SKB

TECHNICAL REPORT

89-17

Field instrumentation for hydrofracturing stress measurements
Documentation of the 1000 m hydrofracturing unit at Luleå University of Technology

Bjarni Bjarnason, Arne Torikka

Augusti 1989

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FIELD INSTRUMENTATION FOR HYDROFRACTURING STRESS MEASUREMENTS

DOCUMENTATION OF THE 1000 M HYDROFRACTURING UNIT AT LULEÅ UNIVERSITY OF TECHNOLOGY

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FIELD INSTRUMENTATION FOR HYDROFRACTURING STRESS MEASUREMENTS

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ABSTRACT

A recently developed system for rock stress measurements by the hydraulic fracturing method is documented in detail. The development effort was initiated by the Swedish Nuclear Fuel and Waste Management Company (SKB). Development and construction work was conducted by the Luleå University of Technology, on the basis of previous experiences from hydraulic fracturing measurements .

The new equipment is intended for measurements in vertical or near-vertical boreholes, down to a maximum depth of 1000 m. The minimum borehole diameter required is 56 mm. Downhole instrumentation comprises a straddle packer assembly for borehole fracturing, equipment for determination of fracture orientations and a pressure transducer. The downhole tools are operated by means of a multihose system, containing high pressure hydraulic tubings, signal cable and carrying wire into one hose unit. The surface components of the equipment include a system for generation and control of water pressures up to approximately 75 MPa, an hydraulically operated drum for the multihose and a data acquisition system. All surface instrumentation is permanently mounted on a truck, which also serves as power source for the instrumentation.

In addition to the description of the instrumentation, the theoretical fundaments and the testing procedures associated with the hydraulic fracturing method are briefly outlined.

CONTENTS

1 INTRODUCTION

The hydrofracturing method for rock stress measurements was introduced at Luleå University of Technology in the year 1982. It began with a loose component field instrumentation of multihose type for measurements to a maximum borehole depth of 500 m. It was later mounted on a field truck. Measurements were conducted in a number of sites in Sweden and in Finland by this first version of the hydrofracturing equipment.

The experience from this first equipment was good. The possibility of measuring rock stresses in continuous vertical profiles in existing field boreholes was new in Scandinavia. The results from the measurements added new and unique data to the knowledge of the state of stress in the upper part of the Baltic crust.

In the light of this experience and due to the needs for rock stress measurements within the Swedish Nuclear Waste Program, a contract of cooperation between Luleå University of Technology and SKB was signed in late autumn 1986. The new 1000 m hydrofracturing field instrumentation documented in this report is the outcome of this cooperation.

2 THE HYDROFRACTURING METHOD

A detailed description of the hydrofracturing method lies outside the scope of this report. The interested reader is referred to Bjarnason 1986, and Bjarnason et al. 1988. The sections below give an introduction to the classical application of the hydrofracturing method to form background to the instrumentation chapters that follow.

2.1 THEORY

The stress calculations for the crystalline rocks in Sweden follow the classical theory for hydraulic fracturing in almost impermeable, isotropic and linear elastic medium, Hubbert and Willis, 1957. The borehole is assumed to lie parallel to one of the principal stress directions in the rock mass. The vertical principal stress Sv is calculated from the weight of the overlying rock mass in each test point according to:

$$Sv = \gamma z \qquad (1)$$

where;

Sv = vertical stress
γ = unit weight of the rock mass
z = depth from the ground level

The horizontal principal stresses are calculated using data from the pressure records obtained from vertical hydrofractures, (coplanar with the borehole axis), according to the following equations:

$$Sh = Ps \qquad (2)$$
$$SHI = 3Sh - Pb + T \quad \text{or} \qquad (3)$$
$$SHII = 3Sh - Pr \qquad (4)$$

where;

Sh = Minimum horizontal stress
Ps = Shut-in pressure on the fracture plane. The shut-in pressure is the water pressure in the test section between the straddle packers when the hydrofracture closes and is equivalent to the normal stress acting on the fracture plane. In case of a vertical hydrofracture this is the same as the minimum horizontal stress in the rock mass at the test depth.
SHI = Maximum horizontal stress calculated by the first breakdown method.
SHII = Maximum horizontal stress calculated by the second breakdown method.
Pb = Breakdown pressure (fracture initiation pressure).

T	=	Tensile strength of intact rock under hydraulic fracturing conditions.
Pr	=	Reopening pressure of the hydrofracture.

The first breakdown method, SHI applies a fixed value for the hydrofracturing tensile strength of the rock, T. The value of T is determined by laboratory tests on core samples from the borehole. A miniature borehole is drilled axially through the center of the core specimen and, pressurized by water until fracturing occurs, Figure 2-1. A scale factor is used to extrapolate the miniature laboratory results to apply for the full scale field borehole.

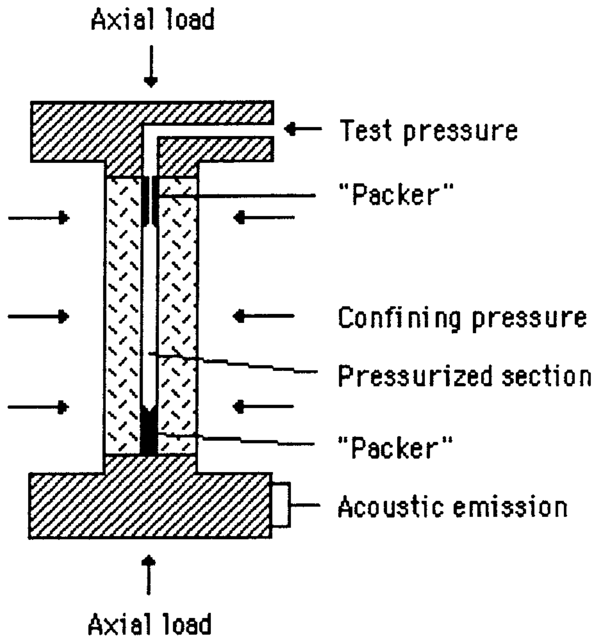


Figure 2-1. Laboratory simulation of hydraulic fracturing for determination of the tensile strength of the rock.

For the second breakdown method the difference between the first and second breakdown pressures, Pc1 - Pc2, is used as a measure of the hydrofracturing tensile strength of the rock at each test point, Figure 2-2.

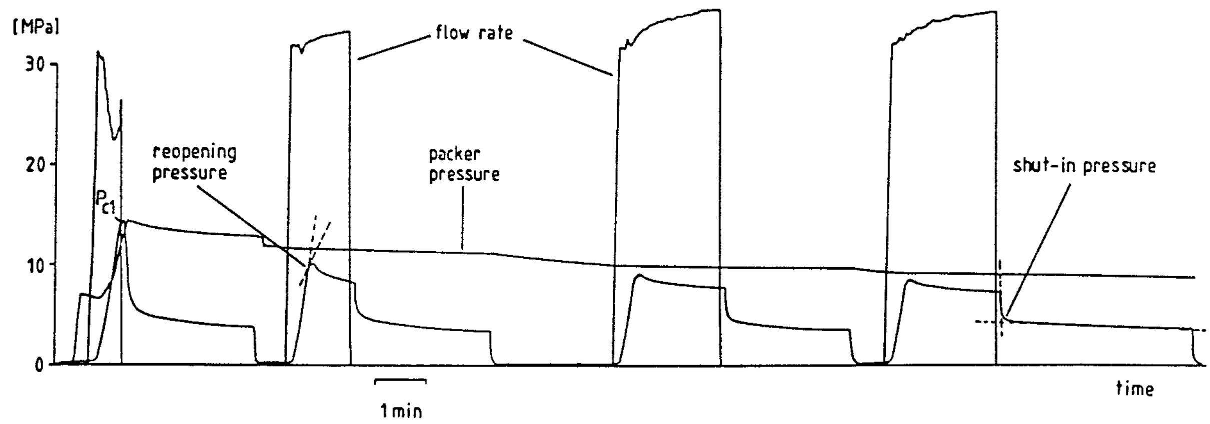


Figure 2-2. A typical hydrofracturing field record for crystalline rocks in Sweden. Getinge, Southern Sweden, 205.1 m depth.

A number of methods can be applied to determine the shut-in and reopening pressures from the test curves. The most common method in our work is to select the shut-in pressure at the point of intersection between two tangent lines. One is drawn to the immediate pressure drop following shut-down of the pressure line and, the other is drawn to the almost linear part of the post-shut-in part of the curve. A typical test curve is shown in Figure 2-2.

Breakdown and reopening pressures are defined as the points for each cycle where the pressure-time curve during pressurization begins to deviate from linearity.

The orientation of the horizontal stresses is determined from the strike of the hydrofractures. In strength isotropic rock material the orientation of hydrofractures will be controlled by the stress directions in the rock mass surrounding the borehole. Therefore, the hydrofracture will initiate in a vertical plane, perpendicular to the minimum horizontal stress. The orientation of the hydrofractures is determined by an impression packer coupled to a single-shot magnetic compass.

2.2 TESTING PROCEDURE

Test points free from macroscopic fractures are chosen from a detailed fracture log of the drill core. A straddle packer is lowered to the test depth and inflated by water, Figure 2-3. The straddle packer and the test interval are pressurized simultaneously to avoid high stress concentrations at the packer ends. The packers are controlled through a separate pressure line and the packer pressure is kept slightly above the test section pressure throughout the test cycle.

Fracturing is conducted at constant flow rate, usually about 3.5 l/minute, resulting in breakdown within 30 to 40 seconds. The test line is shut down immediately after breakdown is observed, and a first shut-in pressure is recorded. The shut-in curve is normally recorded 3 to 4 minutes after shut down. Venting of the test section after each pressurization cycle is normally conducted until pressure rebounds after repeated closing of the test line fade out. The first pressurization cycle is followed by three cycles where pressurization is conducted at the same constant flow rate. The pumping time after reopening the fracture is increased for each cycle. This causes a stepwise propagation of the fracture out from the borehole wall. This is done to record the change in shut-in pressure as a function of fracture extension or geometry.

When the fracturing tests are terminated a preliminary evaluation of the test results is performed. Based on the evaluation, fracture impressions are taken at the test points that give the most promising results. The impression packer is inflated at the test point for 30 - 40 minutes. The orientation of the compression packer, recorded by a magnetic compass during the impression period, enables the determination of the hydrofracture orientation.

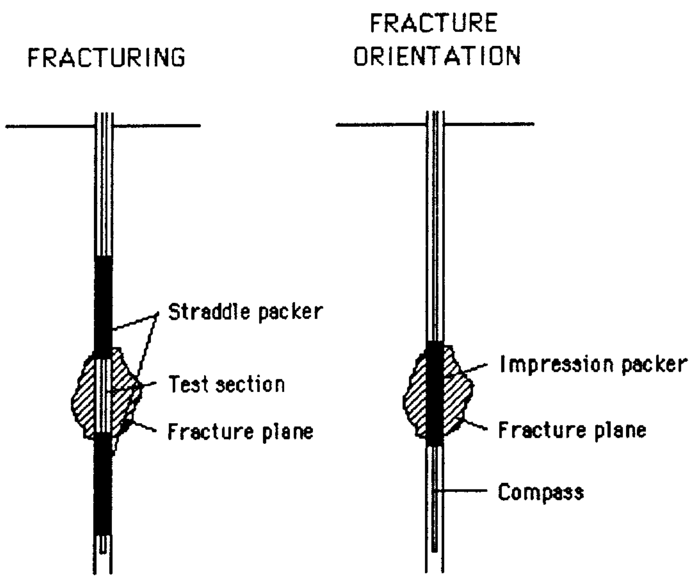


Figure 2-3. Packer configuration in the borehole during testing.

3 THE HYDROFRACTURING INSTRUMENTATION

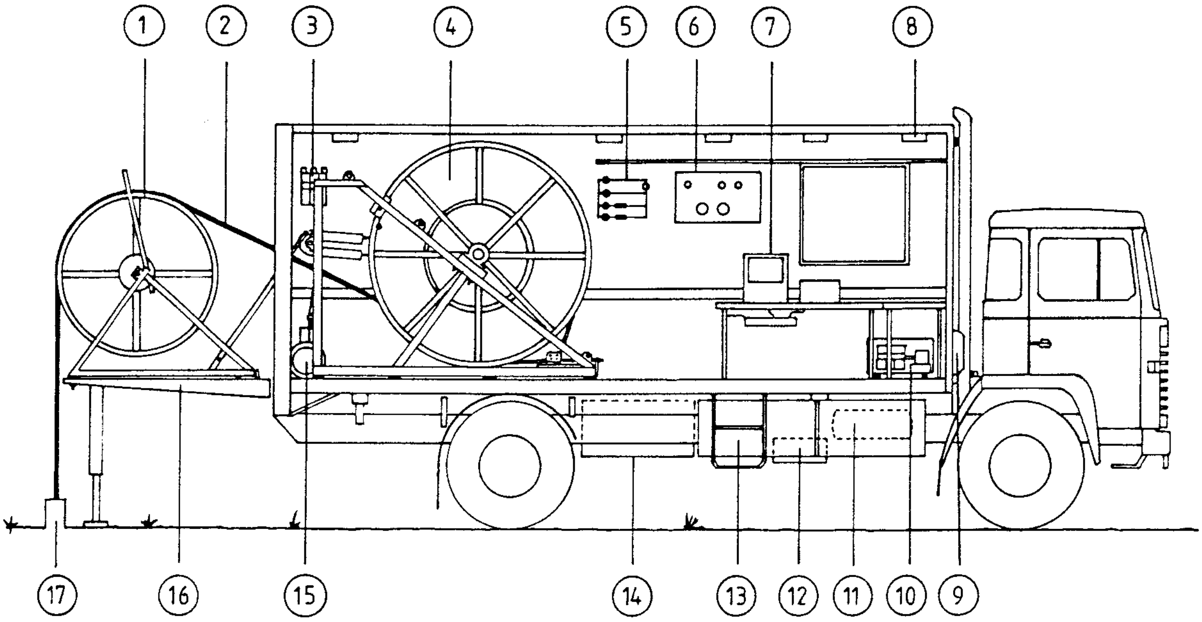
The guidelines for design of the instrumentation were good technical standard to provide high quality test results and fast and effective operation in the field. Depth limits were set to 1000 m which is twice the anticipated depth of a nuclear waste repository in the swedish bedrock. The maximum peak pressure of the system is 80-90 MPa, which was considered adequate for the maximum stress magnitudes expected at 1000 m depth. Maximum flow rates, which are restricted by frictional pressure losses in the hydraulic tubing, are 7-8 l/min. The entire field instrumentation is mounted on a truck and hydrofracturing operations are conducted from inside the truck cabin. All functions of the field unit are powered by the truck engine. Thus, stress measurements are conducted without the aid of a drill rig at the borehole and no external power sources are needed on the test site.

The hydrofracturing instrumentation, cooperatively developed by Luleå University of Technology and SKB, will be described in detail on the following pages.

Drawings and specifications of the instrumentation are dealt with in groups or systems from a functional point of view. First is an overall cross-cut of the field truck showing main components, followed up by detailed drawings of the hydraulic system, the multihose operating system, the water system, the borehole tools and finally the multihose itself.

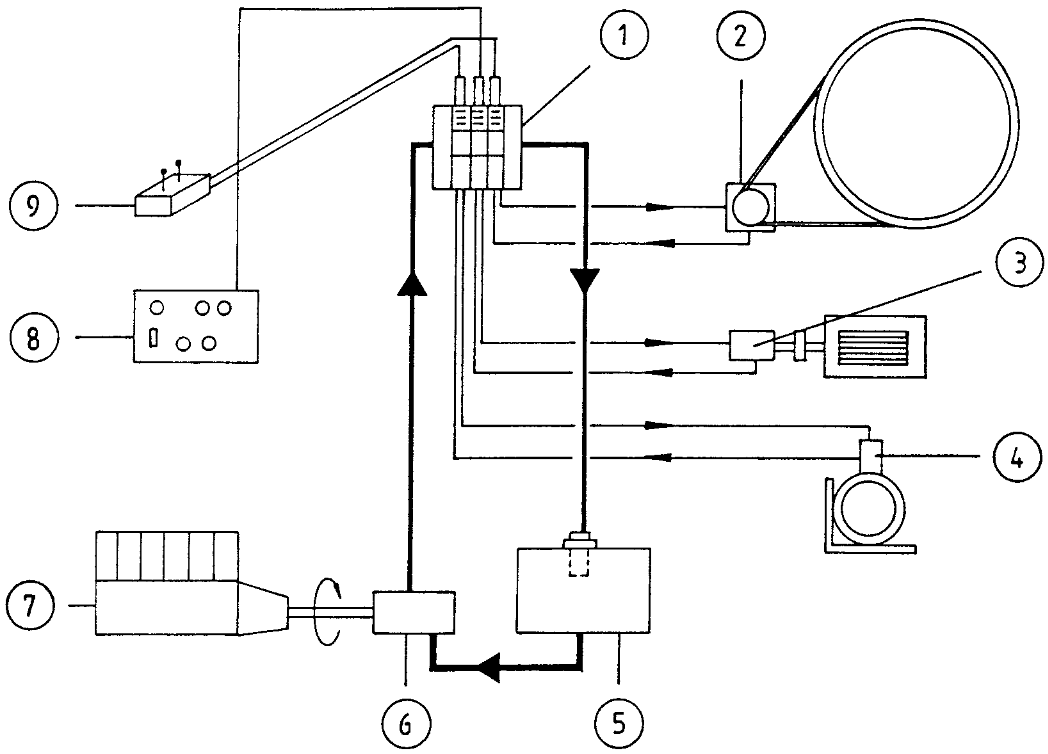
Drawings are not shown in a specific scale and dimensions are rarely shown. The primary purpose of the drawings and the text is to explain the function of the instrumentation for a person who is not accustomed to hydraulic fracturing or to this specific equipment.

Many of the components are constructed at Luleå University of Technology and are not available on the market. However, where standard components are used, the specifications are given together with manufacturer and/or supplier.



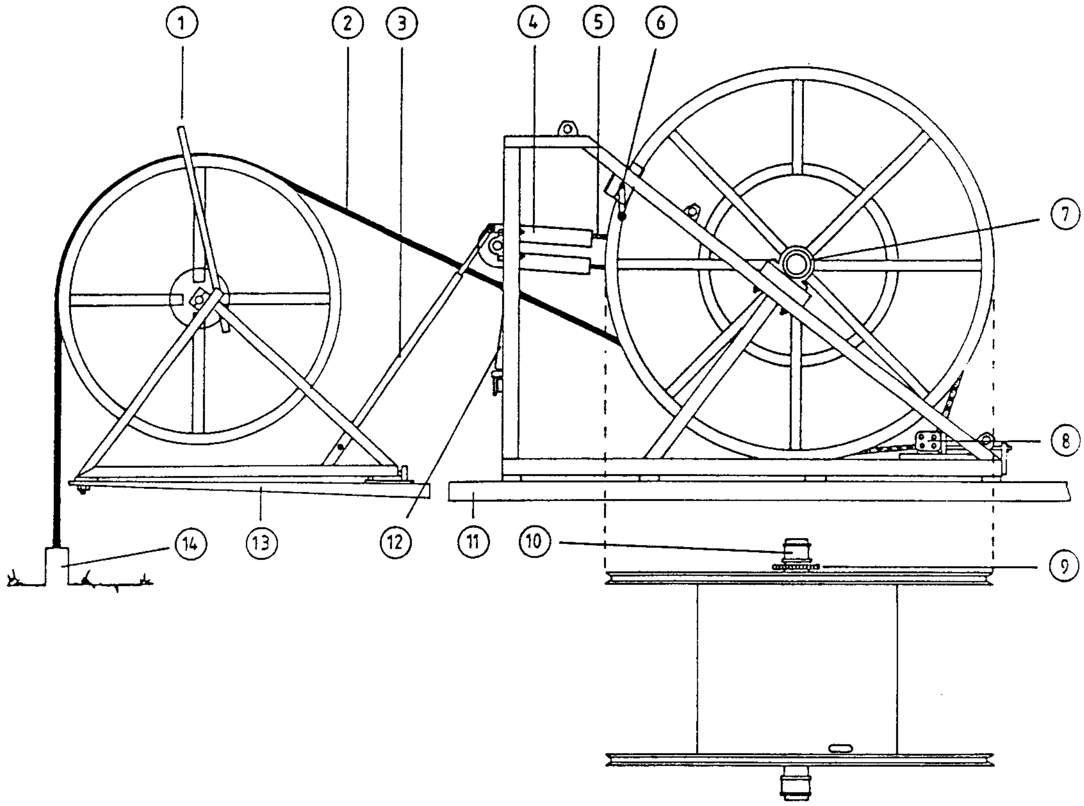
3.1 HYDROFRACTURING FIELD TRUCK - MAIN COMPONENTS

1 Guidewheel for multihose.
2 Multihose.
3 Control unit of the hydraulic system, remote controlled proportional valves.
4 Drum for multihose, 1000 m.
5 Flow meters.
6 Manifold for control of fracturing flow and packer pressure.
7 Data acquisition system.
8 Working lights, 24 v DC and 220 v AC.
9 Cabin heater, 7 kw.
10 High pressure water pump.
11 Compressed air tubes.
12 Hydraulic pump.
13 Diesel fuel tanks, 400 l for long field periods.
14 Hydraulic tank.
15 Winch.
16 Working platform, adjustable height and inclination.
17 Borehole.



3.2 THE HYDRAULIC SYSTEM

1 Remote controlled hydraulic valves for operation of cable drum, water pump and winch, type; Danfoss PVG 60, 3 sections proportional valves.
2 Hydraulic motor to cable drum, type; Danfoss OMT 315 with chock valves.
3 Hydraulic motor to water pump, type; Danfoss OMS 125.
4 Hydraulic motor to winch, type; ASAPPA CML 20 P/X
5 Hydraulic tank, 120 liters, without cooling, oil filter on return line, type; Arlon TXX 5-10.
6 Hydraulic pump, type; SUNFAB 9-17 SR
7 Truck engine powering the hydraulic pump.
8 Electrical switch on manifold for remote operation of water pump.
9 Control box for operation of cable drum and winch.



3.3 CABLE DRUM AND GUIDEWHEEL

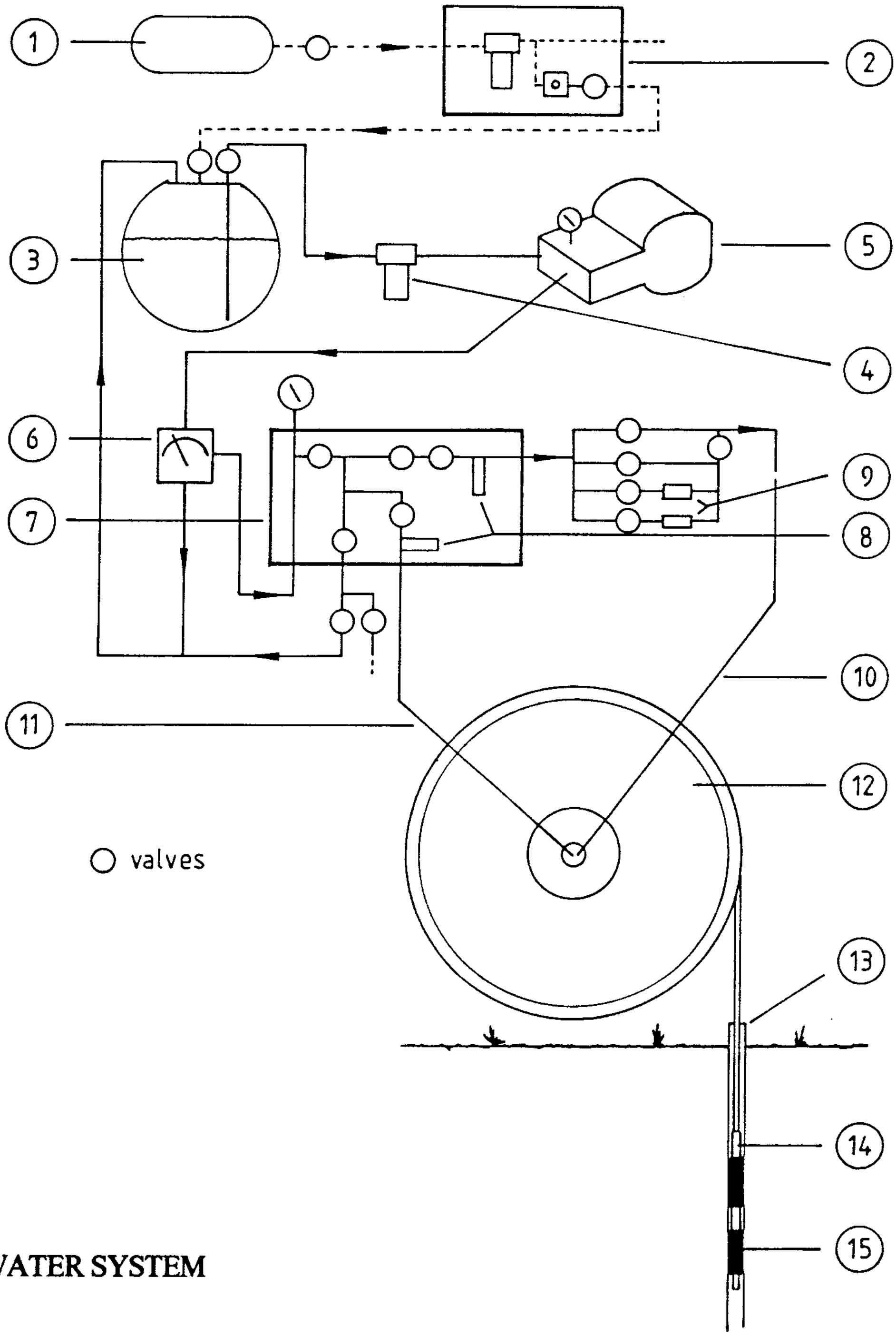
1 Cable guide to prevent multihose from climbing of the guidewheel.
2 Multihose.
3 Guidewheel steering rod.
4 Chain cover.
5 Chain connecting the hub of the cable drum (9) to the gear wheel of the cable steering mechanism.
6 Brake to the cable drum.
7 Slide bearings.
8 Hydraulic motor for drum rotation.
9 Hub gear wheel for cable steering chain.
10 Slide bearing seat.
11 Truckbed.
12 Cable steering mechanism.
13 Adjustable working platform.
14 Borehole.

<u>Specifications</u>

Drive chain for cable drum: Roller chain nr 548
Gear wheel: 13/548

Chain to steering mechanism:
Roller chain nr 462
Gear wheel on drum hub: 47/462
Gear wheel on stearing mechanism: 52/462

Supplier of chains and gear wheels:
KEDJETEKNIK AB
Baragatan 2
212 48 Malmö



3.4 WATER SYSTEM

1 Compressed air at 8 bar, provided by truck engine.
2 Air control panel; air filter, pressure reduction from 8 to 2 bars to pressurize water tank and, 8 bar outlet for pneumatic tools.
3 Water supply tank, 900 liters. Pressurized by air at 2 bars to feed the high pressure pump.
4 Water filter.
5 High pressure pump for fracturing and packer operation. Type; HERMETIK AH30 three cylinder pump. Delivers 17 liter/minute at 750 rpm at a continuous

working pressure of 750 bars. Supplier; Hermetik Hydraulik AB, Lansenvägen 3, 183 65 Täby, Sweden.

6 Bypass valve, adjustable system pressure. Working pressure 1000 bar. Supplier as nr 5.

7 Manifold. Inlet at adjustable pressure through the bypass valve. Four outlets: i) to fracturing line via flow meters, ii) to packer line, iii) return to water tank during venting of the fracture or from packer depressurization, iv) outlet to atmospheric pressure for zero adjustment of pressure transducers.

8 Pressure transducers for fracturing pressure and packer pressure.
Packer. Type; HDA 3041-3-450-000
Fracturing. Type; HDA 3042-3-450-000
Delivered by: HYDAC FLUIDTEKNIK AB, Box 20112, 161 20 Bromma.

9 Two flow meters with different flow ranges in parallel set-up. Types; In-line paddle bladed rotor type. Omniflo FTO series from FLOW TECHNOLOGY, INC. 4250 East Broadway Road, Phoenix, Arizona 85040. Flow ranges:

1	Omniflo	FTO-3	0.02 - 1.3 l/min
2	Omniflo	FTO-4-	0.736 - 4.92 l/min

10 Fracturing line.

11 Packer line.

12 Drum and multihose.

13 Borehole.

14 Downhole pressure transducer for fracturing pressure. Type; KISTLER 4043 Calibrated 0-500 bar.

15 Packers

FLOW METER CALIBRATION

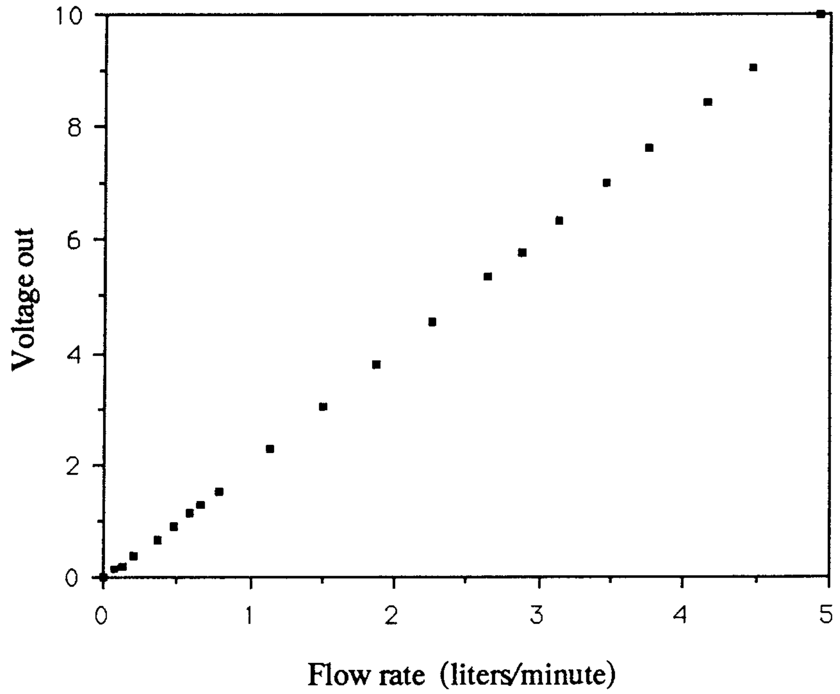
OMNIFLO FTO 4

Flow rate l/min	output voltage
4.920	10.000
4.465	9.062
4.160	8.457
3.762	7.630
3.464	7.004
3.135	6.347
2.872	5.800
2.646	5.341
2.247	4.529
1.872	3.777
1.502	3.054
1.132	2.269
0.782	1.534
0.667	1.298
0.594	1.154
0.477	0.902
0.368	0.686
0.205	0.373
0.121	0.209
0.074	0.120
0	0.002

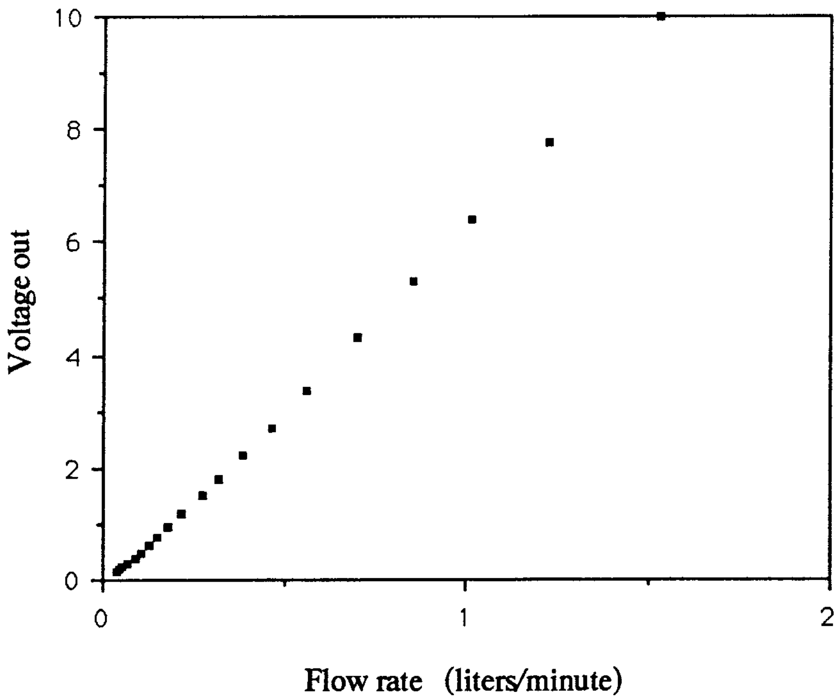
OMNIFLO FTO 3

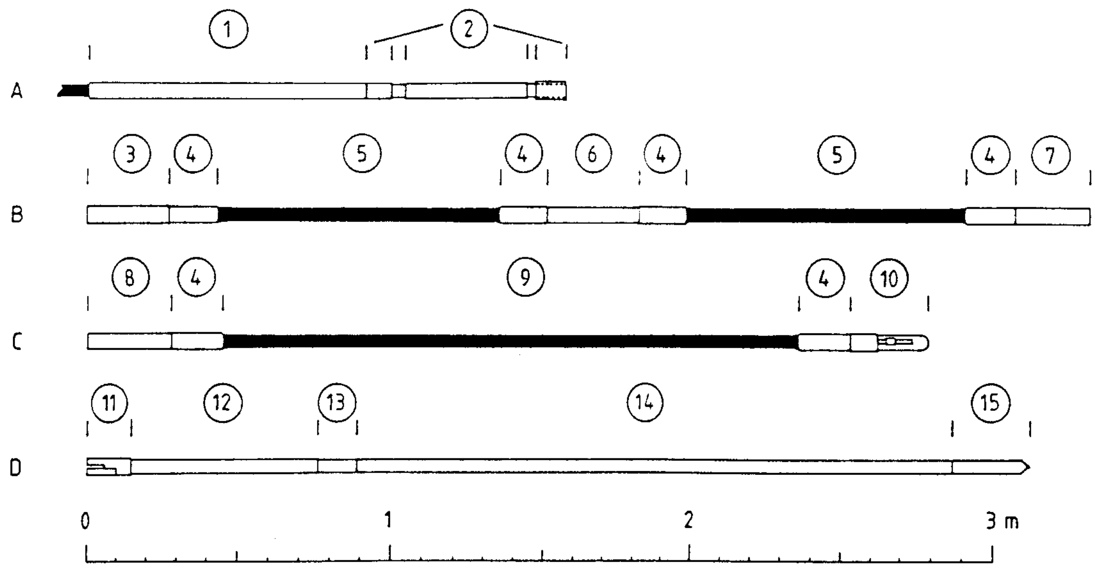
Flow rate l/min	output voltage
1.533	10.000
1.223	7.791
1.015	6.379
0.850	5.295
0.699	4.304
0.557	3.365
0.458	2.704
0.381	2.206
0.316	1.799
0.269	1.505
0.215	1.167
0.179	0.946
0.146	0.75
0.125	0.626
0.102	0.492
0.085	0.393
0.065	0.286
0.055	0.234
0.046	0.189
0.037	0.142

OMNIFLO FTO 4



OMNIFLO FTO 3





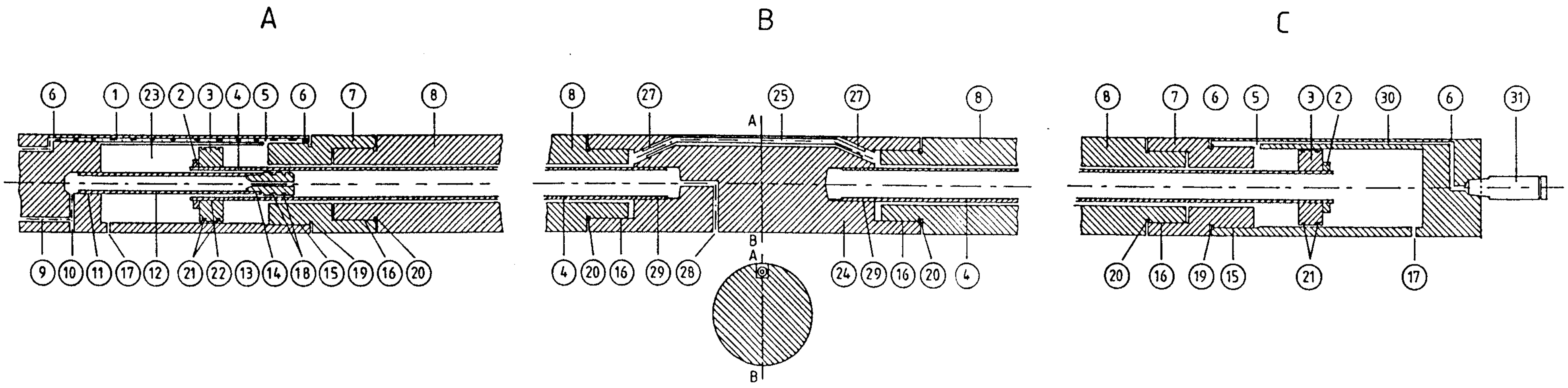
3.5 BOREHOLE TOOLS

A Multihose and cable head.
B Straddle packer for fracturing and injection testing.
C Impression pakcer.
D Single-shot magnetic borehole compass.

1 Cable head connection to multihose. Contains kevlar rope anchor connection and downhole pressure transducer. The kevlar rope, with a pull-off strength of 60 kN, is connected to the cable head via M10 threaded steel bar of 28 kN pull-off strength. In case the borehole tools get stuck in the hole the full length of the multihose can be retrieved by pulling of the threaded steel bar.
2 Cable head.
3 Upper end of fracturing tool. Connects to (2).
4 Packer end. Pressed-on steel binding to the inflatable rubber.
5 Inflatable packer rubber. Nylon reinforced hydraulic hose. Different diameters available.
6 Mandrill.
7 Bottom end of fracturing tool.
8 Upper end of impression tool. Connects to (2).
9 Inflatable part of impression packer. Covered with uncured rubber. Different lengths and diameters available.
10 Bottom end of impression tool.
11 Connection of orientation tool to the impression packer, connects to (10). Fixed orientation against packer. Aluminum.
12 Extension rod, aluminum.
13 Upper end plug to single-shot barrel.
14 Stainless steel barrel to single-shot compass camera.
15 Bottom end plug to the barrel. Fixes the orientation of the single-shot compass camera.

DIMENSIONS OF DOWNHOLE TOOLS
L = length D = diameter (mm)

1	L = 910	D = 53
2	L = 660	Dmax = 53
3	L = 280	D = 53
4	L = 160	D = 52
5	L = 920	D = 48
6	L = 310	D = 50
7	L = 240	D = 53
8	L = 280	D = 50
9	L = 1910	D = 49
10	L = 160	D = 53
11	L = 150	D = 53
12	L = 610	D = 45
13	L = 130	D = 45
14	L = 1980	D = 45
15	L = 250	D = 45

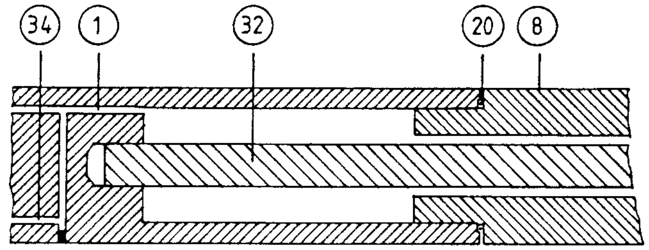


Fracturing tool

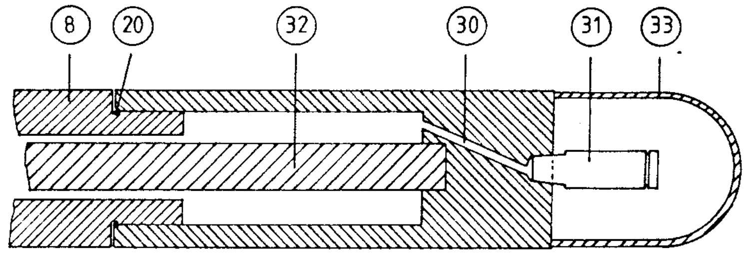
A Packer, upper end
B Mandrill
C Packer, lower end

1 Packer pressure inlet, D = 3.0 mm
2 Nut, thread M 16 x 1
3 Piston, thread M 16 x 1
4 Steel tube, D = 16 x 3 mm, hydraulic tube
5 Packer pressure outlet
6 Plugged end to 1
7 Adapter, packer M 34 x 1,5 to piston system M 40 x 1.5
8 Packer, TK.. M 34 x 1.5
9 Fracturing pressure inlet, D = 4.0 mm
10 Plugged end to 9
11 Thread, M 10 x 0.75 (glued)
12 Steel tube, D 10 x 2 mm (stainless)
13 Thread, M 7 x 1 (glued)
14 Nozzle, D = 3 mm
15 Thread, M 40 x 1.5
16 Thread, M 34 x 1.5
17 Hole for pressure equalizing (to open borehole pressure) D = 4 mm
18 O-ring, 6 x 2 mm
19 O-ring, 34.52 x 3.53 mm
20 O-ring, 31 x 3 mm
21 O-ring, 31.34 x 3.53 mm
22 Thread, M 16 x 1 (glued)
23 Polished surface
24 Mandrill
25 Packer pressure throughlet, stainless steel tube, D = 6 x 1.5 mm
26 Slot for 25, completely welded
27 Drilled hole, D = 6 mm
28 Fracturing pressure outlet, D = 5 mm
29 Thread, M 16 x 1 (glued)
30 Packer pressure release outlet, D = 3 mm
31 Packer pressure release valve, thread 1/4" NPT

A



B



<u>Impression tool</u>

A Packer upper end.
B Packer lower end.

1 Packer pressure inlet.
8 Packer, TK.. M 34 x 1.5
20 O-ring 31 x 3 mm.
30 Packer pressure release outlet, D = 3 mm.
31 Packer pressure release valve, thread 1/4" NPT.
32 Steel bar, D = 16 mm.
33 Hook to fasten single-shot compass camera.
34 Inlet to downhole pressure transducer.

3.6 MULTIHOSE

The multihose was designed to fill two purposes; high quality measurements and fast and effective field work. Our experience with the two multihoses, 500 and 1000 m long, can be summarized as follows:

Advantages

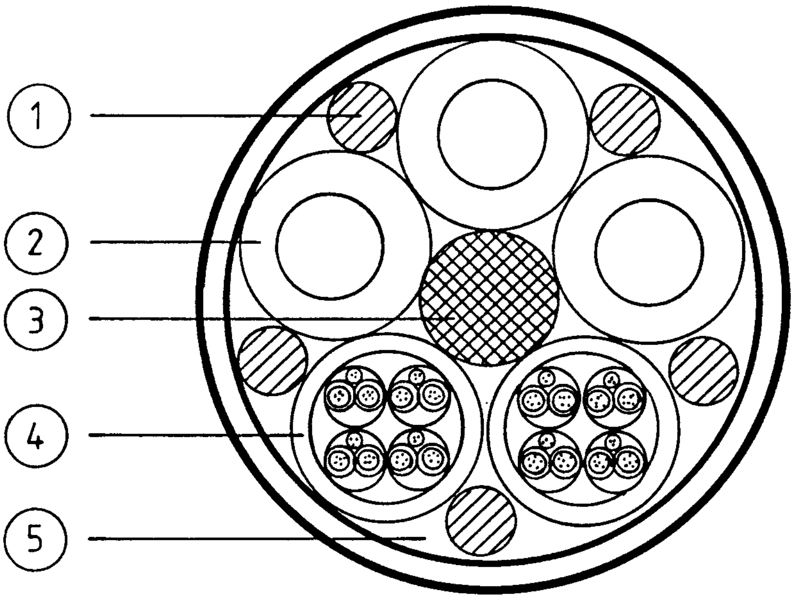
It provides independency of drill rigs, simplicity and efficiency in operation. The same independency can be achieved without the expensive multihose using loose component wireline systems in which the pressure tubing and signal cable are clamped to the wire. The operation of a loose component wireline system is, however, much more cumbersome and the risk of getting stuck is probably larger. Simplicity and efficiency are two important advantages of the present system. Rigging up at the test site takes just a few hours. All fracturing work and impression work can be operated by one person, including installing and removing the packers from the borehole. Travel times in the hole are short, the 1000 m hose is run from the surface down to bottom within 15 minutes and up again in less than 30 minutes. This is particularly important in deep boreholes with a large number of test points (40-50 test points in a 1000 m deep borehole) where the application of the conventional impression method for fracture orientation would otherwise result in excessively long and expensive field periods.

Disadvantages

High initial cost. The manufacturing of the multihose is a highly specialized work, and once finished, no possibility exists to change its design or performance. The risk of getting stuck in the borehole is greater than for conventional drill string operated instruments. The chance of recovering equipment stuck downhole by means of the multihose is small. Therefore the multihose is connected to the cable head by a weak tension link to be torn off in emergency, leaving only the packer assembly in the hole. Further disadvantages are flow-dependent pressure drops in the test lines and the low stiffness of the system. The new high pressure hydraulic hoses are synthetic, of a special high stiffness type. With two parallel connected 1/4" I.D. hoses for fracturing, the pressure drop at 8 l/min is approximately 8 MPa, which is the maximum pressure loss we can allow with the present system. An ideal solution would be to locate flow meters and the shut-in valve downhole, within to the packer assembly, but the small diameter of the boreholes does not allow this.

The multihose is made by: NORDDEUTSCHE SEEKABELWERKE
Aktiengesellschaft, 289 Nordenham,
Germany

Designed and delivered by: MacArtney ApS
Underwater Technology
Guldagervej 2, DK-6710, Esbjerg V
Denmark



Cross-cut of the multihose

1 Filler wires.
2 Hydraulic hoses, 1/4" hose type 520 N-4. Rec. operating pressure: 345 bar, proof pressure: 690 bar, min. burst pressure: 1380 bar.
3 Kevlar stress member, 60 kN. 2% elongation at breaking point.
4 Signal cable, Four pairs, screened and twisted. Conductor cross section: 1,0 mm^2 Polyurethane jacket (4588-1A), OD 12,6 mm.
5 Filler compound.

SPECIFICATIONS

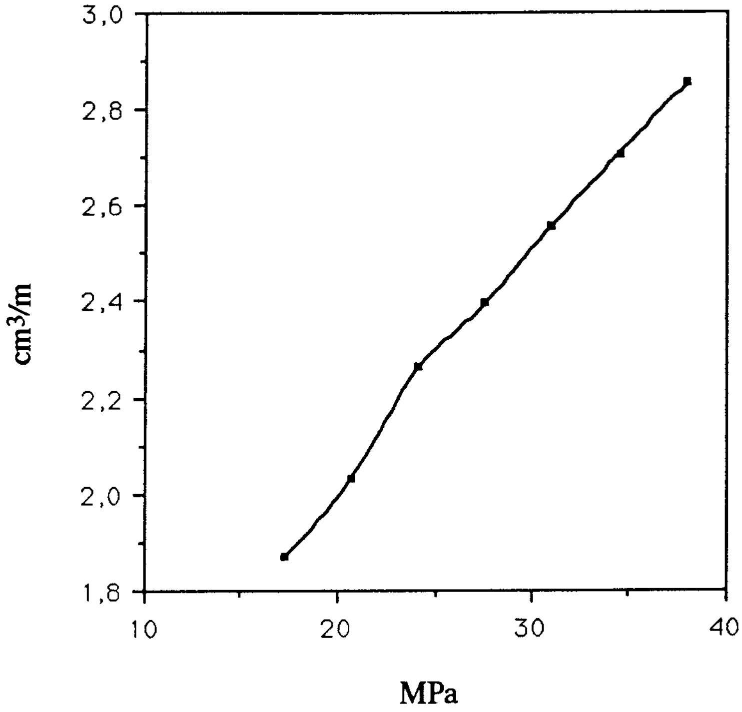
Multihose

Outer diameter: 40 mm
Min. break strength: 60 kN
Weight in air: 1470 kg/km
Weight in seawater: 220 kg/km
Rec. bend radius: 500 mm

Underwater electrical cable

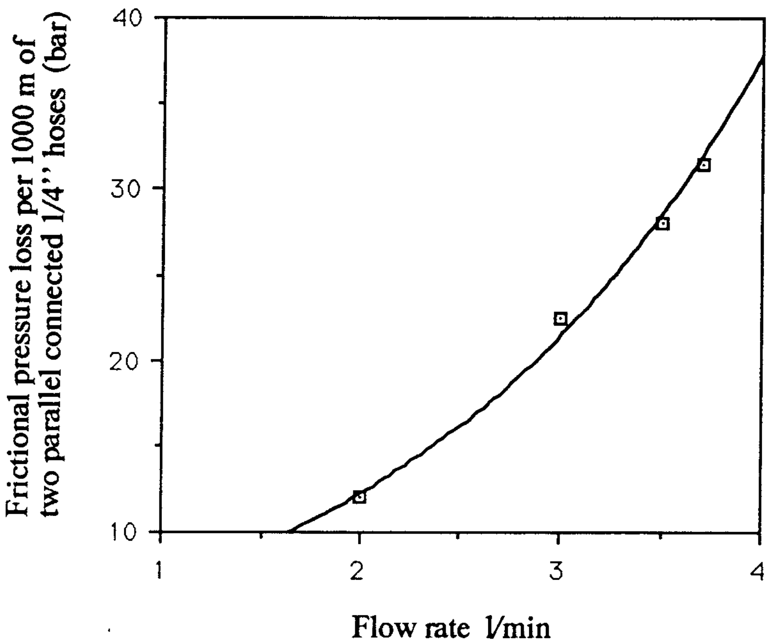
Type no. 4588.1

Construction:
In center; 1.0 mm2 stranded bare copper wires 19 x 0.32 mm insulated with PE of 0.3 mm wall. Two conductor and a drain copper wire twisted, with an overall aluminum tape. Four pairs twisted with a leyer of PETP-foil. Jacket; Polyurethane-orange of 2.2 mm wall.
Mechanical characteristics:
Outer diameter: 12.6 mm
Weight in air: 185 kg/km
Weight in seawater: 80 kg/km
Min. bending radius: 170 mm
Electrical characteristics (at 20°C):
Conductor resistance: 19.5 ohms/km
Insulation resistance: Inner conductor/outer conductor - screen earth 10Giga ohms x km
Screen/outer screen - earth 1 Mega ohms x km
Capacitance: 100 nF/km
Characteristic impedance at 100 KHz: 70 ohms
Attenuation at 100 KHz: 7 db/km.
Test voltage : 1.5 kV, DC.



Volumetric expansion of hydraulic hoses
Synflex 3LVE Series hose 1/4" ID

psi	cm^3/foot	MPa	cm^3/m
2500	0,57	17,237	1,87
3000	0,62	20,684	2,034
3500	0,69	24,132	2,264
4000	0,73	27,579	2,395
4500	0,78	31,027	2,559
5000	0,825	34,474	2,707
5500	0,87	37,921	2,854



Frictional pressure losses as a function of flow rate in Synflex 3LVE Series 1/4" hydraulic hoses. Pressure losses are shown for two parallel connected hoses of 1000 m length for fracturing and injection testing. Flow rate in each 1/4" hose is half the value shown on the x-axis.

Length calibration of the multihose

The jacket of the multihose is marked every meter by the manufacturer. However, as the hose is somewhat elastic these marks can not be relied upon as depth indicators when working in steeply dipping boreholes. The hose has therefore been length calibrated against a constant length surveying tape of steel, hanging parallel with the hose in a vertical borehole. The procedure has been performed three times to follow up time dependent elongation of the hose. Readings are taken every 5 meters on the reference tape and the corresponding hose marking is noted. Calibration has been performed at the following sites and occasions:

Oskarshamn, stress measurements in borehole KAS03, July 1988.
Lansjärv, stress measurements in borehole KLJ01, September 1988.
Luleå University, stress measurements in the laboratory borehole, November 1988.

All calibrations reached a minimum depth of 500 m. Results are presented in the following table. Looking at the last row for 500 m reference depth the following is observed:

- The first calibration of the hose, before stress measurements commence, shows a 0.25 m elongation of the hose compared to the reference.
- The second calibration, after completing stress measurements down to 1000 m depth at Oskarshamn, shows 1.23 m elongation from the reference and a 0.98 m elongation due to the measurements in Oskarshamn.
- The third calibration, after finishing the stress measurements at Lansjärv, shows an elongation of a mere 0.02 m due to the Lansjärv job.

Thus, the multihose appears to have reached a stable length after the relatively large elongation measured after the first field job. However, the hose should be recalibrated after each major field job for a check-up.

Length calibration of 1000 m multihose

Reference	Oskarshamn	Lansjärv	Laboratory	Osk-Lans	Lans-Labb	Osk-Labb	Ref-Lab
5,00	5,05	5,05	4,89	0,00	0,16	0,16	0,11
10,00	10,10	10,13	10,31	-0,03	-0,18	-0,21	-0,31
15,00	15,15	15,21	15,58	-0,06	-0,37	-0,43	-0,58
20,00	20,20	20,28	20,83	-0,08	-0,55	-0,63	-0,83
25,00	25,25	25,32	26,12	-0,07	-0,80	-0,87	-1,12
30,00	30,30	30,37	31,34	-0,07	-0,97	-1,04	-1,34
35,00	35,34	35,38	36,52	-0,04	-1,14	-1,18	-1,52
40,00	40,35	40,39	41,68	-0,04	-1,29	-1,33	-1,68
45,00	45,30	45,32	46,77	-0,02	-1,45	-1,47	-1,77
50,00	50,32	50,33	51,89	-0,01	-1,56	-1,57	-1,89
55,00	55,33	55,34	56,99	-0,01	-1,65	-1,66	-1,99
60,00	60,35	60,34	62,07	0,01	-1,73	-1,72	-2,07
65,00	65,36	65,34	67,12	0,02	-1,78	-1,76	-2,12
70,00	70,36	70,34	72,15	0,02	-1,81	-1,79	-2,15
75,00	75,37	75,33	77,18	0,04	-1,85	-1,81	-2,18
80,00	80,38	80,33	82,18	0,05	-1,85	-1,80	-2,18
85,00	85,39	85,33	87,16	0,06	-1,83	-1,77	-2,16
90,00	90,40	90,33	92,15	0,07	-1,82	-1,75	-2,15
95,00	95,41	95,32	97,14	0,09	-1,82	-1,73	-2,14
100,00	100,43	100,31	102,16	0,12	-1,85	-1,73	-2,16
105,00	105,44	105,29	107,24	0,15	-1,95	-1,80	-2,24
110,00	110,44	110,30	112,30	0,14	-2,00	-1,86	-2,30
115,00	115,45	115,30	117,30	0,15	-2,00	-1,85	-2,30
120,00	120,45	120,29	122,28	0,16	-1,99	-1,83	-2,28
125,00	125,46	125,29	127,26	0,17	-1,97	-1,80	-2,26
130,00	130,46	130,27	132,21	0,19	-1,94	-1,75	-2,21
135,00	135,46	135,26	137,15	0,20	-1,89	-1,69	-2,15
140,00	140,46	140,25	142,07	0,21	-1,82	-1,61	-2,07
145,00	145,46	145,23	146,98	0,23	-1,75	-1,52	-1,98
150,00	150,47	150,22	151,91	0,25	-1,69	-1,44	-1,91
155,00	155,47	155,21	156,82	0,26	-1,61	-1,35	-1,82
160,00	160,46	160,20	161,71	0,26	-1,51	-1,25	-1,71
165,00	165,46	165,19	166,60	0,27	-1,41	-1,14	-1,60
170,00	170,46	170,18	171,51	0,28	-1,33	-1,05	-1,51
175,00	175,46	175,15	176,43	0,31	-1,28	-0,97	-1,43
180,00	180,46	180,14	181,38	0,32	-1,24	-0,92	-1,38
185,00	185,46	185,12	186,29	0,34	-1,17	-0,83	-1,29
190,00	190,46	190,10	191,19	0,36	-1,09	-0,73	-1,19
195,00	195,46	195,08	196,15	0,38	-1,07	-0,69	-1,15
200,00	200,46	200,05	201,14	0,41	-1,09	-0,68	-1,14
205,00	205,46	205,01	206,16	0,45	-1,15	-0,70	-1,16
210,00	210,46	209,98	211,17	0,48	-1,19	-0,71	-1,17
215,00	215,46	214,97	216,16	0,49	-1,19	-0,70	-1,16
220,00	220,45	219,97	221,15	0,48	-1,18	-0,70	-1,15
225,00	225,45	224,97	226,14	0,48	-1,17	-0,69	-1,14
230,00	230,45	229,96	231,12	0,49	-1,16	-0,67	-1,12
235,00	235,45	234,95	236,09	0,50	-1,14	-0,64	-1,09
240,00	240,44	239,94	241,05	0,50	-1,11	-0,61	-1,05
245,00	245,44	244,92	246,00	0,52	-1,08	-0,56	-1,00
250,00	250,43	249,90	250,92	0,53	-1,02	-0,49	-0,92

255,00	255,42	254,88	255,84	0,54	-0,96	-0,42	-0,84
260,00	260,41	259,86	260,77	0,55	-0,91	-0,36	-0,77
265,00	265,40	264,84	265,71	0,56	-0,87	-0,31	-0,71
270,00	270,40	269,83	270,64	0,57	-0,81	-0,24	-0,64
275,00	275,39	274,81	275,58	0,58	-0,77	-0,19	-0,58
280,00	280,38	279,80	280,50	0,58	-0,70	-0,12	-0,50
285,00	285,38	284,78	285,40	0,60	-0,62	-0,02	-0,40
290,00	290,37	289,76	290,32	0,61	-0,56	0,05	-0,32
295,00	295,36	294,74	295,23	0,62	-0,49	0,13	-0,23
300,00	300,35	299,72	300,14	0,63	-0,42	0,21	-0,14
305,00	305,35	304,68	305,08	0,67	-0,40	0,27	-0,08
310,00	310,34	309,67	310,05	0,67	-0,38	0,29	-0,05
315,00	315,33	314,65	315,02	0,68	-0,37	0,31	-0,02
320,00	320,32	319,64	319,99	0,68	-0,35	0,33	0,01
325,00	325,32	324,63	324,98	0,69	-0,35	0,34	0,02
330,00	330,31	329,63	329,95	0,68	-0,32	0,36	0,05
335,00	335,30	334,62	334,91	0,68	-0,29	0,39	0,09
340,00	340,22	339,56	339,78	0,66	-0,22	0,44	0,22
345,00	345,21	344,55	344,71	0,66	-0,16	0,50	0,29
350,00	350,20	349,53	349,67	0,67	-0,14	0,53	0,33
355,00	355,19	352,50	354,64	2,69	-2,14	0,55	0,36
360,00	360,18	359,46	359,62	0,72	-0,16	0,56	0,38
365,00	365,17	364,42	364,59	0,75	-0,17	0,58	0,41
370,00	370,65	369,71	369,57	0,94	0,14	1,08	0,43
375,00	375,15	374,42	374,55	0,73	-0,13	0,60	0,45
380,00	380,13	379,40	379,52	0,73	-0,12	0,61	0,48
385,00	385,08	384,34	384,43	0,74	-0,09	0,65	0,57
390,00	390,06	389,31	389,38	0,75	-0,07	0,68	0,62
395,00	395,05	394,27	394,31	0,78	-0,04	0,74	0,69
400,00	400,04	399,20	399,24	0,84	-0,04	0,80	0,76
405,00	405,03	404,17	404,20	0,86	-0,03	0,83	0,80
410,00	410,01	409,14	409,19	0,87	-0,05	0,82	0,81
415,00	415,00	414,12	414,17	0,88	-0,05	0,83	0,83
420,00	419,99	419,10	419,14	0,89	-0,04	0,85	0,86
425,00	424,98	424,08	424,11	0,90	-0,03	0,87	0,89
430,00	429,97	429,06	429,08	0,91	-0,02	0,89	0,92
435,00	434,95	434,03	434,05	0,92	-0,02	0,90	0,95
440,00	439,93	439,02	439,04	0,91	-0,02	0,89	0,96
445,00	444,92	444,01	444,03	0,91	-0,02	0,89	0,97
450,00	449,90	448,99	449,00	0,91	-0,01	0,90	1,00
455,00	454,88	453,97	453,99	0,91	-0,02	0,89	1,01
460,00	459,87	458,95	458,96	0,92	-0,01	0,91	1,04
465,00	464,85	463,93	463,93	0,92	0,00	0,92	1,07
470,00	469,84	468,90	468,90	0,94	0,00	0,94	1,10
475,00	474,82	473,86	473,84	0,96	0,02	0,98	1,16
480,00	479,80	478,84	478,84	0,96	0,00	0,96	1,16
485,00	484,79	483,81	483,81	0,98	0,00	0,98	1,19
490,00	489,78	488,79	488,78	0,99	0,01	1,00	1,22
495,00	494,76	493,77	493,76	0,99	0,01	1,00	1,24
500,00	499,75	498,77	498,75	0,98	0,02	1,00	1,25

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