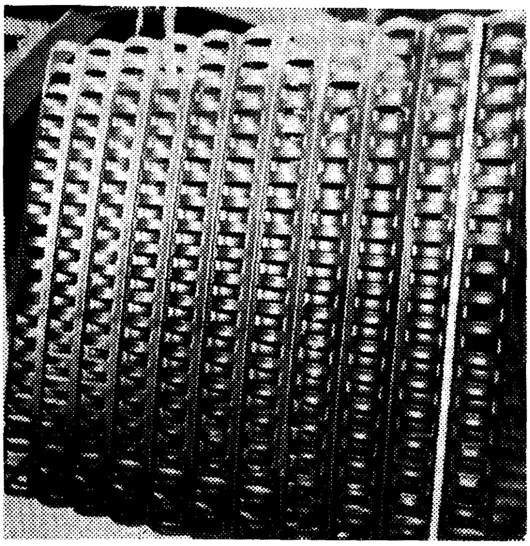


Fig. 2 A ribbed steel sheet.

over the function of the conventional concrete lining. In the event of a marked variation of sound and loose rock a simple comparative calculation with other methods will define the economic limit of the range of application. The rock is assessed for its stability and is then classified according to Lauffer's rock specification as given in SIA Standard 179, table: 2.

	Class 3 Very fragile		Class 4 Crumbly		Class 5 Very crumbly	
L	Limit (months)	T Mean (weeks)	Limit (days)	T Mean (hours)	Limit (mins)	T Mean (mins)
1 m	0.5	1	0.25	3	7	
5 m	:	:	:	:	10	5
4 m	1	2	0.5	6	15	:
3 m	:	:	:	12	30	15
2 m	3.5	8	2	24	90	45

L = Free unsupported width from last supporting arch to tunnel face.

T = Time interval between time of excavation and commencement of major falls.

The length of unsupported excavation in the walls and roof is determined by two factors (1) the nature

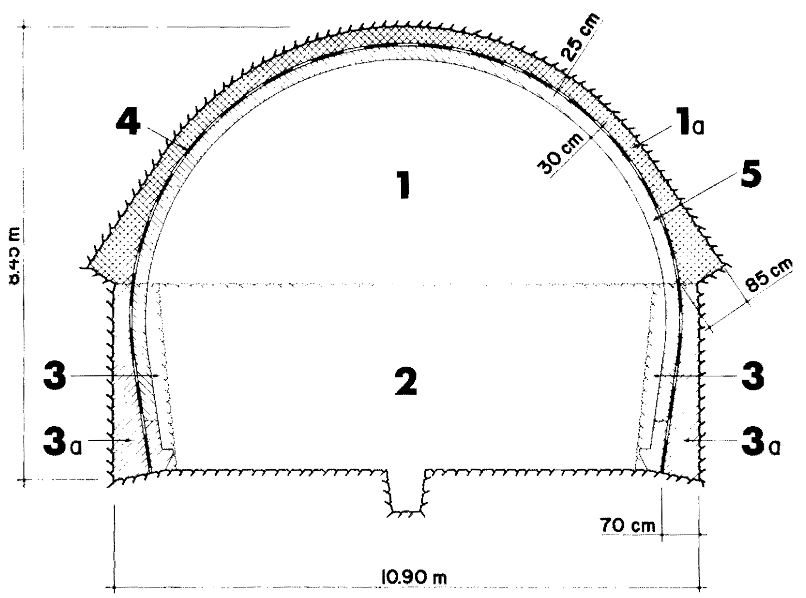


Fig. 1 Cross-section of Flonzaley Tunnel. Sequence of excavation and concreting.

1 Top bench excavation 40 square metres

1a Concrete lining 25 to 85 cm thick, concrete BH 300, Bernold sheets 2 mm

2 Bottom bench excavation

3 Side wall excavation to full width

3a Concrete wall lining 25 to 70 cm concrete BH 300. Bernold sheets 2 mm underpinning arch concrete

4 Gunite minimum 2 cm thick

5 Interior secondary lining 30 cm thick with a coating of Vandex for waterproofing

of the rock, and (2) the time interval 'T'. The length determined by this method should be such that there is sufficient time allowed for concreting this length. On this basis the concrete shuttering method of construction will be particularly advantageous for classes 3 and 4, that is to say for rock which is very fragile down to crumbly.

INSTALLATION OF BERNOLD SHEETS ON THE AUTOROUTE DU LEMAN.

Purpose

Four lengths of twin tunnels are being driven on the section of Autoroute N 9 which is at present under construction along the Lake of Geneva between Montreux and Lausanne, namely Flonzaley (700 m), Criblette (250 m), Chauderon (180 m) and Belmont (340 m). The Canton of Vaud, represented by the Bureau de Construction des Autoroutes (BAR) has appointed to design the project and also to act as site construction supervisors the two engineering firms of Société Générale de l'Industrie SA (SGI) and the Compagnie d'Etudes de Travaux Publics SA (CETP) as experts in the field.

Project

All four schemes are similar in design and conform with the Federal Specification for National Roads. Twin tunnel bores are driven more or less parallel to one another. Width of carriageway 7.75 m, a pavement 0.75 m wide on both sides and a clear height for vehicles of 4.50 m in the Flonzaley Tunnel (fig. 1). Longitudinal ventilation is by means of jet blowers.

Geology

All four lengths of tunnel pass for the most part through sedimentary rock which ranges from crumbly to rock requiring support; a geological formation consisting of strata of sandstone and marl of variable thickness, ranging from a few centimetres to a few metres. In these various strata all types of rock are met with — hard pure sandstones, marly sandstones to sandy marls with inclusions of clay. The composition and strength of the individual rocks vary even within distances of only a few metres. The rocks are cracked and fissured. Water occurs only in a few places where there is dripping water and water flowing from fissures. Tests have shown that the sediments have the following composition:

Sandstone	15%
Marly Sandstone	40%
Marly Clay	45%
Compressive strengths	200—500 kg/cm²

In view of the geological conditions and the restricted length of the individual tunnel projects the length work method of construction was the obvious choice from the start.
When tenders were invited it was envisaged that steel ribs would be used for ground support and that they would be concreted in when the tunnel was lined, using conventional steel shuttering in the ordinary way. In the summer of 1969 the two construction schemes for the Flonzaley Tunnel and the Chauderon Tunnel were entrusted to the consortium Conrad Zschokke and HR Schmalz AG of Puidoux. Because of steel supply shortages existing at that period, resulting in uncertain deliveries and rapidly escalating prices, the consortium suggested the use of the Bernold system to the clients. A comparison of costs with the tender showed in the case of crumbly rock a saving in construction costs of at least 10%. Thanks to the approval granted by the local building directorate, the sheets were used

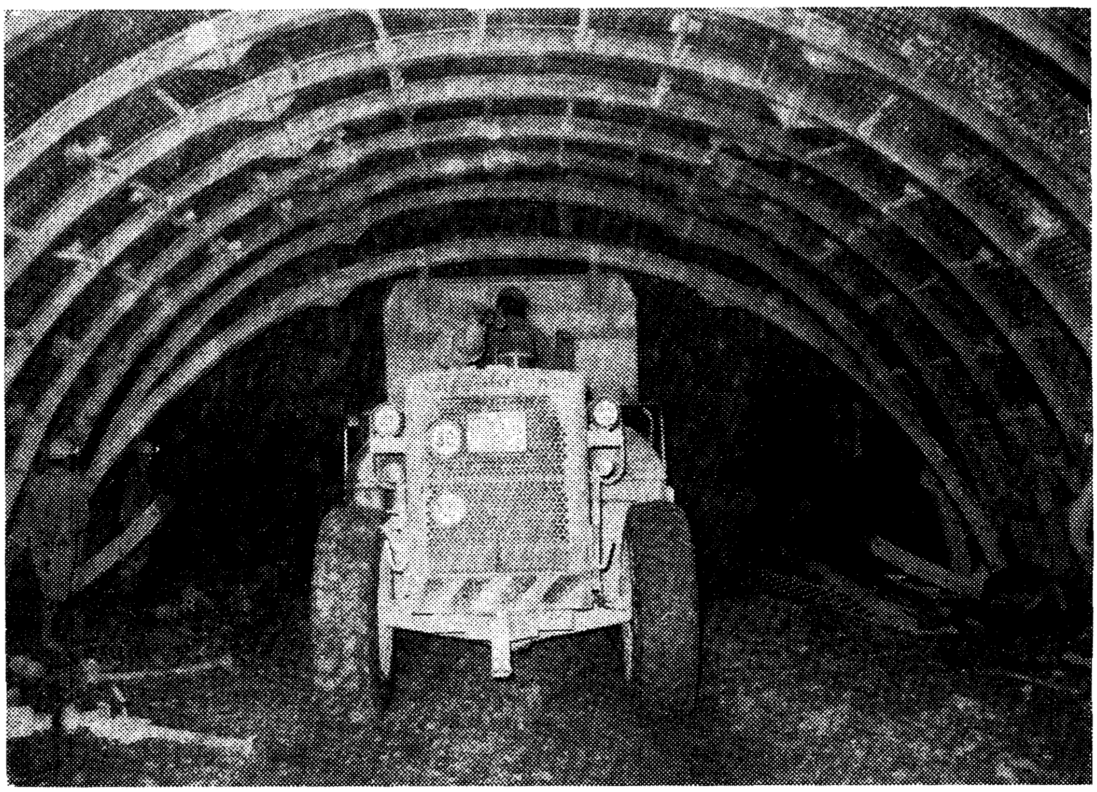


Fig. 3 Moving a temporary arch rib. Note that ends of rib are temporarily folded.

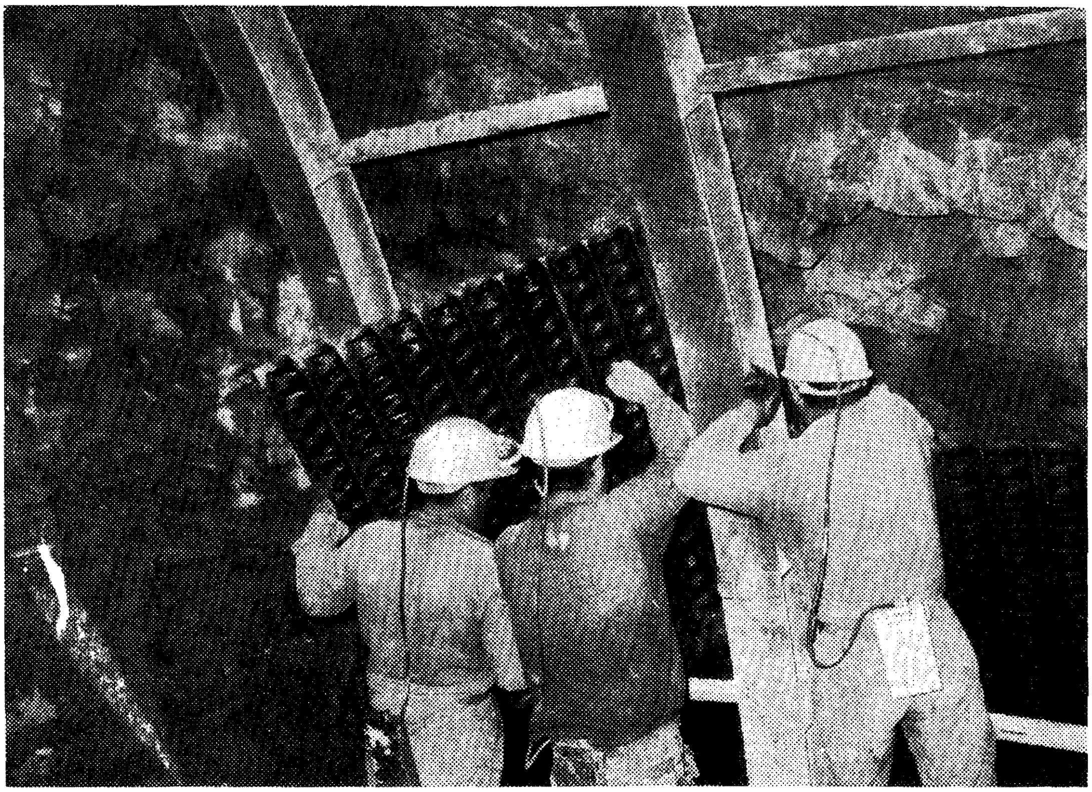


Fig. 4 Erecting a sheet.

for the first time in the Chauderon tunnel. As a result of the excellent results achieved on this experimental section it was decided to use the Bernold system generally for all four lengths of tunnel. Since the construction of all the tunnels was similar it is proposed to deal with the method used in the Flonzaley tunnel only.

The Flonzaley Tunnel Site

As mentioned previously the construction comprises twin tunnel bores of 700 metres length running practically parallel to each other and with a mean *distance* between centres of 35 metres. After passing under the Berne–Lausanne and Puidoux–Vevey railway lines in the loose rock it was possible to make a start with the actual drive in the sedimentary rock at the end of 1970.

Technical data

Cross section area of rock face	78 m^2
Lining:	
Theoretical thickness of concrete in	
crown	25 cm
abutments	85 cm
side walls	25—70 cm
Bernold sheets — thickness	2 mm
Protective gunite — thickness	2 cm
Concrete lining. Bernold sheets/rock face	30 cm

Internal face of gunite treated with Vandex waterproofing agent.

Execution

Since one has to reckon with bad rock all the way, the advance is carried out in two operational phases, using the so-called Belgian method of construction. For the first phase a top bench of 40 m^2 is pushed through the entire length of the tunnel and then for phase 2 the balance of 38 m^2 is excavated (figs. Nos. 1 and 2). When excavating the lower bench, the hearting and sidewalls are blasted in stages so as to prevent undermining of the support for the arch. In order to adapt the construction to this method of operation it was arranged to widen the abutments of the arch to 85 cm. If the quality of the rock is poor then a secondary concrete lining 30 cm thick can be placed continuously or in lengths as required throughout the length of the tunnel. For these operations the Bernold sheets are first coated with gunite and then the final internal 30 cm concrete lining is applied. To ensure watertightness a seal is provided by a brushed-on coating of Vandex on the inside face of the secondary lining.

Advance

As already explained the Bernold system of tunnel lining follows very closely behind the tunnel face. Depending on the stability of the rock the unsupported lengths usually vary between 2 and 3 metres. When rock conditions are 'crumbly' the unsupported length is restricted to 1 metre. For drilling, blasting and excavating a volume of 100 to 120 cu. metres one requires 4 to 5 hours. This determines also the individual lengths of the stages for the concrete lengths. After the end of the excavating operation following blasting, one to three steel arches are erected, depending upon the length of the advance. The spacing between the arches is as a rule 0.96 or 1.20 metres, according to the width of perforated sheets chosen. The steel arches are spaced at the proper centres by spacer tubes (fig. 2) threaded over tie rods.

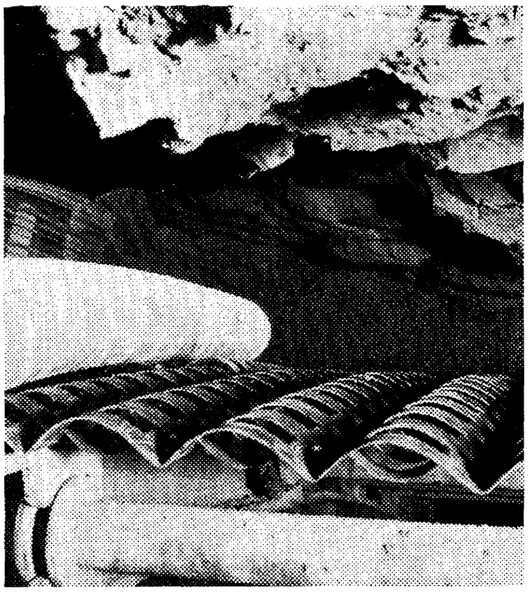
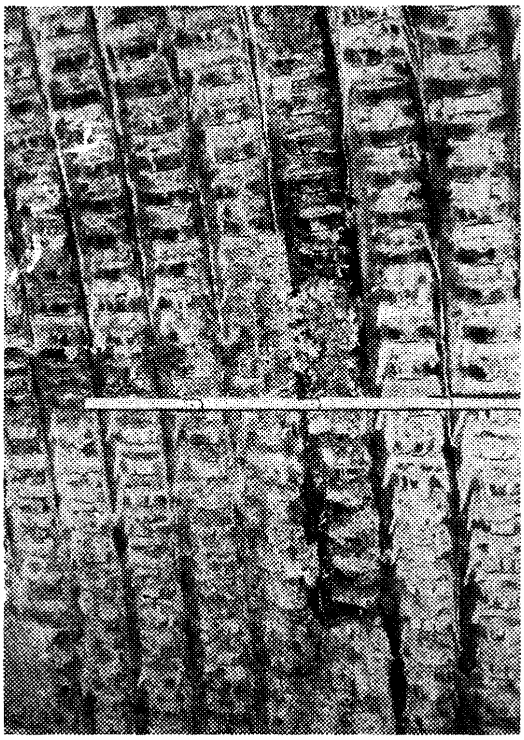


Fig. 5 View of cavity between the sheets and the rock face. When fitting the sheets a concrete of stiff-plastic consistency is poured at the same time. On the left is a flexible concrete supply pipe.

Fig. 6 Bernold sheets showing mortar penetration which provides an excellent key for the final finishing of the concrete lining.



The temporary arches are bent to the radius of the tunnel and are provided with hinged joints at their extremities. These joints make it easy to move the arch without having to dismantle it first (fig. 3). For the moving operation a mechanical front-end-loader can be used and about 10 minutes per arch is required for this. The decisive factor in determining the size of the temporary arch is the rock pressure which is to be expected up to the time when the concrete lining has hardened sufficiently to support the load. For the arched lining in Flonzaley Tunnel a somewhat heavier section, HEB 180, was deliberately chosen. In the case of lighter sections it is likely that undesirable deformations and damage may occur due to the frequent erection and re-erection and to the blasting operations which are constantly having an adverse effect on the equipment. Great importance is attached to the accurate shape and careful moving of the temporary arches, because these arches are used to determine the accuracy of the cross-section of the rock excavation.

The number of temporary arches required depends upon the amount of the daily advance. As a rule 8 to 12 are sufficient. The sheets are laid at both ends of the temporary arches, starting from the floor (fig. 4). As a rule sheets 2 mm thick should be sufficiently strong even for heavy rock and concrete loads. The dimensions of the sheets are standardised. At the present time two sizes are in general use: 1.08×1.20 metres for distances between arches of 0.96 metres, and 1.32×1.20 metres for distances between arches of 1.20 metres. Half sized sheets are also supplied. When removing the arches, the sheets are overlapped on both sides and joined together so that there is no distortion. Simultaneously with the fixing of sheets the gap between the rock and the plate shuttering is backfilled with concrete. The concrete which has been filled in is consolidated with immersion vibrators (fig. 5) until it emerges through the perforations in the sheets. As a result of this one obtains a very tight bonding between sheets and rock. The quality of concrete and method of placing are decisive factors as regards the load-bearing capacity and watertightness at a later date. In Flonzaley a ready-mixed concrete BH 300 with the following particle size distribution is used:

0— 3	35%
3— 8	20%
8—15	22%
15—30	23%

For transportation with lorries over 11 kilometres 125 to 130 litres of water are added per cubic metre of finished concrete, corresponding to a water/cement ratio of 0.41. As the consistency is from earth-moist to stiff plastic this makes the placing operation difficult, so a further 15 litres of water are added per cubic metre on arrival in the tunnel and this is mixed in the drum of the concrete transport truck. The w/c ratio is now 0.48. Increasing the sand content at the expense of the crushed stone favours close bonding of the concrete mortar with the ribs of the sheets (figs. 6 and 7). The compressive strengths on test cubes are reduced as a result of this, but they still reach 260 kg/cm² after 7 days and 380 to 400 kg/cm² after 28 days. Core drillings in situ gave perfect samples with compressive strenghts of 450 to 500 kg/cm². Thorough vibration of the concrete in the crown cannot always be guaranteed. Consequently the density of the concrete in this zone will be doubtful. In the case of seepage water it is a good plan to lay a perforated plastic pipe with a wool thread insert, for example a Drainflex 65 mm in diameter at the concrete joints, that is to say every two or three metres along the tunnel. These pipes should be laid behind the sheets over the entire circumference and then be connected up to the main tunnel drainage system.

Local variations of up to 5 cm from the theoretical line of the crown as a result of sagging in the plates are unavoidable despite careful laying operations.
This is a factor which must be taken into account when determining the dimensions of the interior ring. Factors which also influence the quality of the concrete are the method of handling and consequently the type of apparatus on the concrete truck; it should be borne in mind that it is not merely a question of the rapid filling up of cavities but the preparation of a construction component which is subjected to static stress. The Spirocret S2000 is a suitable apparatus for this purpose. By means of compressed air a moist stiff plastic concrete is applied without any danger of segregation. The rates of placing of the Spirocret S2000 are from 15 to 18 m^3 of finished concrete per hour, whilst in conjunction with the fixing of the sheets one reaches an average concrete output of between 10 and 12 m^3 per hour.
The full cycle of concreting a stage of 2 to 3 metres length takes about 4 to 6 hours, according to the actual volume of concrete required, this in turn being determined by the overbreak and the length of the stage. From this one obtains a rate of progress of about 1.5 hours per m^2 for the complete placing operation (installation, sheets, concrete).
In the Flonzaley Tunnel the Bernold sheets are laid throughout the entire length of the tunnel and over the entire development of the arch. When advancing the face, the sedimentary rock was found to range from slightly fragile to very fragile; for the most part it was dry rock of the above mentioned classes 3 and 4. Systematic excavation is therefore justified. The rock stability times are just sufficient to allow for preparing and concreting a length of from 2.5 to a maximum of 3 metres. With excavation times of 4 to 5 hours and concreting times of 4 to 6 hours it is possible to complete two working cycles per day with 2-shift operation. This gives average daily outpouts of 5 metres advance or 100 metres per month. The prerequisites for such maximum outpouts are the following factors:

Favourable rock conditions (stability time, structure, occurrence of water);
An efficient set of equipment (with spare equipment);
Good organisation and team spirit;
Expertise of the advance crews.

It should be noted that the same men have to date erected over 15,000 square metres of sheets on this contract.

COMPARISON WITH CONVENTIONAL METHODS OF EXECUTION

As experience to date has shown this novel Swiss Concrete Shuttering System brings with it a number of important advantages both from the technical and economic points of view.

Advantages from the point of view of tunnel building technology

According to the basic principle which is generally recognised today, the first requirement of a method of excavation in crumbly rock requiring support is that it should be supported as quickly as possible after the rock has been exposed. This

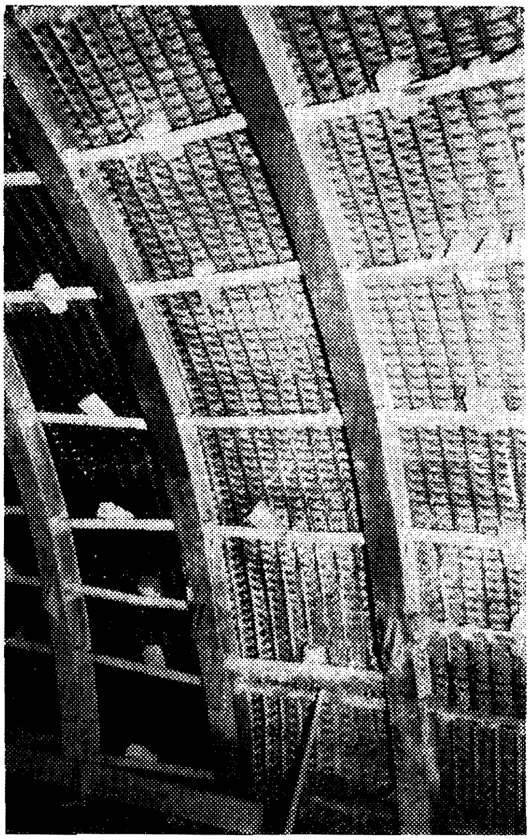


Fig. 7 Temporary arches supporting the concrete lining until it has hardened sufficiently to take the loading.

prevents swelling of the rock which as a rule only occurs a certain time after the release of pressure and by exposure. The method of construction which has just been described fulfils this requirement in the best possible manner. The rapid erection of the temporary arches, the simple handling of the sheets and the use of efficient concreting appliances make it possbile to underpin effectively any open section of rock in the shortest possible time. The temporary arches and sheets carry the loads until the primary concrete lining has hardened sufficiently to take these loads. Contrary to the conventional lining process, the concrete while still fresh is retained and protected from blasting damage by the sheets which act as shuttering and as reinforcement.

Adaptability

When tunnelling in rock the tunnel builder is reminded time and time again of the varying nature of the geological conditions. The structure, positioning and fissures often influence the behaviour of the rock locally from one excavation section to the next. By choosing the number of arches to be installed in advance, the distance between the arches and the thickness of the sheets, it is possible at any time to arrange for the support of any particular quality of rock. The shuttering and the concrete can be pushed forward as far as the face itself. The joining of the sheets in the case of arch underpinning, the design of curves, changes from one cross-section to another and negotiation of cross-sections of different sizes as a result of side galleries, widenings, branches and niches can be carried out without any problems and without any great expense.

Safety

The purpose of any lining or rock reinforcement work is to give an absolute guarantee that collapses and break-throughs will be prevented. However it is a well-known fact that in very crumbly zones it is precisely during the erection work that the most immediate danger to the crew occurs. All too often do we hear of serious accidents precisely during the short periods of time taken by the lining work. Here again the Bernold system shows to advantage. The removal of a temporary arch by means of a mechanical shovel takes only a fraction of the time which would be necessary for the erection of a conventional steel arch or for spraying a thin layer of concrete onto the rock face. In conjunction with the number of sheets laid provisionally the temporary arches form an effective head protection during the actual installation work.

Economy

For the client as for the contractor the economy of a construction method is of decisive importance. Here we compare on a percentage basis three of the usual methods of lining. The example is based on rock conditions such as were encountered when the motorway tunnel was built at Flonzaley, and due regard should be paid to this point.

From the comparisons shown in the table it can clearly be seen that the use of the Bernold lining process is economic in fragile to crumbly rock and soft ground, but on this assumption it will be found that this system offers the lowest constructional costs. The next more expensive process resulted in additional costs of around 1000 Swiss francs per linear metre of tunnel bore or 2 million francs for a twin bore motorway tunnel 1 km in length. However the economics become questionable as soon as the crumbly zones of rock are replaced by longer sections of sound stable rock, so that the continuous use of reinforcing sheets is no longer justified. Briefly it may be stated as follows: 'In good rock the method is bad and in bad rock the method is good!' Furthermore there is the prerequisite that ground water be found only in small quantities because the containing of springs and fissure water, which has to be done by hand if one is to have a perfect tunnel lining, is costly and would unduly disorganise the normal tempo of the work.

It is precisely this working tempo which brings with

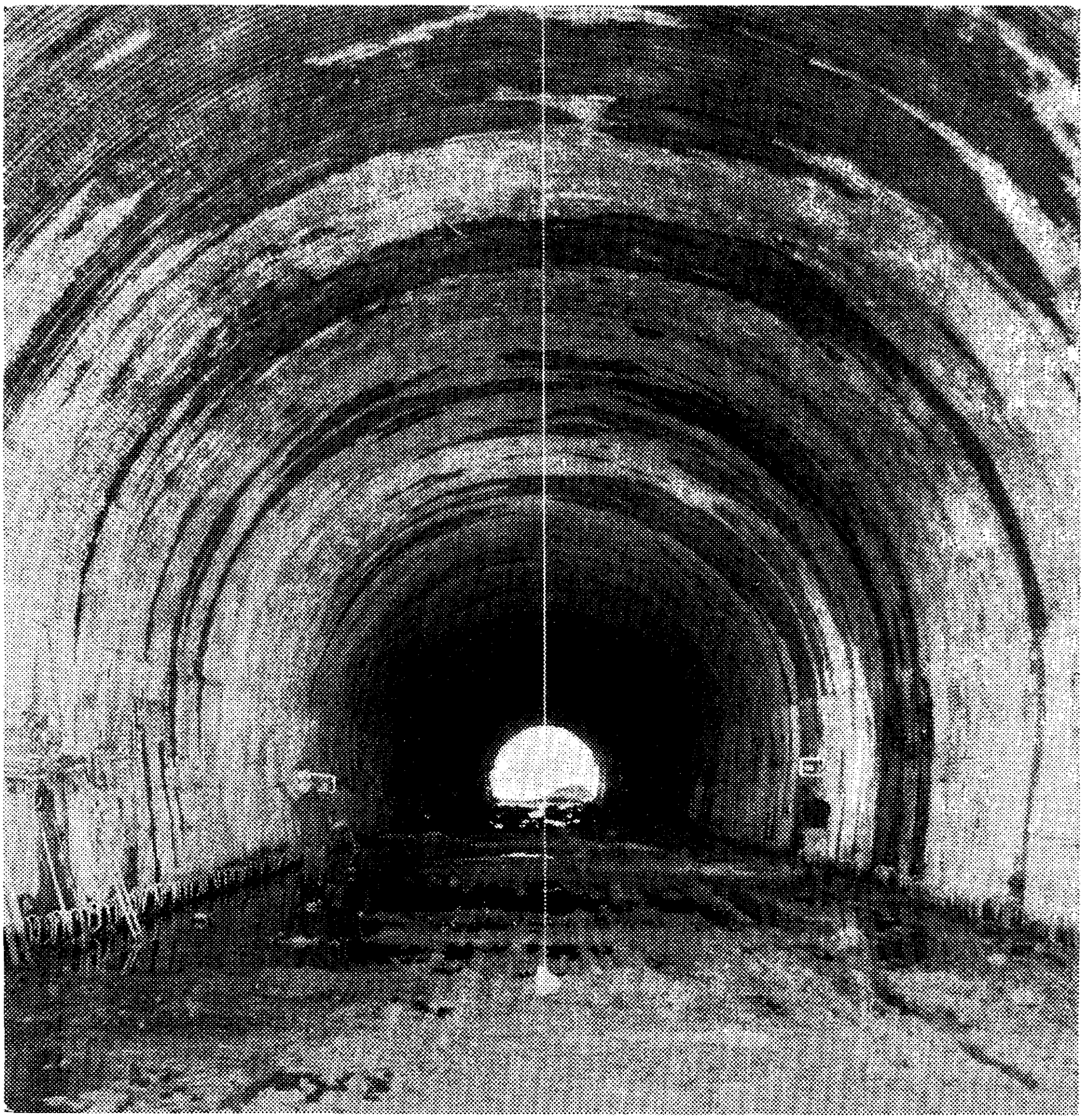


Fig. 8 Chauderon Tunnel. Shown lined with Bernold sheets prior to guniting and secondary lining if necessary.

Comparison of different Tunnel Lining Methods

Cross-sections of Excavation 78 to 87 sq. metres.
Development 22 sq. metres.

Class of Rock	Type of Work	Normal construction as % of Bernold Method	Rock bolting and fixing as % of Bernold Method
Fragile	Fitting Bernold sheets w. 25 cm thick concrete without floor lining	100	100
	Medium-heavy fitment arches HEB 180, partly sheeted and grouted concrete 16 cm without floor lining	116	148
Crumbly	Fitting Bernold sheets with 25 cm thick concrete, with floor lining	112	100
	Heavy fitment HEB 200 partly sheeted and grouted concrete 18 cm with floor lining	136	166
	Heavy fitment HEB 200 with outer lining 50 cm, with floor lining	141	173

When rock conditions permit the use of rock bolts with wire netting and possibly guniting the cost of the lining is in the range of 50 to 80% of the cost when using the Bernold system.

it a further advantage of this system. The blasting and the fixing of the lining are very closely related when it comes to the question of timing. For adequate organisation of the entire advance operations one has to aim at a definite rhythm in the shift and daily outputs. The unknown factor in this rhythmic operation as between blasting and lining is the rock itself. The filling in of cavities resulting from rock falls is time-wasting and costly with all the conventional construction methods. As a result of the rapid installation of the concrete arch this can often be avoided when using the Bernold system. Any major overbreak can be rapidly filled in due to the use of efficient concrete placing plant, without any essential alterations being necessary in the daily programme.

Construction Programme

In any building job the adherence to a contractual construction programme is the first duty both of the client and of the contractor. How often have low and very low advance performances led to delays in the construction programme. Bad rock conditions often influence the entire progress of the work and optimistic completion dates cannot be adhered to. As a result of the advantages we have referred to it is possible with this rational method of installation to achieve quite considerable progress even when rock conditions are unfavourable. The degree of utilisation of the efficient and expensive set of drilling equipment for blasting becomes far better than with the conventional systems. If it is borne in mind that nowadays, even for medium sized construction sites, investments of 2 to 3 millions Swiss francs in plant and general installations are by no means rare, the contractor can readily calculate what savings in interest and depreciation can be achieved in the course of say a month. The client should also be interested in the comparatively lighter repercussions of labour and materials increased costs.

Disadvantages

All construction methods are subject to disadvantages or at least to certain unpleasant features which have to be borne in mind. The author of the project should before the work is started take steps to find out all he can about the nature of the rock and the threat of water which can be expected. In the case of varying stability of the rock, detailed preliminary studies and comparative calculations must be carried out, covering different methods of execution. When one comes to select the concrete shuttering process, the design of the tunnel lining and the method of constructing the arch are determined at the same time; any changeover to a different system during the construction operation — for example to a simple rock reinforcement with shuttering — entails technical difficulties and additional costs. The suitability of the proposed scheme should be thoroughly checked before a start is made on the construction.

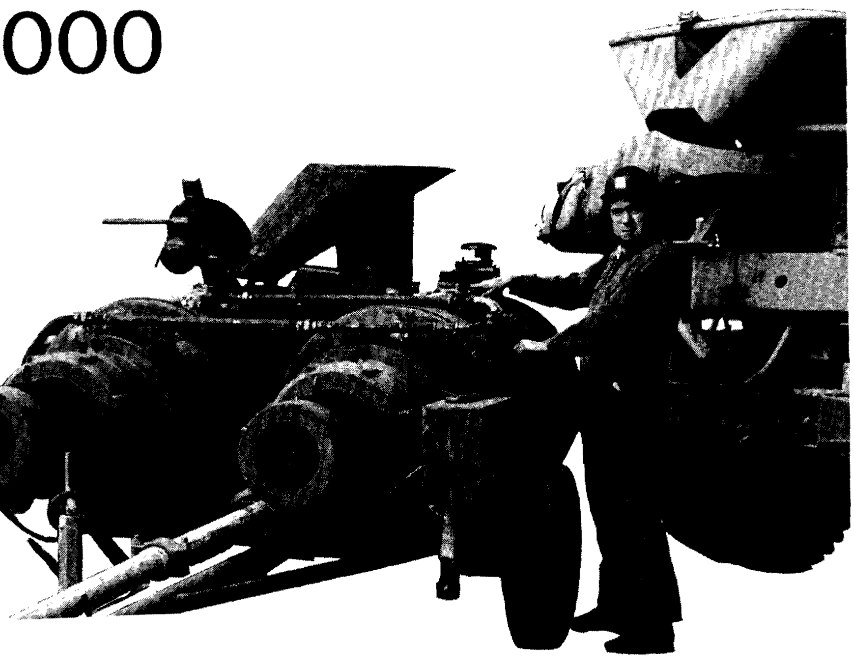
The engineer carrying out the planning and also the engineer putting it into practice will always come up against the question as to the extent to which this shuttering method of construction can replace the steel lining, especially the solid lining in very fragile rock. On this point one should state as follows: It is clear that in the case of very fragile rock the length of advance is reduced to 1 metre and only one arch can be installed each time. For the installation of these short stage lengths — striking, moving and erecting one arch, moving up the plant and backfilling — one usually requires 4 hours exclusive of any special precautions which may have to be taken. During this minimum time, therefore, the exposed rock should remain stable and not break away to any extent. The driving through of a roof gallery, the insertion of the supporting ribs and the concreting of the top arch stage by stage are feasible, but the result would be that this construction system which in itself is economical would to a large extent lose its advantages.

The question which is often posed, as to whether temporary arches and sheets could not be replaced by conventional shuttering hardly calls for an answer. By doing this one would immediately lose the advantages we have referred to of this unit system, without at the same time achieving any other advantages.

Practical experience to date has shown that this novel and original lining system is making an important contribution to progress in tunnel construction.

Spirocret

S 2000



S 1000

Spray-through method through the BERNOLD SHEETS according to the wet spraying method, grading of 0—15 mm and PC 300. The spray nozzle is placed near to the beads in the sheets. Spraying pression approximately 4 atu.

SPIRC

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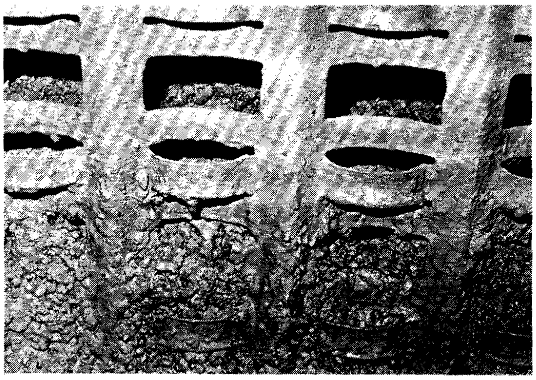
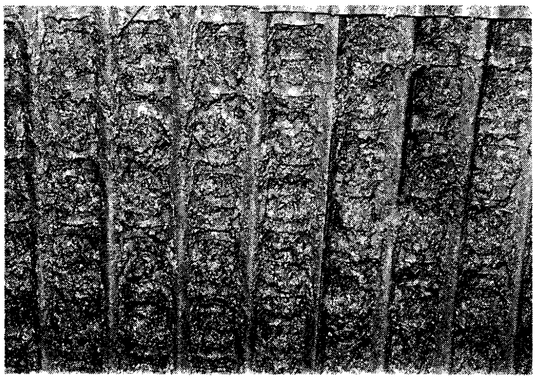
The beads in the BERNOLD SHEETS which have been especially punched out for the spraying through. Section of spraying through 12 × 8 cm. Little return. Void spaces completely filled up.



SPRAY CONCRETE

Surface view of the sheets sprayed through with spraying concrete, W/C factor 0.48—0.52, before guniting.



The SPIROCRET may convey on a total length of up to a hundred meters a concrete of stiff-plastic consistency with a grading of 0—30 mm, PC 200—350 and W/C factor of 0.40—0.50. The conveyance takes place continuously by air lift with a medium pressure of 2—3 atu. For short distances up to 50 m use rubber hoses ∅ 90 or 100 mm and for longer distances concrete conveying tubes.
Capacity:
S 1000 = 8 — 12 m^3/h
S 2000 = 18 — 24 m^3/h

CONVEY

CRET

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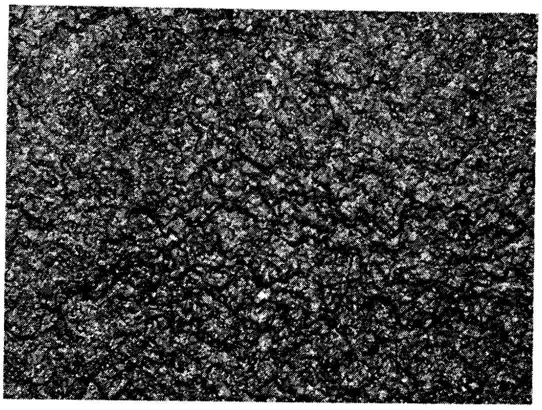
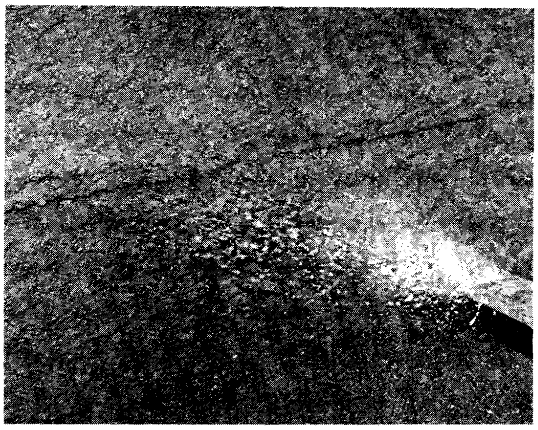
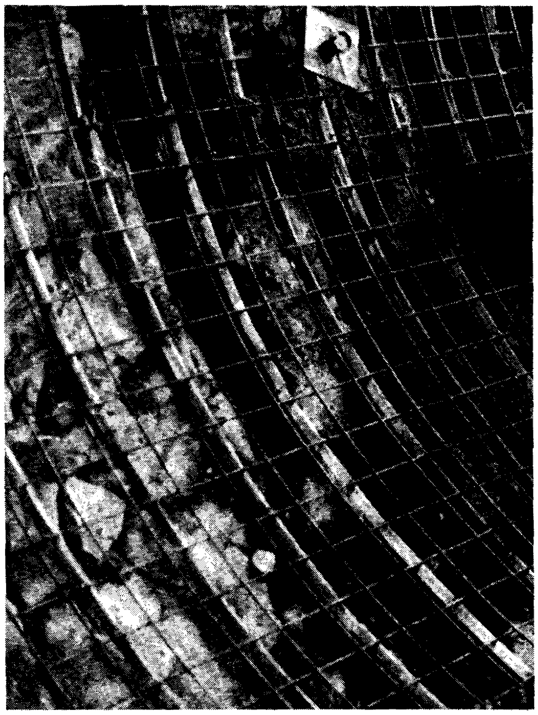
APPLY GUNITE



Sprayed concrete with a grading of 0—15 mm, PC 350 and a W/C factor of 0.42 to 0.45 in thicknesses from 3—6 cm sprayed on the bare rock. Compressive resistance of concrete after 7 days between 280 and 300 kg/cm^2 and between 430 and 480 kg/cm^2 after 28 days. Conveying distance up to 80 m. Capacity 8 to 10 m^3/h.



The special spraying nozzle of the SPIROCRET has a good distributing effect. The concrete which is being conveyed with a pressure of only 4 to 5 atu therefore has good adhering qualities and there is very little return.



Patented BERNOLD ROCK-SECURING MATTING, bent exactly to profile and fixed to the rock by anchors.

Sprayed concrete through BERNOLD ROCK-SECURING MATTING graded 0 to 15 or 0 to 30 mm, PC 300 and W/C factor 0.40 to 0.50. Owing to the special construction of the rock-securing matting, concrete thicknesses of 15 cm from the sole up to the springing height can be put up in one operation. In the roof the thickness of the layer which is put up in one operation should not exceed 5 to 6 cm without addition of a quick binding substance.

NCRETE

The SPIROCRET is manufactured on a prefabricated assembly system, so that every part of the machine can be removed and changed quickly and without difficulty. In addition to the spiral stirring mechanism a special feature of the SPIROCRET is the changeable wearing lining, which is made of special quality material which gives the machine an almost unlimited life span. This is all the more important since all concrete feed machines or concrete mixers are subject to heavy wear from abrasion.

The pressure tank consists of a cylindrical welded construction. The filler opening has a diameter of 350 mm, and after filling is closed by an airtight rapid locking cover or an electropneumatic rapid-locking slide valve. This cover or slider is provided with an excess pressure valve and gauge. The outlet connection is situated at the front on the right, and the discharge connection at the rear in the centre. The top airfeed takes place by special nozzles through the vertical wall of the filler gap, the bottom airfeed directly into the pipeline. The pressure tank usually operates horizontally.

The spiral delivery and mixing unit is a new innovation in connection with a sealed pressure tank. The spiral feeder consists of a shaft housed in the centre of both sections, to which the framework of the spiral is welded. The supports are screwed and welded to this framework, and the spiral developed over the whole length and breadth of the pressure tank. The supports and spiral which is developed over the whole length and breadth of the pressure tank, are screwed and welded to this framework.

The pressure tank is provided with an excellent changeable wear lining 4 mm thick. This comes in two parts. The rear section can be removed, so that in the event of blockage or wear and tear on the spiral mixing or stirring unit, and the wear sheath, repairs can easily be carried out.

The spiral delivers the mix, which is put in at the end of the pressure container, towards the discharge connection.

The spiral is actuated by a 20 HP electric motor over a reversible reduction gear.
The spiral mixing machine is suited even for quick and strong mixing because the material is being moved spirally forward and backward (this is not possible with the usual mixing arms). The supports take up the function of mixing arms and mixing times can be kept down on a minimum.

This machine is built in two types. The first has one container, is mounted on wheels on one axle, the second has two containers, is also mounted on wheels and has one axle too. The machine with the two containers is provided with a rotating feeding hopper which rests on a ball bearing and is easy to operate. It can be actuated electropneumatically as well.

There is either a chassis with rigid axle and pneumatic tires for usage on building sites only or a chassis for circulating on normal roads at a top speed of 80 km/h.

Air consumption:
SPIROCRET S 1000 and S 2000 about 10 m³/min.
Pressure on pipe or hose end 2—4 a.a.p. according to length of pipe.

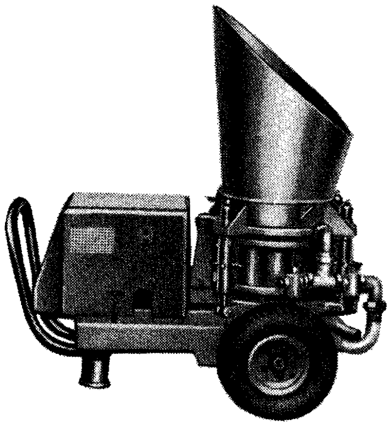
Compressed air control:
Through unilaterally controlled plants with rapid locking cock, venting ball cock, gauge and excess flow safety valve.

BERNOLD AKTIENGESELLSCHAFT
CH-8880 WALENSTADT

TÉLÉPHONE 085 3 56 44 - 45 TÉLEX 74 260

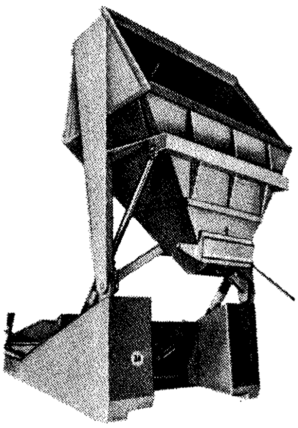
SPRIBAG Aktiengesellschaft - WIDEN / Mutschellen - Telefon 057 / 7 63 94
Maschinenfabrik

Fabrikation von Gunit- und Spritzbetonmaschinen, Betonfördermaschinen, Beschickungsanlagen, Silos, Perfo-Rohren und Stahlankern



SPRIBAG-Rotor MS-05 für Spritzbeton und Gunit

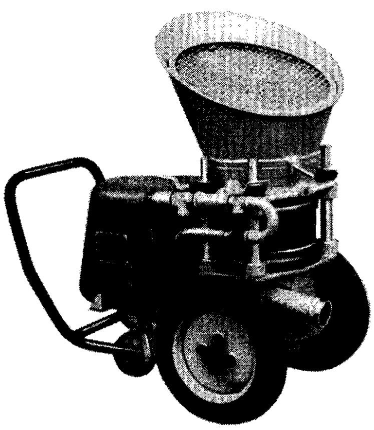
Antrieb	Elektromotor 6 PS oder Druckluftmotor 8 PS
Luftverbrauch	8–15 m³/min bei 4–6 atü
Leistung	5 m³/h Trockengemisch
Korngrösse	0–20 mm
Förderlänge	bis 250 m
Gewicht	ca. 655 kg



SPRIBAG-Kippsilo KS-6

robuste Schweisskonstruktion, fahrbar, selbstaufstellend

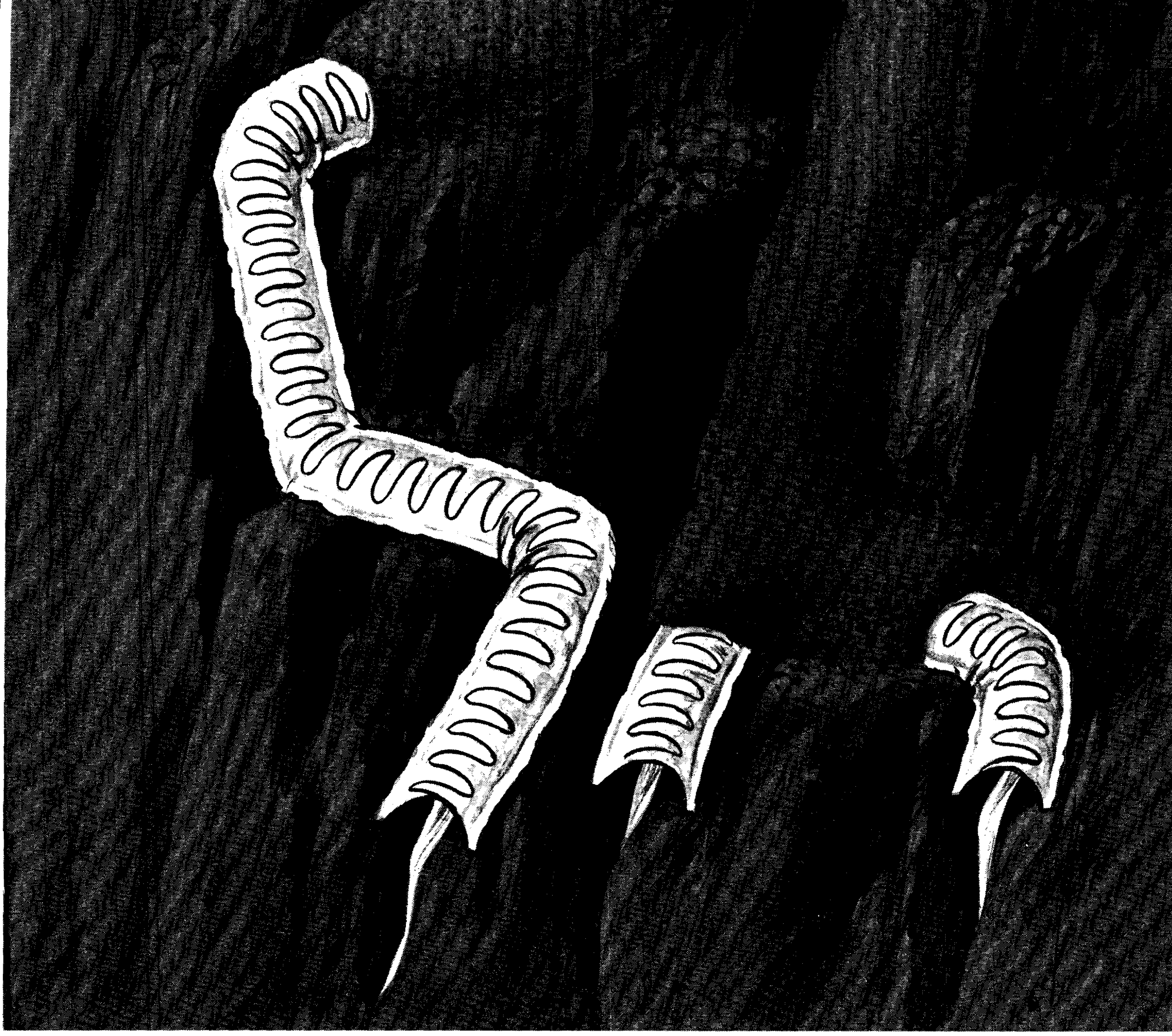
Antrieb	Elektromotor 12 PS / 380 Volt
Hydraulik	Zahnradpumpe mit Oeltank ca. 45 Liter
Hubkraft der Hydraulikzylinder	36 Tonnen
max. Füllgutgewicht	12 Tonnen
Hubzeit	50 Sekunden
Gesamtbreite	2660 mm
Auskipphöhe (ohne Unterlage)	1585 mm
Höhe aufgekippt	4870 mm
Licht- und Signalanlage (auf Wunsch)	6,12 oder 24 Volt
Gewicht (fahrbereit)	3700 kg



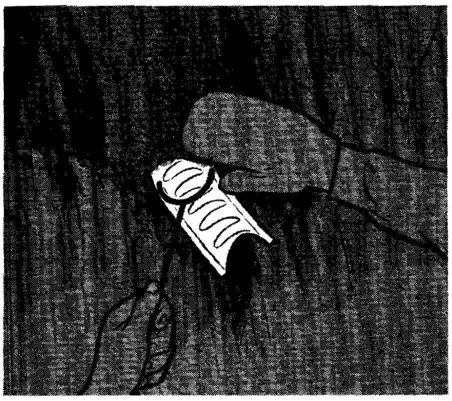
SPRIBAG-Rotor Junior SG-08/15

Sandstrahl-, Gunitier-, Verputz- und Vordichtungsmaschine

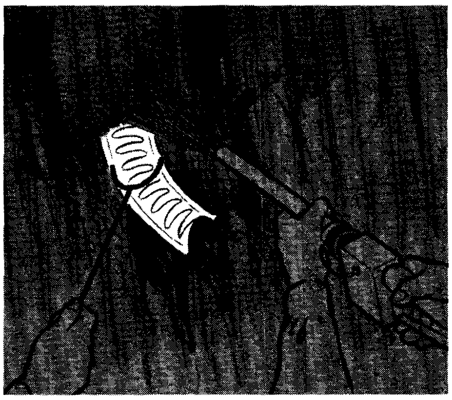
Antrieb	Elektromotor 3 PS
Luftverbrauch	3,5–5 m³/min
Leistung	0,5–2 m³/h Fördergut
Korngrösse	bis 15 mm
Förderlänge	bis 300 m
Gewicht	ca. 280 kg



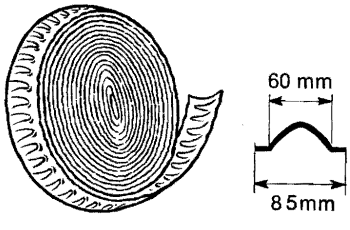
SPRIBAG SIKA-DRAINAGERINNE



Manueller Auftrag



Maschineller Auftrag



Lieferbar in Rollen à 50 Meter

SPRIBAG

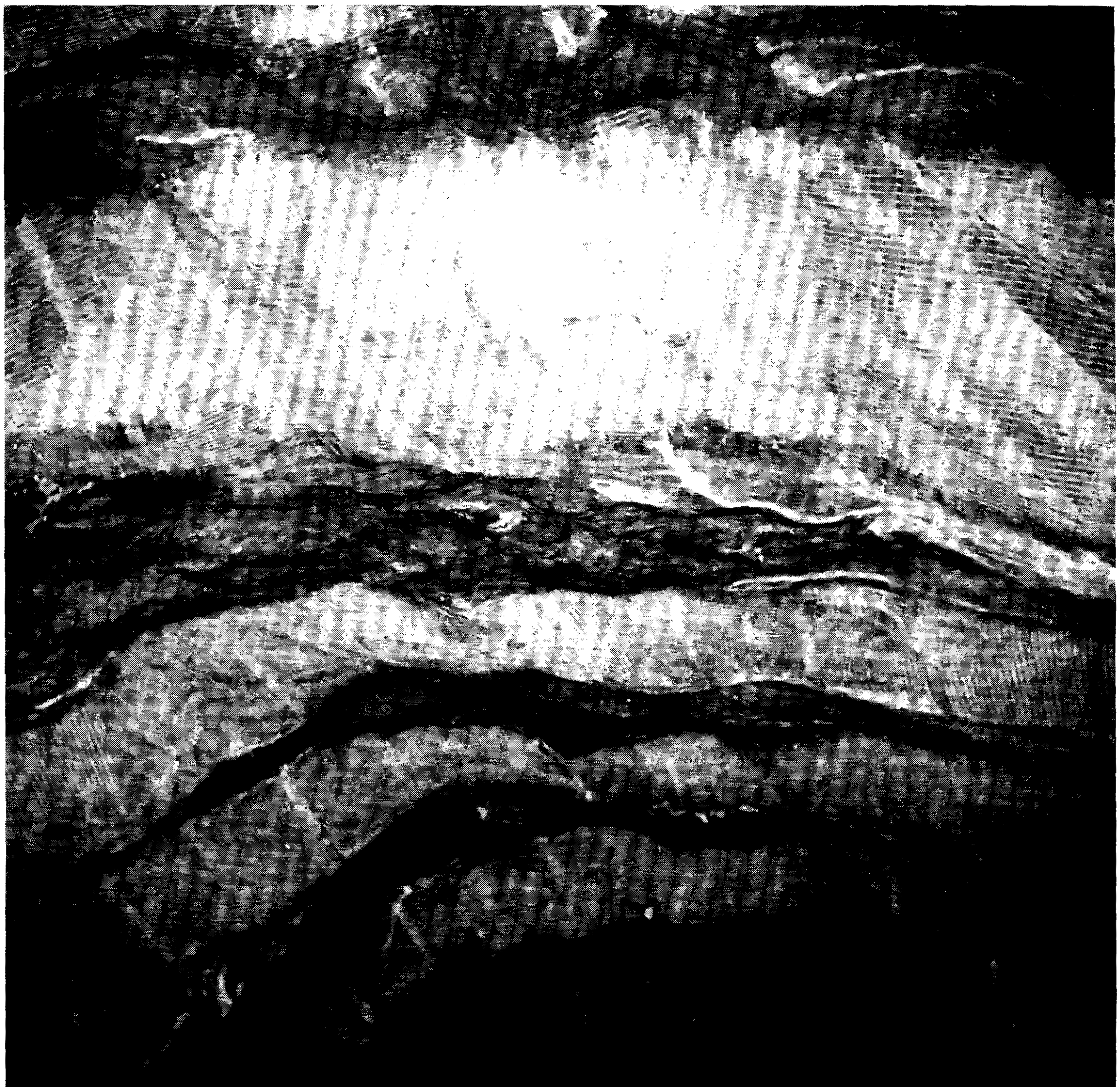
Die SIKA-DRAINAGERINNE wird überall dort Anwendung finden, wo Wasser von Hand oder mit pneumatischer Vordichtung abgeleitet werden muss.
Die Vorteile einer raschen und zweckdienlichen Linienführung der Wasserableitung ergibt sich aus der flexiblen raupenähnlichen Ausbildung der SIKA-DRAINAGERINNE und wird sich bei Unebenheiten auf Beton oder dem Felsprofil sehr gut anpassen, ohne eine wesentliche Einengung des Hohlraumprofils in Kauf nehmen zu müssen. Die Halbschale weist einen Hohlraum-Querschnitt von ca. 6 cm auf.
Ebenfalls können mehrere astähnliche Verzweigungen zu einem Leitungsstrang zusammengefasst werden.
Wurden früher z. B. bei Felsabdichtungen hauptsächlich Eternit- oder Blechkanäle zur Ableitung eingebaut und später mit Gunit überspritzt, so bildet heute die mechanische Abdichtung mit der SIKA-DRAINAGERINNE ein wesentlich einfacheres Verfahren. Die Praxis hat deutlich veranschaulicht, dass mit dem systematischen Einbau der SIKA-DRAINAGERINNE wie zum Beispiel beim nassen Sandstein eine sehr gute Drainierung des Felsprofils und mit dem darüber folgenden armierten Gunit und Spritzbetonaufbau die nötige Verdrängung des Wassers in die Ableitungen mit der SIKA-DRAINAGERINNE erreicht wurde.

En zones très mouillées par de fortes venues d'eau en dispersion application du

GUNIPLAST

sur la roche

Avantages : Etanchement total par captage et drainage des eaux
Rapidité d'exécution par rapport au système habituel
Diminution du coût des travaux de captage



BOOMER 131

Jumbo for drifting and tunnelling

Atlas Copco

Flexible and rugged jumbo speeds production and cuts costs

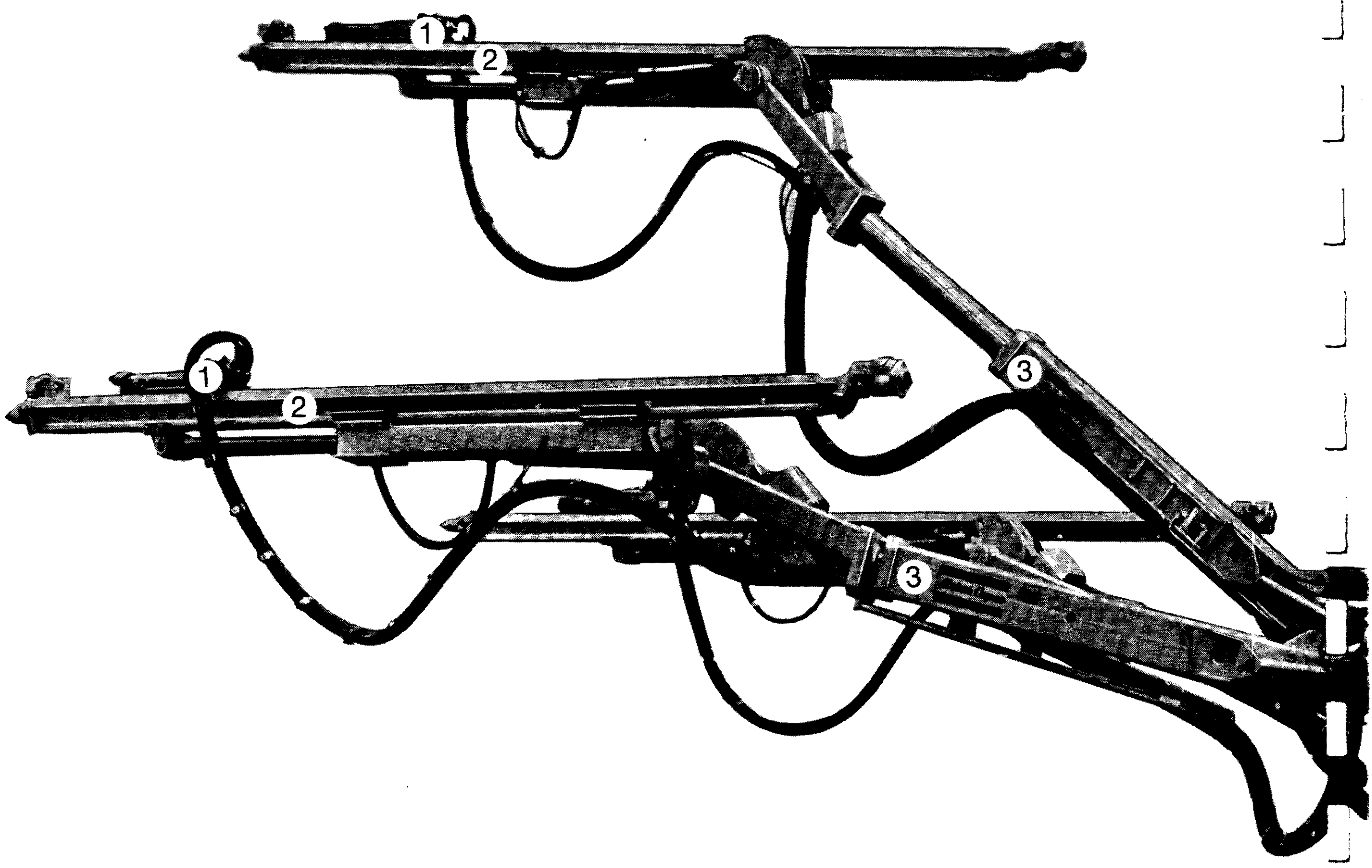
Jumbo for drifting and tunnelling

With both four-wheel drive and centrally articulated steering the Boomer 131 travels easily and swiftly adjusts to a new drilling site. The traction engine has the power reserve to cope with situations out of the ordinary — the brake system is similarly proportioned.

The wide-reaching boom system covers large areas up to 60 m^2 and features excellent alignment facilities. The rigid booms keep solidly to the set positions.

The rock drill has a high torque and an effective impact mechanism, a combination resulting in a high penetration rate with a low drill steel consumption.

The operator's cab is comfortable and the visibility good, both for travelling and for drilling. The operator works his full shift efficiently, without fatigue.



Components of Boomer 131

1. BBC 120 F rock drills. Boomer 131 can also be equipped with the separately rotated, silenced rock drill COP 90 ED.
2. Strong, aluminium-alloy feed beams can be equipped for the automatic return of the rock drill and disengagement of the impact mechanism.
3. The powerful hydraulic booms are operated by double-action cylinders with automatic locks. Horizontal as well as vertical parallel holding are always possible.
4. Two hydraulic jacks and two outriggers hold the jumbo in the set working position and relieve the articulated joint and the rear wheels of the load during drilling.
5. Four-wheel drive with differential locks on both axles. The disc brakes are hydraulically operated through two completely separate circuits.
6. Three air-powered turbo lamps, type FW 16, assure good lighting of the entire drilling site.

Investing in production

Fast and safe travelling between sites leaves more time for actual drilling. Boom alignment and collaring are swift and easy. Add fast and powerful rock drills and there is only one possible result — the ideal ratio between capacity and costs. The capital investment in a Boomer 131 is the safe basis of future profits.

Capital costs are only a small portion of the overall costs of mechanised drifting and tunnelling. If you take **all** phases of operations into account, you'll find that the Boomer 131 will reduce the overall cost of each cubic yard of rock.

Exceptional versatility

The Boomer 131 easily performs any standard jumbo programme but is far from limited to conventional jobs. It drills tunnels with areas ranging from 12 to 60 m^2 (130—650 sq.ft) and can be used for every type of underground drilling — from tunnelling and drifting to crosscut driving, roof bolting and benching. And it still needs only one man to operate it.

The booms can be converted to accomodate different kinds of work thanks to our highly developed standard component system. This means that you get a full return on the capital invested in a Boomer 131.

7. The control panels are placed centrally, always accessible to the operator.
8. The operator's seat is mounted to absorb vibrations and is adjustable in height.
9. The flexible but robust articulated steering has vertical bearings which allow the unit to pivot along its own axis.
10. Two double-action hydraulic cylinders mounted at the articulated centre, are activated by the movement of the steering wheel and turn the front part of the carrier.
11. The air line is 3" and provided with a separator for condensate.
12. Water intake. The 1½" water pipe has a throttle valve for constant pressure.
13. The powerful 118 HP SAE engine provides a tractive force of 12 200 kg (26 900 lb).
14. Hydraulic oil tank with compressed air driven pump.

Rock drills — high drilling rates at low cost

Boomer 131 is fitted, as standard equipment, with Atlas Copco BBC 120F (Buffalo) or COP 90 ED rock drills.

BBC 120 F

The BBC 120 F, with a powerful impact and rotation mechanism, is the natural choice with $1^1/_4''$ or $1^1/_2''$ drill steel equipment. This rock drill has documented reliability and is being widely used for tunnelling, benching and long hole drilling all over the world.

COP 90 ED

The COP 90 ED, for 1″ drill steel equipment, has a reversible, separate rotation mechanism, driven by a vanetype air motor. Both the impact mechanism and the rotation motor are housed in the impact mechanism casing which also functions as a silencer hood. The height of the drill above its centre line is only 79 mm ($3^7/_{64}''$), which facilitates drilling near the roof and sides.

The COP 90 ED is silenced and has an exceptionally low air consumption in relation to its high drilling rate.

A choice of four different types of feed

Screw feeds: the 10 ft BMS 810, 12 ft BMS 812 and 14 ft BMS 814.

Chain feed: the 14 ft BMM 35 K 152.

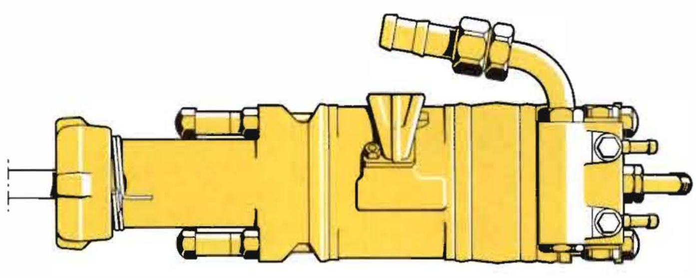
The feeds can be adapted to suit all combinations of hydraulic booms, drills and rods. They can be extended by 1,600 mm (5 ft 3 in) in the feed holders of the hydraulic booms. Equipment for the automatic return of the drill and automatic turn-off of the impact mechanism can also be fitted on the feeds.

Screw feeds

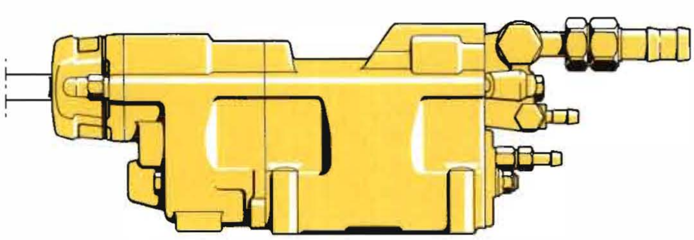
The screw feed sits in a robust but light metal sectional beam. A double-piston, four-cylinder air motor drives the feed screw via a simple gear set. The front drill steel support is fixed in place and has a replaceable guide bush. An intermediate drill steel support prevents deflection of the drill steel and the screw. This support is advanced by the rock drill, providing continuous support; it can be easily opened. The return speed of the feeds is high.

Chain feed

The chain feed has two reinforced U-beams welded together. A cross-piston type motor drives the chain through a worm gear. A chain tensioner is housed at the rear of the feed beam. The solid drill steel supports are easy to open.



BBC 120 F



COP 90 ED

The boom system — versatility and maximum reach

The great reach and excellent alignment properties of the boom system on Boomer 131 allow the coverage of a wide range of faces and patterns without expensive conversions or modifications.

Boom combinations for all cross sections from 12 to 60 m² (130—650 sq. ft)
Boomer 131 can be equipped with three BUT 14 hydraulic booms or two such booms and one boom carrying a charging platform. With various combinations of fixed-length, extension and rotary booms, the jumbo can accomodate all faces from 12 to 60 m² (130 to 650 sq.ft) in area.

Fixed-length boom — BUT 14F
A standard boom for normal areas.

Extension boom — BUT 14E
Specially suitable when great reach is required — for instance, in drilling the upper part of the face in large tunnels. The telescoping mechanism enables the boom to be extended by up to 1600 mm (5 ft 3 in).

Rotary boom — BUT 14RO
Contour holes and bottom holes can be drilled with a minimum deflection angle with the rotary boom. Overbreak is sharply reduced, improving the economy of operations — particularly in the case of concrete-lined tunnels.

The boom covers the whole of the drill pattern area with no reconnection necessary, since it can rotate 360° about its longitudinal axis.

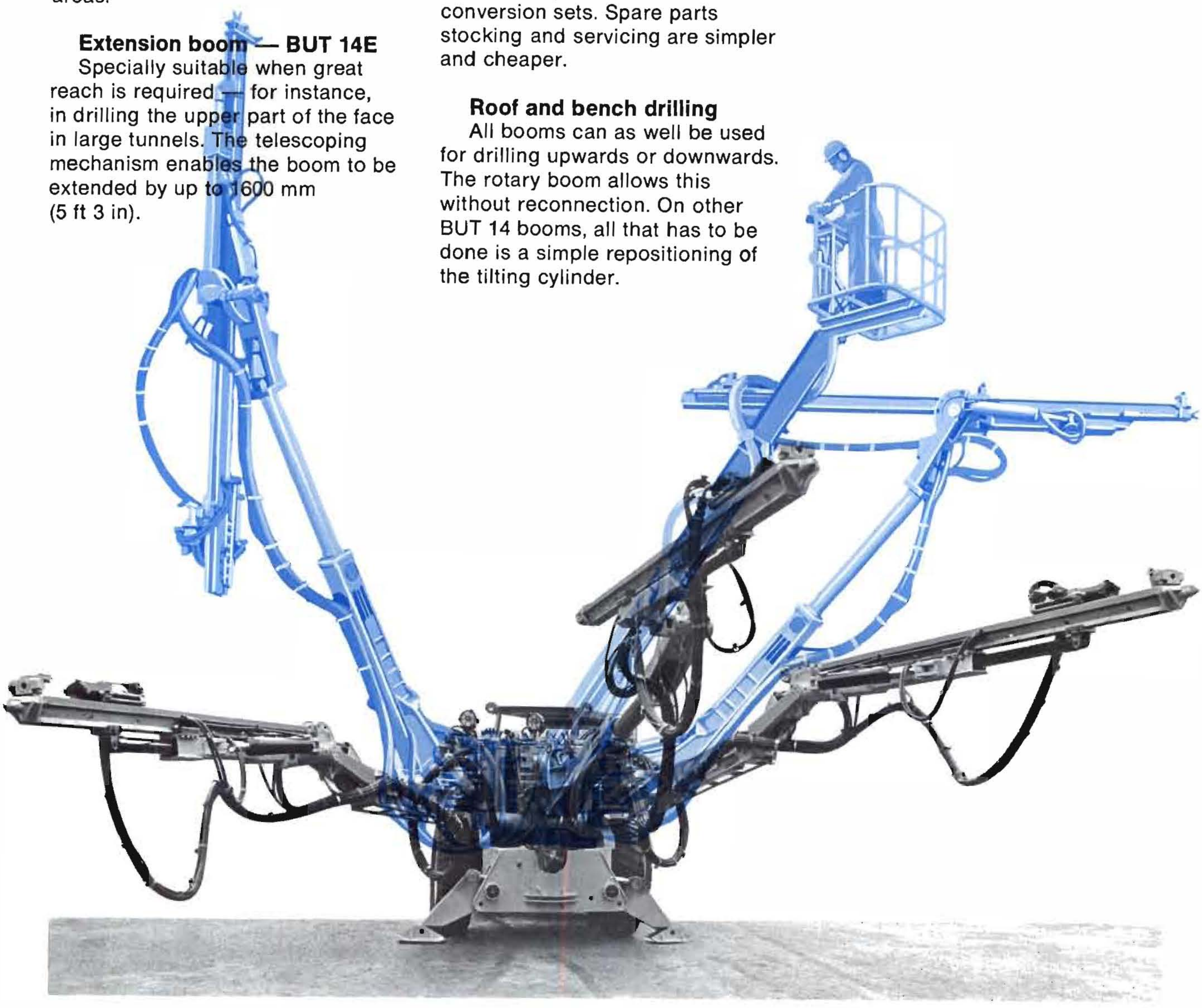
Flexible design
As all types of boom are built up from standard components, the booms can be easily converted and adapted for use on a different tunnel area or shape. A fixed-length boom can be converted to an extension boom or a rotary boom, and vice versa, with the help of standardized conversion sets. Spare parts stocking and servicing are simpler and cheaper.

Roof and bench drilling
All booms can as well be used for drilling upwards or downwards. The rotary boom allows this without reconnection. On other BUT 14 booms, all that has to be done is a simple repositioning of the tilting cylinder.

Charging platform boom for greater flexibility
With a BUT 14E on each side and an HL 32 charging platform boom in the middle, the jumbo can drill large areas and be used for charging or roof bolting simultaneously.

The charging platform boom is made up of rectangular beams and is of the double extension type with a reach of 8.3 m (27 ft). It satisfies the most stringent safety requirements.

The controls are mounted on the platform, where a foot valve to start the pneumatically operated hydraulic pump is also located. As additional equipment, double controls are also available allowing the charging platform to be operated from normal operating position as well.



Accurate and fast alignment

Rapid alignment in the desired position is made possible by the rigid construction of the booms, the powerful hydraulics and the possibilities for accuracy in movements.

Alignment is also made much easier by the articulation of the jumbo. The jumbo can remain stationary while the hydraulic cylinders at the joint alter the relation of front and rear parts to one another and align the booms in the required position. Thus repeated backing movements are not required to bring the jumbo into correct position for drilling. Valuable drilling time is saved.

Suitable for crosscut driving

The movement pattern of the booms and the articulated joint make Boomer 131 extremely well suited for starting side galleries directly from a narrow drift where a unit with rigid chassis would have great difficulties.

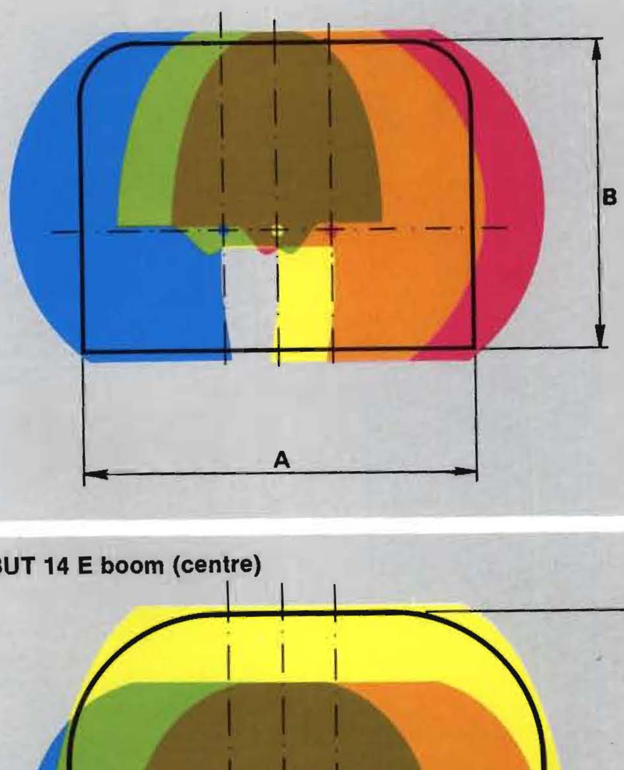
Robust booms prolong drill steel life

The booms are made of rugged micro-alloyed, square steel sections. This gives stability to the feed, increases the accuracy of positioning and reduces the risk of drill steel deflecting. The consumption of drill steel is therefore lower. A long service life and low maintenance costs can be expected from the sturdy construction.

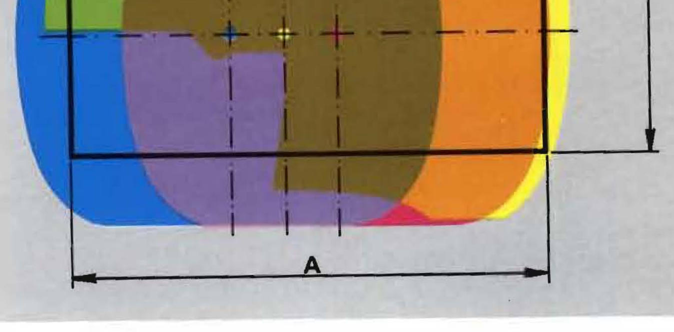
- Left hand boom
- Center boom
- Right hand boom

Fields with mixed colours indicate overlapping of target areas.

Three BUT 14 F booms
Area covered 30 m² (325 sq.ft)
A = 6,2 m (20')
B = 4,8 m (16')



Two BUT 14 RO booms, one BUT 14 E boom (centre)
Area covered 40 m² (430 sq.ft)
A = 7,5 m (25')
B = 6,2 m (20')



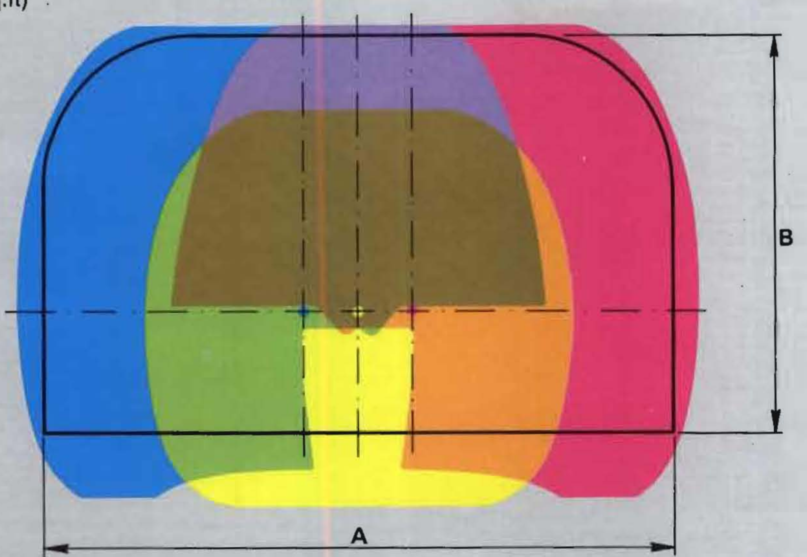
Check valves increase safety
All hydraulic cylinders have automatic check valves. The booms therefore remain in their positions even in the event of breakdown or a leakage of oil.

Automatic parallel holding
The BUT 14F and BUT 14E are equipped as standard with a parallel-holding system (pilot assembly). This maintains the alignment of the feed beam automatically, so that it moves parallel to its previous position when the boom is moved vertically. This is especially important when drilling roof contours where it is difficult to judge boom angles from below and where an error causes a direct increase in overbreak. If required, the BUT 14 RO can also be supplied with automatic parallel holding in the vertical.

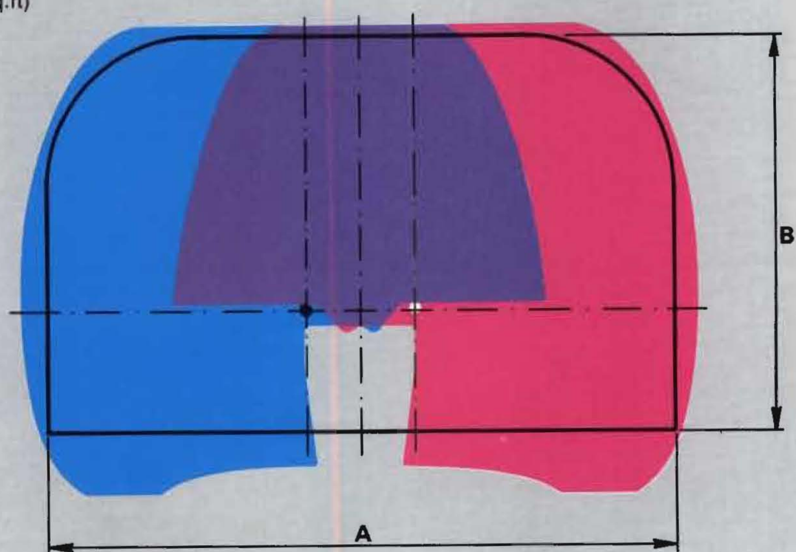
The automatic parallel holding system enables parallel cuts to be drilled with great accuracy, even by an inexperienced operator.

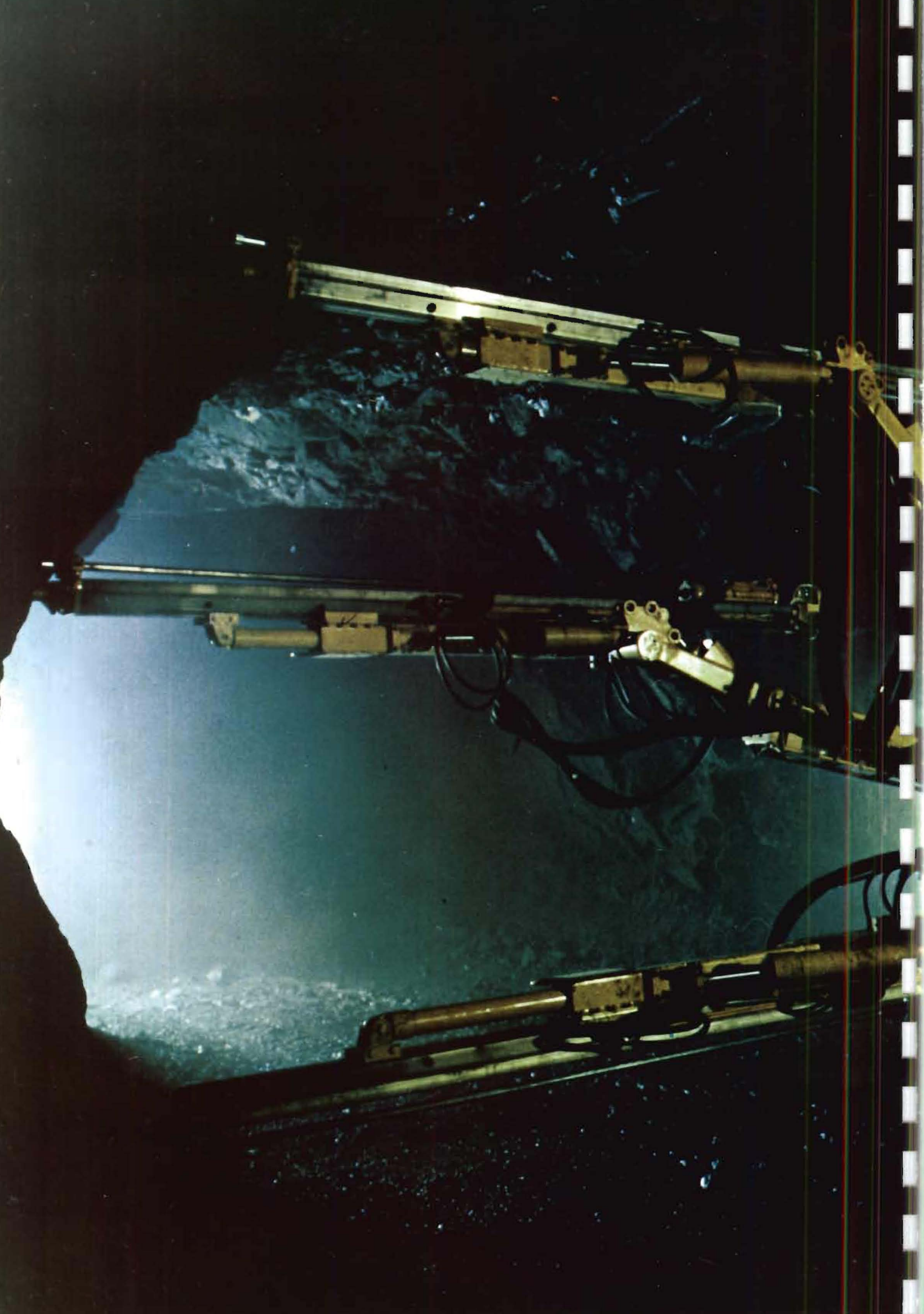
A parallel holding arrangement for transversal movements is also available, an excellent complement to the vertical parallel holding in increasing drilling precision.

Two BUT 14 E booms, one BUT 14 RO boom (centre)
Area covered 60 m² (645 sq.ft)
A = 10 m (33')
B = 6,2 m (20')



Two BUT 14 E booms, one HL 32 charging platform boom (centre)
Area covered 60 m² (645 sq.ft)
A = 10 m (33')
B = 6,2 m (20')



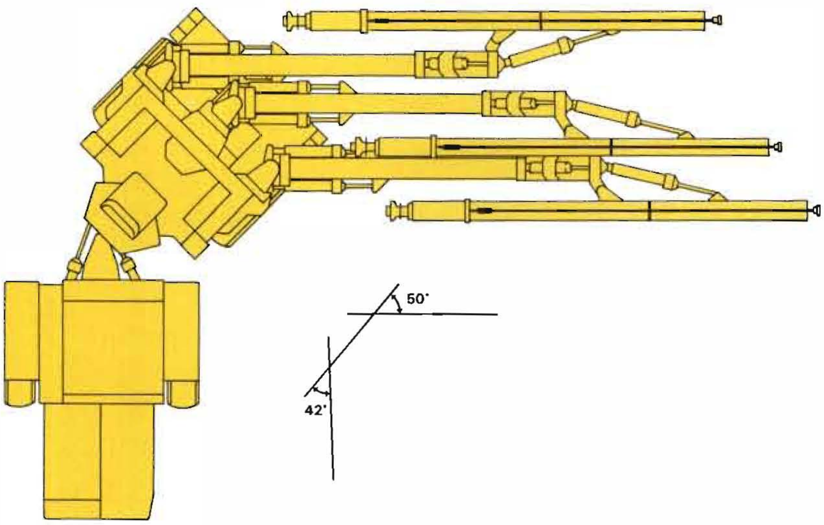


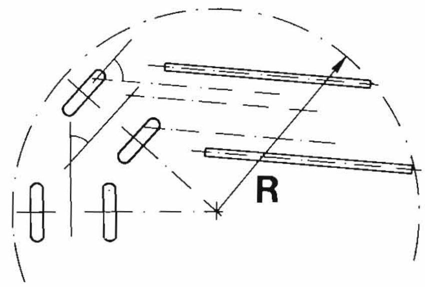
Excellent travelling properties

Boomer 131 moves smoothly over rough ground, on steep inclines, in confined spaces — safely and speedily.

Despite its size, the jumbo is simply and accurately manoeuvred in narrow drifts. It easily rounds corners thanks to the articulated joint and the flexibly mounted booms which can be swung during travelling.

The steering on Boomer 131 is directly **proportional**, that is any movement of the steering wheel always produces a turn of the same angle at the centre joint. This means substantially greater precision in steering than with other articulated machines, where the angular movement continues to increase as long as the steering wheel is out of the neutral position.





Minimum sweep radius
(R) 5,4 m (213 in)

Rapid in drifts — safe on inclines

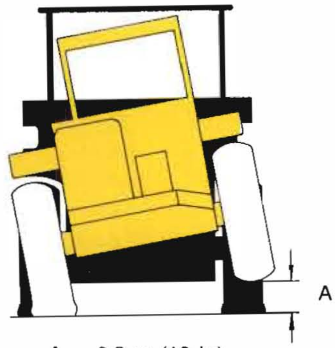
The six-cylinder diesel engine, rated at 118 HP SAE, provides high traction power for a quick advance in drifts and tunnels and steady and assured climbing on gradients The mechanical gearbox has four ratios in both directions of travel while the power transmission has full overload protection.

The maximum speed on level ground is 14 km/h (8.75 mph).

Four-wheel drive means powerful traction

Since all four wheels are driven, the jumbo does not easily get stuck in soft, slippery or uneven ground. All wheels maintain full contact even with rough ground, since the chassis also turns at the pivot along the **longitudinal axis.** Boomer 131 is superior in this respect to conventional jumbos with non-articulated frames and independent suspension of the wheels.

In addition, the Boomer 131 has a **differential lock on each axle.** This ensures that the wheels never spin even on slippery ground.

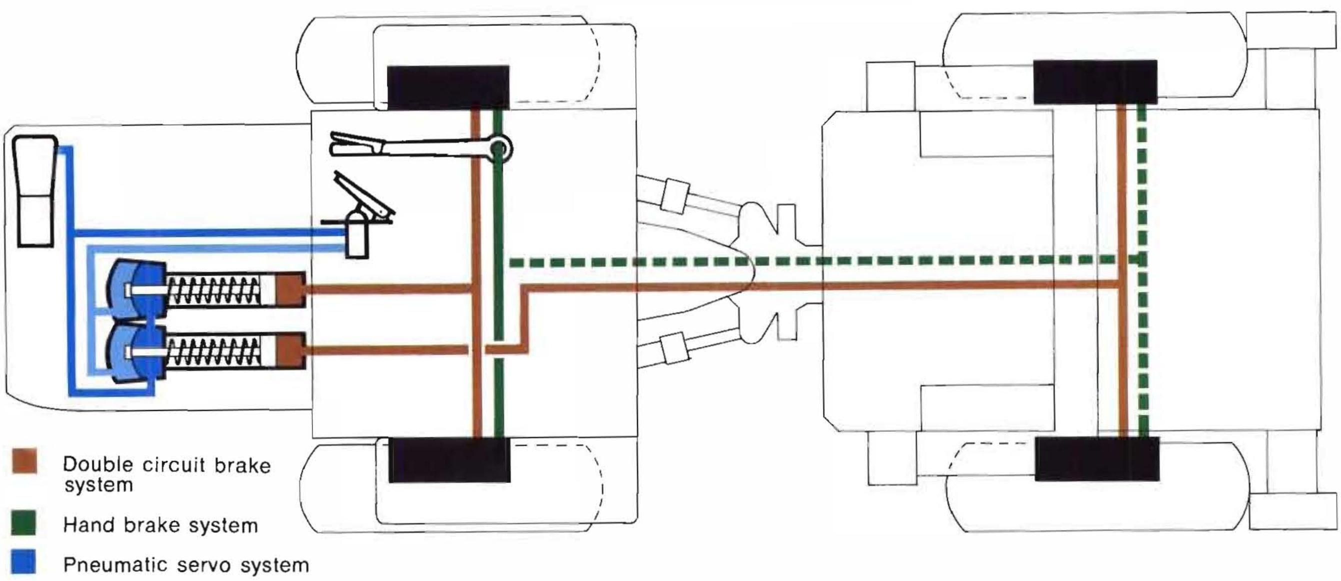


A = 0.3 m (12 in)

Three brake systems for maximum safety

All wheels are fitted with hydraulic disc brakes incorporating a pneumatic servo system (blue). The brakes are of robust design to provide maximum braking force. The brake system is made up of two entirely separate circuits (brown).

The disc brakes on the traction unit can be activated by the hand brake (green) but more important, Boomer 131 has a **fail-safe** brake system — the brakes come on as soon as the air pressure, from the built-in compressor of the jumbo, falls below a certain level. This means that the brakes will be applied if the engine should stall — an important safety feature on steep inclines.



The power supply — reliable and safe

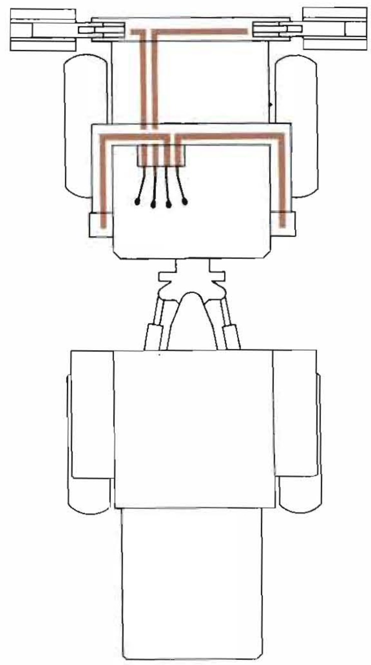
The electrical system
The electrical system of the jumbo has been designed with special reference to underground operations in high humidity, explosion fumes, etc. It has for this reason been fitted with robust screw contacts, well-protected control boxes, encased generators and start buttons, and so on.

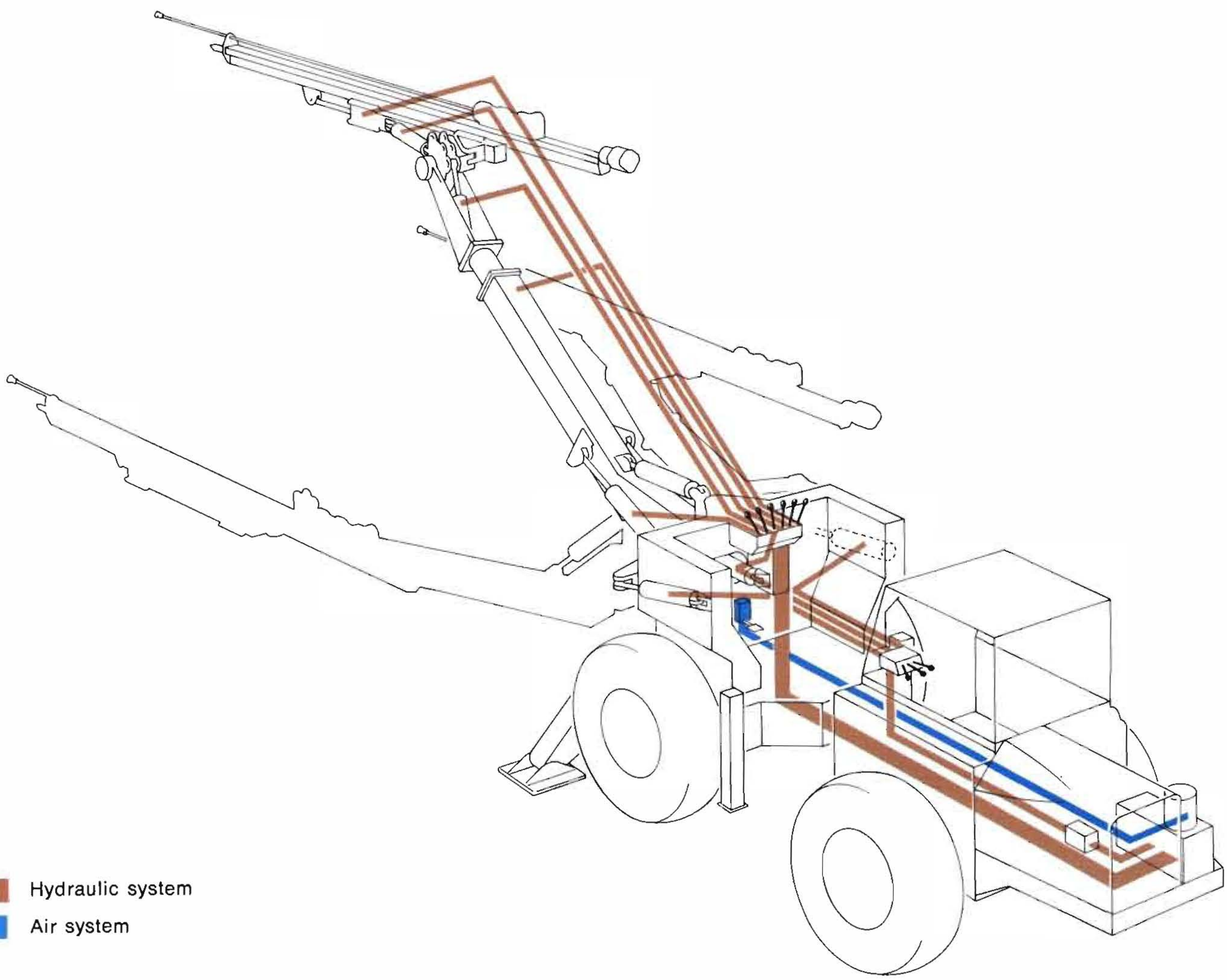
The hydraulic system
Boomer 131 has a separate hydraulic system for the operating cylinders of the booms, the chassis jacks and outriggers (brown). The hydraulic pump is driven by an air motor operated by a pedal in the operator's cab (blue).

As standard equipment, the Boomer 131 is fitted with an additional hydraulic pump which, in conjunction with the hydraulic system, allows the booms to be swung sideways through 50° in either direction during travelling.

The pump is driven by the diesel engine. Such movements of the booms are controlled from the driver's seat. Other boom movements can also be operated by this pump, e.g., raising and lowering the booms when compressed air is not available.

All pumps, valves and other components are protected from impurities by integral suction strainers and return oil filters.





Hydraulic system
Air system

Air and water supply

There is a common intake for air (blue) and water (green). A reducing valve limits the flushing water pressure. A 110-litre (24 Imp.gal) water separator, with cleaning hatch and drain cock, is connected to the air system. Change-over from water flushing to air blowing for cleaning the drill holes is a simple manual operation. An additional outlet for water and air is also available.

Boomer 131 is equipped with a central lubrication system for all rock drills and air motors.

The traction engine

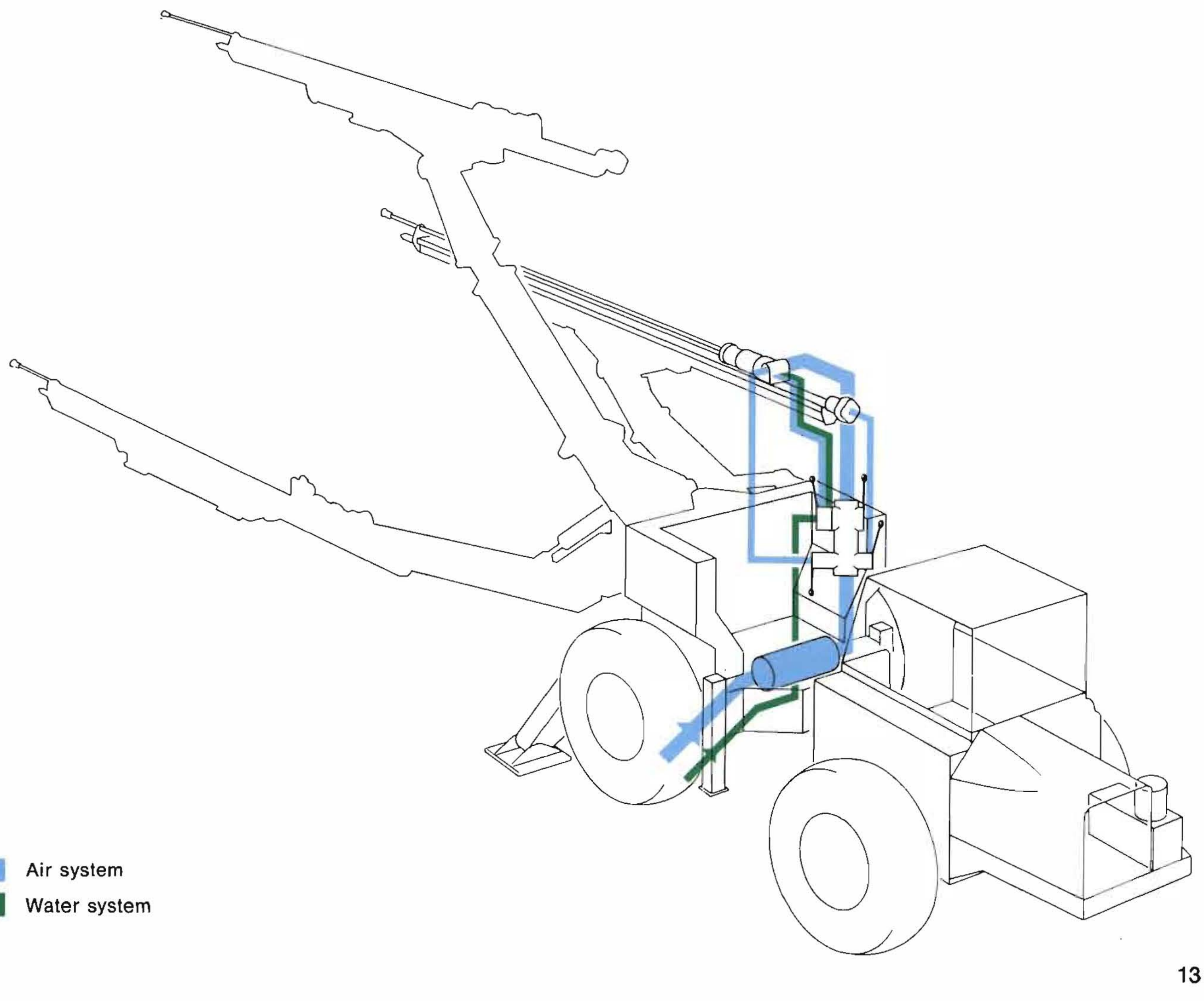
The engine is a six-cylinder direct-injection diesel engine with 118 HP SAE at 2800 rpm. The engine yields a high torque over a wide speed range.

The controls

Each boom has two control units, one for all hydraulically operated movements and the other for the pneumatically operated action of the feed rock drill and for the flushing water supply.

The control valves are grouped in a block, with common connections.

The feed can be started directly at the required pressure, thanks to a throttle valve and a pressure gauge in the air line to the feed motor. The optimum force is therefore immediately available.



Air system

Water system

The drilling platform — designed for efficiency

A well planned workplace is of prime importance for efficient work. It also means that the training time of the new operator will be shorter with less risk of mistakes. Boomer 131 meets all the requirements as regards operator comfort.

Consider the following important points:

The drilling controls are placed so that the operator can handle them either sitting or standing. This means that he can himself choose the working position. The drilling platform is equipped with a comfortable, sprung swivel seat whose height can be adjusted.

The floor is lined with a vibration-damping material.

The operator can move from the drilling to the driving position without having to climb down.

The controls for the booms are mounted separately, but are assembled in groups for convenience.

The hydraulic jacks and outriggers are also controlled from the cab.

The cab is protected by a sturdy roof and the drilling platform can also be fitted with an optional roof.

Pneumatically operated lighting for the drilling site, consisting of three FW 16 air turbo lamps mounted on detachable columns, is supplied as standard equipment. The lamps are of explosion-proof design.

Optional equipment

Automatic vertical parallelling system for BUT 14RO
But 14 F och 14 E are equipped as standard with a vertical parallel holding device and BUT 14RO can on order also be equipped with the same system. (Fig. 1)

Automatic horizontal system for BUT 14 F, 14 E and 14 RO
The booms can be easily modified with a conversion set to maintain lateral parallel alignment. (Fig. 2)

Drilling accuracy is then even further increased.

Protecting roof for the driller
The drilling control platform can be provided with a protecting roof to shield the driller from water and falling stones. The roof allows the driller to stand up and can be taken down while the jumbo is travelling. (Fig. 3)

Automatic return of the rock drill and disengagement of the impact mechanism
When the rock drill has finished drilling the hole, it can be automatically returned to the rear stop position of the feed, and the air supply to the impact mechanism turned off at the same time. (Fig. 4)

This equipment makes it easier for the operator to attend to three drills simultaneously, and also contributes to the reduction of rock drill and drill steel wear.

Exhaust purifier
As an additional safety feature, an exhaust purifier of the catalyst type is available.

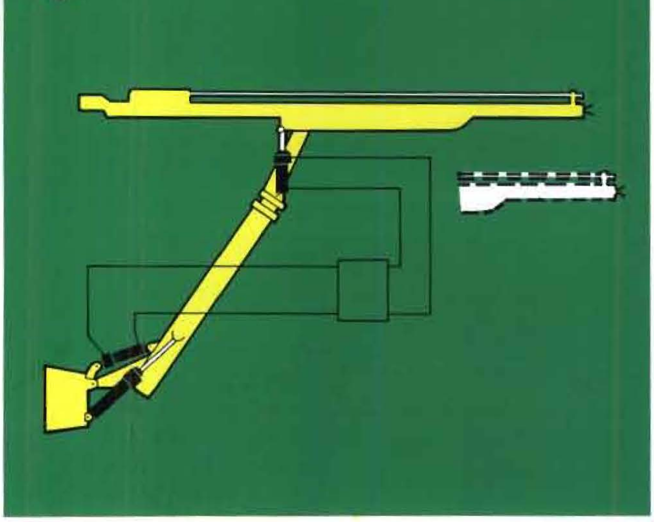


Fig. 1

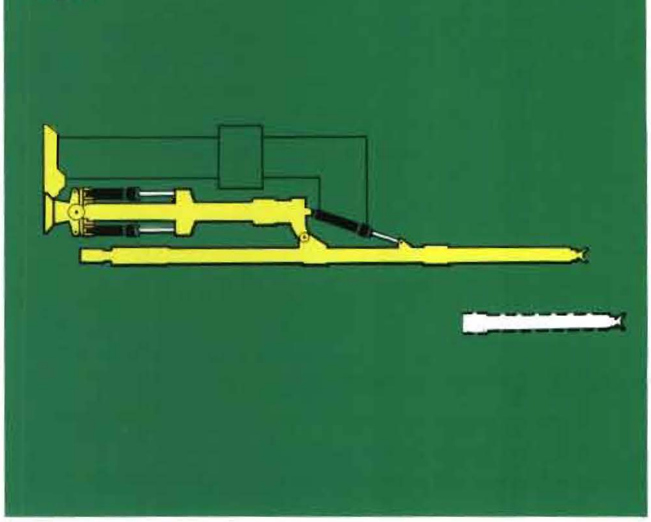


Fig. 2

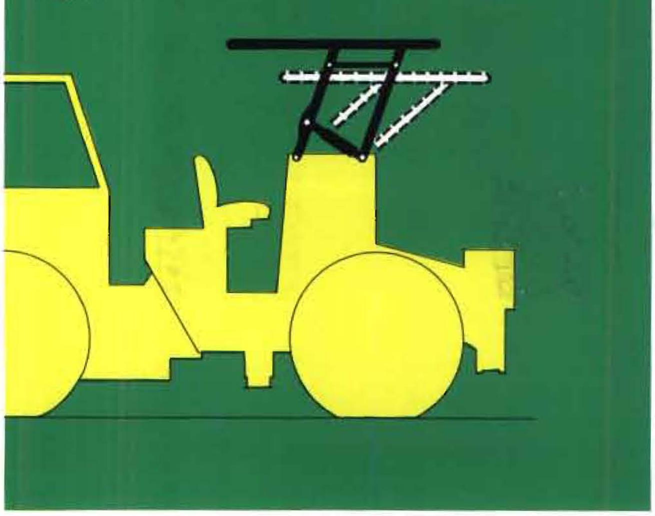


Fig. 3

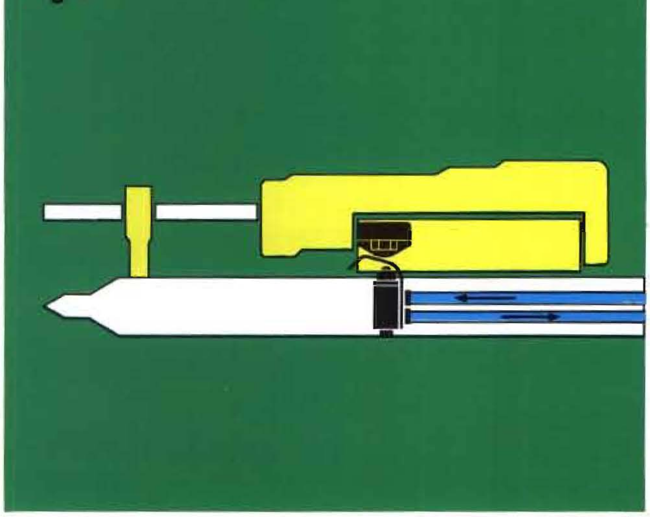
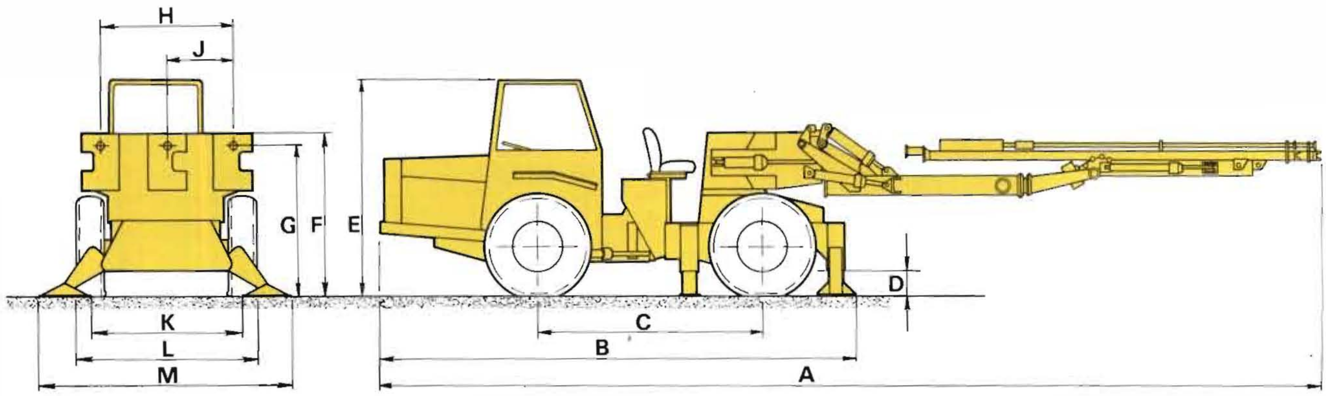


Fig. 4

Principal Technical Data



Principal dimensions

	A	B	C	D	E	F	G	H	J	K	L	M
mm	12,000	6,000	2,925	350	2,700	2,300	1,950	1,700	850	1,900	2,330	3,400
in.	472	236	115	14	106	90	77	67	33.5	75	92	134

Note: We reserve the right to make changes without notice, in accordance with our policy of constant product improvement.

Drill rig

Overall weight with three booms, feeds and rock drills	23 tons 50 700 lb
Weight distribution: front axle	6 tons 13 220 lb
rear axle	17 tons 37 480 lb
Ground clearance	350 mm 14 in.

Chassis
Volvo six-cylinder water-cooled engine
Type D 50 A
Max. output at 2 800 rpm — 118 HP SAE

		Forward		Reverse	
Tractive force	Gear 1	9 430 kg	20 790 lb	12 200 kg	26 900 lb
	Gear 4	2 260 kg	4 980 lb	2 920 kg	6 440 lb
Max. speed	Gear 1	3.3 kmh	2.05 mph	2.6 kmh	1.63 mph
	Gear 4	14.0 kmh	8.75 mph	10.8 kmh	6.75 mph

Drilling equipment

Air hose connection	3″	
Water hose connection	1½″	
Water separator, volume	110 l	24.2 Imp.gal.
Lubricating oil tank, volume	20 l	4.4 Imp.gal.
Hydraulic system, working pressure	170 atg	2 417 psig
Hydraulic oil tank, volume	70 l	15.4 Imp.gal.
Hydraulic booms	BUT 14F, BUT 14E, BUT 14RO	
Charging platform boom	HL 32	
Feeds:		
Screw feed:	BMS 810, BMS 812, BMS 814	
Chain feed:	BMM 35K 152	
Rock drills:	BBC 120F, COP 90 ED	

Rock drills:

Total air consumption (at 6 atg/85 psig)		
with three BBC 120F	30 m³/min	1 060 cfm
with three COP 90 ED	25 m³/min	880 cfm
Total water consumption (at 4 atg/56 psig)		
with three BBC 120F	90 l/min	17.5 Imp.gal./min
with three COP 90 ED	51 l/min	11.1 Imp.gal./min

Sandvik Coromant drill steels

The Sandvik Coromant assortment includes special equipment for drifting, with integral drill steels and extension steels as well as a complete range of bits.

The drill steels are designed to meet high demands for performance and economy. They are made from alloy steel and receive specially developed hardening and anti-corrosion treatments. The carbide tips are made from a patented grade of carbide which has been shown to possess superior hardness, impact strength and resistance to wear.

Atlas Copco SOLD AND SERVICED BY THE WORLD-WIDE ATLAS COPCO ORGANIZATION

Leaflet E1782

ANDERSON & LEMBKE AB/GRAFISK KONTAKT AB
Printed in Sweden

RETRAC DRILL BITS

for trouble-free drilling in difficult rock

SANDVIK Coromant
ROCK DRILL STEELS

January 1970 E 451

Group 4

Drilling through friable, fissured rock often proves troublesome. Loose material collapses into the drillhole and obstructs the withdrawal of the drill steel. This leads to operational hold-ups – and in the worst case to the loss of the drill string and the hole.

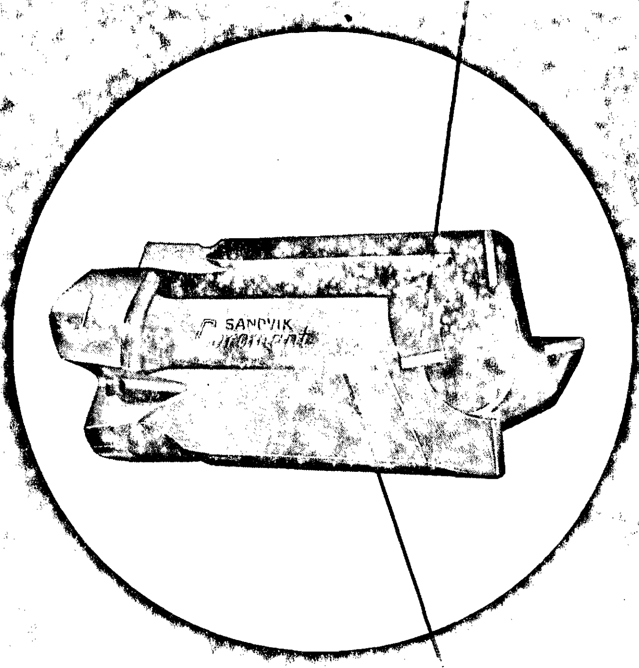
The SANDVIK COROMANT RETRAC bit with extra rear-facing edges solves these problems. It means fewer stoppages and often gives a higher penetration rate, resulting in more feet per drilled shift and improved drilling economy.

Efficient sludge disposal

Good-sized grooves in the body of the bit give better sludge disposal and reduce the risk of getting stuck.

Reverse drilling ability

The rear end of the bit body resembles a milling cutter, with heavy blades covering most of the space between the wall of the hole and the extension rod. When the drill string is withdrawn, using left-hand rotation, the bit "drills" its way out



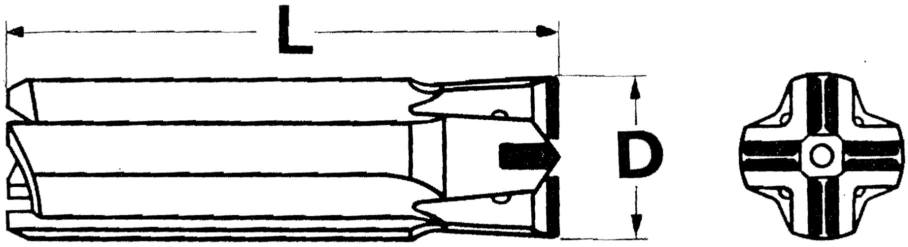
Straighter drillholes – higher penetration rate

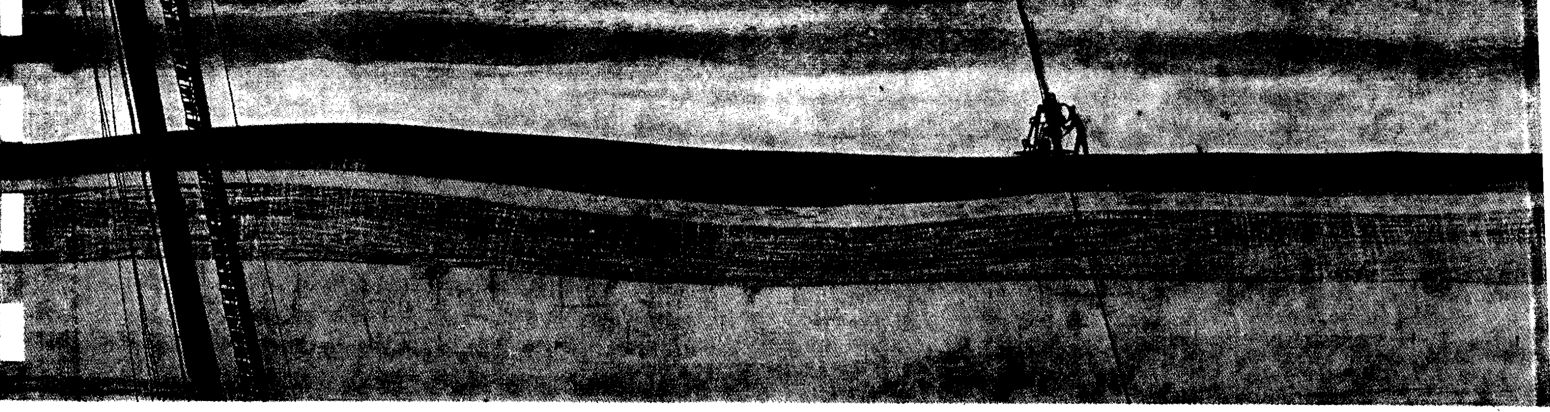
The long bit body, with its longitudinal guiding ribs and a diameter that is only slightly less than the insert diameter, gives the drill bit better guidance (resulting in straighter holes). In most cases, the Retrac bit also achieves a higher penetration rate.

For sizes and catalogue numbers, see overleaf.

Dimensions and Catalogue Number

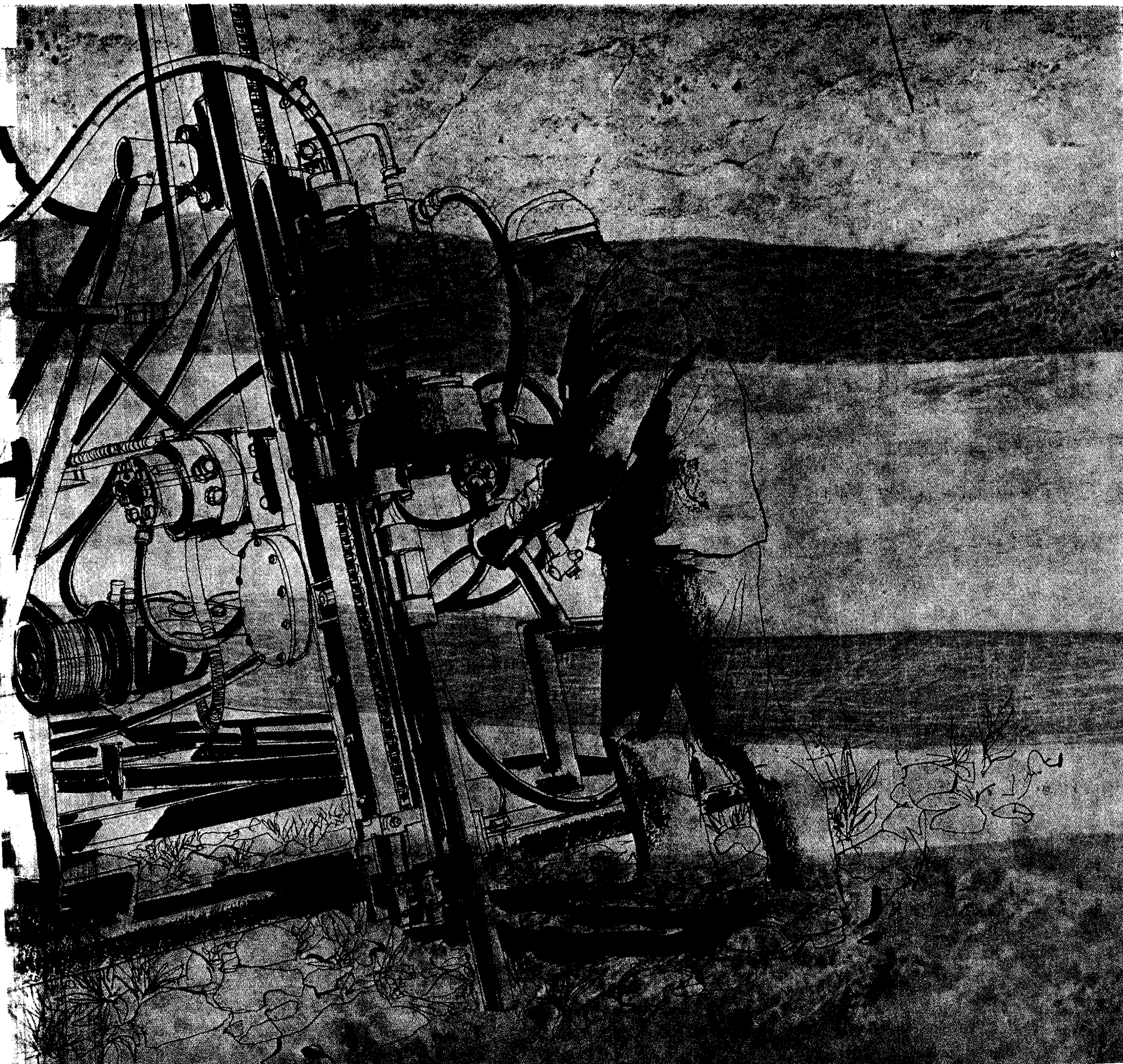
Thread dimension and type	Bit diameter D mm	in	Catalogue Number	Length L mm	in	Weight kg	lb
1¼" rope	48	1⅞"	7733–8148	167	6 9/16"	1,5	3,3
	51	2"	7733–8151			1,8	3,7
	57	2¼"	7733–8157			2,1	4,0
	64	2½"	7733–8164			3,0	6,6
1½" rope	64	2½"	7734–8064	180	7⅛"	3,0	6,6
	70	2¾"	7734–8070			3,4	7,7
	76	3"	7734–8076			4,2	9,3
	89	3½"	7734–8089			5,5	12,2
1½" C17	64	2½"	7550–4864	180	7⅛"	3,0	6,6
	70	2¾"	7550–4870			3,4	7,7
	76	3"	7550–4876			4,2	9,3
	89	3½"	7550–4889			5,5	12,2
1[illegible]" C17	76	3"	7550–5876	193	7[illegible]	5,0	11,0
	89	3½"	7550–5889			5,4	11,9
	[illegible]	[illegible]	7550–5802			5,9	13,0
	[illegible]	[illegible]	7550–5815			6,3	14,0





THE OVERBURDEN DRILLING METHOD

Atlas Copco



DESCRIPTION OF THE METHOD

The Overburden Drilling Method (OD Method) requires special equipment, consisting of Atlas Copco rock drills with powerful, independent rotation, chain feeds and Sandvik Coromant special drill pipes and standard extension steels. High pressure water flushing contributes to a fast penetration rate.

All kinds of overburden are easily penetrated with this type of equipment. Boulders, hard moraine, etc., are drilled without difficulties. A typical cross section of clay, gravel, sand, boulders, moraine and rock is shown in Fig. 1 where the drill pipe has been collared about four inches into bedrock.

The drill pipes are joined together with external coupling sleeves. The first pipe down the hole has a detachable ring bit.

Sandvik Coromant standard 1 1/4" round extension steels are inserted in the drill pipes, the leading steel having a tungsten carbide tipped cross bit which projects 1" beyond the ring bit and acts as a pilot.

The drill pipes and the extension steels inside are drilled simultaneously through overburden including boulders.

The percussive force from the rock drill is transmitted by a special shank adapter to the extension rods and drill pipes. The powerful torque from the separate air motor for rotation is transmitted by the same shank adapter.

If drilling is to be continued after reaching bedrock both the ring bit and the cross bit are collared a few inches into the rock for secure support of the drill pipe. The series of pipes are then disengaged from further drilling by disconnecting the top drill pipe from the shank adapter. An extra rod is added and drilling continued with the extension steels alone.

When the hole has been drilled to a predetermined depth in the bedrock the extension steels are withdrawn leaving the drill pipe as a lining in the overburden section of the hole and thus forming an open connection between the hole in the bedrock and the surface.

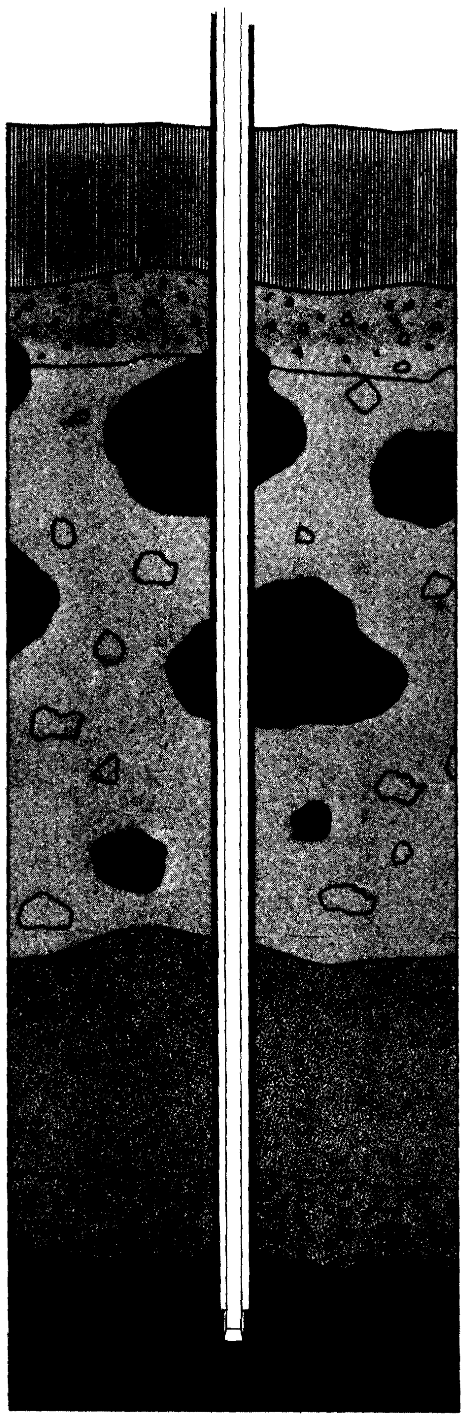


Fig. 1. Principle of the method

During drilling through overburden sampling and testing of the soil may be carried out whenever desired.

The drill pipes and the ring bit are withdrawn after the completion of such operations as the insertion of plastic tubes for charging with explosives or the entry of grouting equipment etc.

The OD method in brief

Double drill equipment

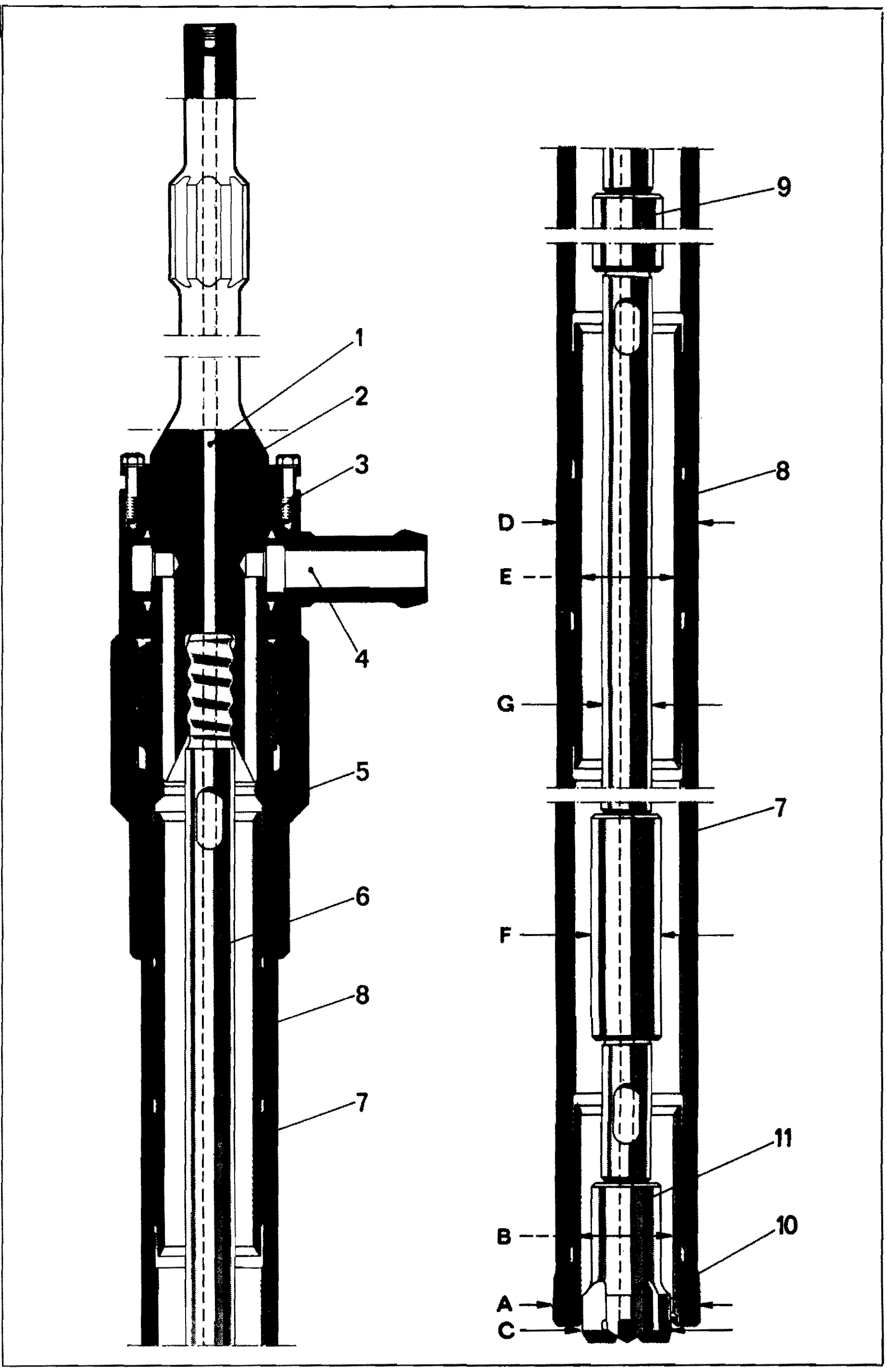
Using a combination of percussion, rotation and high-pressure water flushing, a drill rod and an outer tube are enabled to penetrate the overburden together.
The outer tube carries a ring bit, and the drill rod a cross bit; both bits are tipped with tungsten carbide. The cross bit stands proud of the ring bit, acting as a pilot. As drilling proceeds, extensions are added to the rods and tubes by means of coupling sleeves.

Independent control

of percussion, rotation, feed rate and flushing allows the driller to select the right combination for easy penetration of **any** type of overburden. The drilling action can be changed instantly, as soon as the bits hit a new formation.
If drilling is to be continued after reaching bedrock the drilling equipment is first allowed to collar a few inches into the bedrock. The remainder of the hole is drilled by the cross bit and drill rods alone. It is, of course, also possible to drill in rock with the tube and ring bit.

Open all the way

When full depth has been reached, the rods are withdrawn, the tubes being left as a casing in the overburden section of the hole. The result is an unobstructed hole – from surface to bottom, however loose and unstable the surrounding earth strata – through which various kinds of equipment may be introduced to carry out a great variety of operations.

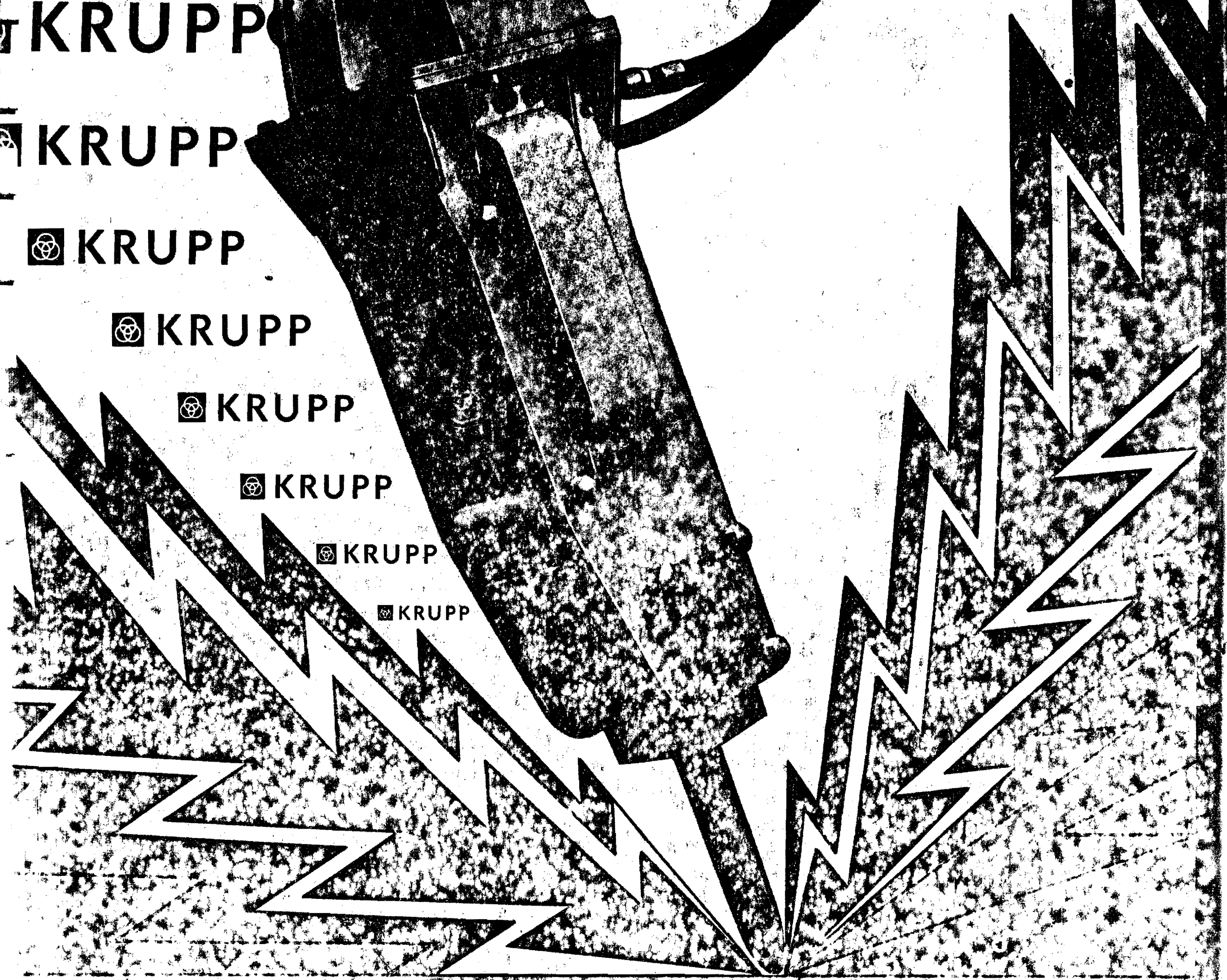


Principal parts of the OD equipment

1. Hole for central flushing
2. Shank adapter
3. Head for separate flushing
4. Hole for separate flushing
5. Adapter sleeve
6. Drill rod
7. Drill tube
8. Coupling sleeve for drill tubes
9. Coupling sleeve for drill rods
10. Ring bit
11. Cross bit

Some dimensions

OD equipment size			2 ¾ in. mm	2 ¾ in. in.	3 ½ in. mm	3 ½ in. in.	5 in. mm	5 in. in.
Ring bit	outer Ø	A	88, 92	3 15/32, 3 5/8	107	4 7/32	153	6
	inner Ø	B	56	2 3/16	73	2 7/8	109	4 9/32
Cross bit	outer Ø	C	51	2	70	2 3/4	102	4
Coupling sleeve for drill tubes	outer Ø	D	86	3 3/8	103	4 1/16	141	5 9/16
	inner Ø	E	–	–	72.5	2 27/32	109	4 9/32
Coupling sleeve for drill rods	outer Ø	F	43	1 11/16	55	2 5/32	55	2 5/32
Drill rods	outer Ø	G	32	1 1/4	38	1 1/2	38	1 1/2



Hydraulik-Hammer HM 400

FRIED. KRUPP GMBH INDUSTRIEBAU UND MASCHINENFABRIKEN ESSEN

wird grobes Haufwerk vom
KRUPP-Hydraulik-Hammer
zertrümmert.

Hydraulik – eine moderne Technik

Verstärkter Wettbewerb und Mangel an geeigneten Arbeitskräften zwingen die Bauwirtschaft zu intensiver Rationalisierung. Abbau der Kosten für mechanisierbare, lohnintensive Arbeiten steht dabei im Vordergrund. In diesem Bereich bietet die Hydraulik-Technik entscheidende Vorteile. Sie liegen im unbestrittenen größeren Wirkungsgrad und der Möglichkeit, kleinere, leichtere Geräte mit großer Arbeitsleistung herzustellen. Diese Vorzüge wurden von der Bauwirtschaft sehr schnell erkannt und führten zu einem verstärkten Einsatz von Hydraulik-Baggern und Ladern auf den Baustellen.

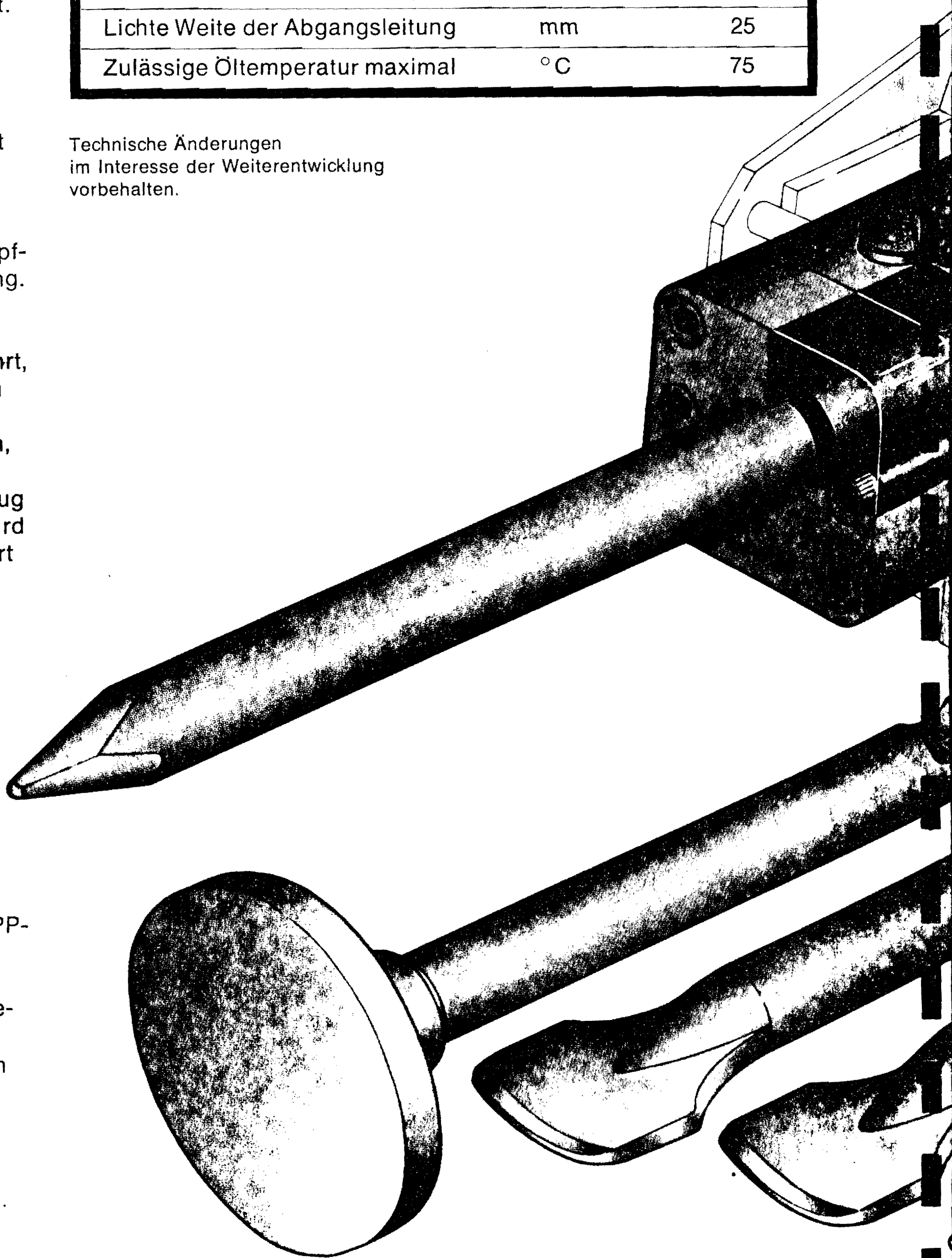
꞊infacher Anbau, ꞊chneller Geräte- ūnd 'Werkzeugwechsel

KRUPP-Hydraulik-Hammer paßt an ꞊eden Bagger-Ausleger. (Voraus-˰esetzt, die Hydraulikleistung entspricht den in der Daten-Tabelle ˉngegebenen Werten.) Mit der ꞊erätehalterung, die auf Wunsch mitgeliefert wird, ist der Hammer mit wenigen Handgriffen montiert.)ie Schläuche für die Hydraulik ˍind mit Schnellkupplungs-anschlüssen versehen und ' rauchen nur zusammengesteckt ɹ werden. Der Hammer kann mit verschiedenen, zur Arbeit passenden Werkzeugen bestückt ᵛerden. Spitzeisen in verschie-ˍenen Längen, Spaten und Stampf-füße stehen zur Zeit zur Verfügung.)er Schaft des Werkzeuges hat inen Durchmesser von 80 mm. Er ist tief im Vorderzylinder geführt, ım die beim Reißen auftretenden Nomente aufzunehmen. Soll ein ·Verkzeug ausgewechselt werden, so wird nur der Querbolzen erausgezogen, und das Werkzeug ꞊t frei. Das nächste Werkzeug wird n den unteren Zylinder eingeführt ınd mit dem Querbolzen fixiert.

Technische Daten

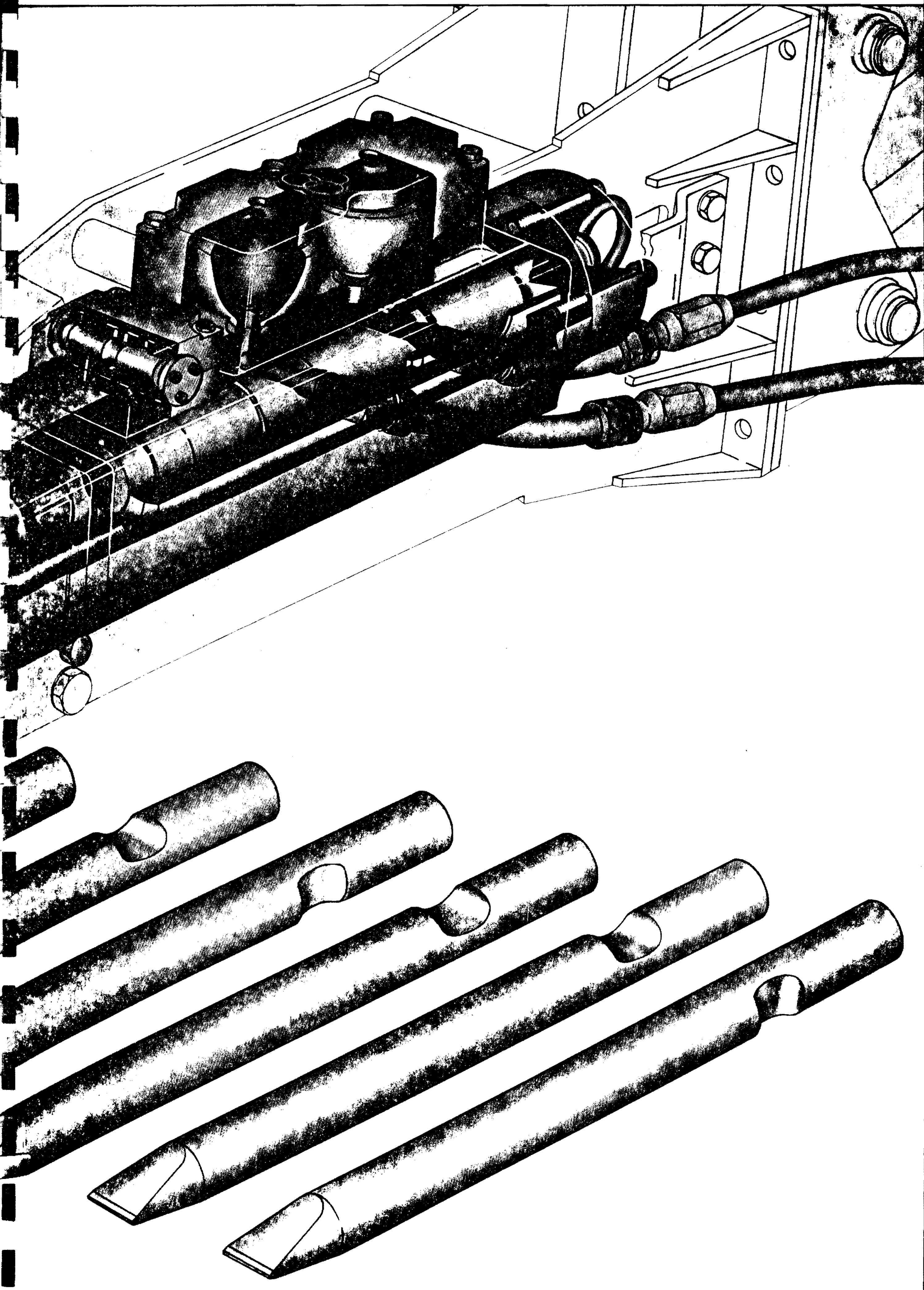
Gewicht	kp	400
Schlagzahl	1/min	580
Öldurchfluß	l/min	60
Betriebsdruck	atü	120–150
Lichte Weite der Druckleitung	mm	20
Lichte Weite der Abgangsleitung	mm	25
Zulässige Öltemperatur maximal	°C	75

Technische Änderungen im Interesse der Weiterentwicklung vorbehalten.



as Schnittbild gestattet einen ·lick ins „Innenleben" des KRUPP-·ydraulik-Hammers.
esonders fällt hier die tiefe ıhrung des Werkzeugs im Halte-. ylinder auf.
eben Werkzeuge stehen für den nsatz des Hammers zur Zeit ır Wahl.
· in Stampfer, zwei Spateneisen, ·ei Spitzeisen (500 und 800 mm ıtzlänge) und zwei Flachmeißel.

·. e auf der nebenstehenden ··chnung dargestellt, werden ·. ateneisen und Flachmeißel · ch mit um 90° versetzter ·ierungsnute geliefert.



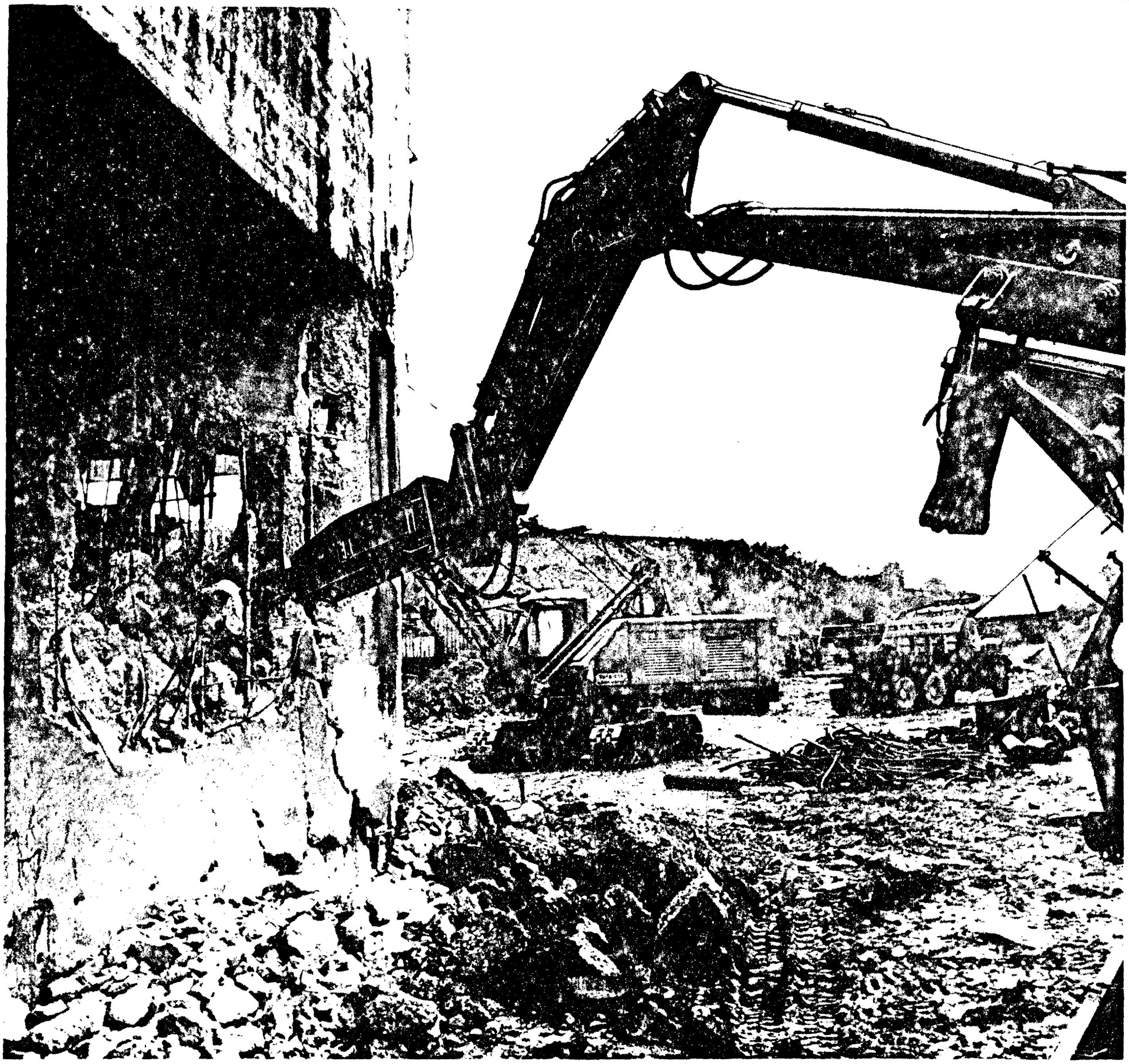
jeder Korrektur des Baggerführers.

Vielfältiger Einsatz 'urch Ausnutzung er Bordenergie

Die Nutzung der Bordenergie zum Antrieb des Hydraulik-Hammers erschließt Baggern und Ladern eine ganze Palette neuer Verwendungsmöglichkeiten. Im Straßen- und Tiefbau, in Steinbrüchen, bei Ab- und Aufbrüchen sowie bei Verdichtungsarbeiten übernimmt die Kombination von Hydraulik-Hammer und Trägergerät die sonst von Menschen ausgeführte harte Knochenarbeit. Die Arbeitsleistung wird gegenüber konventionellen Geräten um ein Vielfaches gesteigert. Nach den aus der Praxis gewonnenen Erfahrungen kann beim Zertrümmern und Aufreißen die Leistung von fünfzehn manuell bedienten Geräten erreicht werden.

KRUPP-Hydraulik-Hammer
kommt überall hin.
Mit einer Hebelbewegung ist er schnell
in die günstigste Arbeitsposition gebracht.

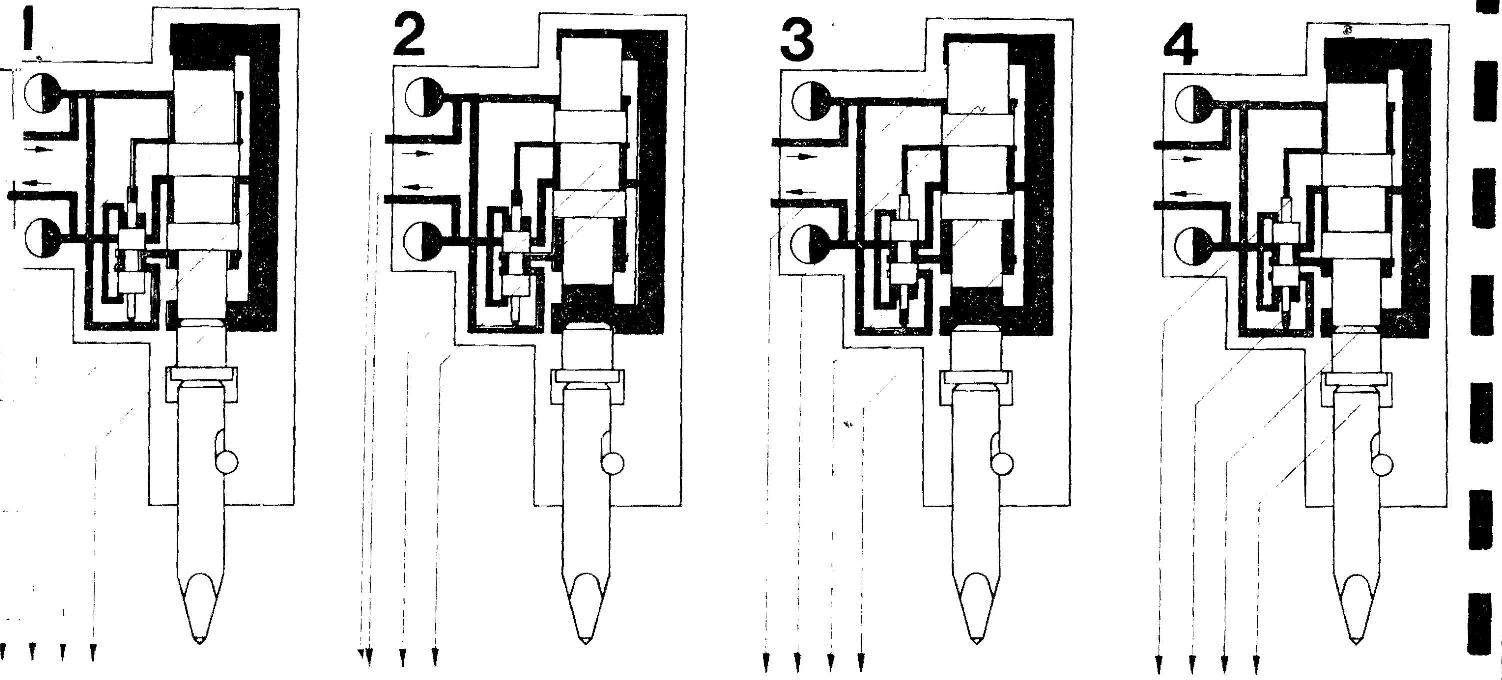
HM 400



Sicher, wendig und ausgesprochen leise

Durch den Einsatz des KRUPP-Hydraulik-Hammers verlieren gefährliche Auf- und Abbrucharbeiten ihren Schrecken.
Der Hammer am langen Arm, mit dem entsprechenden Werkzeug bestückt, führt die gefährliche Arbeit durch. Er wird von der Fahrerkabine aus dirigiert, unabhängig von der Witterung, mit Abstand von der Bruchkante.

Der Baggerführer hat es in der Hand, das Werkzeug in die jeweils günstigste Arbeitsposition zu bringen.
Da der Knickarm eines Baggers in der Auslegerlängsachse unter Zusammenwirken aller Gelenke bis zu 270° schwenkbar ist, kann der Hammer auch an schlecht zugänglichen Stellen arbeiten.
Trotz seiner hohen Leistung ist der Hydraulik-Hammer ein ausgesprochener „Leisetreter“. Sein Lärmpegel bleibt weit hinter dem anderer Baumaschinen zurück. Eine Eigenschaft, die ihn für den Einsatz bei innerstädtischen Bauaufgaben prädestiniert.



Funktions-Schema des KRUPP-Hydraulik-Hammers HM 400

Arbeitsprinzip

Die Bewegung (Schlaghub und Rückhub) des Schlagkolbens resultiert aus der wechselweis Beaufschlagung der Fläche (F 2) mit dem Leitungsdruck (ocker) und dem Abgangsdruck (blau).

1

Beginn des Rückhubs

Nach dem Arbeitshub hat der Schlagkolben (1) die Ringnut (7) und damit die Ventilkolbenfläche (F v 2) mit der Druckleitung (ocker) verbunden. Da die Ventilkolbenfläche (F v 2) größer als (F v 1) ist, wird der Ventilkolben (2) umgesteuert und verbindet die Fläche (F 2) erneut mit der Druckleitung (ocker).

2

Ende des Rückhubs

Der Leitungsdruck (ocker) steht dauernd auf der Fläche (F 1). Da Fläche (F 2) größer als (F 1) ist, wird der Schlagkolben (1) bei der Verbindung der Fläche (F 2) über das Ventil (2) mit dem Leitungsdruck (ocker) nach oben bewegt. An einem bestimmten Punkt hat der Schlagkolben (1) den Durch-

3

gang von Ringnut (7) nach (8) freigegeben, d. h., der Druck auf der Ventilstiftfläche (F v 2) fällt ab, da auf der Ventilstiftfläche (F v 1) immer der Leitungsdruck steht, wird der Ventilkolben (2) in die Stellung gebracht, die die Kolbenfläche (F 2) mit der Abgangsleitung verbindet.

4

Schlaghub

Die Fläche (F 2) ist druckentla[...]t. Der auf die Fläche (F 1) wirke[...] Leitungsdruck treibt den Kolben (1) nach unten. Er nimmt dabei mit wachsender Geschwindigkeit Bewegungsenergie auf, die zu gegebenen Zeitpunkt auf den Zwischenkolben (4) und damit auf das Werkzeug übertragen wird.

Vertrieb:

Generalvertretung für die Schweiz:
MBA MASCHINEN und BAHNBEDARF
Aktiengesellschaft
Kriesbachstrasse 42, Tel. (051) 85 00 21-25
DÜBENDORF-ZÜRICH

Produktion:

FRIED. KRUPP GMBH INDUSTRIEBAU UND MASCHINENFABRIKEN ESSEN

M 307 0709

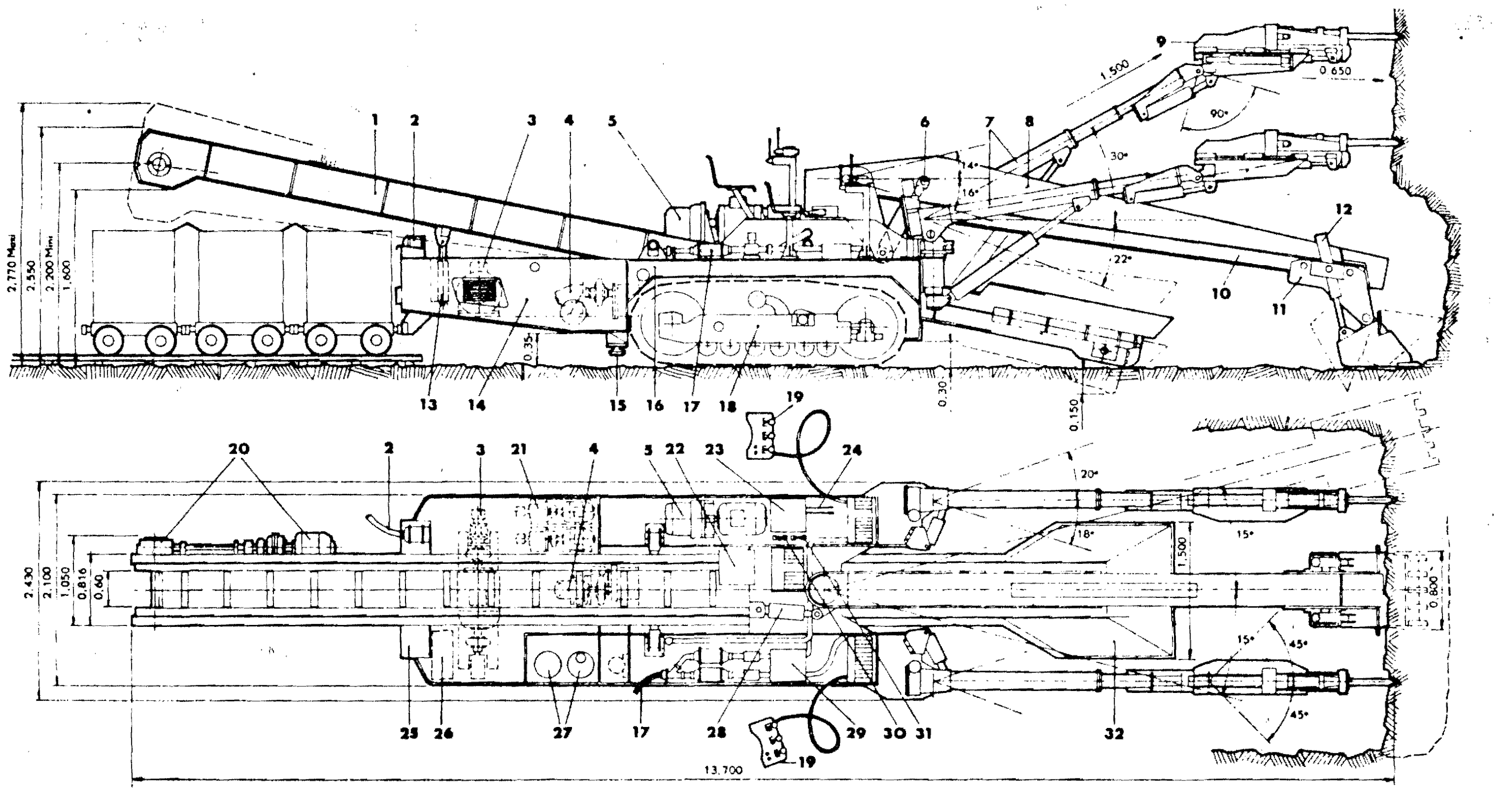
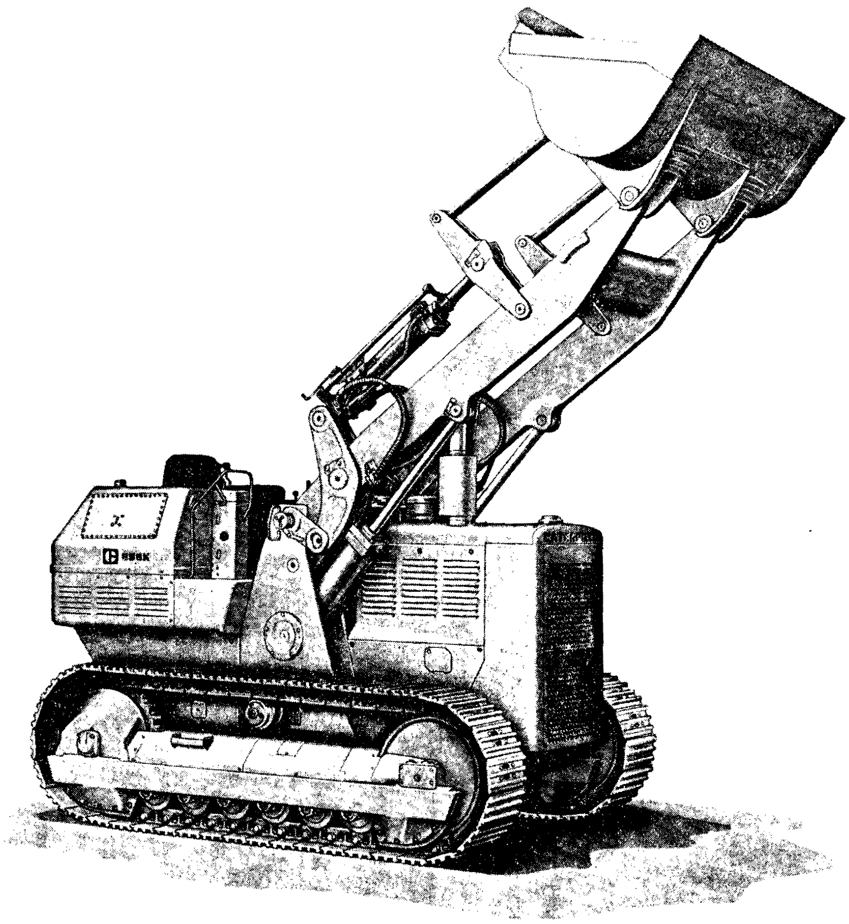


Fig. 2 et 3. — *Elévation et plan du jumbo abatteur et chargeur SECOMA type 225.*

, convoyeur à raclettes ; — 2, prise de courant d'alimentation générale ; — 3, centrale électro-hydraulique de commande du bras de chargement ; — 4, moteur hydrau-ique de traction ; — 5, centrale électro-hydraulique de translation ; — 6, vérin de levage du bras de chargement ; — 7, bras latéraux d'abattage JTH 1500 normaux ; — , bras central de chargement ; 9, super-marteau brise roche sur glissière ; — 10, chemin de roulement du chariot porte-godet ; — 11, chariot porte-godet ; — 12, vérins le cavage du godet ; — 13, vérin de levage du convoyeur ; 14, poutre arrière ; — 15, vérins d'assise ; — 16, châssis principal ; — 17, alimentation d'air comprimé et raisseurs de ligne ; — 18, train de chenilles TP 6 Continental ; — 19, boitiers portatifs de télécommande ; — 20, chaîne cinématique de convoyeur ; — 21, entrales électrohydrauliques de commande des bras latéraux ; — 22, porte de conduite du bras central ; 23, poste de conduite de translation ; — 24, commandes de reinage et de direction ; — 25, armoire électrique ; — 26, résistances de démarrage du moteur ; — 27, filtre à huile ; — 28, vérin de rotation du bras de char-ement ; — 29, poste de commande du bras droit ; — 30, commande de crabotage de la boite de vitesses ; — 31, commande de translation ; — 32, trémie de déver-sement du godet.

CATERPILLAR 955K*



* Kettenlader 955, Serie K

Schaufelbolzenhöhe 3650 mm . . . Schütthöhe 2900 mm . . . Reichweite 1630 mm bei einer Schütthöhe von 2130 mm.

Dreigang-Planeten-Lastschaltgetriebe mit Einhebelschaltung. Max. Geschwindigkeit vorwärts 9,3 km/h und rückwärts 11,3 km/h.

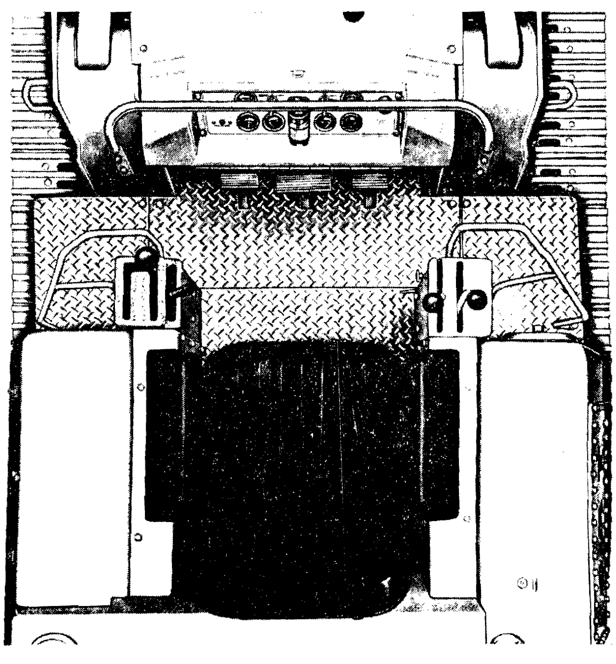
Cat-Dieselmotor mit **115 Schwungscheiben-PS.**

Offener, unverbauter Fahrerstand.

Schwereinsatz-Laufwerk mit 1680 mm Spurbreite, langem Laufwerksrahmen und großdimensionierten Büchsen und Bolzen.

Zwei Normalschaufeln und drei Spezialschaufeln mit Fassungsvermögen von 1,34 bis 1,53 m^3.

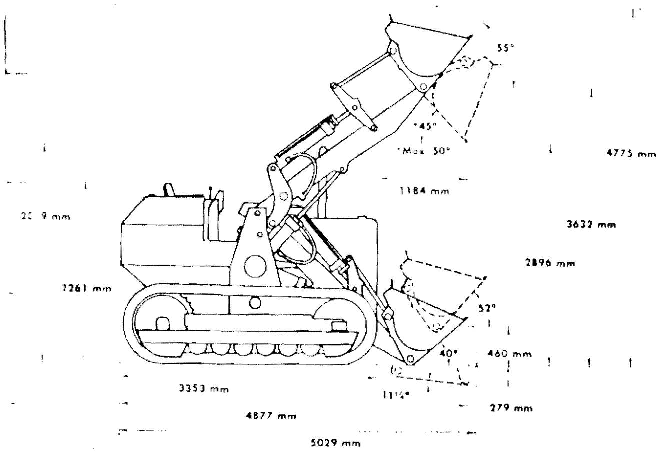
Und diese einsatzbewährten Merkmale: leistungsfähige Pedalsteuerung, automatische Schaufelsteuerung, abgeschlossene Hydraulikanlage, Hydrauliköl im Hauptstrom gefiltert, ölgekühlte Lenkkupplungen und -bremsen, auf Lebensdauer geschmierte Laufrollen, Stützrollen und Leiträder, abgedichtete Ketten.



955 K

I_ETTENLADER

Alle Spezifikationen beruhen auf einer Maschine, die mit einer 1,34-m^3-Normalschaufel ausgerüstet ist, falls nicht anders vermerkt.



MOTOR

Motorleistung . . . . . . 115 PS bei 2 185 U/min

Die Nutzleistung des Standardmotors an der Schwungscheibe wurde unter normalen SAE-Temperatur- und -Luftdruckverhältnissen (29 °C und 746 mm Hg) gemessen. Zur Standardausrüstung des Motors gehören Lüfter, Luftfilter, Wasserpumpe, Schmierölpumpe, Kraftstoffpumpe und Lichtmaschine. Der Motor liefert die volle Leistung bis 3000 m über NN.

Technische Daten

Caterpillar-Viertakt-Vierzylinder-Dieselmotor, Typ D330, Bohrung 121 mm, Hub 152 mm, Hubraum 7 l.
Nachstellfreie Einspritzelemente und -düsen. Unanfällige Vorkammereinspritzung.
Turbolader. Ventile stellitgepanzert, Ventilsitze aus Legierungsstahl, Ventildreher.
Spritzölgekühlte, oval geschliffene, konische Kolben aus Aluminiumlegierung mit drei Kolbenringen. Stahlverstärkte Aluminiumlager, Laufflächen der Kurbelwelle induktiv gehärtet. Druckschmierung, Schmieröl im Hauptstrom gefiltert und gekühlt. Trockenluftfilter mit Haupt- und Sicherheitselementen.
Der Motor läuft mit jedem handelsüblichen Dieselkraftstoff mit einer Cetanzahl von mindestens 35 einwandfrei. Teure, hochwertige Kraftstoffe können verwendet werden, sind aber nicht erforderlich.
Elektrischer Anlasser (24 Volt) in zwei Ausführungen - für normale oder extrem tiefe Temperaturen. Glühkerzen zum Vorwärmen der Vorkammer gehören zu beiden Ausführungen.

DREHMOMENTWANDLER

Einstufig, einphasig

GETRIEBE

Schaltung unter Vollast in allen drei Vorwärts- und Rückwärtsgängen. Einhebelschaltung. Planetensätze sofort und weich durch hydraulisch betätigte Kupplungen geschaltet. Schmier- und Hydrauliköl unter Druck gefiltert und gekühlt.
Fahrgeschwindigkeiten bei Nenndrehzahl des Motors:

Vorwärts:	km/h	m/min
1.	0 – 3,2	0 – 55
2.	0 – 5,6	0 – 93
3.	0 – 9,3	0 – 155
Rückwärts		
1.	0 – 4,0	0 – 66
2.	0 – 6,8	0 – 112
3.	0 – 11,3	0 – 187

ABMESSUNGEN

Spurbreite	1 680 mm
Breite. ohne Schaufel	2 060 mm
Bodenfreiheit	410 mm
Max. Reichweite bei 2 130 mm Schütthöhe und 45° Kippwinkel	1 630 mm
Planierwinkel	75°

LENKUNG

Lenken und Bremsen durch je ein Pedal pro Kette. Drittes Pedal nur zum Bremsen, kann zum Abstellen der Maschine festgestellt werden.

Kupplungen
ölgekühlte, hochbelastbare Mehrscheibenkupplungen

Bremsen	ölgekühlte Bandbremsen
Kupplungsbelag	metallisch
Zahl der Reibflächen pro Kupplung	28

Ausrücken der Kupplung
hydraulisch unterstützt, mechanisch betätigt

KETTEN

Abgedichtete Ketten verlängern die Lebensdauer von Büchsen und Bolzen bis zu 30 % und reduzieren den Verschleiß an Kettengliedern, Laufrollen und Stützrollen. Laufrollen, Stützrollen und Leiträder sind auf Lebensdauer geschmiert. Kettenführungsplatten mit angeschraubten Verschleißstreifen gehören zur Standardausrüstung.

Laufwerksrahmen	mit 6 Rollen, starr.
Zahl der Bodenplatten (je Seite)	41
Breite der Standardbodenplatte	380 mm
Tragende Kettenlänge	2 340 mm
Bodenauflagefläche	1,78 m^2

HYDRAULIKANLAGE

Völlig geschlossen, damit Verschleiß verursachender Schmutz nicht eindringen kann. Durch Hauptstromfilter geschützt. Ein Filter in der Rücklaufleitung verhindert, daß Fremdkörper aus der Hydraulikanlage für Zusatzgeräte in den Tank eintreten. Die Messerpumpe mit hoher Förderleistung gleicht Verschleiß selbstätig aus. Doppeltrommel-Steuerventile, durch Feder zentriert, gut geschützt im Tank montiert. Stahlrohre und Hochdruckschläuche mit Flanschverbindungen.

HEBELSTELLUNGEN

Stellungen des Hubhebels
Heben, Senken, Halten, Gleiten
(Automatische Ausschaltung, im Bereich der letzten 610 mm der Hubhöhe verstellbar.)
Stellungen des Kipphebels
Rückkippen, Halten, Abkippen
(Automatischer Schaufeleinsteller, auf vorgewählten Einstechwinkel einstellbar.)

ZYLINDER, beidseitig wirkend

Hubzylinder, Bohrung und Hub . . .	140/830 mm
Kippzylinder, Bohrung und Hub . . .	127/590 mm

FÜLLMENGEN

Kraftstofftank	216 l
Kühlanlage	42 l
Schmieranlagen:	
Kurbelgehäuse	18,9 l
Getriebe	37 l
Tellerrad-, Lenkkupplungsgehäuse und Lenkmechanismus	72 l
Seitenantriebe (je Seite)	9,5 l
Hydraulikanlage (Schaufelhydraulik)	98 l

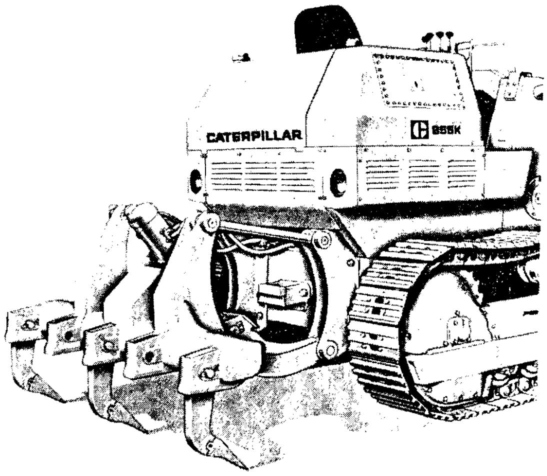
STANDARDAUSRÜSTUNG

Automatische Hubendausschaltung, automatischer Schaufeleinsteller, Kraftstoff-Entlüfterpumpe, Wartungsanzeiger für den Luftfilter, verschleißfester Kühlerkern, Drucklüfter, Kurbelgehäuseschutz, Motorseitenverkleidung, Abdeckung für das Armaturenbrett, Anzeiger für Hydraulikfilterwechsel, Werkzeuge, Werkzeugkasten, verstellbarer Sitz, Unterbrecherschalter mit Schlüssel, Schwereinsatz-Kühlerschutz, hydraulische Kettenspanner, Kettenführungsplatten mit angeschraubten Verschleißstreifen.

VERSANDGEWICHT, ca.

Einschl. Schmiermittel, Kühlmittel
und 10 % Auftankung . . . . 12 700 kg

955 K
KETTENLADER



Weiteres Zubehör für die 955:

Luftansaugvorreiniger mit Vorabscheider. (Ersetzt Standard-Vorreiniger.)

Schaufelzähne, warmvergütet, Speziallegierung, anschraubbar, mit langen und kurzen auswechselbaren Zahnspitzen.

Puffer, hinten (kann mit Gegengewicht verwendet werden).

Sicherheitsverschlüsse für Kraftstoff- und Hydrauliktank.

Gegengewicht, heckmontiert, 475 und 780 kg.

Schaufelüberlaufplatte. Verhindert Verschütten von losem Material.

Lüfter, umkehrbar.

Zughaken, vorn.

Hydraulikanlage mit zusätzlichen Ventilen zum Betrieb von Kombi- oder Seitenkippschaufel, oberer Halteklammer der Holzgabel oder Aufreißer.

Beleuchtungsanlage.

Holzgabel.

Zapfwelle.

Kaltstartanlage (mit 20-A-Lichtmaschine und größerem Startermotor).

Werkzeugkasten (Steckschlüssel und Fettpresse).

Obere Halteklammer für die Holzgabel.

Laufrollenschutz, verhindert Eindringen von Fremdkörpern.

Mittelflachplatten, 380 mm.

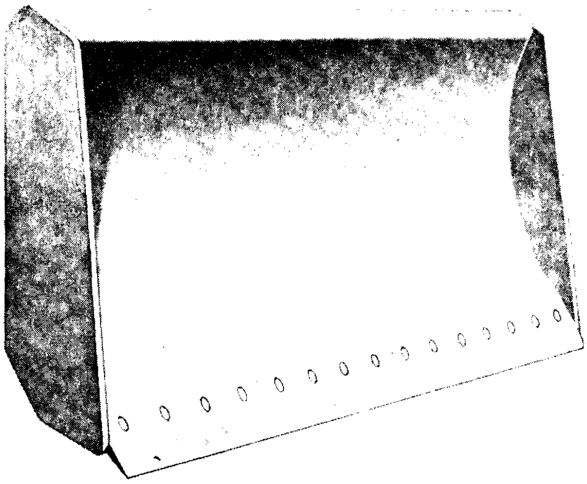
Hyster-Zugwinde D4E.

955-Aufreißer

Zahl der Reißschenkel	3 (4. und 5. wahlweise)
Abstand der Reißschenkel:	
3 Reißschenkel innen	430 mm
Reißschenkel außen	510 mm
Zahnspitzen	auswechselbar, warmvergüteter Legierungsstahl
Max. Reißtiefe	355 mm
Gewicht	910 kg

Starres Planierschild (unten):
an den Hubarmen montiert.

Breite	2310 mm
Höhe	860 mm
Gewicht	410 kg



Änderungen vorbehalten

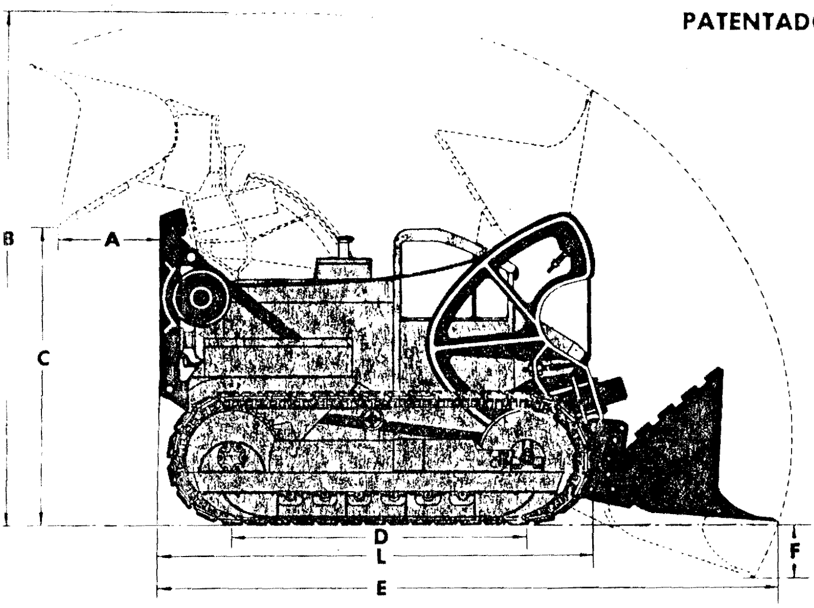
CATERPILLAR

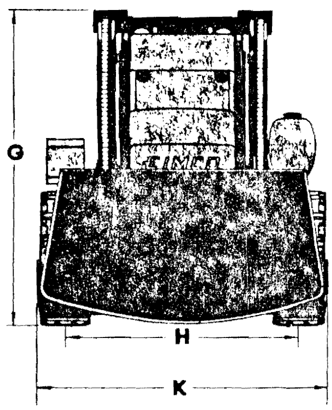
AG040443 (3-70)

Printed in W. Germany

ᴉMCO 105 . . . CARACTERISTICAS DEL TRACTOR-EXCAVADOR

PATENTADO. NUEVAS PATENTES EN TRAMITACION





ᴉncio posterior de descarga — ɔtada al camión o vagón a cargar. libre necesaria		
Máquina de descarga alta	16'4"-17'7"	4980-5360 mm.
Máquina normal	13'2"-15'9"	4015-4800 mm.
ı de descarga sobre el suelo (puede variarse para su adap- ·ón a las necesidades existentes)		
Máquina de descarga alta	10'3"-11'6"	3125-3505 mm.
Máquina normal	7'6"-9'6"	2290-2895 mm.
·ud de apoyo sobre el suelo de cadenas de oruga	95"	2415 mm.
ıd total — con la cuchara bajada		
Máquina de descarga alta	16'0"-18'0"	4875-5490 mm.
Máquina normal	15'0"-17'0"	4570-5180 mm.
didad de excavación bajo la ınte	17"	430 mm.
total — con la cuchara bajada		
Máquina de descarga alta	9'6"	2895 mm.
Máquina normal	8'6"	2590 mm.
, de vía	74"	1880 mm.
total	7'8"	2340 mm.
ɔd mínima (con la cuchara en posición de transporte)	11'8½"	3570 mm.

Ancho de las zapatas	16"	405 mm.
Capacidad de la cuchara (normal)	1½ yardas³	1,15 m³ aprox.
Peso de la máquina completa (normal)	38.500 lbs	17.480 Kg.
Potencia en el volante del motor, al nivel del mar	H.P.	125 ó 143
Esfuerzo máximo de tiro sin resbalamiento de las cadenas de oruga (al nivel del mar)	55.000 lbs	24.970 Kg.
Esfuerzo de tiro calculado con equipo de carga normal y zapatas planas	23.000 lbs	10.440 Kg.
Velocidad con la primera relación de transmisión ("baja"), hacia adelante o hacia atrás	0-200 pies/min	0-61 m./min.
Velocidad con la segunda relación de transmisión ("alta"), hacia adelante o hacia atrás	0-480 pies/min	0-146 m./min.
Altura libre sobre el suelo	11"	280 mm.
Capacidad del depósito de combustible	45 galones U.S.	170 litros
Superficie de contacto con el suelo	3.040 pulgadas²	19.610 cm²

EQUIPO [illegible]

ɪcador de gases de escape. Equipo de arranque para tiempo ertas de gran resistencia para los rodillos de oruga. Luces. Ventiıaspiración. Barra de tiro. Cabina cerrada para invierno. Cuneciales. Dientes de cuchara. Equipo de descarga alta. Luz de de averías. Motor diesel turboalimentado para trabajar a altitudes de hasta 13000 pies (3962 m.) Salientes para las zapatas. Filtro de aire doble "Dual". Dispositivos con hoja de empuje ("bulldozer"). Coraza envolvente trasera. Equipo de arranque de aire comprimido. Equipo de arranque hidráulico "Hydrostarter".

THE EIMCO CORPORATION

Salt Lake City, Utah—U.S.A. • Export Offices: Eimco Bldg., 52 South St., New York City

New York, N. Y. Chicago, Ill. San Francisco, Calif. El Paso, Tex. Birmingham, Ala. Duluth, Minn. Kellogg, Ida. Baltimore, Md. Pittsburgh, Pa. Seattle, Wash. Cleveland, Ohio Houston, Texas Vancouver, B. C. London, England Gateshead, England Paris, France Milan, Italy Johannesburg, South Africa

1048, 2-58, 50M

Impreso en U.S.A.

Leaflet 826a Printed in Scotland

RH20

the M & C RH20 roadheader

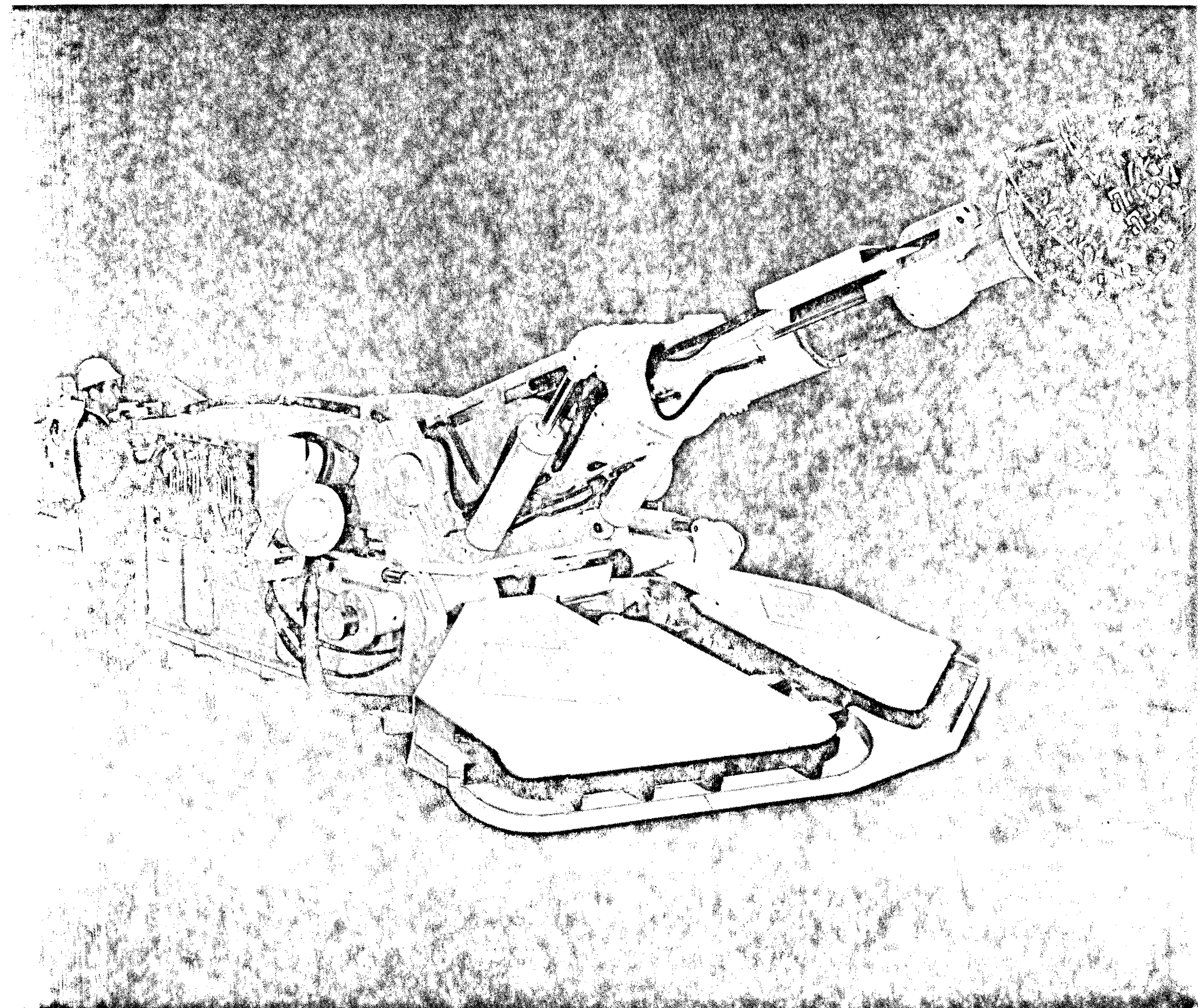
This versatile 130hp machine is designed to cut and load most of the rocks found in normal coal measure strata. It is capable of rapid drivage and, provided the services to the machine are well organised, good overall advance rates can be obtained.

A 65hp air cooled electric motor drives the cutting head through a two-stage epicyclic gearbox. The head can revolve at 38rpm in which case the pick speed is low—a factor necessary for efficient cutting in stone. Higher speeds (57rpm, 85rpm) are available if required. This single head enables rocks to be cut selectively if required and the concentration of power in it gives fast effective cutting. Where rock is interlain with mineral, the selective head allows each to be cut and loaded separately. From one machine position, a maximum (standard) height of 13′ 9″ (4190mm) and width of 22′ 3″ (6780mm) can be cut. A greater height range is available for special application. The boom on which the cutting head is mounted is telescopic and has a stroke of 20″ (508mm). This allows the cutter to sump in while the body of the machine remains stationary.

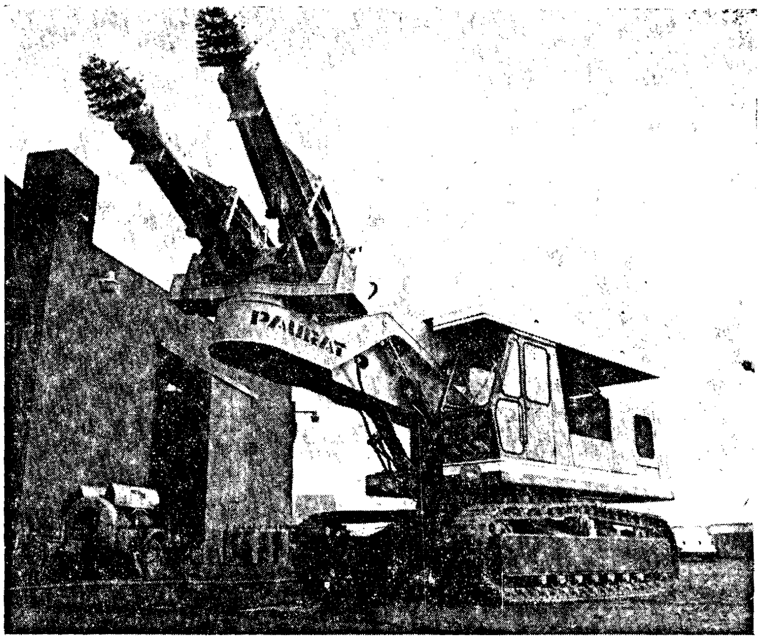
A 65hp air cooled electric motor drives a three-stage pump which provides hydraulic power for all other movements: all these operations are controlled from the operator's position. The machine works on a 40/60 invert emulsion or mineral oil.

The twin chain gathering head can be supplied in three standard widths to suit the tunnels. The chain conveyor through the machine has a fixed discharge. The machine can be supplied at voltages between 380 and 1100 volts.

The RH20 can be fitted with crawler tracks or a walking mechanism, whichever is preferred. Two spragging jacks, one at each front corner, lock the Roadheader in position while cutting: this keeps the cutting head in continuous contact with the rock and gives a maximum cutting effect. Floor spragging jacks are available for wider tunnels.



PAURAT Tunnelling Machines



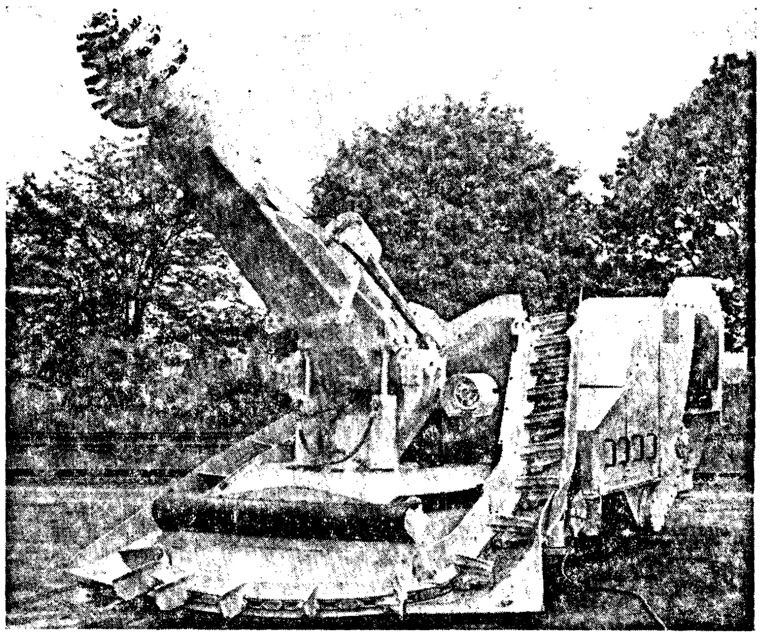
PAURAT Trenching Machines

for soft and medium rock up to
800 kp/cm² compressive strength

for any size up to 50 feet height

with single or dual cutting heads

cutting units for incorporation in tunnel
shields or in shaft-sinking frames

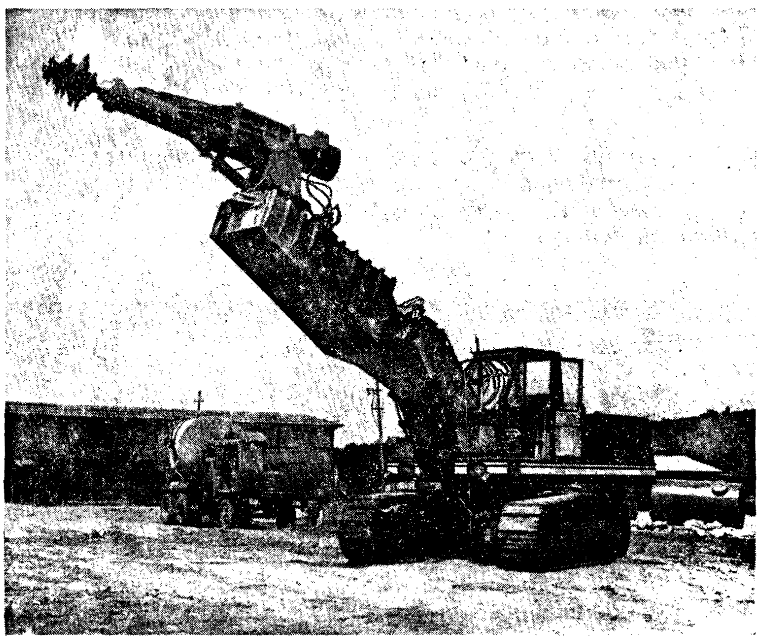


PAURAT

for a complete range of versatile machines or purpose-built rigs, all using standard basic components, all thoroughly proved through long experience in many countries

PAURAT GMBH

Grubenausbau Stahlbau Maschinenbau



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Friedrichsfeldniederrhein

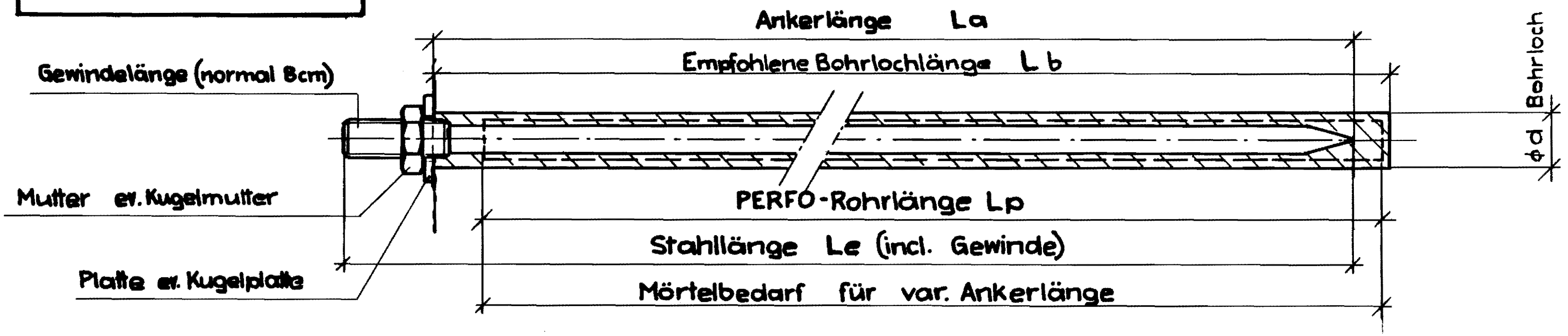
For further information please enter Ref. No. 260 on reader reply card

Aktiengesellschaft - 8967 WIDEN/Mutschellen Maschinenfabrik

Blatt 1

TECHNISCHE ANGABEN über PERFO-ANKER

Normalausführung Siehe Blatt 2!

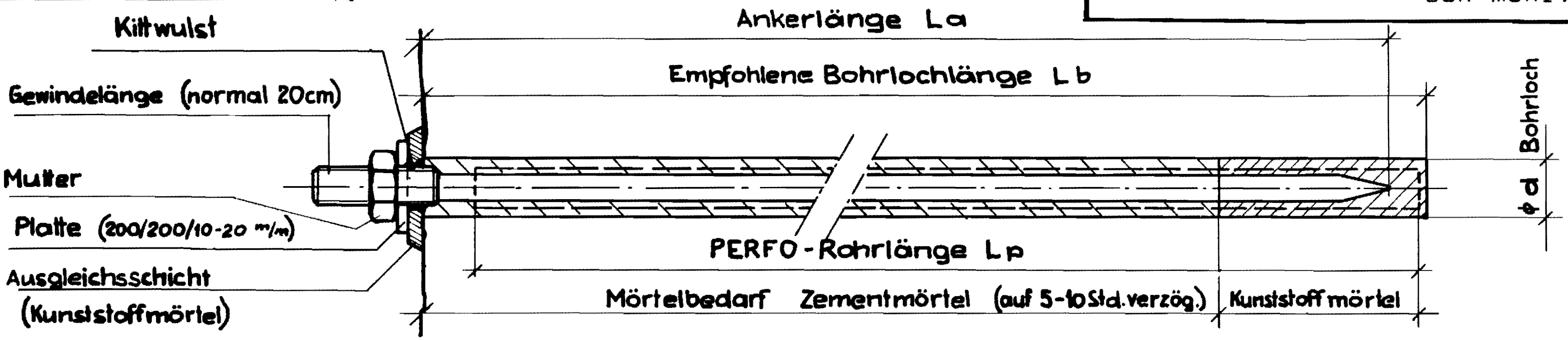


Bei Anwendung der Monobloc-Bohrung sollen die PERFO-Schalen entsprechend dem Lochquerschnitt etwas überfüllt werden !

Bei beiden Ausführungen:

Zementmörtel: Zement:Sand 0-2 mm 1:1
Kunststoffmörtel: SIKA Haftmörtel oder SIKA Fliessmörtel (mit Zusatz von Zuschlagstoffen bis kein Fliessen mehr!)

Vorgespannte Anker Siehe Blatt 3!



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TECHNISCHE ANGABEN über PERFO-ANKER **Normalausführung** Blatt 2

BOHRART	Anker-länge l_a m	Empfohl. Bohrloch-länge l_b m	Stahl-länge inkl. Gew. l_e m	ANKER Ø 20 mm: Bohr-loch Ød mm	ANKER Ø 20 mm: Perfo-Rohr Øi mm	ANKER Ø 20 mm: Perfo-Rohr-länge l_p m	ANKER Ø 20 mm: Theor. Mörtel-bedarf ltr.	ANKER Ø 26 mm: Bohr-loch Ød mm	ANKER Ø 26 mm: Perfo-Rohr Øi mm	ANKER Ø 26 mm: Perfo-Rohr-länge l_p m	ANKER Ø 26 mm: Theor. Mörtel-bedarf ltr.	ANKER Ø 30 mm: Bohr-loch Ød mm	ANKER Ø 30 mm: Perfo-Rohr Øi mm	ANKER Ø 30 mm: Perfo Rohr-länge l_p m	ANKER Ø 30 mm: Theor. Mörtel-bedarf ltr.
MONOBLOCBOHRER	1,50	1,55	1,60	35-34		1,50	0,93	43-42		1,50	1,22				
	2,00	2,10	2,10	35-33		2,00	1,24	43-41		2,00	1,63				
	2,50	2,65	2,60	35-32	27	2,50	1,55	43-40	31	2,50	2,03				
	3,00	3,15	3,10	35-32		3,00	1,86	43-40		3,00	2,43				
	3,80	3,95	3,90	35-31		3,80	2,34	43-39		3,80	3,08				
	4,50	4,65	4,60	--	--	--	--	43-38		4,50	3,65				
VERLAENGERUNGSBOHRER	2,00	2,05	2,10			2,00	1,24			2,00	1,62			2,00	2,14
	3,00	3,10	3,10	32	27	3,00	1,86	38	31	3,00	2,43			3,00	3,21
	4,00	4,15	4,10			4,00	2,48			4,00	3,34	46	36	4,00	4,28
	5,00	5,20	5,10			5,00	3,10			5,00	4,05			5,00	5,35
	6,00	6,25	6,10							6,00	4,86			6,00	6,42
	7,00	7,30	7,10							7,00	5,67			7,00	7,49
	8,00	8,30	8,10											8,00	8,56
	9,00	9,30	9,10											9,00	9,63
	10,00	10,30	10,10											10,00	10,70

Widen, im Juli 1968 KF/m

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1. Bei vorgespannten Ankern Ø 20/ Ø 26/ Ø 30 mm sind alle Angaben auf Blatt 1 und 2 gültig, resp. anzuwenden, ausser dem theoretischen Mörtelbedarf.

2. Bei der Verwendung von Kunststoffmörtel ist wie folgt vorzugehen (siehe Blatt 1)

- Füllen der PERFO-Schalen auf die Strecke mit verzögertem Zementmörtel
- Anmachen und füllen der PERFO-Schalen auf die Strecke mit Kunststoffmörtel
- Zusammenklappen der Schalen zu einem Rohr
- Binden des PERFO-Rohrs alle 1 m mit 1 mm Draht
- Einschieben des PERFO-Rohrs in das Bohrloch
- Ankerstahl eintreiben mit Ankerschlagkopf und pneumatischem Hammer
- Kittwulst erstellen ca. 5 mm stark um den Stahl beim Bohrlochmund
- Ausgleichsschicht mit Kunststoffmörtel, wenn notwendig
- Ankerplatte aufsetzen und senkrecht zum Anker mit Mutter leicht anpressen
- Nach ca. 2 Stunden ansetzen der Zugvorrichtung und gewählte Vorspannkraft geben, sowie Mutter von Hand anziehen.

3. Kunststoffmörtel

SIKA-Haftmörtel (Handmischung ca. 1 ltr.) oder
SIKA-Fliessmörtel (Handmischung ca. 1 ltr.) Zugabe von Zuschlagstoffen (trockener Sand) bis Mörtel nicht mehr fliesst.

- Intensives Mischen der Trockenkomponenten, alles Harz (flüssig) beigeben und gut durchmischen

	Anker Ø PERFO-Rohr Øi	Ø 20 mm Ø 27 mm	Ø 26 mm Ø 31 mm	Ø 30 mm Ø 36 mm
Ergibt bei Verwendung von einer Handmischung à 1 ltr. (1 Kessel)		3 Anker	2 Anker	1 Anker
mit einer Haftlänge von		ca.50 cm	ca.60 cm	ca.80 cm

Achtung auf Temperatur !!!

4. Verzögerter Zementmörtel
Den Zementmörtel (Sand 0-2 mm) 1:1 soviel SIKA-Retarder beigeben, dass die Zeit der Verzögerung des Abbindens ausreicht um den Vorspannvorgang durchzuführen.

Widen, im Juli 1968 KF/m

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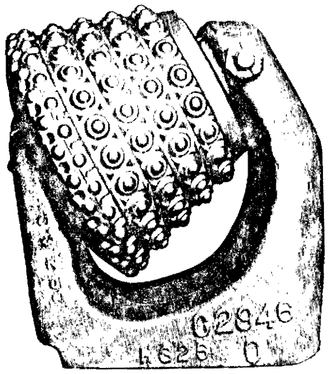
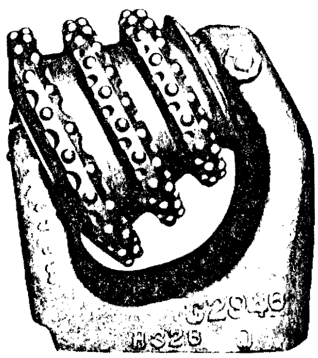
Reed Tunneling Cutters for every formation

Interchangeability

Reed Tunneling Cutters are designed for complete and easy interchangeability. All series of Reed Tunneling Cutter assemblies fit in the same saddle. A cutter may be used in any position on the bit, permitting the most efficient and economical use of cutters. Drillers can replace cutters quickly on the job without long, costly delays.

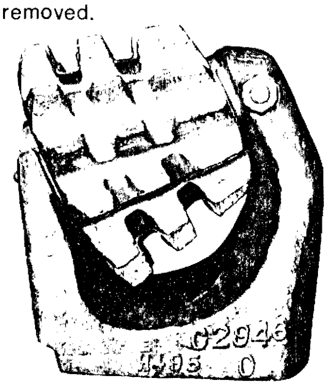


QC SERIES—A tungsten carbide insert cutter universally suited for applications in extremely hard igneous formations: diorite, granite, quartzite, basalt, chert, etc. Unique PAD MOUNTED inserts allow greater penetration and better insert retention.



QKC SERIES—A tungsten carbide insert type cutter with the circumferential kerf pattern for medium hard formations. Principal use is for tunneling where large chips are quickly removed from the cut face. The QKC affords a high rate of penetration through mixed formations.

QK SERIES—A circumferential tooth, kerf-type cutter for a wide range of soft to medium hard formations. It is especially designed for tunneling where cutting removal is no problem and larger chips are quickly removed.



QS SERIES—A tooth-type cutter for soft to medium hard formations, such as soft to medium shale, clay, limestone, sandstone, etc.

QH SERIES—A tooth-type cutter for medium to hard formations, such as hard shale, tight sand, limestone, dolomite, sandstone, etc.

CUTTER SELECTION

Determination of the type of cutter most suited to drill a particular rock ultimately depends on trial and error results. However, unique characteristics of each cutter design lend themselves best to particular drilling problems.

CUTTER SELECTION GUIDE

Description	Compressive Strength (PSI)	Typical Formations Encountered	Type Cutters Normally Used
Soft	6,000 maximum	Shale, clay red beds, mudstone, siltstone	QK, QS
Medium	6,000—12,000	Limestone, sandstone, rhyolite, marble tuffs	QK, QH
Medium Hard	12,000—25,000	Dolomite, gneiss, granite, greywacke, schist, feldspar	QKC
Hard	25,000 minimum	Diorite, quartzite, hornblende, argillite, basalt, chert	QC

Rock Testing

Customers have at their disposal the facilities of the G. W. Murphy Industries' laboratory in Houston for up-to-date drillability analysis of rock samples. In order to receive the most accurate recommendations for weight, torque, R.O.P. and cutter types, customers should send all information about the hole to be drilled and include a sample of each type of formation that will be encountered. Samples should be hand samples the size of an orange or core samples six inches in length.