IAD Handpump Project

MEASURING PROGRAM IAD

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INTERACTION DESIGN ARNHEM THE NETHERLANDS

FIRST SEMESTRIAL REPORT period: 01.08.88 till 31.01.89

March 1989 IADHPP89.01

THE IAD HANDPUMP PROJECT

This project is being carried out at the instigation of the Netherlands Minister for Development Cooperation and has for its main goal: To provide a substantial contribution to the improvement of the (communal) drinking-water supply and small scale irrigation, notably in Third World countries.
In this stage the project concentrates on the improvement of deepwell handpumps, in view of:
- reliability and easier maintenance,
- more profitable and simpler management.

Furthermore the project will support any activities:
- stimulating management of the water supply by its users,
- leading to the production of the required pump parts in the Third World.

It is thereby in line with similar projects that have been carried out in recent years under the auspices of the World Bank.

First and foremost the project concentrates on measuring and analyzing the dynamic behaviour and the stresses in the vital parts of the deepwell pump, especially in the rising main. Physical models will be developed to support the analyses. The experiences are integrated into recommandations and design rules for handpumps which will be published at regular intervals and be put for discussion. The project results are public domain.

At the instigation of the Office for Research and Technology from the Ministry of Foreign Affairs, the project partners have joined research on deepwell handpumps in the IAD Handpump Project. The partners and their contribution to the second project phase:
- DHV works out project publications ('laiting'), advices by the formulation of the project and design rules.
- IAD coordination, realization of data acquisition hard- and software, execution of measuring program and has final responsibility.
- JV manufacturer and supplier of the Volanta pump, analyzing of measuring results.
- SWNV manufacturer and supplier of the SWN81 pump, makes available part of their infrastructure on their site in Nunspeet, assists in the erection and conversion of the test-unit.
- TUE advices on the planning and execution of the program, analyses the results, physical modelling of the dynamic behaviour of the pump, fatigue analysis.

The partners cooperate by the formulation of advices and design rules and the realisation of related publications.

For carrying out the measuring program a test-unit has been arranged on the the SWNV-site, consisting of an enclosed boring having a depth of 100 metres, in which the water level can be varied as required and data acquisition hard- and software to enable the different variables on the handpumps to be measured. This infrastructure is owned by the Ministry.

Test-side situated at: SWNV, Industrieweg 47, 8071 CS Nunspeet
Telephone: 03412-54046, extension 51.

Any new orders will be welcomed by the team. For additional information, please contact the Project Coordinator: Jos Besselink
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Publication number: IADHPP89.01

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APPENDICES

1. INTRODUCTION

The present is a report on the progress of the measuring program on the SWN81 and Volanta deepwell handpumps, forming part of the IAD Handpump Project (BUZA-number: WW/86/043). This report covers the period August 1st, 1988 up to January 31st, 1989, being the first semester of the second phase of the project.

1.1 IADHPP RESEARCH DURING THE SECOND PROJECT PHASE

Summary of the goals of the examination in the second phase of the project: to gain a better insight in the dynamic behaviour of the deepwell handpump, notably of the pumprod, the rising main and the valves and for its consequences for the stresses occuring in the material, so as to minimize the causes of the breakdowns now occuring too frequently in handpumps.

This objective has led to the following approach:
1. measuring experiments on deepwell handpumps, notably the SWN81 and the Volanta;
2. direct analysis of the measuring results with a view to the consequences for fatigue in the pumprod and riser;
3. analysis based on physical models, to be developed by the project, so as to gain a better insight in the factors governing the dynamic behaviour.

Section 1, concerning the measuring experiments, is executed by IAD. The present document reports of the progress. Project partner TUE takes care of section 2 and 3 and they have reported the progress in the first semester in:
- "Design rules for fatigue life of PVC rising mains and stainless steel pump rods of handpumps" by P.Beekman and J. de Jongh [BEE89].
- "The dynamic behaviour of man driven piston lift pumps; semestrial report. Period: 01.10.1988 till 31.01.1989" by J. Grupa [GRU89].

1.2 THE SET-UP OF THE MEASURING PROGRAM

In the planning of the measuring tests two basic considerations have been the starting point for this examination:
- the examination must lead to instantly useable recommandations for the pump manufacturer whose pump is the subject of the examination and for other interested parties;
- the examination must procure background information, enabling a thorough analysis of the factors that define the dynamic behaviour of the handpump.

For that reason a scheme for the measuring tests has been planned in consultation with the project partners (including the pump manufacturers), in which the various elements get full attention:
- Ascertaining the dynamic behaviour of, and the stresses occuring in the rising main and the pump rod, at various pumping frequencies, length of stroke and heads (up to 100 metres) in:

a. the SWN81: without/with 'swivel', 'flexible riser fixing' and 'riser centralizers,
without/with supported cylinder
superstructure out of plumb.

b. the Volanta: with 9 mm screwed pump rods,

with 8 mm pump rods with hook and eye connection respectively screwed pump rods,
with various valve weights and valve lifts.

and time permitting (not very likely!):
c. a hybrid of the SWN-superstructure with Volanta substructure.

N.B. 'Swivel' = flexible pump rod fixing.

The experiments with the Volanta starts with the riser of 80 mm outside diameter and 77.5 m length. A smaller flywheel will be tested as well.

Beside the named elements, the influence will be ascertained of:
- immersion depth (=depth of cylinder inlet under water level),
- driving system (pump handle versus flywheel, manual drive versus mechanical drive),
- diameter of rising main and wall thickness (SWN versus Volanta),
- riser coupling system (SWN),

on:
- the propagation velocity of pressure waves,
- the dynamic behaviour, including 'snaking',
- the stresses in pump rod and rising main,
- the fatigue strength,
- the volumetric and mechanical efficiencies.

1.3 PROGRESS OF THE MEASURING PROGRAM

After the time planned for the experiments had elapsed and the most important measuring experiments had been carried out on the SWN81 pump, these tests were finalized and after that the Volanta pump was erected for testing. Out of more than 200 files of SWN81 measuring data (16 channels and per file 8 to 10 subfiles), 60 have been processed in the mean time, i.e. of each signal the maximum and minimum readings have been taken and recorded per subfile on sheets. For further details see: Chapter 4 'Experimental procedure', Chapter 5 'Measuring and results' and Appendix A 'Summary of datafiles of SWN81 measuring program'.

IAD as well as TUE started analyzing these data. Following the reactions of TUE a number of additional measurements have been taken: to gain a better insight in the dynamic behaviour of the SWN pump and the displacement transducers.

Owing to the delays in the SWN experiments and because the experimental set-up of the Volanta pump could not possibly be realized within the month planned for it, the Volanta measuring program is only in its initial stage.

Beside the experiments with the Volanta, the analysis of the SWN measuring data will be continued.

IAD and DHV are preparing publications on the project, to be published in WorldWater, Waterlines and Low-cost Pumping Systems.

2. EXPERIMENTAL SET-UP

2.1 INTRODUCTION

In the planning of the measuring schemes as well as in the erection of the experimental set-up around the SWN81 and the Volanta, the widely differing requirements of the manufacturers involved in the project have been taken into consideration, as are the specific possibilities and limitations inherent in the differing designs, among other things in relation to the relative (in)-accessibility of certain pump components and transducers. For example, with the Volanta it is possible to adjust the valve lift quicker than with the SWN, whereas with the SWN the rising main is comparatively better accessible.

2.2 THE SWN81 EXPERIMENTAL SET-UP

2.2.1 BASIC SET-UP

The standard SWN81 superstructure (stand + pump head with pump handle) was mounted on a steel stool (365 mm high), which was fitted on to a concrete foundation. The rising main was suspended from the stand into the well. See figure 3.1 on the next page. In the well of 100 metres deep (with tight bottom) and having an inner diameter of 170 mm, any desired water level could be created; depending on the length of the riser and the desired depth of immersion.

Beside the pump a mechanical drive had been installed, which by means of a connecting rod attached to the pump handle, could drive the pump. The speed of the mechanical drive was infinitely variable, so that the pumping frequency could be varied between 0.6 and 2.0 Hz.
The over-dimensioned drive and a flywheel on the driving shaft were to provide a constant angular velocity of the driving mechanism. However when pumping at high lift even the 2.2 kW drive had trouble in maintaining a constant angular velocity.

The pumped water flowed via an open return duct through a filter back into the well.

2.2.2 VARIANTS OF THE EXPERIMENTAL SET-UP AND ACCESSORIES

By placing a metal tube on the bottom of the shaft it was possible to create an artificial shaft bottom at any desired level (to -20 metres). Owing to lack of time this cylinder support has only been used with a length of the riser of 96.2 metres.

The manufacturer SWNV supplied some accessories with the standard pump, such as the swivel, the flexible riser fixing and centralizers for the riser. All of which have been applied in varying combinations during the experiments.

An adjustable angle of deflection (in regard to the vertical) of the stand has been created by fitting T-section steel of different heights near the retaining bolts between the stand and the stool.

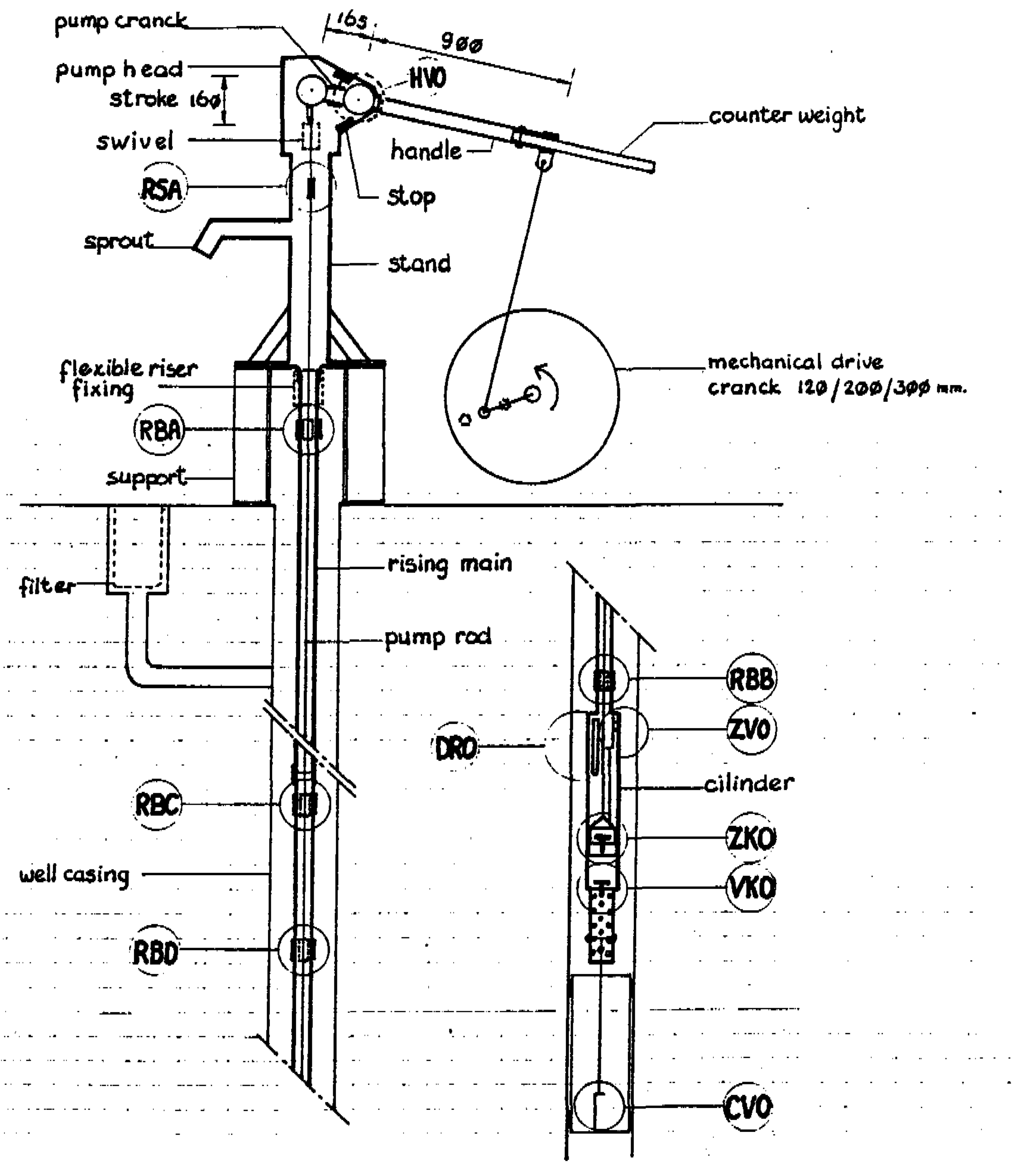
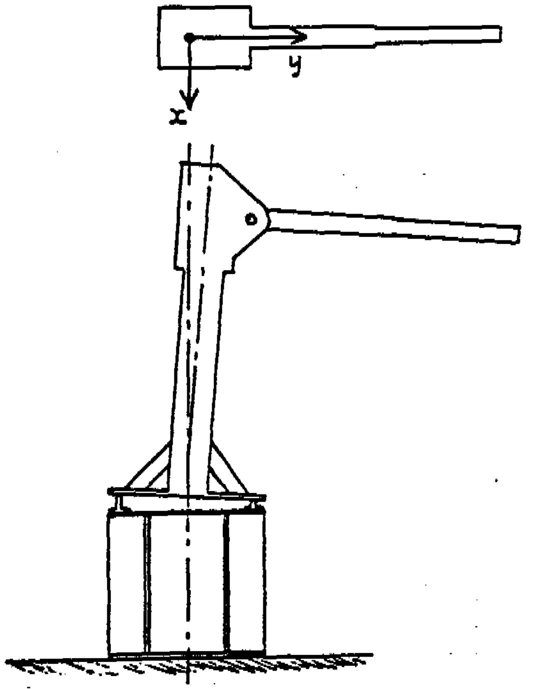


Figure 2.1 The SWN81 experimental set-up.



With adapter sleeves around the retaining bolts, the stool can be adjusted stepwise to higher or lower positions: on behalf of the experiments with stepwise increased cylinder support.

Figure 2.2 SWN81 stand out of plumb.

2.3 THE VOLANTA EXPERIMENTAL SET-UP

2.3.1 BASIC SET-UP

The Volanta stand is beside the well on a stool of 120 mm high I-sections. The steel plate from which the riser is suspended into the well is also fixed on the stool. The initial experiments are carried out with a riser of 77.5 metres in length, having an outside diameter of 80 mm ('small tube').

The mechanical drive is erected beside the pump. The drive of the flywheel of the pump will be effected by means of a flat belt. The diameter of the driving pulley has been so chosen that the pumping frequency can be varied between 0.3 and 1.7 Hz (for the standard flywheel).

The pumped water flows via an open duct through the inlet filter back into the well.

2.3.2 VARIANTS OF THE EXPERIMENTAL SET-UP AND ACCESSORIES

In the experiments with the Volanta the weight of the valves will be varied. For that purpose the manufacturer has supplied a set of loose valve weights.

Some adjustments had to be made in order to be able to vary the valve lift. The lower end of the pump rod is at the same time the limit stop for the valve, so that by rotation of the pump rod the valve lift may be varied. A similar construction has been made for the foot-valve.

The manufacturer JV has supplied an additional flywheel, the diameter of which is smaller by half.

Three sets of pump rods have been supplied with the pump:
- 9 mm diameter stainless steel rods with M10 rolled screw-threads,

- 8 mm diameter rods with M8 screw-threads,
- 8 mm diameter rods with hook and eye connection.

Time permitting, the following experiments will be carried out with:
- additional axial elasticity in the lower part of the pump rod,
- elastic clamping of the collar, from which the riser is suspended.

If possible, experiments with an SWN81 superstructure on the substructure of the Volanta, the so-called 'Hybrid', may be considered at a later stage.

3. MEASUREMENT EQUIPMENT

3.1 INTRODUCTION

Taking measurements on the pump has to be done under difficult conditions, i.e.:

- Measuring is done on components sometimes in violent motion: riser hitting the shaft wall, etc
- Various transducers, amplifiers and cable connections are submerged for an extended period of time at varying pressures of more than 100 metres water column.(10^6Pa)
- These transducers are located at distances up to 100 metres from the supply-source and the recording instruments. And from the team-members.

The measuring set-up must be flexible and rigid, because of the fact that at regular intervals changes have to be made in the set-up; other riser lengths, etc.

For these reasons straight forward solutions have been chosen, several of these solutions have been developed by the team-members themselves. This concerns, for instance knots in measuring cables, conditioner casing and displacement transducers with measuring ranges in the order of tens of centimetres for the use under water.

In data-acquisition the so-called 'Current loop principle' is used. That is to say that the signal that can be measured above-ground is directly proportional to the current in the feeder cables of the various amplifiers. When using this principle, two cable cores per transducer and simple and cheap analogue amplifiers will suffice. Thereby, the resistance (thus the length and temperature!) of the measuring cables has no influence whatever, neither have the fluctuations in the power voltage. The amplifier chip controls the current in the power-loop, proportional to the alteration in strain of the strain gauge.

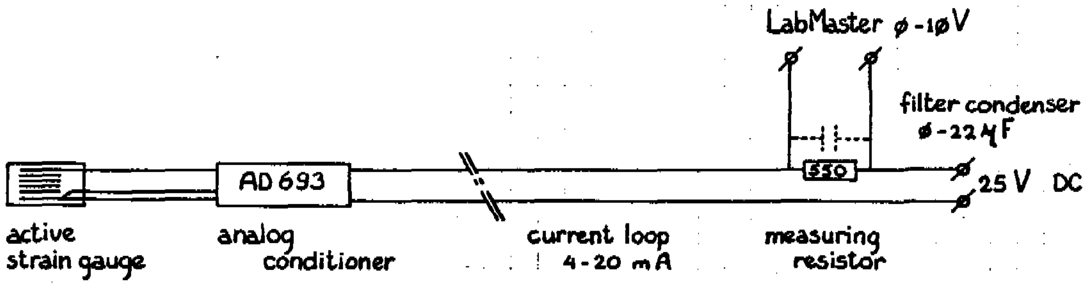


Figure 3.1 The current loop principle.

This arrangement has led to a reasonably workable, reliable and flexible measuring set-up, with an acceptable signal/noise ratio. A 'Bes-box' is being used to provide the feed of the transducers and for transmitting the measuring signals in the desired sequence.

The analogue signals are multiplexed (read one after another) and digitalized (12 bits) with a LabMaster. The LabMaster-chart is controlled by software with the data-acquisition package ASYSTANT+. This menu-controlled application of

ASYST is also used in processing and analizing the measuring results.

The project has two AT-computers available, with co-processors, hard disc and 5.25" floppy-drives.

3.2 THE TRANSDUCERS IN THE SWN MEASURING EXPERIMENT

On the SWN81-pump has been measured, as a function of time:		through transducers:
1. axial strain in upperpart of pumprod		RSA 31, 32, 33, 34
2. axial strain in upperpart of riser		RBA 41, 42, 43, 44
3. strain in lower end of riser	axial	RBB 51, 52, 53, 54
	tangential	55
4. axial strain in riser at abt. 13 m above bottom end		RBC 61, 62, 63, 64
5. axial strain in riser, 1.3 m below RBC-transducers		RBD 71, 72, 73, 74
6. angular displacement of pump handle		HVO
7. pressure in cylinder, above piston		DRO
8. axial displacement of cylinder		CVO
9. displacement of piston relative to the cylinder		ZVO
10. opening and closing moment of piston valve		ZKO
11. opening and closing moment of foot valve		VKO

TRANSDUCERS AND THEIR LOCATION IN THE SWN81 MEASURING EXPERIMENT
(See figure 3.1)

RBA: Strain gauges in axial direction, glued to the outside of the riser, 0.25 m from the upper end. (*)

RBB: 51 thru to 54 are strain gauges in axial direction, 55 is in tangential direction, glued to the outside of the riser, at 0.2 m from the lower end. (*)

RBC: Strain gauges in axial direction, glued to the outside of the riser, 13 m above the lower end of the riser, at 0.3 m below the riser-coupling. (*)

RBD: Strain gauges in axial direction, glued to the outside of the riser, at 1.3 m below the RBC group, half-way a riser section. (*)

RSA: Strain gauges in axial direction, glued to the pump rod, which was ground square locally for this purpose, at 0.2 m below the pump rod bearing. (*)

(*) For the location in relation to one another, as well as their position, see the set-up schedules.

ZKO: A magnetic field sensor, in the middle under the piston valve, reacting to the displacement (in axial and radial! sense) of a bar-magnet in the valve-fins.

VKO: As ZKO, in the middle under the foot valve.

ZVO: A strain gauge, glued in axial direction to a stainless steel strip, which bends in proportion to the displacement of the piston in the cylinder. At right angles with the strip another strip is fitted, to which is hooked a piece of elastic, connected with its other extremity to the piston. This transducer will, therefore, measure the relative displacement of the piston. This attachment is fitted in the cylinder, above the piston.

CVO: Construction as ZVO. Measures the axial displacement of the pump cylinder. The whole transducer is located under the pump in a PVC-tube, which is retained in its place by rubber pads pressed against the shaft-wall.

DRO: An absolute pressure transducer, in a cylindrical titanium encasing with vulcanized feeder cable and strain relieving core. This transducer was placed in the cylinder, above the piston.

HVO: A digital absolute encoder, connected up with the pump handle.

N.B. A shielded 24 core cable (with every core-pair twisted) provided the feed for the transducers RBB, ZVO, CVO, ZKO and VKO. The DRO had a separate feeder cable with strain relieving core. Another 24-core cable provided the feed for the RBC and RBD transducers. Each cable has its own reel. Each of the multi-core cables was connected to a steel wire cable with a view to strain relieving. All these cables were freely suspended into the well, along the rising main.

The various transducers based on strain gauges were coupled to the amplifiers, which were fitted near the transducers upon and in the pump. These amplifiers built by the project, on the basis of a loop-powered sensor transmitter chip of Analog Devices (AD 693), were cast in wax in an aluminium U-section, including the cable connections. With these 'third generation' amplifiers the leakage problems, also those under 120 m water column, have been solved in a compact and effective way. (After melting down, however, all components are accessible again).

See for further details and calibration data the Appendices C and B.

In order to enable the transducers and amplifiers to be fitted and measuring cables to be passed through, a number of adjustments had to be carried out on the pump. The most important:

- A fixture to receive the pressure transducer and the piston displacement transducer has been fitted in the upper part of the cylinder,
- The original connecting sleeve between the riser and the cylinder was substituted by a PVC block, on behalf of the passage of measuring cables through the cylinder wall,
- To protect the strain gauges and the amplifiers, which were fitted on the outside of the riser, soft PVC protection rings were fitted around the riser.
- To facilitate the fitting work it was decided, in consultation with the SWN manufacturer, to substitute flat neoprene rings for the teflon tape sealing in the pipe couplings.

The water level could be measured with a simple level meter (float-switch device on measuring tape). Through the response of the pressure transducer it was possible to check the depth of immersion, before pumping the riser full of water.
N.B. As a result of the riser being pumped full of water, the water level in the well fell somewhat! This fact was taken into account in the measuring schedule.

In order to ascertain the water delivery per stroke, the pumped water is caught during a given number of pump strokes and lapse of time, and subsequently weighed on household scales.

3.3 THE TRANSDUCERS IN THE VOLANTA MEASURING EXPERIMENT

On the Volanta-pump will be measured, as a function of time:		through transducers:
1. axial strain in upper end of pump rod		RSA 31, 32, 33, 34
2. axial strain in upper end of riser		RBA 11, 12, 13, 14
3. strain in bottom part of riser	axial	RBB 21, 22, 23, 24
	tangential	25, 26
4. angular displacement of pump flywheel		HVO
5. pressure at 0.2 m above cylinder, in riser		DRO
6. axial displacement of cylinder		CVO
7. displacement of piston relative to the cylinder		ZVO
8. opening and closing moment of piston valve		ZKO
9. opening and closing moment of foot valve		VKO

TRANSDUCERS AND THEIR LOCATION IN VOLANTA MEASURING EXPERIMENT

RBA: Strain gauges in axial direction, glued to the outside of the riser, at 0.25 m from the upper end. (*)

RBB: 21 thru to 24 are strain gauges in axial direction, 25 and 26 are in tangential direction, glued to the outside of the riser, at 0.25 m from the bottom end. (*)

RSA: Strain gauges in axial direction, glued to that part of the rod that has been ground square for that purpose, at 0.3 m below the enlarged upper end of the pump rod. (*)

(*) For the location in relation to one another as well as their position, see the set-up schedules.

ZKO: A magnetic field sensor, fitted sidewise under the piston valve, reacting on (almost exclusively axial) displacements of a bar-magnet in the valve-fins.

VKO: As ZKO, sidewise under the foot valve.

ZVO: Its construction deviates slightly from the version as used in the SWN experiment: in connection with reduced sensitivity for non-axial movement. Fitted in a framework mounted on the top of the cylinder.

CVO: Same construction as ZVO. See SWN81 set-up.

DRO: See SWN81 set-up. The transducer is fitted in a framework on the cylinder, in the bottom end of the riser. In future experiments the transducer will be fitted at other heights in the riser.

HVO: A digital absolute encoder, coupled to the flywheel shaft by means of a sprocket-wheel and chain transmission.

N.B. The multi-core feeder cable of the RBB-group and CVO is suspended outside and along the riser into the well. The feeder cables of DRO and of ZVO, ZKO and VKO are suspended inside the riser along the pump rod: recesses have been made in the rod centralizers to allow for this.

The remaining data-acquisition components are identic.

In order to enable the transducers and amplifiers to be fitted and measuring cables to be passed through, a number of adjustments had to be carried out on the Volanta pump. The most important:

- A framework is fitted on the cylinder to receive the pressure transducers and the piston displacement transducer.
- Bar-magnets are fitted in the valves, magnetic field sensors are fitted sidewise under the valves.
- To protect the strain gauges and the amplifiers, fitted on the outside of the riser, soft PVC protection rings have been fitted around the rising main.
- The centralizers for the pump rod inside the riser are provided with recesses for the feeder cables to pass through.
- A spout has been made on the outlet sleeve to allow the feeder cables to be led along the pump rod guide bush into the riser.

4. EXPERIMENTAL PROCEDURE

4.1 INTRODUCTION

The starting point for the SWN-measuring schedule was as follows:

* Of each <u>identic</u> variant of the measuring set-up for the SWN81 measurings will be taken with manual drive, as well as with the mechanical drive.
* Each scan consists of the intake of transducer responses into the memory of the computer, during 5 seconds. Each response is measured ('sampled') 100 times per second (=sample frequency), resulting in a total of 500 samples/transducer/scan. With 16 channels this is 16*500 samples/scan.
  N.B. In some scans a sample frequency of 25 Hz is used, enabling the longer term effects to be measured.
* The measuring data of the scan are stored on the hard disc as a subfile.
* A series of maximum 10 scans resp. subfiles (in identic set-up and drive) forms a measuring file.
* A <u>series</u> of scans of 'pumping with manual drive' consists of:
  - a set of two 'rest-scans' beforehand, when the pump handle is kept in a fixed position:
    1. horizontal handle
    2. handle against the stop (with pump cranck in BDC='Bottom Dead Centre')
  - a total of eight scans of:
    - 'normal way of pumping': with little exertion and quiet strokes
    - 'pumping against the stops': pumping with maximum stroke (this way of pumping requires more power)
    - 'water milling': pumping with full power with long strokes (with the whole body),
    - 'fluttering': pumping with short, quick strokes.

    For the sake of safety two scans are taken of each way of pumping.
* A <u>series</u> of scans on the mechanically driven SWN pump consists of:
  - a set of three 'rest-scans' beforehand:
    1. pump handle in horizontal position
    2. mechanical drive in TDC (=BDC for pump cranck)
    3. mechanical drive in BDC (=TDC for pump cranck)

    N.B. In this case the handle stops will not be reached.
  - scans at increasing pump frequencies, in stages of 0.2 Hz: minimum 0.6 Hz up to a maximum of 2.0 Hz.(upper limit is lower at great heads).
* Each series of scans is carried out according to transducer schedule A as well as D: if possible, immediately after one another.
* The water delivery is, in principle, determined at each scan.
* The scan is taken in a stationary condition, i.e.:
  - ample time has passed before a scan is being taken, to allow the transducers to attain a condition of equilibrium (in connection with warming-up phenomena),
  - the SWN81 pump has already been kept inactive for some time, or else has been driven for some time at a constant frequency, (insofar as this is feasible with a manual drive) before a scan is being taken.

N.B. A similar procedure will be followed in the measuring schedule for the Volanta pump.

Apart from the check-up and calibration measuring, all measurements will be taken on the complete SWN pump.

The data acquisition hard- and software has been calculated for the processing of a maximum of 16 analog signals. As the number of transducers per measuring set-up is more than 16, the signals were read into the computer memory in two each other partly overlapping schedules (A and D), and processed. See section 4.2 'Transducer schedules'.

The measuring and processing results are saved on the hard disc, and floppies respectively. The floppies are used as archive for the measuring data and copies are made available to TUE. Safety copies are saved on tape, which will be stored in a safe in Arnhem.

4.2 TRANSDUCER SCHEDULES SWN MEASURING EXPERIMENT

Schedule A:		Schedule D:	
Channel nr.	Transducer nr.	Channel nr.	Transducer nr.
0	RBA 41	0	HVO
1	42	1	RBA 42
2	43	2	RBB 55
3	44	3	RBA 44
4	RSA 31	4	RBB 51
5	32	5	52
6	33	6	53
7	34	7	54
8	ZVO	8	RBC 61
9	CVO	9	62
10	ZKO	10	63
11	VKO	11	64
12	DRO	12	RBD 71
13	HVO	13	72
14	RBB 55	14	73
15	---	15	74

In order to enable a comparison of the two schedules both of them include:
- HVO: the absolute encoder
- RBA 42 and 44: two axial strain transducers in upper part of the riser.

The responses in schedule A give a general view of the dynamic behaviour of the SWN pump, schedule D gives a one-sided but detailed insight in the strains and stresses occurring in the riser.

4.3 ARRANGEMENT OF MEASURING SCHEDULE

Based upon the agreed measuring schedule (see section 1.2) the following set-up variables have been chosen:

VARIABLES IN THE SET-UP (in hierarchical order):

Lengths of riser : 20, 40, 60, 80, 96 m
Immersion depth : 20, 10, 5, 2, 0 m
Yes/No : - Stand position out of plumb: x-direction 1.6 degrees
y-direction 1.6 degrees

- Swivel
- Flexible riser fixing

Repetition, only at great heads (60, 80 and 96 m) with:
- centralizers
- cylinder support

In every set-up a measuring series should, in principle, be finalized, without any changes in the mean time being made and in quick succession, with transducer schedule A as well as D, and with manual as well as mechanical drive.

Since such a comprehensive program could by no means be completed within three months, which would not have made sense either, it was decided to start exploratory measuring work. Based on the very first and later experiences in relation to:
- the priority of certain variants in the set-up and clusters thereof,
- the influence of the variables on the dynamic behaviour and the stress curve of the material,
- whether or not the transducers are functioning properly,
- the time required for certain measurements and conversion of the set-up,
- the remaining time,

the measuring schedule has gradually been adjusted and restricted.

When the influence of a certain variable, for example of an angle of deflection of the stand, had to be measured, the point of departure was each time a series of measurings of the stand without this deflection, thereafter (a series) with, and subsequently another (short) series, again without the deflection. Such a cluster of measurements will therefore contain a number of duplications:
- in order to judge any signs of drift in the transducer responses during the measuring of a cluster,
- so as to check if all the transducers in the set-up variant are still functioning properly after the measurements have been taken,
- in order to judge if any coincidences in the measurements have occurred (for instance: interference pulses),
- in order to be able to draw, from a statistical point of view, more reliable conclusions.

4.4 NUMERATION OF MEASURINGS AND MEASURING FILES

Two systems of numeration are used side by side:
- consecutive numbers,
- a number of 8 characters, from which it may be derived on what set-up variant the measurement was taken.

SWN81 measuring numbers begin with an S, Volanta measuring numbers with a V. The files of measuring data have the same number, derived from the set-up, as the measuring itself, except that the suffix .DAT has been added.

THE NUMBER RELATED TO THE SET-UP

- 1st character: S = SWN81 V = Volanta
- 2nd and 3rd characters:
  number of set-up, depending on the set-up, the sum of:

SWN measurements:
0 = standard / without
1 = with swivel
2 = with flexible riser fixing
4 = deflecting superstructure
8 =
16 = with centralizers
32 = with cylinder support

Volanta measurements:
0 = standard / without
1 = varying valve lift
2 = varying valve weight
4 = extra elasticity in pump rod
8 = extra elasticity in riser fixing
16 = 8 mm pump rods
32 = smaller flywheel
64 = handle drive

- 4th character: H = manual drive M = mechanical drive
- 5th character: transducer schedule number (A, B, D...)
- 6th character: riser length ÷ 10 (rounded off)
- 7th and 8th character: consecutive number of measurings on identic set-up under identic conditions.

4.5 CALIBRATIONS

See for the results of several calibrations Appendix B.
The calibrations and the files with the measuring data of the calibrations are numbered as follows: CAL***XX.DAT. In this case '***' is short for the transducer name and 'XX' for the consecutive number of the calibration of the transducer concerned.

THE STRAIN TRANSDUCERS: RSA, RBA, RBB, RBC, RBD

These strain transducers are calibrated on the calibrating bench: the response of each transducer-amplifier unit has been measured and recorded as a function of the axial strain load. That part of the riser with the RBB strain transducer group has also been calibrated on inward pressure.
In order to limit the influence of gravity, the pump rod part with the RSA transducers was clamped vertically for the calibrations. The longer riser sections had to be clamped in a horizontal position. To attain an idea if the gravity did have some influence, if the section was bent, if there were obliquely cut screw threads on rod and tube extremities, or a strain load acting not exactly on the centre line, etc., the measurings were repeated in positions that were turned each time 90 degrees around the longitudinal axis.

Based on the graphics of these responses, it was possible to gain an insight in the influence of the afore mentioned factors and the reliability of the calibration. With this knowledge the most probable conversion factor was decided upon for each transducer: i.e. the relation between the outward axial load and the response of the transducer-amplifier unit.

The responses of the transducers on pump parts at no-load, the so-called 'absolute zero-values' appeared to drift to some extent during the measuring experiment on the complete SWN measuring set-up, so that these values can only be used as a reference.

THE PRESSURE TRANSDUCER: DRO

This transducer is calibrated in that the response has been ascertained at different known immersion depths (in the fully filled-up well). Up to 100 m water column. The response of this transducer is so stable, that in processing the SWN measuring data, beside the conversion factor also the absolute zero-value may be used.

THE PISTON DISPLACEMENT TRANSDUCER: ZVO

This transducer built by the project (for want of a better device!) is calibrated statically and dynamically, in air as well as in water. The piece of elastic forming part of the transducer was sensitive to the influence of water and to being stretched tight for some extended period of time. Hence checking the transducer for its proper functioning has been done on the basis of the rest-scans at the outset of each measuring series. And by re-calibrating the device at regular intervals during the SWN measuring experiment.

THE CYLINDER DISPLACEMENT TRANSDUCER: CVO

Ditto. To check the proper functioning, the calibration has been repeated during the measuring experiment. After the pump had been installed in the well, the proper functioning was again checked by lifting the upper end of the riser.

THE ABSOLUTE ENCODER: HVO

For the experiment on the SWN81 pump a transducer was used on a temporary basis, pending the delivery of the TEKEL-HVO.
The transducer is calibrated by determining the difference between the maximum and minimum response values after several rotations. The linearity of the transducer depends on the precision with which the digital disc has been manufactured, and that is better than half a scale division (= the smallest measurable angle). Unfortunately, the transducer made mistakes in counting in certain places of the disc, so that locally a pulse-shaped response resulted. These miscalculations have to be corrected by hand in the SWN measuring files, a time-consuming matter.

THE VALVE DISPLACEMENT TRANSDUCERS: ZKO and VKO

As these transducers not only reacted to axial movements of the valve, but also to radial movements and to displacement around its axis, it was, at best, possible to use the responses to ascertain whether the valve rested on its seat or not. However, for this experiment it was sufficient to have a reliable indication of the moment of opening and closing of the valves, and in this respect the transducers proved satisfactory. 'Valve movement transducer' would have been a better name.

4.6 TAKING THE MEASUREMENTS

Preceding the measuring, the SWN measuring set-up is erected or converted into the required variant. In this set-up a test-run is made to test the transducers.

After the set-up schedule and the test-sheet have been completed (including the names of the calibration files bearing relation to the experiment) and after the pump and transducers are warmed up, a measuring file is opened by means of the data-acquisition package ASYSTANT+ for recording the readings of the measuring signals.
The name of the file is put in, as well as the number of signals (channels), the channel with which to start, the starting signal ('trigger') to be expected, the sample frequency and the number of samples per channel.

When the SWN measuring set-up is finished, the actual measuring can start. I.e. during 5 to 20 seconds the signals are read and subsequently visualized on the monitor. When the scan is found to be in order, the measuring data are saved on the hard disc. If not, the measuring is repeated. In this way a maximum of 10 scans are taken for one measuring series, according to the schedule as described in section 4.1 'Introduction'. Immediately after each scan of the signals of a pump in operation, the pumped water is caught for 20 to 60 seconds, at the same time counting the pump strokes. This quantity of water is weighed before it is led back into the well. The results of these determinations are recorded on the test-sheet.

The measuring series is completed herewith. The time required for measuring bears no relation whatever to the time required for erection and conversion of the set-up!

Finally, at the end of the measuring day the measuring files are saved on floppy and at regular intervals on tape.

4.7 PROCESSING THE MEASURING DATA

When a cluster of measuring series is finished, the measuring data will be processed.

The calibration data relating to the measuring series are entered upon standard 'processing sheets', this concerns among other things the 'zero-values' and 'conversion factors'. Further there are some other values inserted relating to the experiment and set-up: material section, etc. As X, Y and Z respectively.

The technical quantities (strain, angle, etc.) are determined therewith according to the formula:

(transducers response - zero-value) * conversion factor / cross section.

The 'zero-values' (= either the transducer responses in starting position, or the response on the component under no-load condition being measured) are derived from respectively:
- the calibrations; these give 'absolute zero-values'; or from
- the rest-scans (= first and second scan of the measuring file); this leads to 'relative zero-values'.

The measuring values from the first scan are used as zero-values for the displacement transducers (ZVO and CVO) and the absolute encoder (HVO); with pump handle in horizontal position.

The zero-values of the strain transducers are derived from the second scan of the measuring file, taken with pump cranck in BDC (= Bottom dead centre). In this position it is with reasonable reliability predictable how the load resulting from the water column in the riser will act upon the riser and the pump rod. In order to take up this position, the piston is moved downward, owing to which the full load caused by the water pressure acts on the cylinder (bottom). This load situation can be calculated with reasonable precision. The measuring values of the scan are corrected for this load. This provides the 'relative zero-value'. Appendix D provides details on the calculations.

The data-acquisition package offers the possibility of programming (to a limited extent) the function keys. This programming may be saved as a function file, by the suffix: .SAV . This possibility is used to process, in accordance with standard procedures, the files of measuring data per subfile. Each transducer schedule must have its own function file.

The transducer responses (per scan of 16*500 samples) are converted by means of function files into:
- technical quantities: strain, pressure, displacement, etc.
- tensile and bending stresses,
- compound bending stresses,
- total stresses: resultant of tensile-, bending-, tangential and radial stresses,
- angular velocity and angular acceleration of pump handle,
- axial displacement of pump rod upper end,
- absorbed energy.

For further details of a function file, see Appendix D.

All these values can be visualized on the monitor, after which the maximum and minimum values are recorded on a sheet (with the exception of irrelevant peaks), as well as a summary of the course of events.
These sheets of the 10 interrelated subfiles are stored in a filing folder, together with the test sheet and the processing schedule. If so required a print of the responses will be added.

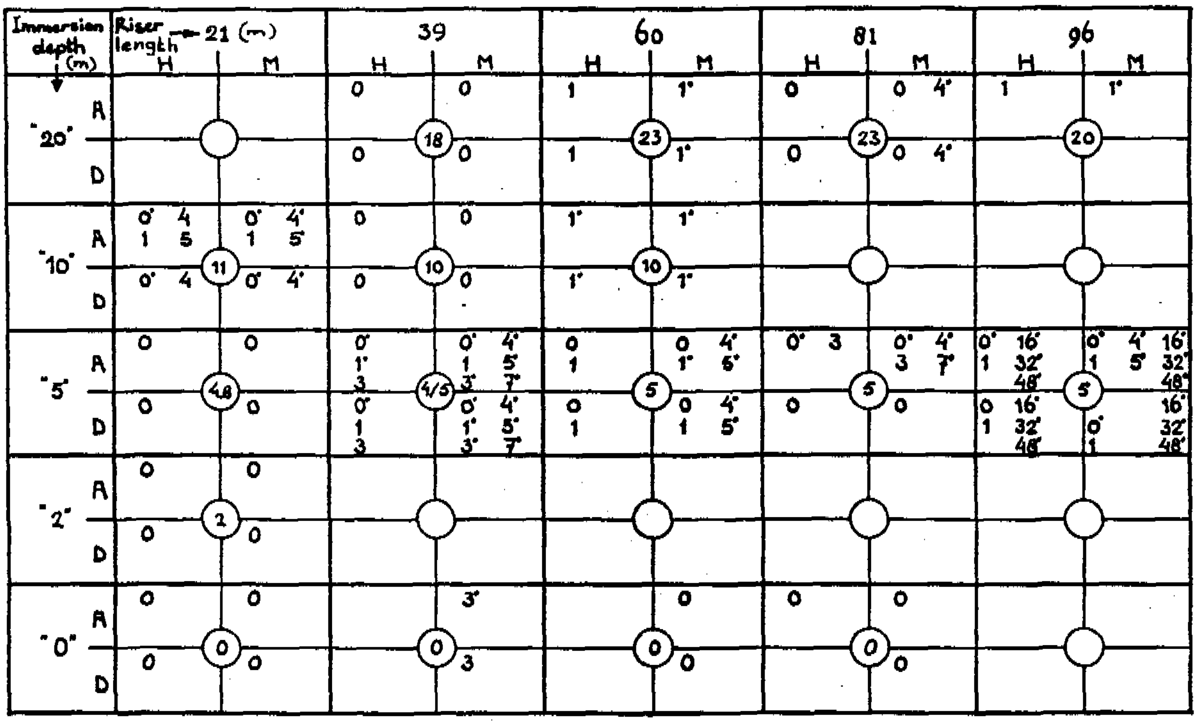
On the basis of a cluster of files processed according to this procedure, analyses are made with regard to the influence of the different set-up variants.

5. MEASURING AND RESULTS

5.1 INTRODUCTION

Hereinbelow a diagrammatic representation shows in outline the measurements taken on the SWN81.

- The numbers (1 thru to 48) in the boxes refer to the variant of the set-up, i.e. to the 2nd and 3rd character of the numeration of the measuring series or the measuring file, in accordance with the codification as given under the table. The dot means that several measurements have been taken at that same variant of the set-up.
- The number in the circle represents the depth of immersion at which the measurements have been taken.
- H = manual pumping, M = mechanical drive.
- A and D are the two transducer schedules.



Immersion depth (m)		Riser length → 21 (m)			39			60			81			96		
		H		M	H		M	H		M	H		M	H		M
"20"	A				0	18	0	1	23	1•	0	23	0 4•	1	20	1•
	D				0		0	1		1•	0		0 4•			
"10"	A	0• 4 1 5	11	0• 4• 1 5•	0	10	0	1•	10	1•						
	D	0• 4		0• 4•	0		0	1•		1•						
"5"	A	0	48	0	0• 1• 3	4/5	0• 4• 1 5• 3• 7•	0 1	5	0 4• 1• 6•	0• 3	5	0• 4• 3 7•	0• 16• 1 32• 48•	5	0• 4• 16• 1 5• 32• 48•
	D	0		0	0• 1 3		0• 4• 1• 5• 3• 7•	0 1		0 4• 1 5•	0		0	0 16• 1 32• 48•		16• 0• 32• 1 48•
"2"	A	0	2	0												
	D	0		0												
"0"	A	0	0	0		0	3•		0	0	0	0	0			
	D	0		0			3			0			0			

Code:
0 = standard SWN81
1 = swivel
2 = flexible riser fixing
3 = swivel + flexible riser fixing
4 = stand out of plumb
5 = stand out of plumb + swivel
7 = stand out of plumb + swivel + flexible riser fixing
16 = centralizers
32 = cylinder support
48 = support + centralizers

Diagram 5.1 Concise survey of SWN81 measuring program.

For a complete review of measurements taken, see Appendix A.

The results of the measuring experiments consist, for the time being, notably of measuring data, as the analysis has only just begun.

The set-up around the Volanta pump has been realized in the meantime. Nearly all transducers and amplifiers have been renewed and improved in details. The function files that will be used for processing the Volanta measuring data are finished, as are the sheets on which the measuring data and the progress of the program will be kept.

5.2 MEASURING FILE CLUSTERS AND ANALYZING POSSIBILITIES

As can be derived from diagram 5.1, measurings have notably been taken at an immersion depth of about 5 metres. The influence of the riser length can thus be determined. When taking into account that, as far as the behaviour of the pump is concerned, the variants 0 and 1 of the set-up are practically identic, it appears that per riser length the influence of the immersion depth can be determined. Moreover, as the set-up is varied (with/without swivel, flexible riser fixing and stand deflection in various combinations) at a fixed immersion depth and riser length, it is possible to determine the influence of these variants in conjunction with one another or separately. This applies to manual as well as to mechanical drive.

The variants 'centralizers' and 'cylinder support' have been studied at only one riser length and immersion depth: In view of the limited time available and because the measurements taken are considered to be sufficiently representative. A measuring experiment at another riser length would have taken days/weeks of extra time for the conversion of the set-up! Besides, the fact played its part that there were protection rings around the riser and the cylinder (to guard the transducers and amplifiers) so therefore a set-up entirely without centralizers was already out of the question.

The measurements taken at an immersion depth of 0 m are meant to gain an insight in the behaviour of the pump when air is sucked in.

60 out of about 200 measuring files have been processed. It is not necessary for all the files to be processed in this way, because a number of them are reserve and check files.

5.3 PRELIMINARY RESULTS OF THE ANALYSIS

On the basis of table S001 the following graphs have been made (see next page):

- S001/01: Maximum and minimum axial tensile stress in the upper end of the SWN81 riser.
- S001/02: Ditto in the pump rod.
- S001/03: Maximum difference in axial tensile stress in the top end of the SWN81 riser and pump rod.
- S001/04: Water delivery per stroke.

The above relates to: manual pumping, against the handle stops and at an immersion depth of 5 metres. The riser length stands out along the X-axis. The measuring results with supported cylinder are at the same time shown in the graphs (data from measuring files S173, S189, S191).
The dotted lines in the diagrams show the values on the basis of quasi-static approximation (without accelerations or pressure waves).

FILE	STAND AT	CYLINDER SUPPORT
S173	485 mm	−
S189	365	+
S191	325	+ +

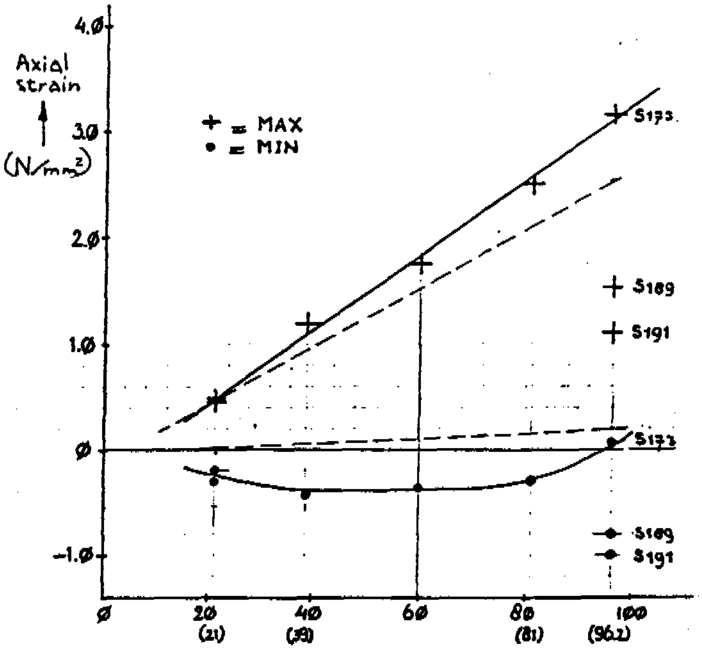


FIGURE S001/01 ——> Riser length (m)

The strain of transducer pairs 41+43 and 42+44 have been averaged

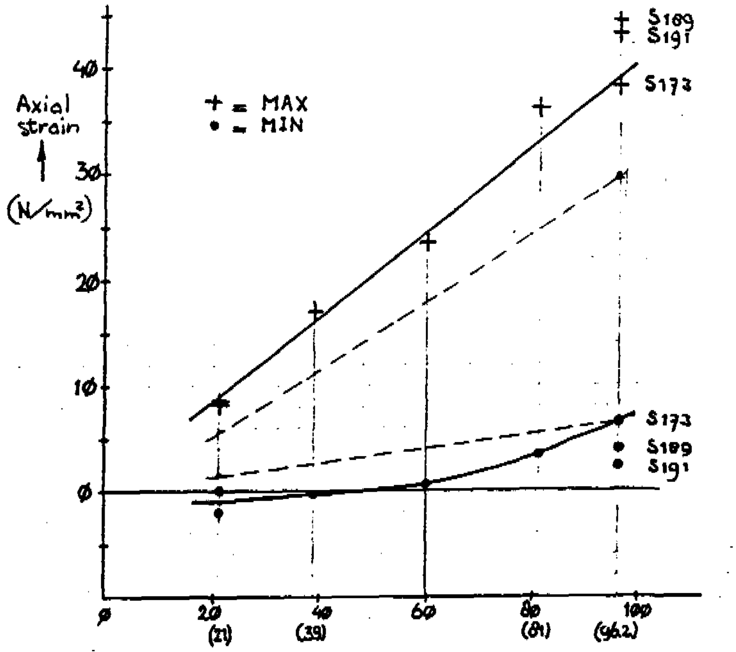


FIGURE S001/02 ——> Riser length (m)

The strain of transducer pairs 31+33 and 32+34 have been averaged

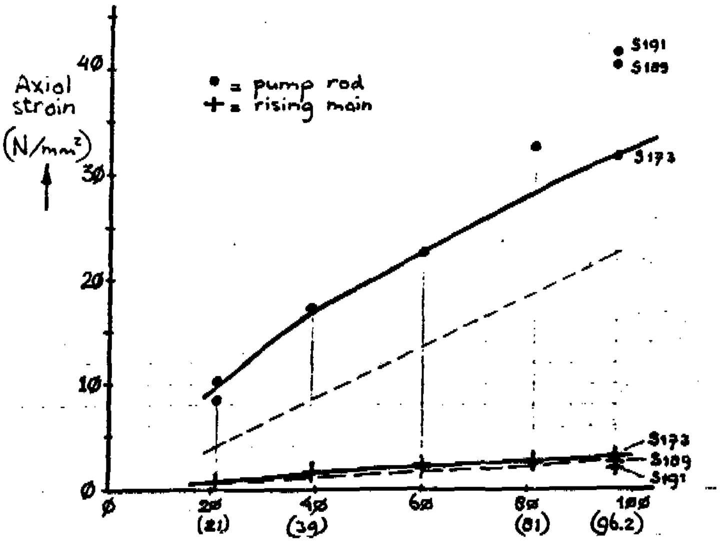


FIGURE S001/03 ——> Riser length (m)

The strain of the transducer pairs have been averaged

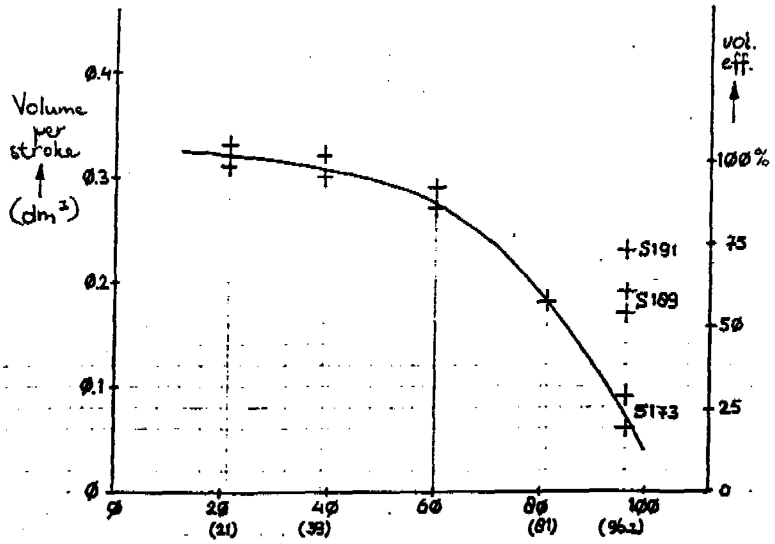


FIGURE S001/04 ——> Riser length (m)

Nominal volume per stroke = 0.16 * $\pi/4$ * 0.05^2 = 0.314 dm³

From diagrams S001/01 and S001/02 it is evident that the maximum tensile stresses are a linear function of the riser length. The minimum stresses are negative when the riser length is small, but will become positive as the riser length is increased.

As was to be expected, the tensile stresses in the riser will be reduced when the cylinder is supported. Apparently, a greater friction between pump rod and riser is created by the support, because an extra force acts on the rod opposite of the direction of movement of the rod.

From diagram S001/04 it is evident that the water output per stroke declines drastically at greater riser lengths. This is mainly caused by axial deformation of the riser, allowing the cylinder to move up with the piston. Cylinder support gives a reasonable counter-effect: by limiting the upward movement of the cylinder. However, it should be noted that, in order to reach the values as indicated at measuring point S191, the riser had been jammed between the stand and the bottom of the well. (And even then it appears that the cylinder is being lifted from its support during part of the upward piston stroke).

N.B. When pumping in the normal way, the output at a riser length of 80 metres and more, without cylinder support, will be practically 0!.

When pumping at a riser length of 96 metres, without cylinder support, it appeared that an up to now unknown phenomenon occurred:
- During the upward piston stroke, the piston moves downward(!) in relation to the cylinder. (As per response ZVO).
- During the upward stroke the water output is zero, during the downward stroke very little water is emanating from the spout.
- This bears no relation to dynamic effects, because even if there is a waiting time of one minute after each slow pump stroke, the same phenomenon will appear.

The concentration of air bubbles in the pumped water was ascertained in the course of the different experiments. It appeared that this concentration was so low that it was not measurable with the applied method: i.e. less than one per mille. With the exception of the experiments in which the depth of immersion was almost zero. In those cases concentrations of a comparatively high percentage occurred, owing to which 'pumping' got a totally different character.

The riser moves in a radial sense as well during the act of pumping. However, the analysis of the measuring files with transducer schedule D will have to be awaited, before conclusions in regard to this phenomenon can be drawn. (For a hypothesis of the movements and the deformations of the riser, see Chapter 6).

5.4. EXPERIENCES WITH THE SWN81 TEST PUMP

The SWN81 has, after certain adjustments in the beginning (among which neoprene seal rings to substitute the teflon tape) survived the test program without any problems. Only traces of wear have been discovered on the piston sealing, and there was also a distinct increase in the play in the crank bearing. The neoprene sealing rings have given complete satisfaction, also in re-use. The sealing of the pump as a whole (valves, couplings, etc.) was excellent throughout the tests: after standing idle for days on end, water emanated from the spout after one pump stroke!

Despite of the fact that the pump has been subjected to a reasonably severe testing program, one should, however, be aware that the IADHPP experiment was by no means an endurance test!

In those cases where the riser has an excessive length, cylinder support is an effective means to have the output per stroke increased. However, as water can only be pumped up from great depths which such large strokes that the handle touches the handle stops, it must be stated that this pump is not exactly suitable to cope with situations where riser lengths of 80 m and more are to be applied.

The counter-weight in the pump handle is effective and necessary for pumping from great depths. The transition handle/counterweight and the bolted connection should, however, be more comfortable for the user, notably to prevent injuries of the hands.

Various matters in connection with the outcome of the experiment with the SWN81 will be discussed more detailed in a report on this subject, which will be published before long.

To the members of the IAD test-team it was encouraging to notice that the recommendations that had been given in the meantime to SWNV, the manufacturers of the SWN81, have led to a serious study and improvements in the pump design.

5.5 PROBLEMS DURING MEASURING EXPERIMENTS

It is, apparently, an impossible task to comply with a planning as drawn up for the IADHPP measuring experiments. Specially technical problems in keeping the measuring set-up in working order are the cause of the trouble. It is no small beer to arrange and maintain a measuring set-up in good working order under the prevailing circumstances, which has, moreover, to be wholly or partly converted at regular intervals.

However, the closing of the measuring experiments on the SWN81 means to the members of the IAD test-team that by far the most part of those problems lies behind them. The operation of the measuring set-up has meanwhile become much more reliable and, besides, the execution of the measuring program on the Volanta pump demands less drastic 'conversions'.

Here is a selection from the technical problems the test-team had to cope with:

* Some strain gauges broke down under the violence of the measuring program. When an important transducer was involved this meant sometimes a delay of at least one week:
  - pump to dismantle: at least one working day for two persons,
  - defect to be detected and repaired, testing and re-adjusting the transducer circuit: several working days,
  - to calibrate the new transducer circuit,
  - pump to mount and, subsequently, test the functioning of the transducers: at least two working days for two persons.
* Unexpected long delivery-time for the absolute encoder: 6 weeks was promised when the goods were ordered end of July '88 but ultimately this proved to be 5 months: actual date of delivery of the transducer in operation was early

January '89. For that reason the whole range of experiments on the SWN81 was carried out with an HVO built by the project, but the way it functioned was not optimal. This absolute encoder, at certain angles, made mis-readings, owing to which a pulse-shaped deformation of the signal was caused. These mis-readings can only be corrected by hand: by adjusting with the aid of ASYSTANT+ the sample values of the saved response one by one. (N.B. The 'SMOOTH'-function available within 'ASYTANT+' would affect, too, the signal before and after the pulse. These time-consuming adjustments account for the fact that only 60 measuring files have been processed up to now.

* The tube in which the CVO was contained appeared at a given moment to be moving downward. This tube is to be retained in its place against the sides of the well by means of rubber blocks. However, the well-side proved to be so greasy (paraffin from the PVC?) that the braking strength of the blocks became insufficient. To remedy this trouble it proved necessary to dismantle the whole set-up and to de-grease the well-side.
* Unfortunately, the response of the absolute encoder is unreliable in a number of cases, because after the encoder had been refitted, it was omitted to tighten the bolt of the carrier on the encoder axle. GGRRRR!
* In the course of the measuring tests on the SWN81, the transducers ZVO and CVO emitted regularly responses of which the pattern and size did not comply with the expectations. Relatively much attention has, therefore, been paid to the testing of these transducers. In most cases the conclusion was that the sub-structure of the handpump had indeed been cutting capers.

5.6 RECOMMENDATIONS TO MANUFACTURERS OF SWN- AND VOLANTA PUMPS

N.B. 1. The interpretation of project recommendations by the pump manufacturer and the ensuing adjustments in the design, if any, are the initiative and responsibility of the manufacturer concerned.
2. The adjustments that have been effected in the design are in most cases not solely the result of project recommendations. In the majority of cases the manufacturer was aware of problems, but tried to find the best solution. The project recommendation had a guiding effect in such cases.

5.6.1 RECOMMENDATIONS TO SWNV AND ADJUSTMENTS IN THE SWN81 DESIGN

The SWN81, without cylinder support, is in its present form unfit to cope with situations in which a riser length of 80 metres and more is required. By pumping 'in the normal way' the pump will deliver (practically) no water. Though it does by pumping 'against the handle stops', yet the output also in this latter case is limited.

Cylinder support has a positive effect on increasing the output (by pumping 'against the handle stops'). However, the counter-weight protrudes at maximum length from the handle when pumping from great depths, which means that by pumping 'against the handle stops' a stroke of 150 cm with the hands is made! This requires, moreover, an effort that can only be put forth by physically grown-up people.

A smaller diameter of the piston is likely to have a positive effect on the SWN81, in that it makes the pump more comfortable to work with by pumping from greater depths: Because the forces on the pump handle decrease and the axial deformation of the riser is reduced (= greater 'volumetric efficiency').

Substitution of the teflon tape for sealing the riser screw-couplings by elastic plastic sealing rings
- makes assembly of the pump simpler,
- prevents the problem of lack of tape during re-assembly when the pump has been lifted on the site, and
- provides probably a better sealing at high internal pressures, so great riser lengths.

RECOMMENDATIONS PRECEDING THE SECOND PROJECT PHASE

Riser couplings in a slightly longer form (a sleeve extending 10 mm past the screw-thread) do not have the desired effect of reducing the bending stresses in the screw-thread.

The swivel is effective in limiting the bending stresses in the upper end of the pump rod (where the highest loads occur): this applies to bending stresses caused by mis-alignment of rods, screw-threads, etc.

A special wrench was required for assembling and dismantling the piston sealing. By applying a slightly longer securing sleeve with an opening in it for a thick pin, the special tool becomes superfluous. (This has meanwhile become the standard construction.)

As the threaded part of the pump rod sections was sometimes longer than the space in the long coupling-nut could contain, the glued joint came loose as the nuts were tightened up. (By lengthening the nuts, not only the protruding part of the screw-thread became shorter, but it also provided a larger surface for the glued joint.)

The glued joint between the riser and the screwed sleeve (on one extremity of the tube) was not resistant to water. (This flaw was to be attributed to incorrect use of the glue, as well as to its poor quality, and has meanwhile been remedied.)

5.6.2 RECOMMENDATIONS TO JV AND ADJUSTMENTS EFFECTED IN THE VOLANTA DESIGN

The fitting of centralizers for the 9 mm pump rod is a useless and time-consuming job, as there is hardly any space for turning the spanners. (A suggestion has been made to adapt the form of the centralizers).

The threaded ends of the pump rod connections have such a tight fit that it must be feared that they will break. (Probably this problem occurs only in the proto type rods that have been made available for the project).

The supplied pump rods are greasy (and dirty for that matter). Cleaning before installation is essential with a view to the quality of the pumped water. The instruction manual does not make any mention of it. (Proto-type problems?)

Besides, some proposals have been made as regards pump variants, worth measuring:
- Flexible fixing of the sleeve from which the riser is suspending.
- Axial flexibility in the connection of the piston with the pump rod.
- A smaller flywheel in connection with the question if the large standard

flywheel is necessary. (A flywheel of 75 cm in diameter has meanwhile been supplied by JV on behalf of the project.)

N.B. At the request of Mr. Bliemer, J.V., it was agreed that, if possible, a series of measuring experiments would be carried out with new glued joints of the riser.

RECOMMENDATIONS PRECEDING THE SECOND PROJECT PHASE

A smaller diameter of the riser is desirable in connection with the then possible use of the Volanta pump on 4" boreholes.

Using the same piston diameter in a riser with an inner diameter of 70 mm requires only minor adjustments of the cylinder.

Testing a 'Hybrid' of the Volanta substructure in conjunction with a handle drive mechanism (for instance of SWN81) is worth being looked into, so as to be able to judge the differences between the two drive-systems (material stresses!) and to examine the necessity of the voluminous flywheel. (Measurements will be taken on a hybrid, if time permits.)

6. DEFORMATION OF THE RISING MAIN
(hypothesis)

6.1 INTRODUCTION

It appears that the plastic rising main is still a weak point in handpumps, notably in the case of deeper heads. Sooner than one might expect the pipes break/tear off at the upper end, close to the suspension, but sometimes also not far from the lower end of the pipe. Apparently the material is exposed to loads that will lead too soon to fatigue of the plastic material. In the computation of the stresses to be expected, there are most probably too optimistic estimations and/or a number of factors that have not been recognized. This is not to be wondered at, as the picture of the deformations occuring in the riser is very incomplete. Besides, it is not exactly known to most designers what loads the plastic can stand under 'field conditions'.

Therefore, in this chapter an attempt will be made to give a more complete analysis of the deformations as a consequence of static and dynamic loads that may occur in the act of pumping and in rest (notably) in the riser. (This is only a hypothesis!) To this end the different kinds of deformations that may be expected will be looked upon more closely in the following sections. In practise these deformations may be said to take superposition, which not only hampers the analysis of the IAD measuring experiments, but also the prediction of the behaviour and, consequently, of the stresses occurring in the riser of other pump designs.

Factors that may weaken the plastic itself, like inferior material and manufacture, UV light, higher working temperatures, chemical attack (glue!), and so on, are beyond the scope of this chapter.

6.2 FATIGUE

It can be stated that fatigue is the main cause of breaking of the plastic riser and the stainless steel pump rod. Therefore a short digression on the matter is justifiable. For more details, see Beekman and De Jongh [BEE89].
The occuring stresses in the rising main and the pump rod are well below the maximum tensile strain for static loads. However, the many million pump strokes, to endure over several years, make that fatigue becomes an important factor.
Pumping causes a frequent load fluctuation (on top of the static loads). The load fluctuation causes a gradual reduction of the strength of the material. To prevent a collapse of the material at long term under these relatively small fluctuating loads, the pump parts will need to be dimensioned and constructed as such that the maximum occuring stresses will be well below the tensile strain.
Grooves and cracks worsen the situation, because this results in local stress concentration. This is the case with screw threads, but the action of glue can cause similar effects.
Besides, it has been proved that PVC will even age and weaken under static loads!

The report of Beekman and De Jongh shows that for calculating the necessary diameters and wall thickness of the rising main and the pump rod the static loads hardly play any role! The expected amplitude of the fluctuating stresses, its frequency and the measure and the shape of grooves (threads!) in the material, are the determining factors!

These facts give support to the project objectives to study the dynamic behaviour of the handpump, for a better understanding of the cause of the oscillating bending and tensile stresses.

6.3 DEFORMATION AS A CONSEQUENCE OF STATIC LOAD

In the case of static loads one should in the first place think of the weight of the riser itself as the riser is (mostly) suspended from the upper end. Besides, during standstill of the pump, think of the weight of the water column. (A cylinder support, if any, may mean a certain relief.) In the first place this will cause axial tensile stresses in the riser, which are heaviest in the upper end. In the bottom end of the riser the axial stresses will only be caused by the pressure of the water. However, the water pressure also creates tangential and radial tensile stresses in the tube, proportional to the difference in pressure over the tube-wall in situ.

Beside these stresses, also bending stresses may occur in the riser, for instance because:
- the riser itself is bent,
- the glued or screwed joints are not straight,
- the stand, from which the riser is suspended, is not in line with the rising main (either inclined or anchoring beside the centre-line of the borehole),
- the well itself is not drilled straight.

The resulting bending stresses caused by the undesired deviations are rather difficult to judge (excluding those caused by the stand inclination). The occurrence of not in-line joints is probably the most important.

Besides, the material stresses may in some places be higher, because of:
- variations in wall thickness ('local manufacture'),
- scratches and cracks in the wall of the riser,
- screw threads: decrease in diameter, abrupt transitions and additional stresses caused by the coupling itself ('tighten up firmly!'),
- glued sockets: abrupt transitions to another pipe diameter and force fits, and lesser elasticity where glue acted on the riser wall.

It is self-evident that these latter factors play a much more important part in dynamically changing loads!

In handpumps the axial stresses will cause a lengthening of the riser and, therefore, a reduction in diameter and wall thickness as a result of contraction. Besides, the inside overpressure will cause a widening of the pipe and a reduction in wall thickness (and also a slight shortening of the pipe).

Thermoplastic synthetic materials (like PVC) will remain permanently plastic! Eventhough the elastic properties are apt to diminish by ageing (among other things owing to evaporation of the solution from the basic material and fracture of the long molecules under the influence of UV-light). This may lead to brittleness and cracks. The action of glue will have similar consequencies.

In case of imposing a tensile load or a compression load, the deformation of the material will continue: this is called 'creep'. As long as the load is exercised, the material will deform further! As soon as the load is removed, the material will try to resume its original form! However, the material will need much more time for this: more than 10 times! [ICI80] This means that the pipe, even during short, but sufficiently frequent tensile loads, will continue to extend! (Think of piston pumps!)

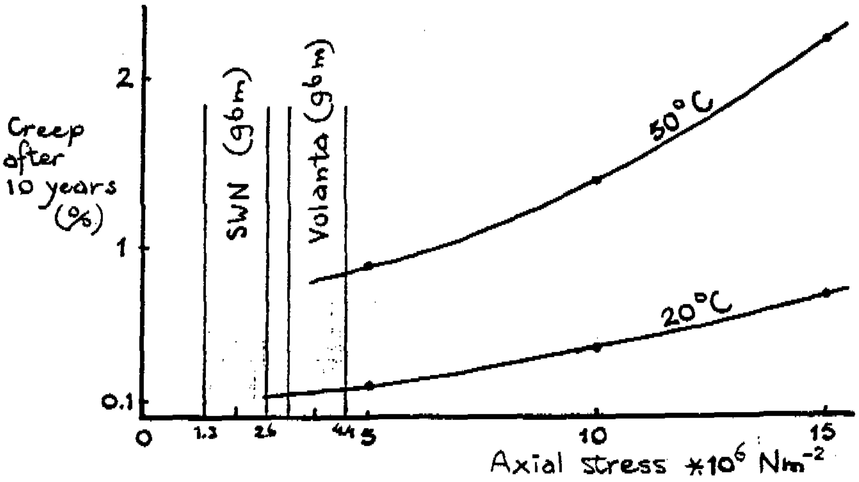


Figure 6.1 Creep in uPVC as a function of the tensile stress and the temperature. (Source: Wavin R&D)

In the figure are drawn the axial tensile stresses for:
- SWN81: by a riser length of 96 m, d_u = 47.5 mm d_i = 36 mm
- Volanta: ditto d_u = 80 mm d_i = 70 mm

$\sigma_{axial,static}$ [$*10^6$ Nm^{-2}] in riser	top end:	bottom end:	mean:
SWN81	2.6	1.3	2.0
Volanta	4.4	3.1	3.8

(N.B. 0.1% of 96 m is almost 10 cm!)

6.4 DEFORMATION AS A CONSEQUENCE OF DYNAMIC LOADS

The following causes for varying loads in the riser can be distinguished:
- the upward piston stroke and pressure valve closed, relieving the cylinder bottom, followed by the downward piston stroke, applying the load of the pressure prevailing in the cylinder to the cylinder bottom;
- acceleration of the piston (and the cylinder!), causing pressure waves that will travel through the whole riser;
- closing of the foot- and pressure valves: this will cause minor pressure waves;
- friction of the piston seal: acts upon the inside cylinder wall in the direction of the piston stroke in regard of the cylinder;
- friction between pump rod (-guidance) and riser;
- friction between riser and shaft wall;
- reaction forces of the shaft wall on the lateral motions of the riser and cylinder;
- any motions of the stand (owing to poor fastening and ample flexibility of the stand).

These factors cause tensile stresses (in axial and radial direction) as well as bending stresses. They may lead to axial and radial deformation of the riser, to swinging, 'snaking' (and buckling).

To gain inside in this complex of events the following quantities have been determined as part of the IADHPP experiments: the axial and bending stresses, the pressure inside the cylinder, the axial movements of the piston and the cylinder.
The development of physical sub-models by project partner TUE is limited in the first stage to describing the axial deformation, in relation to the pressure fluctuations in the pump. This is complicated enough, for the present.
The axial dynamic deformations of the riser can be described quite accurate in relation with the momentane speed of the water in the pump (-cylinder) and the occuring pressure fluctuations. See section 6.5 for more details.

Related to the bending of the riser, there can be distinguished between:
- bending caused by buckling, especially in the bottom part of the riser;
- snaking: a transient transversal wave in the riser.

During the upward piston stroke it will even be possible that axial pressure stresses occur in the riser of the SWN81 (to say nothing of the bending stresses). In the upper end of the riser the axial pressure forces may rise to about half the load that would cause buckling of the riser. In the bottom end the critical buckling load can even be exceeded! If even the pump rod prevents a real buckling, yet during the time that this pressure force occurs the (never truly straight) riser will bend between the pump rod centralizers and couplings respectively and eventually it might touch the rod (if it were not for the fact that the whole SWN pump rod had been provided with a protecting PE-tube). The pump rod therefore limits also the maximum bending stresses, which may be caused in the riser as a result of this lateral deflection 'around the rod'. It will be obvious that there will be a greater friction between the riser and the pump rod, especially near the cilinder.

N.B. The effects referred to above can have such a great impact that during the upward piston stroke the cylinder will make an even greater upward stroke. This means that during the upward stroke the piston in the cylinder moves downward! This phenomenon has been ascertained in the SWN81 with a riser length of 96 metres and it appeared that, when pumping very slowly, this phenomenon still existed (that is to say without the additional pressure waves and with counter-acting friction forces of the piston seal).

Moreover, the rather sudden relief and reloading respectively of the cylinder bottom at the beginning of the piston strokes probably causes the phenomenon called 'snaking'; a fierce oscillating and waving motion of the riser, probably a transient transversal wave. See for details section 6.6 'Snaking'.

6.5 TRANSIENT PRESSURE WAVES IN THE RISING MAIN (by J. Grupa/TUE)

To pump water out of the cylinder, the water needs to be accelerated, by the upward moving piston and/or downward moving cylinder, relatively to one another. The water will 'resist' against this acceleration because of its inertia mass. This will express itself by a suited increase of the local pressure in the water, opposing the related displacement of the piston and/or cylinder. This local increase of the pressure will then lead a live of its own: it will run the riser up and down as a 'pressure wave'.

These pressure waves can be described by a theoretical model. Calculations with this model lead to a propagation velocity of these pressure waves (= speed of sound) of about 450 to 500 m/s for the SWN81 and the Volanta pumps. (By pumps with a riser of steel-tube this is about 1500 m/s!)

By generating the pressure waves in just the right rhythm, the waves will amplify one another. The waves together will form a much stronger pressure wave of which the amplitude may become as large as the static pressure. This phenomenon is called 'resonance'.

With the model a simple interrelation has been derived for the resonance frequency:

$$f_{res} = C / 4L$$

in which: f_{res} = resonance frequency [Hz]
C = propagation velocity [ms^{-1}]
L = length of the riser [m]

These resonance frequencies have been proved by experiments.

This formula shows that the front of the pressure wave travels 4 times the riser (twice over up and down) to generate one complete pressure fluctuation (= called 'pressure wave') in the cylinder.

The pressure fluctuations in the cylinder, generated by pumping, are influenced by these travelling pressure waves. Frequency analysis of the pressure fluctuations in the cylinder, however, show that the pressure fluctuates mainly by the pump frequency and its higher harmonics.

The effects of the pressure waves, travelling with the speed of sound through the riser, only show in the magnitude of the pressure fluctuation in the cylinder and the delay of the fluctuation ('phase shift'). When the pump is operated with a frequency, equal to the resonance frequency of the travelling pressure waves (or a multiple or half or a third of this frequency), then resonance will occur, resulting in (much) higher pressure fluctuations in the cylinder (and the riser!). Up to 1.5* the static pressure has been measured!

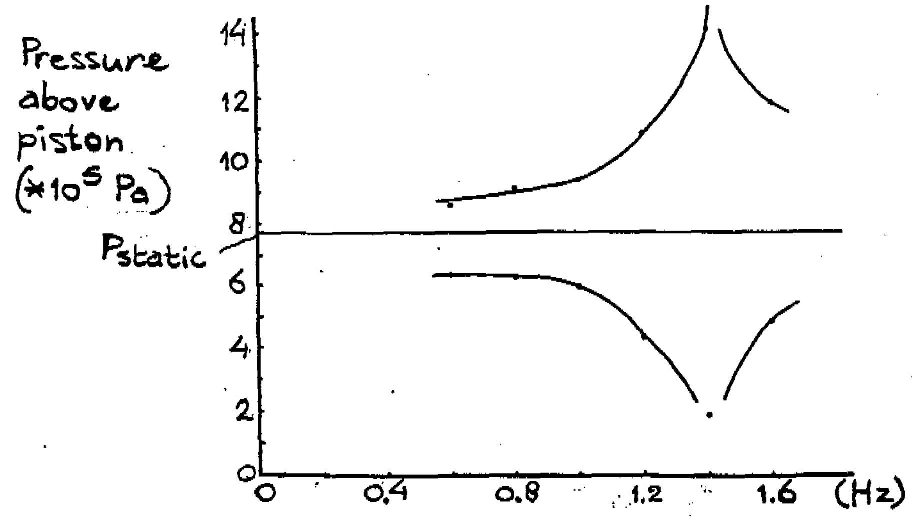


Figure 6.2 Pressure fluctuations in the Volanta cylinder as a function of the pump frequency. (Data file: V00MA802.DAT. Riser length: 77.5 m)

The magnitude of the pressure fluctuation is hard to calculate; theoretical models do not yet have enough accuracy. (Project partner TUE is working on this matter.) As rule of thumb it can be stated that the pressure fluctuations closest to the resonance frequency will be amplified the most.

A main constraint in calculating the amplitude of the pressure fluctuations in the cylinder and the riser is the necessity to know the acceleration of the water or the velocity profile at the bottom end of the rising main. This local velocity of the water is determined by a delicate interaction of the piston, cylinder- and valve movements and the travelling pressure waves.

P.S. Note that the person driving the pump adapts his way of pumping and the pumpfrequency to the pressure fluctuations in the cylinder and so to the travelling pressure waves! (He/she can feel the fluctuations in the handle.) This is probably the explanation for the common seen 'fluttering' (fast pumping with a short stroke).

6.6 SNAKING

Any change in axial tensile stress in the riser and the rod is 'communicated' by means of longitudinal waves (of which the vibration direction and propagation direction coincide) at high velocity over the whole length [BAU]:

$$C_{long} = \sqrt{E / \rho * (1 - \mu) * (1 - 2\mu)}$$

in which:

C_{long}	= propagation velocity	$[ms^{-1}]$
E	= Young's modulus of elasticity	$[Nm^{-2}]$
ρ	= mass density of fluid	$[kgm^{-3}]$
μ	= Poisson's ratio of contraction	[-]

For a uPVC tube with $\mu = 0.35$, $E = 2.5*10^9$ and $\rho = 1380$, $C_{long} = 594\ ms^{-1}$. For $\mu = 0.4$ $C_{long} = 466\ ms^{-1}$. (N.B. For the SWN riser a contraction factor of 0.4 has been measured.)

But when it is a question of considerable and sudden changes transversal waves may arise (vibrations perpendicular to the direction of propagation). This pulsation is accompanied by a relatively great vibration amplitude and relatively low propagation velocity. This is probably the phenomenon that is called 'snaking'.
The next relation will give an indication for the propagation velocity of transversal waves in the riser:

$$C_{trans} = \sqrt{\sigma_{axial} / \rho}$$

in which:

C_{trans}	= propagation velocity	$[ms^{-1}]$
σ_{axial}	= axial stress	$[Nm^{-2}]$

(This formula is valid for transversal waves in ropes. [CRE87])

During the downward piston stroke the tensile stress in the riser is maximal. By the SWN81, with a riser length of 80 m, is in the upper part of the riser: $\sigma_{axial} = 2.3*10^6\ Nm^{-2}$. This would lead to a propagation velocity of $C_{trans} = 41\ ms^{-1}$. In the bottom end of the riser the mean stress will then be

about 1.1*10^6 Nm^{-2}, which means C_{trans}= 28 ms^{-1}.
During the upward piston stroke the stress is less, as will be the propagation velocity: in the top-end about 28 ms^{-1}, and in the bottom end about 0!
These are ruff estimations as the trustworthiness of the formule has not yet been proved for PVC risers filled with water.

It is even possible that standing oscillations arise temporarily in the rod and the riser.

Probably the deformations in the rising main are greater as a result of 'snaking' and it is here that the highest bending stresses will occur, in the pump rod (except the rod upper end!) as well as in the riser. In the case of a standing wave the frequency with which the bending stresses fluctuate is probably much higher.

The deflection of the riser is so great that the riser and the cylinder can possibly hit the shaft wall, if this would not be impeded by means of centralizers.

In every-day practise of pumping the phenomena above referred to do not really get sufficient time to develop entirely: the pumping strokes usually succeed each other too quickly for that. This means that there will be a superposition of different wave phenomena, owing to which new conditions of equilibrium may be attained. And this hampers notably the analysis of the measuring results of these phenomena.

To express a definite opinion on these phenomena would at the present moment be premature. The measuring data will have to be further analyzed in the first place. Thereby physical models for a description of these phenomena will have to be appreciated at their proper value. Only then it will be possible to draw up any justified recommandations to check the adverse effects of these waves, such as perhaps:
- a flexible suspension of the riser,
- irregular spacing of centralizers,
- a smaller ratio diameter of piston / inner diameter of riser.

7. CONCLUSIONS

A treasure of information about the dynamic behaviour of the SWN81 pump is now available. And the same will be the case in the near future with regard to the Volanta.

The measuring experiments on the SWN 81 have again cost more time than originally estimated. It remains difficult to enforce the progress of such experiments.

IAD have hardly been able to make a start with analyzing the measuring data because of the delays and owing to the fact that priority had to be given to the erection of the Volanta set-up (before winter had set in?). However, in co-operation with TUE some main lines of the dynamic behaviour have been analyzed.

The teething troubles that have pestered the measuring experiments in the beginning, seem to have now been surmounted. Considering the difficult working conditions, most transducers are now functioning quite properly.

The measuring program on the SWN81 has been completed, with the exception of the measurements with centralizers and cylinder support at other riser lengths than 96 metres. For reasons of lack of time and because it wil most likely be possible to gain sufficient insight by the gathered measuring data.

A number of recommendations have already led to improvements to the SWN81 pumps. A further analysis of the measuring data will certainly result in more recommendations.

Based on the experiments it may be concluded that the SWN81 pump in its tested version, and certainly without the cylinder support, is unsuitable for heads of 80 metres and more. The delivery per stroke decreases so much that it is only possible to pump up water while using the maximum stroke of the pump.

Air bubbles in the pumped water will probably hardly play a part in handpumps, since the concentration of air bubbles at normal immersion depths (minimum a few metres) is less than 0.1 %. At immersion depths less deep (~0 m.) air bubbles may cause a complete change in the behaviour of the pump.

And last but not least:
With the experience of all the project partners and with the measuring data, it must be possible to raise the insight in the phenomenon of the deepwell handpump to a higher level and to give answers to the most important questions with regard to controlling the dynamic behaviour.

8. REFERENCES

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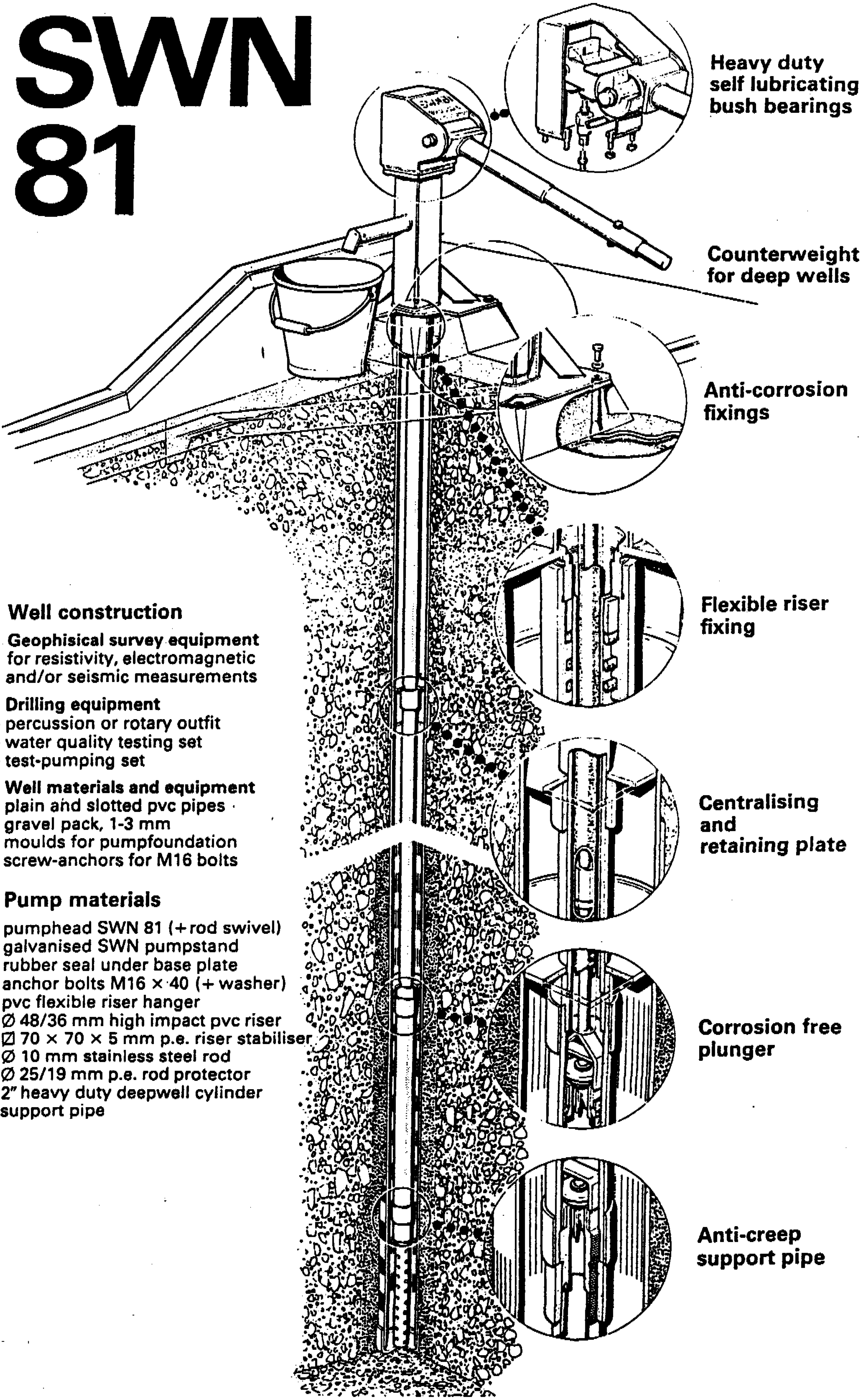
SWN 81



Well construction

Geophisical survey equipment for resistivity, electromagnetic and/or seismic measurements

Drilling equipment
- percussion or rotary outfit
- water quality testing set
- test-pumping set

Well materials and equipment
- plain and slotted pvc pipes
- gravel pack, 1-3 mm
- moulds for pumpfoundation
- screw-anchors for M16 bolts

Pump materials

- pumphead SWN 81 (+rod swivel)
- galvanised SWN pumpstand
- rubber seal under base plate
- anchor bolts M16 × 40 (+ washer)
- pvc flexible riser hanger
- Ø 48/36 mm high impact pvc riser
- ⊠ 70 × 70 × 5 mm p.e. riser stabiliser
- Ø 10 mm stainless steel rod
- Ø 25/19 mm p.e. rod protector
- 2″ heavy duty deepwell cylinder
- support pipe

APPENDIX A

Summary of datafiles of SWN81 measuring program

OVERZICHT PROEVEN SWN 81 BLAD Nr. 1

PROEF VOLGNR.	NUMMER v/d PROEF FILE *. DAT	DATUM	ONDERZOEKER	PROEF-OPSTELLING	cil. ondersteuning	centralizers	stijgbuis lengte	dompeldiepte	riser hanger	swivel	uitwijkhoek v.d. stand	hand of mech.	opnemer groep	pomp + freq. pompslag	zwengelgewicht (cts)	opmerkingen m.b.t. de proef	MAGN. OPSLAG			FUNKTIONEREN VAN OPNEMERS																										
																	doos + floppy proefdata	floppy uitgewerkte data	tape +	RBA				RBB					RBC				RBD				RSA									
																				41	42	43	44	51	52	53	54	55	61	62	63	64	21	22	23	24	31	32	33	34	ZVO	CVO	ZKL	VKL	DRO	HVO
S001	S00 HA 201	10.6.88	r.b.	S200	0	0	21	11	0	0	0	H	A	—	0	W*	1-04	x																												
S002	S00 HB 201	"	"	"	0	0	"	"	0	0	0	H	B	—	"	W	"								~																					
S003	S00 MB 201	"	"	"	0	0	"	"	0	0	0	M	B	0.8-1.0/r=70	"	W	"								~																					
S004	S00 MA 201	"	"	"	0	0	"	"	0	0	0	M	A	"	"	W	"																													
S005	S00 RA 201	17.6.88	"	S201	0	0	"	"	0	0	0	-	A	—	"		"																													
S006	S00 RB 201	"	"	"	0	0	"	"	0	0	0	-	B	—	"		"																													
S007	S00 RB 202	"	"	"	0	0	"	"	0	0	0	-	B	—	"		"																													
S008	S00 RA 202	"	"	"	0	0	"	"	0	0	0	-	A	—	"		"																													
S009A	S00 RD 201	5.7.88	"	"	0	0	"	"	0	0	0	-	D	—	"	na 3 wk. rust	2-05																				vocht ~	~								
S009B	S00 RA 203	"	"	"	0	0	"	"	0	0	0	-	A	—	"		1-04																													
S010	S00 HA 202	11.7.88	"	"	0	0	"	"	0	0	0	H	A	—	"		1-05																									~		—		
S011	S00 HD 201	"	"	"	0	0	"	"	0	0	0	H	D	—	"		"								~																					
S012	S00 MD 201	"	"	"	0	0	"	"	0	0	0	M	D	0.8-2.0/r=120	"		"								~																					
S013	S00 MA 202	"	"	"	0	0	"	"	0	0	0	M	A	"	"		"																									~		—		
S014	S04 MA 201	"	"	"	0	0	"	"	0	0	x+0.76	M	A	"	"		"																									~		—		
S015	S04 MD 201	"	"	"	0	0	"	"	0	0	x+0.76	M	D	"	"		"								~																					
S016	S04 MD 202	"	"	"	0	0	"	"	0	0	x+1.6	M	D	"	"		"								~																					
S017	S04 MA 202	"	"	"	0	0	"	"	0	0	x+1.6	M	A	"	"		1-06																									~		—		
S018	S04 MA 203	"	"	"	0	0	"	"	0	0	x+3.2	M	A	"	"		"																									~	—	—		
S019	S04 MD 203	"	"	"	0	0	"	"	0	0	x+3.2	M	D	"	"		"								~																					
S020	S04 HD 201	"	"	"	0	0	"	"	0	0	x+3.2	H	D	—	"		"								~																					
S021	S04 HA 201	"	"	"	0	0	"	"	0	0	x+3.2	H	A	—	"		"																									~	—	—		
S022	S04 MA 204	"	"	"	0	0	"	"	0	0	x-1.6	M	A	0.8-2.0/r=120	"		"																									~	—	—		
S023	S04 MD 204	"	"	"	0	0	"	"	0	0	x-1.6	M	D	"	"		"								~																					
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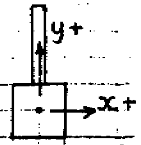
S025	S04 MA 205	"	"	"	0	0	"	"	0	0	y+1.6	M	A	"	"		"																									~	—	—		
S026	S04 MA 206	"	"	"	0	0	"	"	0	0	y-1.6	M	A	"	"		"																									~	—	—		
S027	S04 MD 206	"	"	"	0	0	"	"	0	0	y-1.6	M	D	"	"		"								~																					
S028	S00 MD 202	"	"	"	0	0	"	"	0	0	0	M	D	"	"		"								~																					
S029	S00 MA 203	"	"	"	0	0	"	"	0	0	0	M	A	"	"		"																									~	—	—		
S030	S01 HA 201	12.7.88	"		0	0	"	"	0	1	0	H	A	—	"		"																									—	—	—		
S031	S01 MA 201	"	"	"	0	0	"	"	0	1	0	M	A	0.8-2.0/r=120	"		1-08																									—	—	—		
S032	S05 MA 201	"	"	"	0	0	"	"	0	1	x+1.6	M	A	"	"		"																									—	—	—		
S033	S05 HA 201	"	"	"	0	0	"	"	0	1	x+1.6	H	A	—	"		"																									—	—	—		
S034	S05 MA 202	"	"	"	0	0	"	"	0	1	y+1.6	M	A	0.8-2.0/r=120	"		"																									—	—	—		
S035	S00 HA 203	28.7.88	"	S202	0	0	"	"	0	0	0	H	A	—	"		"																										—			
S036	S00 MA 204	"	"	"	0	0	"	"	0	0	0	M	A	0.8-2.0/r=120	"		"																										—			
S037	S00 MD 203	"	"	"	0	0	"	"	0	0	0	M	D	"	"		"																													
S038	S00 HD 202	"	"	"	0	0	"	"	0	0	0	H	D	—	"		1-09																													

*. W= Wateropbrengstbepaling gedaan.



bovenaanzicht SWN Kop

OVERZICHT PROEVEN SW.1 01. BLAD Nr. 2

																	MAGN. OPSLAG				FUNKTIONEREN VAN OPNEMERS																										
																					RBA				RBB					RBC				RBD				RSA									
PROEF VOLGNR.	NUMMER v/d PROEF FILE *.DAT	DATUM	ONDERZOEKER	PROEF-OPSTELLING	cil. ondersteuning	centralizers	stijgbuis lengte	dompeldiepte	riser hanger	swivel	uitwijkhoek v.d. stand	band of mech.	opnemer groep	pomp + frekw. pompslag	zwengelgewicht (ch)	opmerkingen m.b.t. de proef	doos + floppy	proefdata	floppy uitgewerkte data	tape +	41	42	43	44	51	52	53	54	55	01	02	03	04	11	12	13	14	31	32	33	34	ZVO	CVO	ZKL	VKL	DRO	HVO
S039	S00 MA 205	2.8.88	r.b.	S 202	0	0	21	4.0	0	0	0	M	A	0.8-2.0/r=120	0	W*	1.09	●	X																									–			
S040	S00 HA 204	"	"	"	0	0	"	4.0	0	0	0	H	A	–	"	W	"	●	X																									–			
S041	S00 MD 204	"	"	"	0	0	"	4.0	0	0	0	M	D	0.8-2.0/r=120	"	W	"																														
S042	S00 HD 203	"	"	"	0	0	"	4.0	0	0	0	H	D	–	"	W	"																														
S043	S00 MD 205	"	"	"	0	0	"	2.0	0	0	0	M	D	0.8-2.0/r=120	"	W	"																														
S044	S00 HD 204	"	"	"	0	0	"	2.0	0	0	0	H	D	–	"	W	"																														
S045	S00 MA 206	"	"	"	0	0	"	2.0	0	0	0	M	A	0.8-2.0/r=120	"	W	1-10		X																									–			
S046	S00 HA 205	"	"	"	0	0	"	2.0	0	0	0	H	A	–	"	W	"																										–			
S047	S00 HA 206	"	"	"	0	0	"	0	0	0	0	H	A	–	"		"																										–			
S048	S00 MA 207	"	"	"	0	0	"	0	0	0	0	M	A	0.8-2.0/r=120	"		"	●	X																									–			
S049	S00 HD 205	"	"	"	0	0	"	0	0	0	0	H	D	–	"		"																														
S050	S00 MD 206	"	"	"	0	0	"	0	0	0	0	M	D	0.8-2.0/r=120	"		"																														
S051	S00 RA 204	3.8.88	"	"	0	0	"	0	0	0	0	–	A	–	"	alleen DRO + HVO	"																														
S052	S00 HD 401	5.8.88	"	S401	0	0	39	18	0	0	0	H	D	–	"	W	"																														
S053	S00 MD 401	"	"	"	0	0	"	18	0	0	0	M	D	0.8-2.0/r=120	"	W	2-01																														
S054	S00 HA 401	"	"	"	0	0	"	18	0	0	0	H	A	–	"	W	"				?~																										
S055	S00 MA 401	"	"	"	0	0	"	18	0	0	0	M	A	0.8-2.0/r=120	"	W	"	●	X		?~																							–			
S056	S00 HA 402	"	"	"	0	0	"	10	0	0	0	H	A	–	"	W	"				~																							–			
S057	S00 MA 402	"	"	"	0	0	"	10	0	0	0	M	A	0.8-2.0/r=120	"	W	"				–																							–			
S058	S00 MD 402	"	"	"	0	0	"	10	0	0	0	M	D	0.8-2.0/r=120	"	W	"																														
S059	S00 HD 402	"	"	"	0	0	"	10	0	0	0	H	D	–	"	W	"																														
S060	S00 HD 403	8.8.88	"	"	0	0	"	5	0	0	0	H	D	–	"	W	2.02																														
S061	S00 MD 403	"	"	"	0	0	"	5	0	0	0	M	D	0.8-2.0/r=120	"	W	"																														
S062	S00 MA 403	"	"	"	0	0	"	5	0	0	0	M	A	0.8-2.0/r=120	"	W	"				–																							–			
S063	S00 HA 403	9.8.88	"	S402	0	0	"	5	0	0	0	H	A	–	"	W	"				–																							–			
S064	S00 HA 404	11.8.88	"	S403	0	0	"	5	0	0	0	H	A	–	"	W	"	●	X		~																							–			
S065	S00 MA 404	"	"	"	0	0	"	5	0	0	0	M	A	0.8-2.0/r=120	"	W	"	●	X		–																							–			
S066	S00 MD 404	"	"	"	0	0	"	5	0	0	0	M	D	0.8-2.0/r=120	"	W	"																														
S067	S00 HD 404	"	"	"	0	0	"	5	0	0	0	H	D	–	"	W	2-03																														
S068	S04 MD 401	"	"	"	0	0	"	5	0	0	x+1.6	M	D	0.8-2.0/r=120	"	W	"																														
S069	S04 MD 402	"	"	"	0	0	"	5	0	0	y+1.6	M	D	0.8-2.0/r=120	"	W	"																														
S070	S04 MA 401	"	"	"	0	0	"	"	0	0	y+1.6	M	A	0.8-2.0/r=120	"	W	"				?																							–			
S071	S04 MA 402	"	"	"	0	0	"	"	0	0	x+1.6	M	A	0.8-2.0/r=120	"	W	"				–																							–			
S072	S01 HA 401	12.8.88	"	"	0	0	"	"	0	1	0	H	A	–	"		"				–																							–			
S073	S01 MA 402	18.8.88	"	S404	0	0	"	4	0	1	0	M	A	0.8-2.0/r=120	"	W	"	●	X																												
S074	S01 HA 402	"	"	"	0	0	"	"	0	1	0	H	A	–	"	W	2-04	●	X																												
S075	S01 MD 402	"	"	"	0	0	"	"	0	1	0	M	D	0.8-2.0/r=120	"	W	"																														
S076	S01 HD 402	"	"	"	0	0	"	"	0	1	0	H	D	–	"		"																														
S077	S01 MD 403	"	"	"	0	0	"	"	0	1	0	M	D	0.8-1.6/r=200	"		"																														
S078	S01 MA 403	"	"	"	0	0	"	"	0	1	0	M	A	0.8-1.6/r=200	"		"	●	X																												
S079	S05 MD 401	"	"	"	0	0	"	"	0	1	x+1.6	M	D	0.8-1.6/r=200	"		"																														
S080	S05 MA 401	"	"	"	0	0	"	"	0	1	x+1.6	M	A	0.8-1.6/r=200	"		"	● ●	X																												
S081	S05 MA 404	"	"	"	0	0	"	"	0	1	x+1.6	M	A	0.8-2.0/r=120	"		2-05	●	X																												
S082	S05 MD 404	"	"	"	0	0	"	"	0	1	x+1.6	M	D	0.8-2.0/r=120	"		"																														
S083	S05 MD 403	"	"	"	0	0	"	"	0	1	y+1.6	M	D	0.8-2.0/r=120	"		"																														
S084	S05 MA 403	"	"	"	0	0	"	"	0	1	y+1.6	M	A	0.8-2.0/r=120	"		"	● ●	X																												?~
S085	S05 MA 402	"	"	"	0	0	"	"	0	1	y+1.6	M	A	0.8-1.6/r=200	"		2-04	● ●	X																												

OVERZICHT PROEVEN SWN 81 BLAD Nr. 3

																	MAGN. OPSLAG			
PROEF VOLGNR.	NUMMER v/d PROEF FILE *.DAT	DATUM	ONDERZOEKER	PROEF-OPSTELLING	cil. ondersteuning	centralizers	stijgbuis lengte	dompeldiepte	riser hanger	swivel	uitwijkhoek v.d. stand	hand of mech.	opnemer groep	pomp + frekw.	pompslag zwengelgewicht (cts)	opmerkingen m.b.t. de proef	doos+floppy proefdata	floppy uitgewerkte data		tape +
S086	S05 MD 402	18.8.88	r.b	S404	0	0	39	4	0	1	y+1.6	M	D	0.8-1.6/r=200	0		2.05			
S087	S03 HD 401	23.8.88	"	"	0	0	"	"	1	1	0	H	D	–	"	W	"			
S088	S03 MD 402	"	"	"	0	0	"	"	1	1	0	M	D	0.8-1.6/r=200	"	W	"			
S089	S03 MD 401	"	"	"	0	0	"	"	1	1	0	M	D	0.8-2.0/r=120	"	W	2-06			
S090	S03 MA 401	"	"	"	0	0	"	"	1	1	0	M	A	0.8-2.0/r=120	"	W	"			
S091	S03 MA 402	"	"	"	0	0	"	"	1	1	0	M	A	0.8-1.6/r=200	"	W	"	●	X	
S092	S03 MA 403	"	"	"	0	0	"	"	1	1	0	M	A	0.8-1.6/r=200	"	riser hanger niet aangedr. W	"	● ●	x	
S093	S03 HA 401	"	"	"	0	0	"	"	1	1	0	H	A	–	"	W	"	●	X	
S094	S07 MA 401	"	"	"	0	0	"	"	1	1	x+1.6	M	A	0.8-1.6/r=200	"		"	●	X	
S095	S07 MD 401	"	"	"	0	0	"	"	1	1	x+1.6	M	D	0.8-1.6/r=200	"		"			
S096	S07 MD 402	"	"	"	0	0	"	"	1	1	y+1.6	M	D	0.8-1.6/r=200	"		"			
S097	S07 MA 402	"	"	"	0	0	"	"	1	1	y+1.6	M	A	0.8-1.6/r=200	"		2.07	●	X	
S098	S03 MA 405	24.8.88	"	"	0	0	"	0	1	1	0	M	A	0.8-1.6/r=200	"	} pompt nog net water.	"			
S099	S03 MD 405	"	"	"	0	0	"	"	1	1	0	M	D	0.8-1.6/r=200	"		"			
S100	S03 MA 406	"	"	"	0	0	"	"	1	1	0	M	A	0.8-1.6/r=200	"	pompt net geen water	"			
S101	S01 HA 601	25.8.88	"	S601	0	0	60	23	0	1	0	H	A	–	"	W	"			
S102	S01 MA 601	"	"	"	0	0	"	"	0	1	0	M	A	0.6-1.4/r=200	"	W	"	● ●	X	
S103	S01 MA 602	"	"	"	0	0	"	"	0	1	0	M	A	0.6-1.8/r=120	"	W	"	● ●	X	
S104	S01 MD 602	"	"	"	0	0	"	"	0	1	0	M	D	0.6-1.8/r=120	"	W	"			
S105	S01 MD 601	"	"	"	0	0	"	"	0	1	0	M	D	0.6-1.4/r=200	"	W	2-08			
S106	S01 HD 601	"	"	"	0	0	"	"	0	1	0	H	D	–	"	W	"			
S107	S01 MD 603	"	"	"	0	0	"	10	0	1	0	M	D	0.6-1.4/r=200	"	W	"			
S108	S01 HD 602	"	"	"	0	0	"	"	0	1	0	H	D	–	"	W	"			
S109	S01 MD 604	"	"	"	0	0	"	"	0	1	0	M	D	0.6-1.8/r=120	"	W	"			
S110	S01 MA 603	26.8.88	"	"	0	0	"	"	0	1	0	M	A	0.6-1.4/r=200	"	W	"	● ●	X	
S111	S01 MA 604	"	"	"	0	0	"	"	0	1	0	M	A	0.6-1.8/r=120	"	W	"	● ●	X	
S112	S01 HA 602	"	"	"	0	0	"	"	0	1	0	H	A	–	"	W	"			
S113	S01 HA 603	"	"	"	0	0	"	"	0	1	0	H	A	–	18	W	2-09			
S114	S01 HD 603	"	"	"	0	0	"	"	0	1	0	H	D	–	"	W	"			
S115	S01 MD 605	"	"	"	0	0	"	5	0	1	0	M	D	0.6-1.4/r=200	"	W	"			
S116	S01 HD 604	"	"	"	0	0	"	"	0	1	0	H	D	–	18	W	"			
S117	S01 MA 605	29.8.88	"	"	0	0	"	"	0	1	0	M	A	0.6-1.4/r=200	"	W	"	●	x	
S118	S01 HA 604	"	"	"	0	0	"	"	0	1	0	H	A	–	18	W	"	●	x	
S119	S05 MA 601	"	"	"	0	0	"	"	0	1	x+1.6	M	A	0.6-1.4/r=200	"		"	●	X	
S120	S05 MD 601	"	"	"	0	0	"	"	0	1	x+1.6	M	D	0.6-1.4/r=200	"		"			
S121	S05 MD 602	"	"	"	0	0	"	"	0	1	y+1.6	M	D	0.6-1.4/r=200	"		2-10			
S122	S05 MA 602	"	"	"	0	0	"	"	0	1	y+1.6	M	A	0.6-1.4/r=200	"		"	●	X	
S123	S00 HA 601	30.8.88	"	"	0	0	"	"	0	0	0	H	A	–	18	W	"	●	X	
S124	S00 MA 601	"	"	"	0	0	"	"	0	0	0	M	A	0.6-1.4/r=200	"	W	"	●	X	
S125	S00 HD 601	"	"	"	0	0	"	"	0	0	0	H	D	–	18	W	"			
S126	S00 MD 601	"	"	"	0	0	"	"	0	0	0	M	D	0.6-1.4/r=200	"	W	"			
S127	S04 MD 601	"	"	"	0	0	"	"	0	0	x+1.6	M	D	0.6-1.4/r=200	"	W	"			
S128	S04 MA 601	"	"	"	0	0	"	"	0	0	x+1.6	M	A	0.6-1.4/r=200	"	W	"	●	X	
S129	S04 MA 602	"	"	"	0	0	"	"	0	0	y+1.6	M	A	0.6-1.4/r=200	"	W	3-01	●	X	
S130	S04 MD 602	"	"	"	0	0	"	"	0	0	y+1.6	M	D	0.6-1.4/r=200	"	W.	"			
S131	S00 MA 602	"	"	"	0	0	"	"	0	0	0	M	A	0.6-1.4/r=200	"	500Hz/500 s.	"	●	X	

	FUNKTIONEREN VAN OPNEMERS																										
	RBA				RBB					RBC				RBD				RSA									
PROEF VOLGNR.	41	42	43	44	51	52	53	54	55	61	62	63	64	71	72	73	74	31	32	33	34	ZVO	CVO	ZKL	VKL	PRO	HVO
S086																											
S087																											
S088																											
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S124																											
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S126																											
S127																											?
S128																											—
S129																											—
S130																											?
S131																											

Proef S087 t/m S138 met Philips weegschaal.
Daarvoor en daarna Tejal

OVERZICHT PROEVEN / SWN 02 / BLAD Nr. / 4 /

																		MAGN. OPSLAG			FUNKTIONEREN VAN OPNEMERS																										
																					RBA				RBB					RBC				RBD				RSA									
PROEF VOLGNR.	NUMMER v/d PROEF FILE *.DAT	DATUM	ONDERZOEKER	PROEF-OPSTELLING	cil. ondersteuning	centralizers	stijgbuis lengte	dompeldiepte	riser hanger	swivel	uitwijkhoek v.d. stand	hand of mech.	opnemer groep	pomp + frekw. pompslag	zwengelgewicht (cb)	opmerkingen m.b.t. de proef	doos + floppy proefdata	floppy uitgewerkte data	tape +		41	42	43	44	51	52	53	54	55	61	62	63	64	11	12	13	14	31	32	33	34	ZVO	CVO	ZKL	VKL	DEO	HVO
S132	S00 MA 603	30.8.88	r.b	S601	0	0	60	0	0	0	0	M	A	0.6-1.4/r=200	18		3-01 ●	X																													
S133	S00 MD 602	31.8.88	"	"	0	0	60	0	0	0	0	M	D	0.6-1.4/r=200	"		"																														
S134	SNELMA	"	"	S801	0	0	81	233	0	0	0	M	A	1.2/r=200	"		"																														
S135	S00 HA 801	1.9.88	"	"	0	0	"	"	0	0	0	H	A	—	38	W	" ● ●	X																									—				
S136	S00 MA 801	"	"	"	0	0	"	"	0	0	0	M	A	0.6-1.4/r=200	"	W	"																														
S137	S00 MD 801	2.9.88	"	"	0	0	"	"	0	0	0	M	D	0.6-1.4/r=200	"	W	"																														
S138	S00 HD 801	"	"	"	0	0	"	"	0	0	0	H	D	—	38	W	3-02																														
S139	S04 MD 801	"	"	"	0	0	"	"	0	0	x+1.6	M	D	0.6-1.4/r=200	"		"																														
S140	S04 MA 801	"	"	"	0	0	"	"	0	0	x+1.6	M	A	0.6-1.4/r=200	"		"																														
S141	S04 MA 802	"	"	"	0	0	"	"	0	0	y+1.6	M	A	0.6-1.4/r=200	"		"																														
S142	S04 MD 802	"	"	"	0	0	"	"	0	0	y+1.6	M	D	0.6-1.4/r=200	"		"																														
S143	S00 MD 802	13.9.88	"	"	0	0	"	0	0	0	0	M	D	0.6-1.6/r=200	"		"																														
S144	S00 MA 802	"	"	"	0	0	"	0	0	0	0	M	A	0.6-1.6/r=200	"		"																														
S145	S00 MA 001	19.9.88	j.b	S001	0	0	2	0	0	0	0	M	A	0.8-2.0/r=200	"	}dyn.calib.	" ●	~																													
S146	S00 HA 001	20.9.88	"	"	0	0	"	0	0	0	0	H	A	—	"		3-04 ●	~																													
S147	S00 HA 802	21.9.88	r.b	S802	0	0	81	0	0	0	0	H	A	—	28	dyn. cal.	" ●	~																									—					
S148	S00 HA 803	22.9.88	"	"	0	0	"	5	0	0	0	H	A	—	38	W	"																														
S149	S00 MA 803	"	"	"	0	0	"	"	0	0	0	M	A	0.6-1.6/r=200	"	géén water	" ● ●	X																													
S150	S00 MD 803	"	"	"	0	0	"	"	0	0	0	M	D	0.6-1.6/r=200	"	géén water	"																														
S151	S00 HD 803	"	"	"	0	0	"	"	0	0	0	H	D	—	38		"																														
S152	S04 MA 803	"	"	"	0	0	"	"	0	0	x+1.6	M	A	0.6-1.6/r=200	"	géén water	"																														
S153	S04 MA 804	"	"	"	0	0	"	"	0	0	y+1.6	M	A	0.6-1.6/r=200	"	geen water	"																														
S154	S00 HA 804	"	"	"	0	0	"	"	0	0	0	H	A	-	38	Stang ½ slag gedraaid	3-05																														
S155	S00 HA 805	3.11.88	"	S803	0	0	"	"	0	0	0	H	A	-	38	25/500	"																														HVO:
S156	S00 MA 805	"	"	"	0	0	"	"	0	0	0	M	A	0.6-1.4/r=300	"	25/500	" ● ●	X																													
S157	S00 MA 806	"	"	"	0	0	"	"	0	0	0	M	A	0.6-1.4/r=300	"	W	" ● ●	X																													
S158	S00 HA 806	"	"	"	0	0	"	"	0	0	0	H	A	—	38		" ● ●	X																													
S159	S03 HA 801	8.11.88	"	"	0	0	"	"	1	1	0	H	A	—	38		" ● ●	X																													
S160	S03 MA 801	"	"	"	0	0	"	"	1	1	0	M	A	0.6-1.4/r=300	"		" ● ●	X																													
S161	S07 MA 801	"	"	"	0	0	"	"	1	1	x+1.6	M	A	"	"		" ● ●	X																													
S162	S07 MA 802	"	"	"	0	0	"	"	1	1	y+1.6	M	A	"	"		3-06 ● ●	X																													
S163	S01 HA 901	10.11.88	"	S901	0	0	96	20	0	1	0	H	A	—	58	W neerw. slag geeft water	"																														
S164	S01 MA 901	"	"	"	0	0	"	"	0	1	0	M	A	}0.6-1.6	"	W	" ● ●	X																													
S165	S01 MA 902	"	"	"	0	0	"	"	0	1	0	M	A	r=300	"	25/500	" ● ●	X																													
S166	S01 MA 903	"	"	"	0	0	"	"	0	1	0	M	A	0.6-1.6/r=200	"	geen water	" ● ●	X																													
S167	S01 MA 904	14.11.88	"	"	0	0	"	5	0	1	0	M	A	0.6-1.6/r=300	"	W	"																										—				
S168	S01 HA 902	"	"	"	0	0	"	"	0	1	0	H	A	—	58	W	"																										—				
S169	S01 MD 901	"	"	"	0	0	"	"	0	1	0	M	A	0.6-1.6/r=300	.		"																										—				
S170	S01 HD 901	"	"	"	0	0	"	"	0	1	0	H	A	—	58		3-07																										—				
S171	S05 MA 901	"	"	"	0	0	"	"	0	1	x+1.6	M	A	0.6-1.6/r=300	"	geen water	"																										—				
S172	S05 MA 902	"	"	"	0	0	"	"	0	1	y+1.6	M	A	0.6-1.6/r=300	"	geen water	"																										—				
S173	S00 HA 901	21.11.88	jb	S902	0	0	96.2	"	0	0	0	H	A	—	58	W	"																														
S174	S00 MA 901	"	r.b	"	0	0	"	"	0	0	0	M	A	0.6-1.6/r=300	"	geen water	"																														
S175	S00 MA 902	"	"	"	0	0	"	"	0	0	0	M	A	0.6-1.6/r=300	.	25/500. geen water	"																														

Vanaf S155 : HVO slipt

Vanaf S167 t/m 172 : CVO kapot

Proef S 087 t/m S138 met Philips weegschaal
daarna Tefal

Bij demontage na S158 bleek trekstangaardedraad afgeknapt (bij waarsch. 155 t/m 158)

Vanaf S159 : bok met versteviging

Vanaf S163: alleen neerwaartse slag geeft water!

OVERZICHT PROEVEN /SWN81/ BLAD Nr. /5/

																			MAGN. OPSLAG		
PROEF VOLGNR.	NUMMER v/d PROEF FILE *.DAT	DATUM	ONDERZOEKER	PROEF-OPSTELLING	cil. ondersteuning	centralizers	stijgbuis-lengte	dompeldiepte	riser hanger	swivel	uitwijkhoek v.d. stand	hand of mech.	opnemer groep	pomp + frekw.	pompslag zwengelgewicht (cm)	opmerkingen m.b.t. de proef	doos + floppy proefdata	floppy uitgewerkte data	tape +
S176	S00 MD 901	21.11.88	r.b	S902	0	0	96.2	5	0	0	0	M	D	0.6-1.6/r:300	58	geen water	3-07		
S177	S04 MA 901	"	"	"	0	0	"	"	0	0	x+1.6	M	A	0.6-1.6/r:300	"	geen water	"		
S178	S04 MA 902	"	"	"	0	0	"	"	0	0	y+1.6	M	A	0.6-1.6/r:300	"	geen water	3-08		
S179	S00 HA 902	23.11.88	"	"	0	0	"	"	0	0	0	H	A	—	58	stand +485mm	"	● ● X	
S180	S00 MA 903	"	"	"	0	0	"	"	0	0	0	M	A	0.6-1.6/r:300	"	" "	"	X	
S181	S00 MD 902	"	"	"	0	0	"	"	0	0	0	M	D	0.6-1.6/r:300	"	" "	"	X	
S182	S00 HD 901	"	"	"	0	0	"	"	0	0	0	H	D	—	58	" "	"		
S183	S32 HA 901	"	"	"	1	0	"	"	0	0	0	H	A	—	58	stand +425mm	"	X	
S184	S32 MA 901	"	"	"	1	0	"	"	0	0	0	M	A	0.6-1.6/r:300	"	" "	"	·	
S185	S32 MD 901	"	"	"	1	0	"	"	0	0	0	M	D	0.6-1.6/r:300	"	" "	"	X	
S186	S32 HD 901	"	"	"	1	0	"	"	0	0	0	H	D	—	58	" "	"		
S187	S32 HD 902	"	"	"	1	0	"	"	0	0	0	H	D	—	58	stand +365mm	"	·	
S188	S32 MA 902	24.11.88	"	"	1	0	"	"	0	0	0	M	A	0.6-1.6/r:300	"	W. " "	3-09	·	
S189	S32 HA 902	"	"	"	1	0	"	"	0	0	0	H	A	—	58	W. " "	"	● ● X	
S190	S32 MD 902	"	"	"	1	0	"	"	0	0	0	M	D	0.6-1.6/r:300	"	" "	"	X	
S191	S32 HA 903	"	"	"	1	0	"	"	0	0	0	H	A	—	58	W " " stand+305mm	"	● ● X	
S192	S32 MA 903	"	"	"	1	0	"	"	0	0	0	M	A	0.6-1.6/r:300	"	* " "	"	·	
S193	S32 MD 903	"	"	"	1	0	"	"	0	0	0	M	D	0.6-1.6/r:300	"	" "	"	X	
S194	S32 HD 903	"	"	"	1	0	"	"	0	0	0	H	D	—	58	" "	"		
S195	S16 MA 901	7.12.88	"	S903	0	1	"	"	0	0	0	M	A	0.6-1.6/r:300	"	stand+485mm	"	·	
S196	S16 HA 901	"	"	"	0	1	"	"	0	0	0	H	A	—	58	W. "	"	X	
S197	S16 MD 901	"	"	"	0	1	"	"	0	0	0	M	D	0.6-1.6/r:300	"	" "	"	X X	
S198	S16 HD 901	"	"	"	0	1	"	"	0	0	0	H	D	—	58	" "	3-10		
S199	S48 HA 901	12.12.88	"	"	1	1	"	"	0	0	0	H	A	—	48	W ↑	"	X	
S200	S48 MA 901	"	"	"	1	1	"	"	0	0	0	M	A	0.6-1.6/r:300	"	W	"	·	
S201	S48 MD 901	"	"	"	1	1	"	"	0	0	0	M	D	0.6-1.6/r:300	"		"		
S202	S48 HD 901	"	"	"	1	1	"	"	0	0	0	H	D	—	48	stand +	"		
S203	S48 HA 902	14.12.88	"	"	1	1	"	"	0	0	0	H	A	—	58	365	"	● ● X	
S204	S48 MA 902	"	"	"	1	1	"	"	0	0	0	M	A	0.6-1.6/r:300	"		"	● ● X	
S205	S48 MD 902	"	"	"	1	1	"	"	0	0	0	M	D	0.6-1.6/r:300	"	(= bok)	"	·	
S206	S48 HD 902	"	"	"	1	1	"	"	0	0	0	H	D	—	58	↓	"		
S207	S16 HD 902	"	"	"	0	1	"	"	0	0	0	H	D	—	58	stand +485mm	"		
S208	S16 MD 902	"	"	"	0	1	"	"	0	0	0	M	D	0.6-1.6/r:300	"	" "	3-11	·	
S209	S16 MA 902	"	"	"	0	1	"	"	0	0	0	M	A	0.6-1.6/r:300	"	" "	"	● ● X	
S210	S16 HA 902	"	"	"	0	1	"	"	0	0	0	H	A	—	58	" "	"	● ● X	

FUNKTIONEREN VAN OPNEMERS

PROEF VOLGNR.	RBA				RBB					RBC				RBD				RSA									
	41	42	43	44	51	52	53	54	53	61	62	63	64	21	22	23	24	31	32	33	34	ZVO	CVO	ZKL	VKL	DEO	HVO
S176																											HVC
S177																											
S178																											
S179																											
S180																							~				
S181																											
S182																											
S183																											
S184																											
S185																											
S186																											
S187																											
S188																											
S189																											
S190																											
S191																											
S192																											
S193																											
S194																											
S195																							—				
S196																						~					
S197																											
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S199																											
S200																											
S201																											
S202																											
S203																											
S204																											
S205																											
S206																											
S207																											
S208																											
S209																											
S210																											

n.b. proeven gedaan op: stand +365 mm (bokhoogte), tenzij anders vermeld.

* S192: na subf.4 V-snaar gespannen.

Vanaf S155: HVO slipt! t/m 202

Bok met versteviging (vanaf S159)

Vanaf S163: alleen neerwaartse slag geeft water. t/m 186. (Bij vrij hangende stijgb. v.g6.2 m)

Vanaf S187 (stand +365mm) bij op/en neerwaartse slag water; ook bij kortere neerw. slag

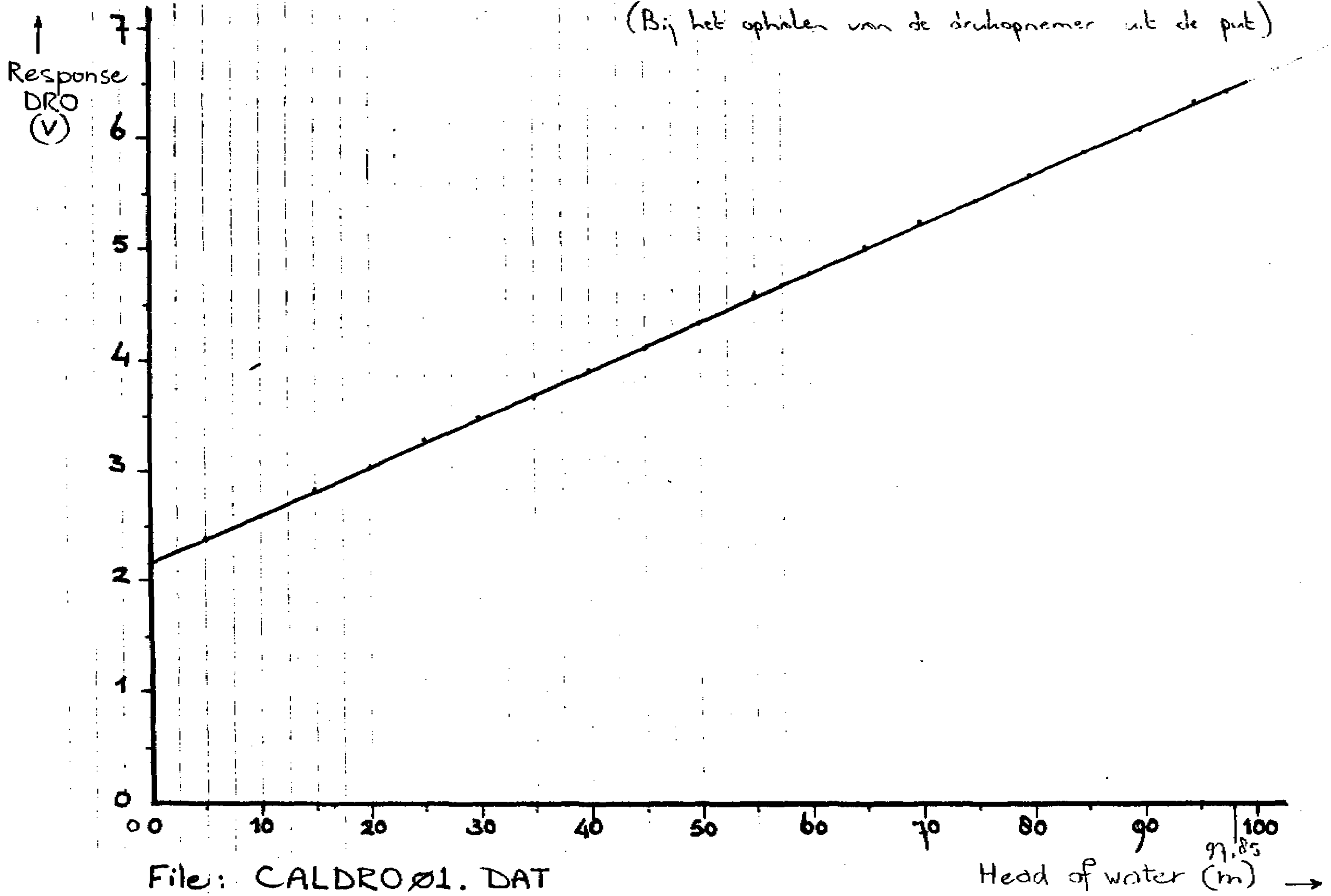
S203 t/m 210 is 'n herhaling van S195 t/m 202 (i.v.m slippende HVO)

APPENDIX B

Calibration data

Datum: 07-03-'88 Grafiek kalibratie drukopnemer CALDRO 01.

(Bij het ophalen van de drukopnemer uit de put)



File: CALDRO01. DAT

CALCVO 13. DAT

24.12.88

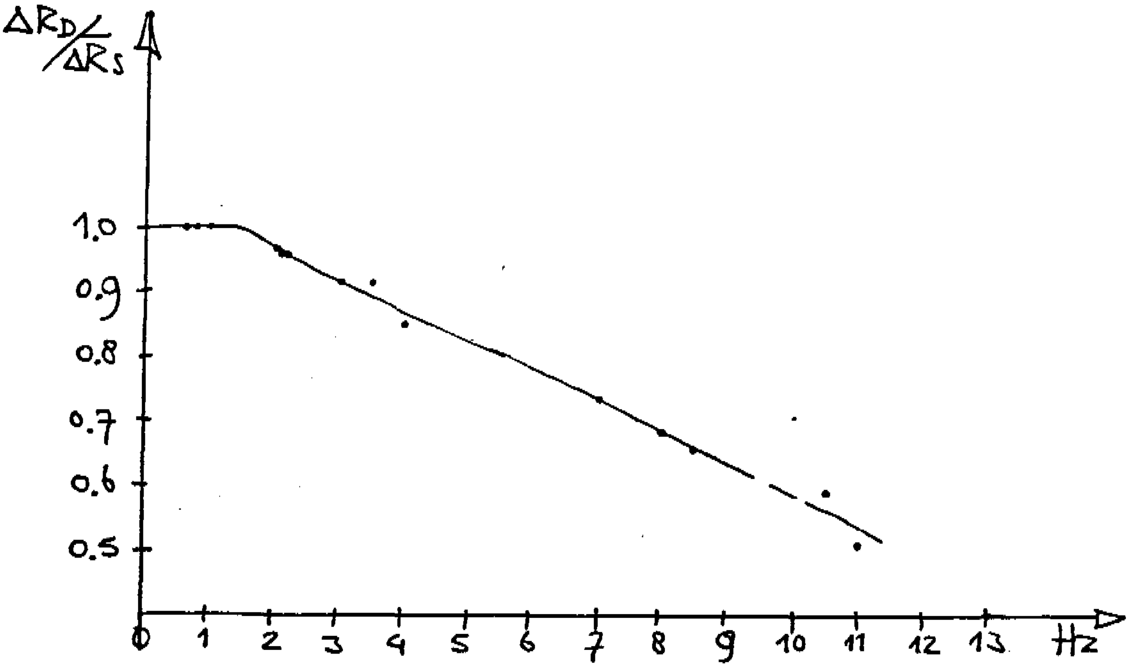
statisch:

Subf 1	R	ODP = 2130	BDP = 3590	ΔR_S = 1460	$\Delta \bar{R}_S$ = 1445
2	S	2120	3550	1430	
10	Z	2120	3560	1440	

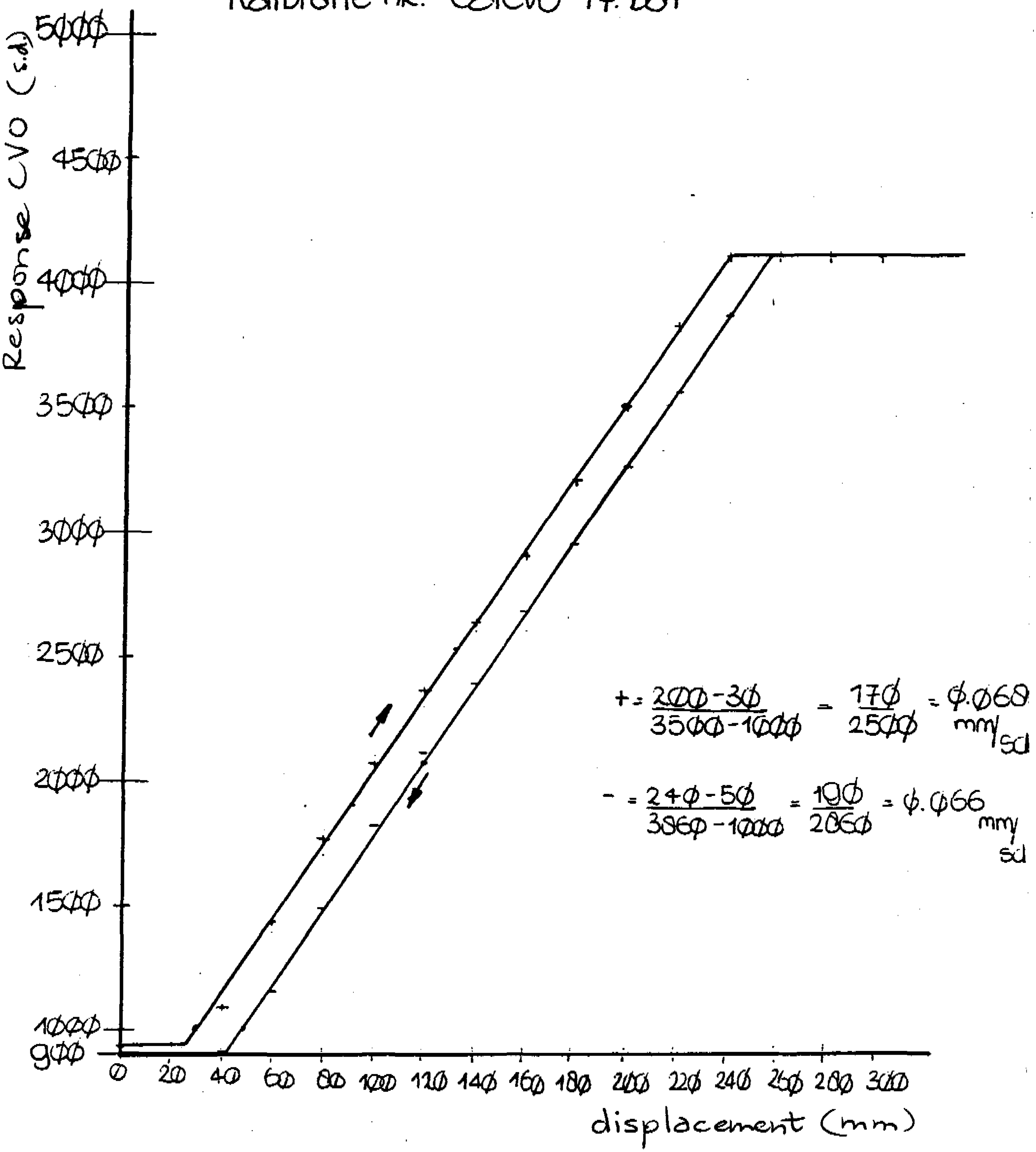
Dynamisch

Subf 3	T	1.0 Hz	ODP = 2110	BDP = 3560	0.6 Hz	ODP = 2105	BDP = 3560
4	U	2.2	2180	3560	0.75 Hz	2130	3570
5	V	7.0	2330	3380	3 Hz	2180	3510
6	W	8.0	2350	3330	2 Hz	2120	3520
7	X	8.5	2360	3320	3.5	2150	3480
8	Y	10.5	2350	3200	4	2200	3430
9	Z	11	2460	3190	2.3	2140	3520

frekwentie	ΔR_D	$\Delta R_D / \Delta \bar{R}_S$
0.6 Hz	1455 (sd)	
0.75	1440	1.0
1.0	1450	1.0
2.0	1400	0.97
2.2	1380	0.96
2.3	1380	0.96
3.0	1330	0.92
3.5	1330	0.92.
4.0	1230	0.85
7.0	1050	0.73
8.0	980	0.68
8.5	960	0.66
10.5	850	0.59
11.0	740	0.51.



Kalibratie nr. Calcvo 17.dat



$$+ = \frac{200-30}{3500-1000} = \frac{170}{2500} = 0.068 \ \mathrm{mm/sd}$$

$$- = \frac{240-50}{3860-1000} = \frac{190}{2860} = 0.066 \ \mathrm{mm/sd}$$

de vertikale hysteresis = 260 sd

de Horizontale hysteresis = 10 mm.

C101

KALIBRATIE NR.	ONDERDEEL / PLAATSING	ONDERZ.	BLAD
CALRBA 50	stijgbuis Volanta bovenaan	JB.	1

DATA FILE NR.: CALRBA50.DAT

OPSTELLING: Horizontale inspanning tussen moffenklemmen. (mof draai t met buis mee)

DATUM: 27-12-88

TEMP.: 20°C

ROW	KAN.	OPN.	VERST	Rspan	Rnul		Gemidd.0	Gemidd.F2
1	0	11	11	12Ω	1651			4.53652
2	1	12	12	12Ω	2.351			4.3530
3	2	13	13	12Ω	2308			4.6452
4	3	14	14	12Ω	1.682			4.5049

OPNEMERS NR.

BOVEN

WAND

	11	
14	A	12
	13	

LAST	SUBF	V	11	12	13	14		
0	1	R	1733	1542	1522	1656		
3	2	S	2341	2204	2191	2308		
4	3	T	2569	2442	2390	2520		
5	4.	U	2794	2665	2608	2749		
6	5.	V	3023	2895	2817	2972		
0	6	W	1733	1548	1522	1653		
Faktor		F2	4.3951	4.3442	4.7941	4.5220		
		F3						

BOVEN

WAND

	14	
13	B	11
	12	

0	7	R	1728	1538	1509	1643		
3	8	S	2357	2229	2151	2263		
4	9	T	2571	2443	2360	2490		
5	10	U	2796	2669	2592	2729		
6	11	V	3015	2890	2810	2957		
0	12	W	1731	1538	1513	1646		
Faktor		F2	4.5655	4.5377	4.5520	4.3276		
		F3						

BOVEN

WAND

	13	
12	C	14
	11	

0.	13	R	1724	1530	1509	1648		
3	14	S	2408	2178	2106	2303		
4	15	T	2621	2407	2325	2530		
5	16	U	2834	2631	2547	2750		
6	17	V	3049	2863	2767	2978		
0	18	W	1723	1532	1521	1648		
Faktor		F2	4.6006	4.3838	4.5326	4.4430		
		F3						

BOVEN

WAND

	12	
11	D	13
	14	

0	19	R	1722	1526	1516	1649		
3	20	S	2345	2165	2162	2318		
4	21	T	2557	2400	2389	2526		
5	22	U	2774	2646	2609	2743		
6	23	V	2987	2802	2827	2958		
0	24	W	1724	1532	1519	1649		
Faktor		F2	4.6728	4.1851	4.5000	4.6892		
		F3						

BOVEN

WAND

	11	
14	E=A	12
	13	

0	25	R	1716	1527	1516	1638		
3	26	S	2325	2203	2182	2275		
4	27	T	2557	2434	2304	2494		
5	28	U	2704	2662	2592	2712		
6	29	V	3012	2898	2002	2936		
0	30	W	1727	1540	1517	1646		
Faktor		F2	4.3606	4.3143	4.8387	4.5420		
		F3						

OPMERKINGEN:
Z.O.Z.

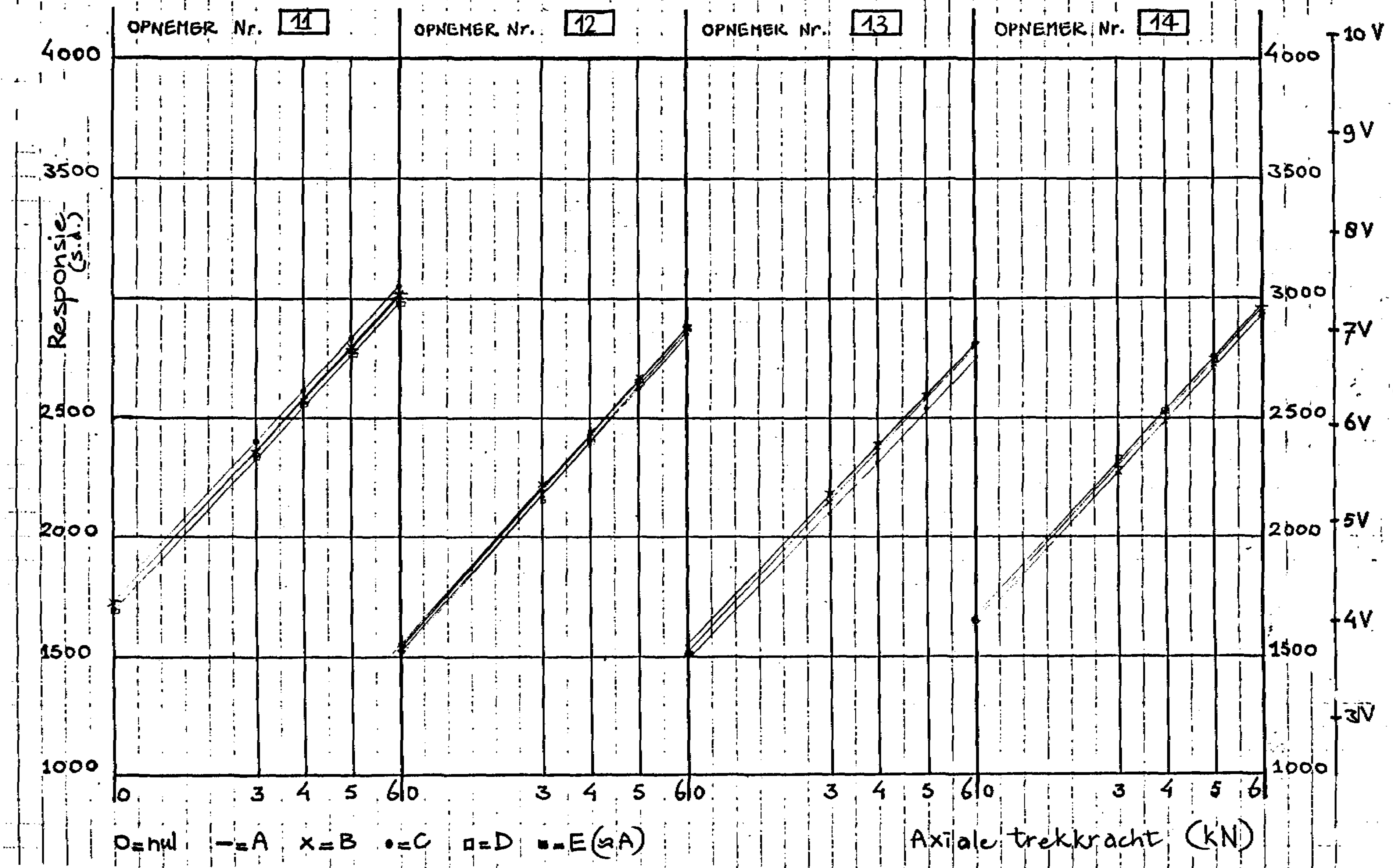
KALIBRATIE Nr. CALRBA 50

BLAD Nr. 1

DATUM 27.12.00

Volanta Stijgbuis bovenaan

ONDERZOEKER T.Z.



C102

KALIBRATIE NR.	ONDERDEEL / PLAATSING	ONDERZ.	BLAD
CALRSA 27	rvs trekstangdeel Volanta / 40cm	T.Z.	1

DATA FILE NR.: CALRSA 27 .DAT

OPSTELLING: Trekproef verticale inspanning tussen stangkoppen

DATUM: 20-12-00

TEMP.: 19°C

ROW	KAN.	OPN.	VERSI	Rspan	Rnul		Gemidd.Ø	Gemidd. F2
1	0	31	31	4.30	2.559	22 μF op nabeskast		5.26
2	1	32	32	4.30	1.956			5.02
3	2	33	33	4.30	1.956			4.78
4	3	34	34	4.30	2.636			4.98

OPNEMERS NR.

BOVEN
32
31 A 33
34
WAND

LAST	SUBF	V	31	32	33	34		
0	1	R	2306	2351	1951	2123		
3	2	S	2922	2943	2602	2705		
4	3	T	3009	3136	2010	2896		
5	4	U	3291	3341	3022	3098		
6	5	V	3490	3539	3247	3303		
0	6	W	2399	2350	1951	2100		
Faktor		F2	5.3244	5.0359	4.6567	5.0188		
		F3						

BOVEN
31
34 B 32
33
WAND

0	7	R	2397	2360	1960	2102		
3	8	S	2927	3027	2611	2602		
4	9	T	3123	3232	2013	2706		
5	10	U	3320	3428	3010	2994		
6	11	V	3518	3635	3221	3202		
0	12	W	2401	2358	1942	2087		
Faktor		F2	5.0778	4.9301	4.9249	5.0100		
		F3						

BOVEN
34
33 C 31
32
WAND

0	13	R	2401	2362	1956	2096		
3	14	S	2993	2957	2543	2655		
4	15	T	3183	3160	2747	2856		
5	16	U	3374	3365	2951	3058		
6	17	V	3559	3552	3161	3261		
0	18	W	2400	2355	1941	2088		
Faktor		F2	5.3005	5.0492	4.8555	4.9558		
		F3						

BOVEN
33
32 D 34
31
WAND

0	19	R	2413	2364	1946	2090		
3	20	S	2927	2958	2624	2671		
4	21	T	3120	3137	2041	2879		
5	22	U	3304	3334	3050	3089		
6	23	V	3492	3527	3257	3297		
0	24	W	2413	2344	1960	2081		
Faktor		F2	5.3088	5.2794	4.7350	4.7 951		
		F3						

BOVEN
32
31 E=A 33
34
WAND

0	25	R	2410	2357	1962	2084		
3	26	S	2921	2993	2632	2627		
4	27	T	3100	3197	2040	2021		
5	28	U	3294	3393	3057	3019		
6	29	V	3491	3618	3269	3213		
0	30	W	2415	2351	1947	2075		
Faktor		F2	5.2712	4.8206	4.7132	5.1165		
		F3						

OPMERKINGEN:
Z.O.Z.

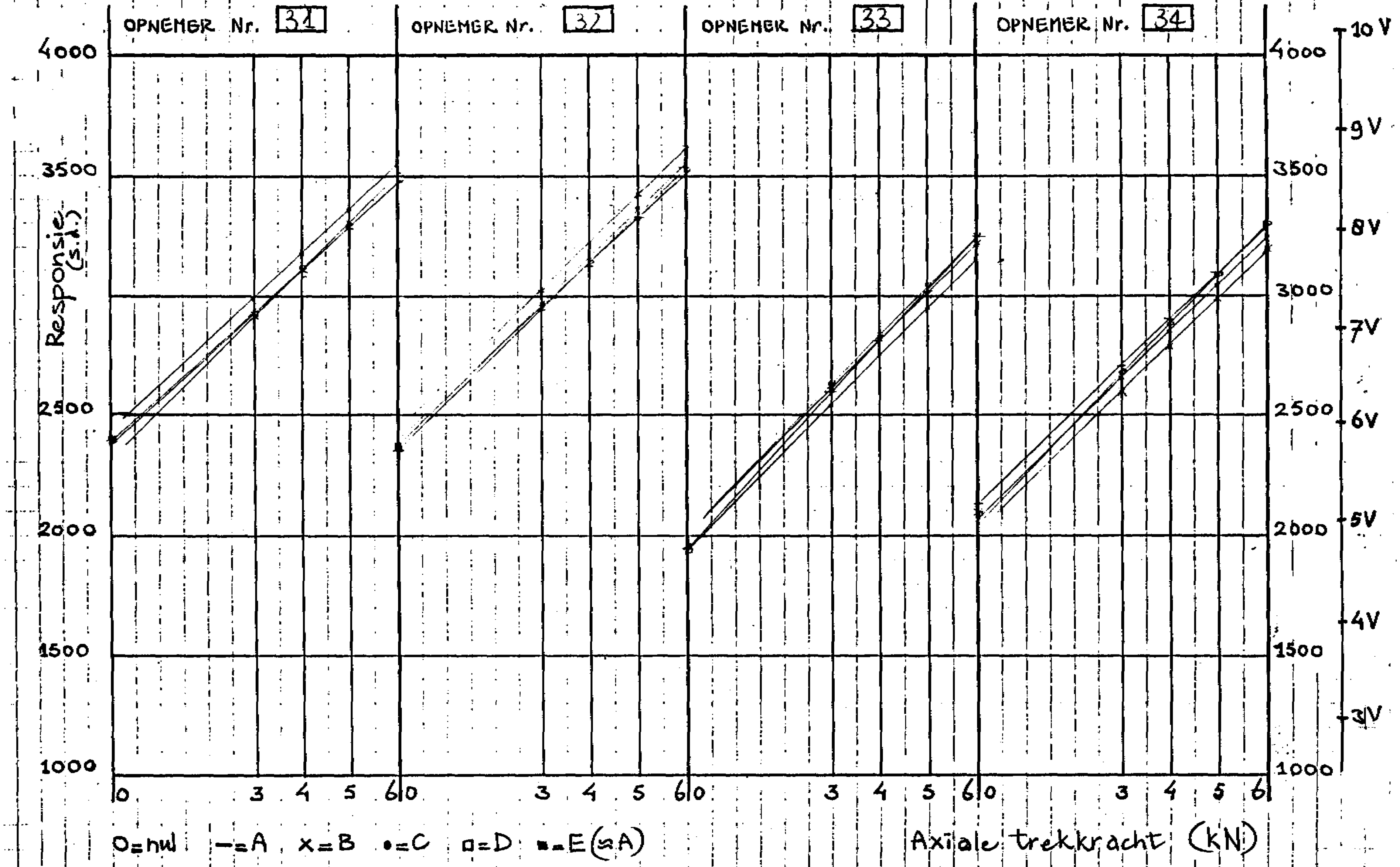
KALIBRATIE Nr. CALRSA 27

BLAD Nr. 2

DATUM 28.12.88

Trekstang vertikaal - 40cm

ONDERZOEKER T.Z.

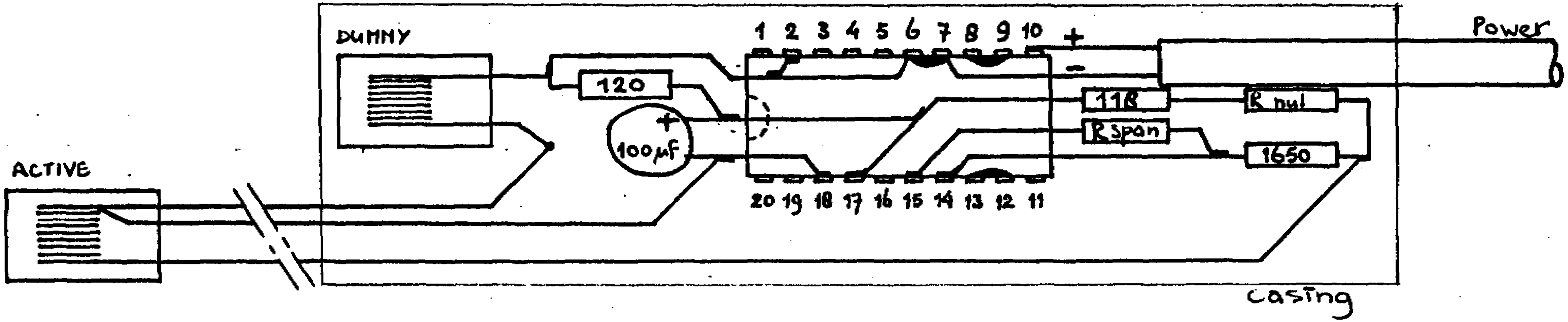


O=nul —=A x=B •=C □=D ■=E(≅A)

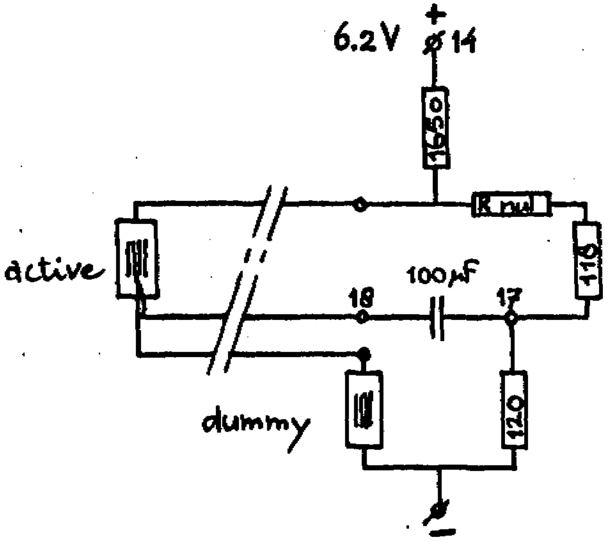
APPENDIX C

Measurement equipment

AD 693



IADHPP STRAIN TRANSDUCER/ CONDITIONER



1. Temperatuur gekompenseerde brug d.m.v.
   - een 3-aderige rekstrookaansluiting
   - het opnemen van een dummy, gelijmd op hetzelfde basismateriaal.

2. Filter: druppeltantaal condensator over de bruguitgang (17-18)
   $\frac{1}{RC} = \frac{1}{120 \times 10^{-4}} = 83$ Hz kantelfrekwentie.

3. Ruisarme metaalfilm weerstanden.

4. Analog Devices AD 693 chip: analoge versterker, die stroom in de voedingskring stuurt, als funktie van de spanning over 17-18.

6.12.88

SPECIFICATIONS (@ +25°C and V_S = +24V, Input Span = 30mV or 60mV, Output Span = 4-20mA, R_L = 250Ω, V_{CM} = 3.1V, with external pass transistor unless otherwise specified)

Model	Conditions	AD693AD Min	Typ	Max	Units
LOAD POWER OPERATION					
TOTAL UNADJUSTED ERROR[1,2]			±0.25	±0.5	% Full Scale
T_{min} to T_{max}			±0.4	±0.75	% Full Scale
100Ω RTD CALIBRATION ERROR[3]	(See Fig. 17)		±0.5	±2.0	°C
LOOP POWERED OPERATION[2]					
Zero Current Error[4]	Zero = 4mA		±25	±80	µA
	Zero = 12mA		±40	±120	µA
	Zero = 0mA[5]	+7	+35	+100	µA
vs. Temp.	Zero = 4mA		±0.5	±1.5	µA/°C
Power Supply Rejection (RTI)	$12V \leq V_{OP} \leq 36V$[6] $0V \leq V_{CM} \leq 6.2V$		±3.0	±5.6	µV/V
Common-Mode Input Range	(See Fig. 3)	0		$+V_{OP} - 4V$[6]	V
Common-Mode Rejection (RTI)	$0V \leq V_{CM} \leq 6.2V$		±10	±30	µV/V
Input Bias Current[7]			+5	+20	nA
T_{min} to T_{max}			+7	+25	nA
Input Offset Current[7]	$V_{SIG} = 0$		±0.5	±3.0	nA
Transconductance					
Nominal	30mV Input Span		0.5333		A/V
	60mV Input Span		0.2666		A/V
Unadjusted Error			±0.05	±0.2	%
vs. Common-Mode	$0V \leq V_{CM} \leq 6.2V$				
	30mV Input Span		±0.03	±0.04	%/V
	60mV Input Span		±0.05	±0.06	%/V
Error vs. Temp.			±20	±50	ppm/°C
Nonlinearity[8]	30mV Input Span		±0.01	±0.05	% of Span
	60mV Input Span		±0.02	±0.07	% of Span
OPERATIONAL VOLTAGE RANGE					
Operational Voltage, V_{OP}[6]		+12		+36	V
Quiescent Current	Into Pin 9		+500	+700	µA
OUTPUT CURRENT LIMIT		+21	+25	+32	mA
COMPONENTS OF ERROR					
SIGNAL AMPLIFIER[9]					
Input Voltage Offset			±40	±200	µV
vs. Temp			±1.0	±2.5	µV/°C
Power Supply Rejection	$12V \leq V_{OP} \leq 36V$[6] $0V \leq V_{CM} \leq 6.2V$		±3.0	±5.6	µV/V
V/I CONVERTER[9,10]					
Zero Current Error	Output Span = 4-20mA		±30	±80	µA
Power Supply Rejection	$12V \leq V_{OP} \leq 36V$[6]		±1.0	±3.0	µA/V
Transconductance					
Nominal			0.2666		A/V
Unadjusted Error			±0.05	±0.2	%
6.200V REFERENCE[9,12]					
Output Voltage Tolerance			±3	±12	mV
vs. Temp.			±20	±50	ppm/°C
Line Regulation	$12V \leq V_{OP} \leq 36V$[6]		±200	±300	µV/V
Load Regulation[11]	$0mA \leq I_{REF} \leq 3mA$		±0.3	±0.75	mV/mA
Output Current[13]	Loop Powered, (Fig. 10)	+3.0	+3.5		mA
	3-Wire Mode, (Fig. 15)		+5.0		mA
AUXILIARY AMPLIFIER					
Common-Mode Range		0		$+V_{OP} - 4V$[6]	V
Input Offset Voltage			±50	±200	µV
Input Bias Current			+5	+20	nA
Input Offset Current			+0.5	±3.0	nA
Common-Mode Rejection			90		dB
Power Supply Rejection			105		dB

Model	Conditions	AD693AD Min	 Typ	 Max	Units
Output Current Range	Pin I_X OUT	+0.01		+5	mA
Output Current Error	Pin V_X – Pin I_X		±0.005		%
TEMPERATURE RANGE					
Case Operating[14]	T_{min} to T_{max}	−40		+85	°C
Storage		−65		+150	°C

NOTES

[1] Total error can be significantly reduced (typically less than 0.1%) by trimming the zero current. The remaining unadjusted error sources are transconductance and nonlinearity.

[2] The AD693 is tested as a loop powered device with the signal amp, V/I converter, voltage reference, and application voltages operating together. Specifications are valid for preset spans and spans between 30mV and 60mV.

[3] Error from ideal output assuming a perfect 100Ω RTD at 0 and +100°C.

[4] Refer to the Error Analysis to calculate zero current error for input spans less than 30mV.

[5] By forcing the differential signal amplifier input sufficiently negative the 7μA zero current can always be achieved.

[6] The operational voltage (V_{OP}) is the voltage directly across the AD693 (Pin 10 to 6 in two-wire mode, Pin 9 to 6 in local power mode). For example, $V_{OP} = V_S - (I_{LOOP} \times R_L)$ in two-wire mode (refer to Figure 10).

[7] Bias currents are not symmetrical with input signal level and flow out of the input pins. The input bias current of the inverting input increases with input signal voltage, see Figure 2.

[8] Nonlinearity is defined as the deviation of the output from a straight line connecting the endpoints as the input is swept over a 30mV and 60mV input span.

[9] Specifications for the individual functional blocks are components of error that contribute to, and that are included in, the Loop Powered Operation specifications.

[10] Includes error contributions of V/I converter and Application Voltages.

[11] Changes in the reference output voltage due to load will affect the Zero Current. A 1% change in the voltage reference output will result in an error of 1% in the value of the Zero Current.

[12] If not used for external excitation, the reference should be loaded by approximately 1mA (6.2kΩ to common).

[13] In the loop powered mode up to 5mA can be drawn from the reference, however, the lower limit of the output span will be increased accordingly. 3.5mA is the maximum current the reference can source while still maintaining a 4mA zero.

[14] The AD693 is tested with a pass transistor so $T_A \cong T_C$.

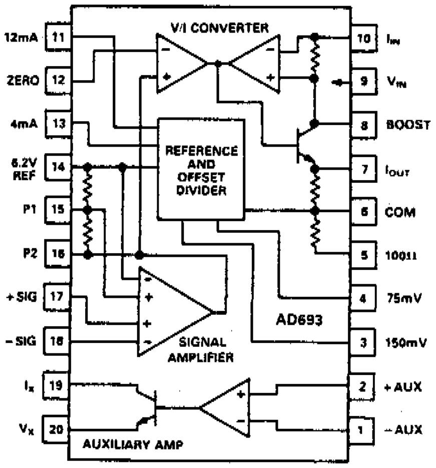
Specifications subject to change without notice.

Specifications shown in boldface are tested on all production units at final electrical test. Results from those tests are used to calculate outgoing quality levels. All min and max specifications are guaranteed, although only those shown in boldface are tested on all production units.

ABSOLUTE MAXIMUM RATINGS

Supply Voltage	+36V
Reverse Loop Current	200mA
Signal Amp Input Range	−0.3V to V_{OP}
Reference Short Circuit to Common	Indefinite
Auxiliary Amp Input Voltage Range	−0.3V to V_{OP}
Auxiliary Amp Current Output	10mA
Storage Temperature	−65°C to 150°C
Lead Temperature, 10sec Soldering	+300°C
Max Junction Temperature	+150°C

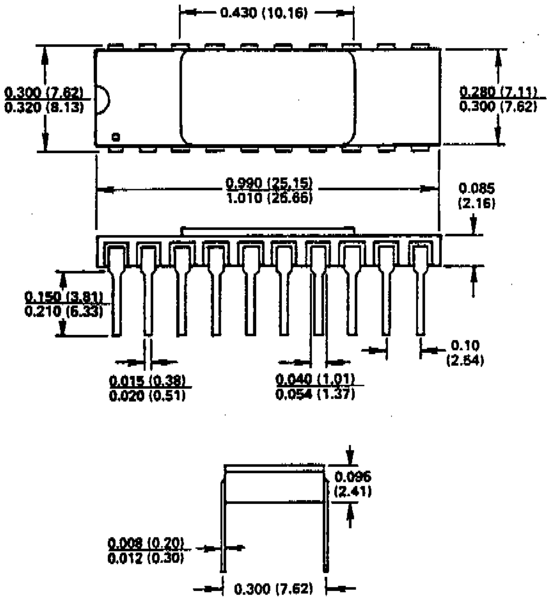
PIN CONFIGURATIONS



AD693 Functional Diagram

OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).



*HEAVY INDUSTRIAL ABSOLUTE SHAFT ENCODERS SERIES "TKC 50"

HOW TO ORDER (see page 30-31)

SPECIFICATIONS

Resolution	16 - 32 - 64 - 128 - 256 - 512 - 1024 - 2048 18 - 30 - 36 - 60 - 72 - 90 - 120 - 144 - 180 - 240 - 288 - 360 - 480 - 720 - 1440 250 - 500 - 1000 - 2000
Code	GRAY or BINARY or BCD (8-4-2-1)

MECHANICAL (see also page 14)

Dimension	see drawings
Mounting	"F" square flange standard "SG" servo-graffe as optional
Weight	520 gr. approx.
Slewing speed	10,000 rpm for short period 6,000 rpm for normal operation
Shaft	10 mm. dia. standard 6-8-9, 52 mm. dia. as optional
Shaft seal	available
Starting torque at 25 °C	~0.025 Nm ~0.07 Nm with shaft seal
Low torque	available
Bearing life	10^9 revolutions

ELECTRICAL

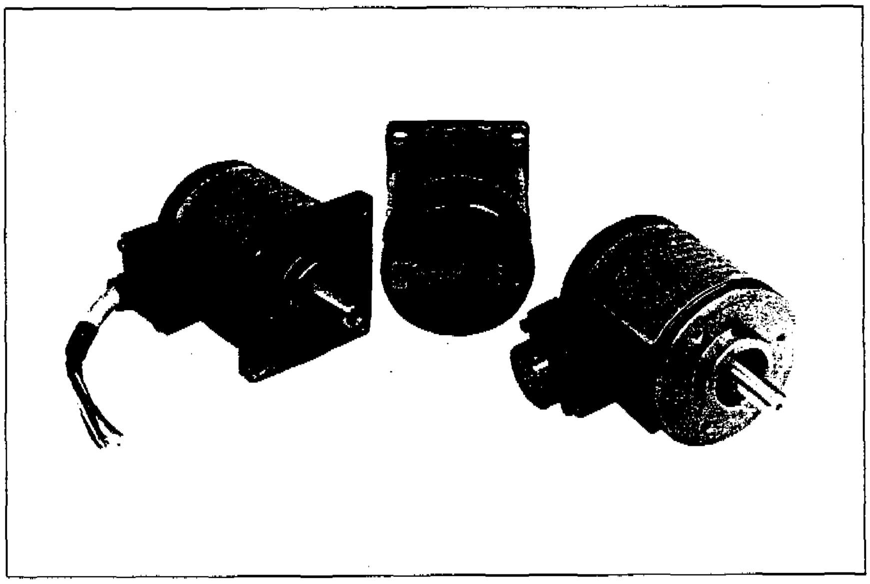
Supply voltage	5 V d.c. ±5% or 8 ÷ 24 V d.c. ±10%
Electronic	available electronic see on page 23
Protection	against reverse polarity 30 days burn-in for all electronic components
Frequency range (T = 0 °C + 60 °C)	0 ÷ 20 KHz (L.S.B. read without error)
Connections	screened cable 1 mt long axial as standard, radial as optional Different cable lengths as optional On connector: MS 26482-851-O2E-16-23P axial standard, radial optional Mating connector: MS 26482-851-O6EC-16-23S as optional On connector: DE 25P only axial

ENVIRONMENTAL

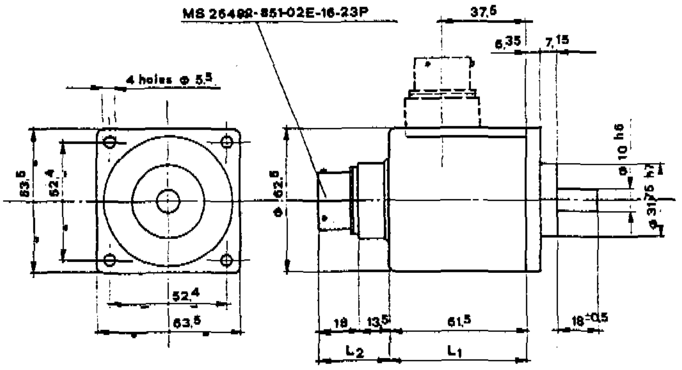
Temperature	Operating from 0 °C to +60 °C Storage from —30 °C to 80 °C (extended range on demand only for encoders operating at 5 V d.c.)
Protection	~IP 55 DIN 40050 without shaft seal ~IP 65 DIN 40050 with shaft seal - IP 66 DIN 40050 on demand - possible execution only with connector: MS26482-851-O2E-16-23P
Humidity	up to 98% R.H. without condensation
Vibration	10 G (10 ÷ 2000 Hz)
Shock	20 G per 11 ms

MATERIAL

Mainframe	"AL" termically stabilized
Housing	Aluminium
Shaft	stainless steel antimagnetic
Light source	Ga. As. infrared light emitting diode MTFB 100,000 Hrs min.
Cable	Colour and equivalent functions (see prospect on page 29)
Connectors	Pin designation (see drawings on page 28)



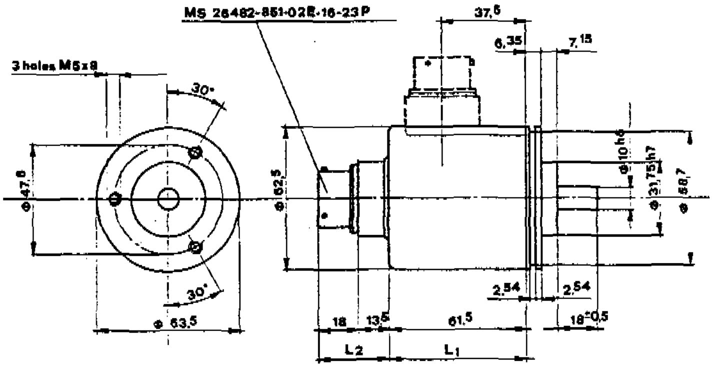
F



ON VERSION WITH DE 25 P CONNECTOR $L_1 = 71$ $L_2 = 8$

(see page 28-33)

SG



ON VERSION WITH DE 25 P CONNECTOR $L_1 = 71$ $L_2 = 8$

(see page 28-33)

*Analogue interface available

ABSOLUTE ENCODERS TKC 50 – TKC 60 – TKC 100 H.D.
SERIES

ANALOGUE INTERFACE TECHNICAL CHARACTERISTICS

Resolution	720, 1000, 1024 (10 bit) on 360° 512, 256, 128, 64 on 360° 512 on 180° 256 on 90° 128 on 45°
Output	± 20 mA standard (on demand) 4÷20 mA standard On demand : 1÷5 Volt 0÷10Volt ± 5 Volt ± 10 Volt
Optional	-up/down programmable - ZERO signal (TTL level) - ZERO signal displayed - STROBE signal (TTL level)
Digital frequency	20 KHz max
Conversion frequency	200 KHz
Error	± 1 bit max
Supply voltage	18÷30 Vdc
Current requirement	450 mA max
Electrical connections	- on shielded cable 1 mt long axial exit - standard radial exit - optional different lengths (as optional) - on MIL circular connector axial exit - standard radial exit - available on TKC 50 and TKC 100 - on connector DE 25 P - only axial
Useful connector types	If ZERO and STROBE signals excluded: MS 3102 A 16 S1P included MS 3106 A 16 S1S on demand If ZERO and STROBE signals operative : MS 3102 A 18 1P included MS 3106 A 18 1S on demand For all version : DE 25 P included DE 25 S on demand

For any other characteristics, mechanicals, environmentals, please refer to absolute encoders catalogue - Section model TKC.

Druck

SMALL BORE DEPTH TRANSMITTER

Type PTX 160/D

Excellent linearity and hysteresis
±0.1% B.S.L. for ranges to 60 bar

Encapsulated electronics

High overload capability

17.5mm diameter

Good thermal stability
±0.3% total error band −2° to +30°C

Two wire, 4-20mA

The PTX 160/D transmitter has been specifically designed where a small diameter (17.5mm) is necessary for certain bore hole applications, although it can be used in reservoirs, the sea and many other depth measurement applications. The titanium body is electron beam welded and a polyurethane sheathed cable is moulded to the body to complete a high integrity waterproof assembly.

The cable is tough, and complete with an integral vent tube and Kevlar strain cord.

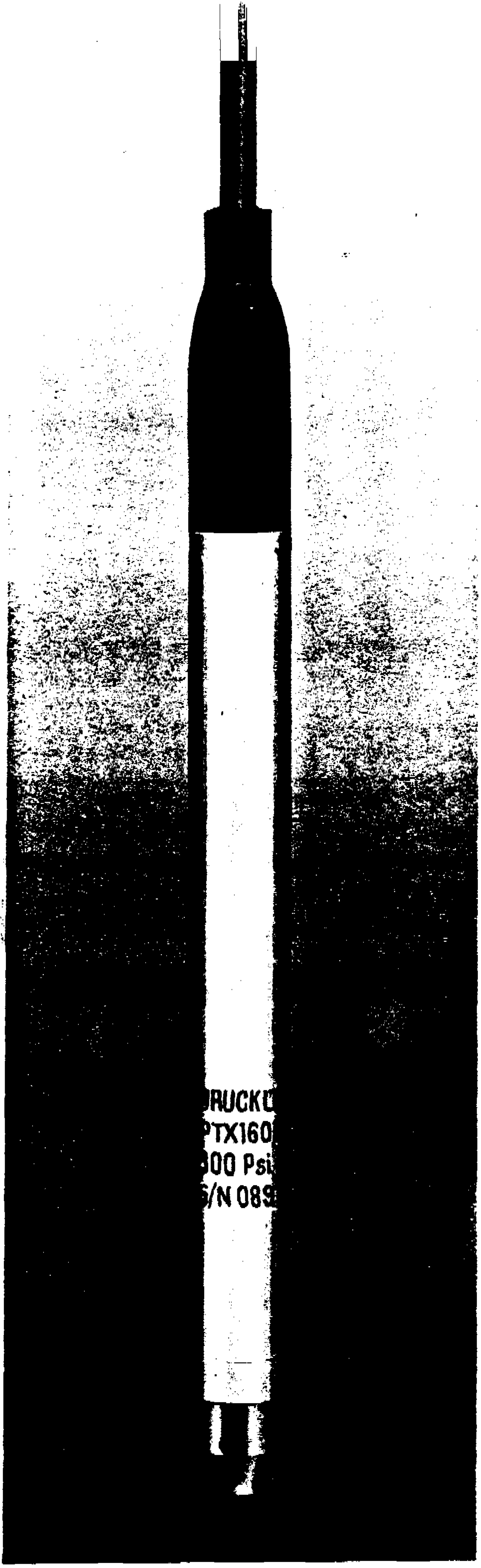
The standard accuracy is 0.1% F.S. (0.06% F.S. is available) and the new electronic circuit gives very good thermal stability.

Operating pressure ranges
70mbar, 175mbar, 350mbar, 700mbar, 1, 1.5, 2, 3.5, 5, 7, 10, 15, 20, 35, 60, 70 and 135 bar gauge.
Other pressure units can be specified, e.g. mH$_2$O.
Intermediate pressure ranges are available.

Overpressure
The rated pressure can be exceeded by the following multiples causing negligible calibration change:-
4 x for 70 to 350mbar ranges
2 x for 700mbar range and above.

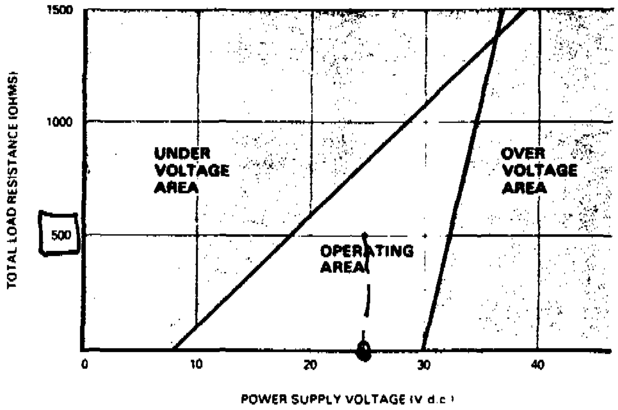
Pressure media
Fluids compatible with quartz and titanium.

Transduction principle
Integrated silicon strain gauge bridge.



Transmitter supply voltage

9-30V d.c.
This voltage must appear across the transmitter terminals and the positive supply must be earthed.



For other supply voltages please refer to manufacturer.

Supply sensitivity

0.003% F.S.O./Volt and excellent 50Hz and 100Hz supply rejection.

Output current

4mA at zero pressure
20mA at full range pressure.

Resolution

Infinite.

Combined non-linearity and hysteresis

±0.1% B.S.L. for 70mbar to 60 bar ranges
±0.2% B.S.L. for 70 to 135 bar ranges
±0.06% B.S.L. available for ranges to 20 bar on request. Please refer to manufacturer.

Zero offset

±0.5% F.S.O., set @ 20°C

Sensitivity setting

±0.5% of reading, set @ 20°C

Operating temperature range

—20° to +60°C

Temperature effects

±0.3% total error band —2° to +30°C
75mbar range ±0.5% total error band —2° to +30°C.
For special applications it is possible to give improved temperature compensation over a wider temperature range.

Mechanical shock

1000g for 1ms in each of three mutually perpendicular axes will not affect calibration.

Dimensions

17.5mm diameter × 220mm length

Weight

113 gms. nominal.

Electrical connection

1 metre integral vented cable supplied which incorporates a Kevlar strain relieving core.
Longer lengths available on request.

2 Core shielded cable

Red	Supply positive
Blue	Supply negative
Screen	N/C to transmitter body

Pressure connection

Illustrated front end delrin cone fitted as standard. This incorporates a hydraulic damper to protect the device from high pressure pulses caused by underwater impact.

Pressure connections (optional)

G ¼ B
¼" N.P.T. } Flat end
G ¼ B 60° Internal cone
7/16" U.N.F. as MS. 33656-4
M12 x 1.5 Ermeto
M14 x 1.5mm 6 DIN
Others available on request.

Intrinsic safety (optional) — PTX 160/D/IS

This transmitter can be certified for use with barrier systems to EEX ia gas group IIC with a T4 rating at an ambient temperature of 80°C to BS5501 part 7 and Cenelec EN50020.

Options available

Pressure transducer PDCR 830 (see separate data sheet).
Pressure connections (see above).
Intrinsically safe version (see above).

Ordering information

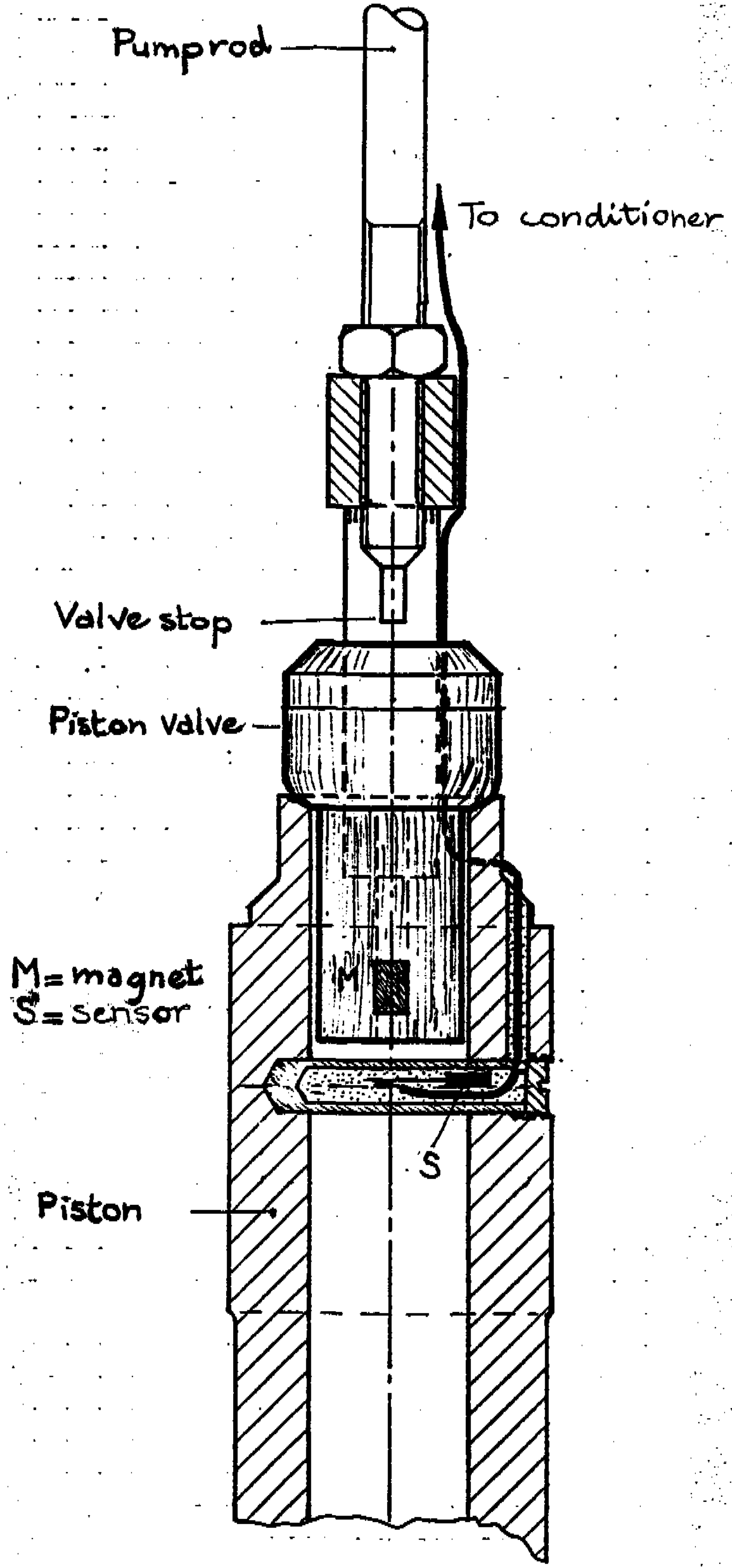
Please state the following:-
(1) Type number
(2) Pressure range
(3) Cable length
(4) Pressure media

For non-standard requirements please specify in detail.
Continuing development sometimes necessitates specification changes without notice.

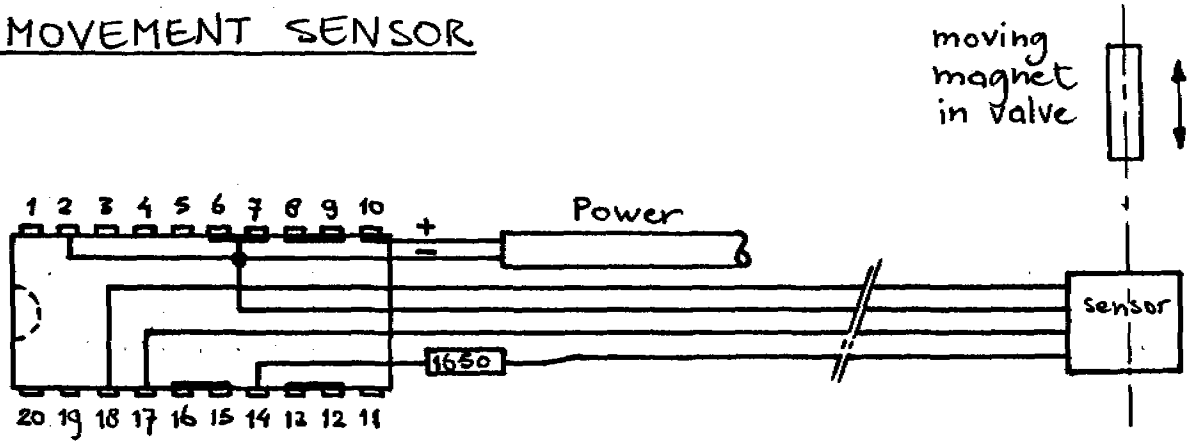
Druck Limited
Fir Tree Lane, Groby,
Leicestershire LE6 0FH, England.
Telephone: Leicester (0533) 878551
Telex: 341743, Telefax: (0533) 875022

Agent:
DRUCK NEDERLAND B.V.
POSTBUS 232
2990 AE BARENDRECHT
TEL: 01806-11555

ZKO: PISTON VALVE MOTION TRANSDUCER



VALVE MOVEMENT SENSOR



- Loop-Powered 4-20mA Sensor Transmitter:
  Analog Devices AD693

- Magnetic Field Resistor: KMZ 10 B

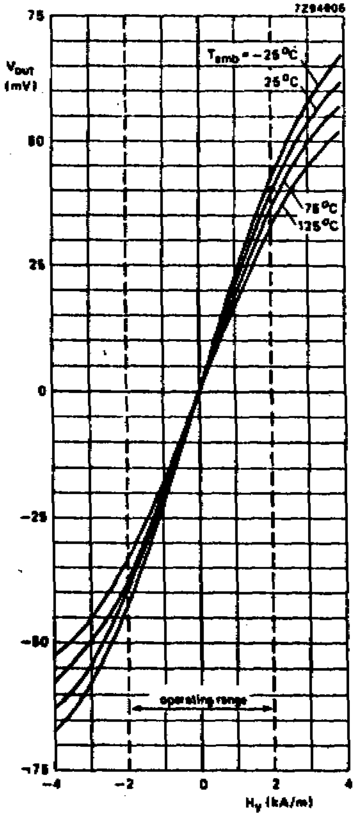


Fig. 6 I_B = constant = 3 mA; H_x = 3 kA/m.

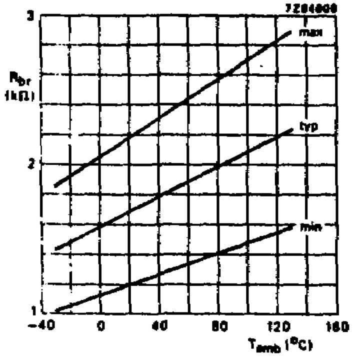


Fig. 7 Bridge resistance.

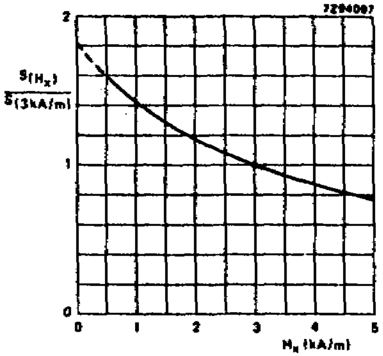


Fig. 8 Relative sensitivity (ratio of sensitivity at certain H_x and sensitivity at H = 3 kA/m).

MAGNETIC FIELD SENSOR

The KMZ10C is a magnetic field sensor employing the magneto resistive effect of thin film permalloy. Its properties enable this sensor to be used in a wide range of applications for current and field measurement, revolution counters, angular or linear position measurement and proximity detectors, etc.

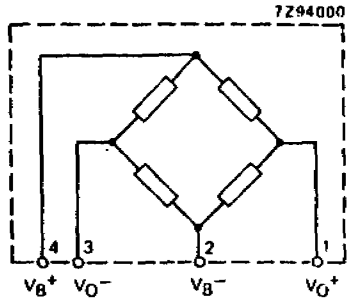
QUICK REFERENCE DATA

Bridge supply voltage	V_B	typ.	5	V
Magnetic field range	H_y	=	± 2	kA/m
Auxiliary field	H_x	=	3	kA/m
Sensitivity	s	typ.		$\frac{mV/V}{kA/m}$
Operating temperature	T_{op}	−40 to	+ 150	°C

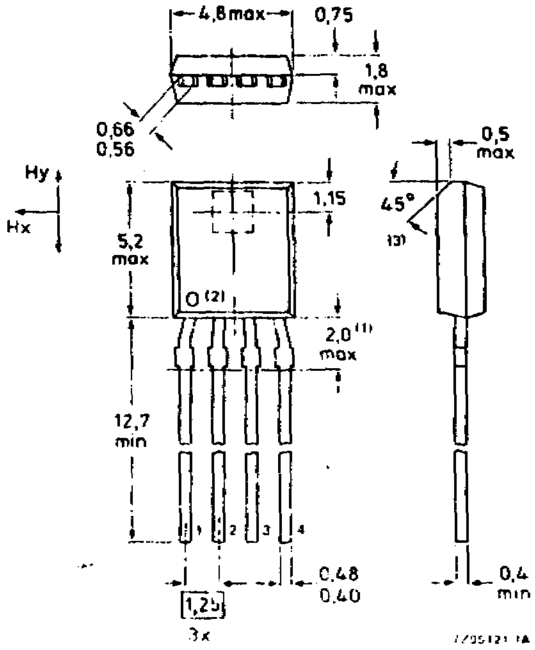
MECHANICAL AND ELECTRICAL DATA

Dimensions in mm

Fig. 1 VO-52B.

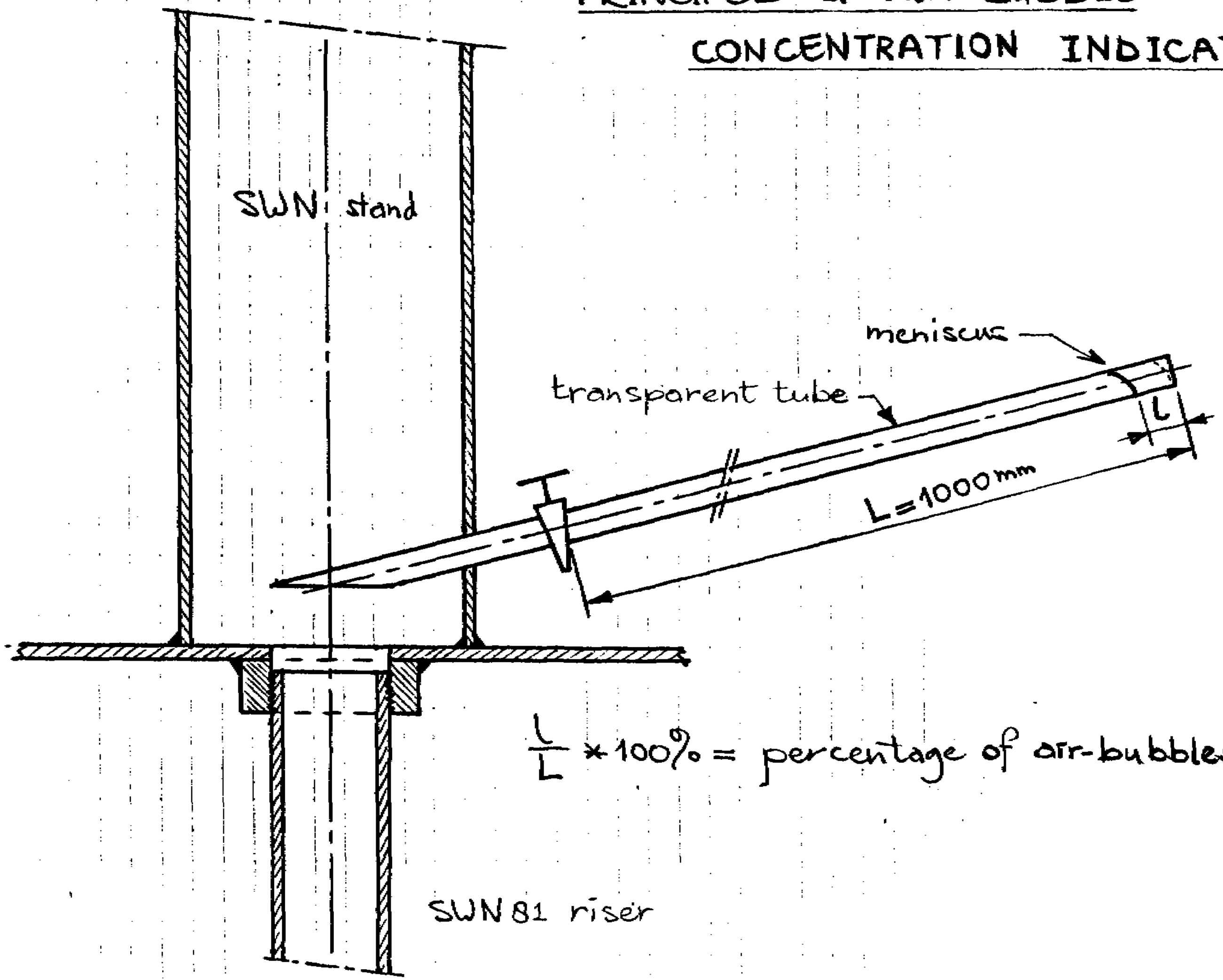


V_B = supply voltage
V_O = output voltage



(1) Terminal dimensions uncontrolled within this area
(2) Until October 1985
(3) Starting October 1985.

PRINCIPLE OF AIR-BUBBLE CONCENTRATION INDICATOR



$\frac{l}{L} * 100\% =$ percentage of air-bubbles

APPENDIX D

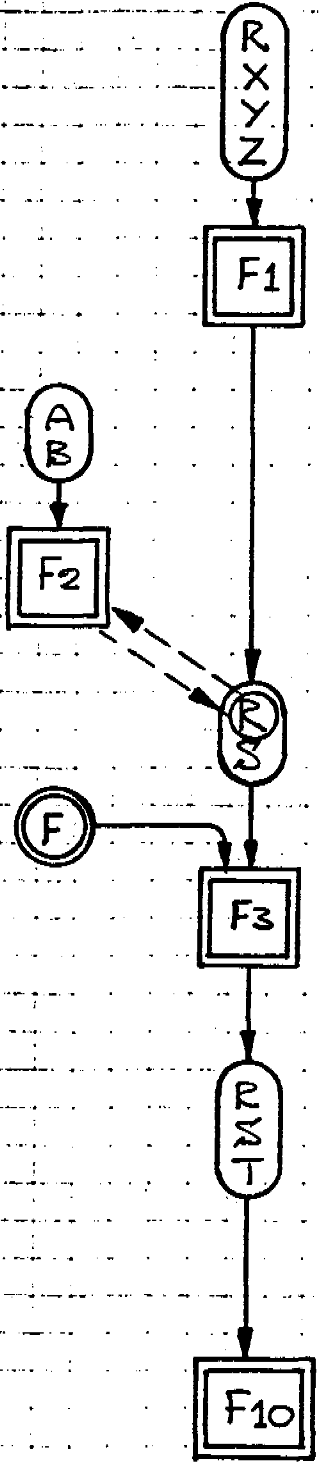
Function file (example)

/VOLANTA FUNKTIE-FILE **VUNKTIEA.SAV**

Aansluitschema A
Sample frekwentie 100 Hz
Samples/kanaal 500

ZENITH/Asystant+ 1.1

F INVULLEN!!



R = opnemer responsies = 16 * 500 int.
X = 0-waarden = 16 real
Y = omrekenings faktoren = 16 real
Z = oppervlaktes, etc = 16 real

F1: Omrekenen van opnemer responsies R naar technische eenheden op basis van X, Y en Z en berekenen van 'absolute zuigerverplaatsing' S[1]

A = begin-row
B = aantal opeenvolgende te filteren rows

F2: Filteren van opnemerresponsies R: B rows, te beginnen met row A. Zonodig te herhalen. (Kan ook vóór F1 en ná F3)

R = omgerekende (eventueel gefilterde) opnemer responsies
S row 1 = 'absolute zuigerverplaatsing'

F = straal van aandrijfkruk (mm)

F3: Berekenen van axiale- en tangentiale spanningen, buig- en trekspanningen en samengestelde spanningen. Berekenen van de axiale verplaatsing en versnelling van het trekstang boveneind.

R = omgerekende responsies: spanningen, etc.
S = verplaatsingen van onder- en boveneind v/d trekstang
T = samengestelde spanningen

F10: Wissen van de parameters (behalve F) en van de variabelen (behalve X, Y en Z)

NB. De berekeningen zijn gebaseerd op 9mm trekstangen en stijgbuizen $\varnothing_u=80$ mm en $\varnothing_i=69.7$ mm.

VOLANTA FUNKTIEFILE **VUNKTIEA.SAV** 7.03.09 j.b.

Aansluitschema A : 16 kanalen
Sample frekwentie : 100 Hz
Samples/kanaal : 500 Hz

Input: R = 16 * 500 INT = resp subfile 1 - 10 (?)
X = 0-waarden = 16 real
Y = omrekeningsfaktoren = 16 real
Z = oppervlaktes, etc = 16 real

F = aandrijfkruklengte (mm)

ZENITH/Asystant + 1.1

```
F1    500  4  NM:RAMP  STORE S
      500  4  NM:RAMP  STORE T
      R TRANS X - Y Z / * TRANS STORE R
      R TRANS [ 15 ] R TRANS [ 16 ] + S [ 1 ] =
      1111.1111  I =                      (='absolute zuiger verpl)

F2    R < A , B , 1 ; -1 > SMOOTH
      R < A , B , 1 ; -1 > =
      2222.2222  H =

F3    R TRANS 1. / STORE R
      1.000  A = ⊗  1.000  B = ⊗  2 C = F4   3 C = F4
      1.026  A = ⊗  1.004  B = ⊗  6 C = F4   7 C = F4
      4 C =  5 D =  1 E =  F5
      8 C =  9 D =  2 E =  F5  F6  F7

F4:   C 2 + D =
      R [ C ] DUP R [ D ] DUP ROLL + 2. / A *
      R [ C ] =  - 2. / B * R [ D ] =
                               (=σtrek  = σbuig)
F5:   R [ C ] DUP * R [ D ] DUP * +
      SQRT T [ E ] =                (= samengestelde buigsp)

F6:   R [ 2 ] T [ 1 ] + T [ 3 ] =   (= totale Spanning=
      R [ 6 ] T [ 2 ] + T [ 4 ] =    σbuig MAX + σtrek )

F7:   R [ 1 ] COS F * 435600② R [ 1 ] SIN F *
      DUP * - SQRT + 660③ - -1. * S [ 2 ] =   (verpl. bovenkeind stang
      S [ 2 ] DIFF SMOOTH 100 * S [3] =        snelheid  "  "
      S [ 3 ] DIFF 100 * S [ 4 ] = F8          versnelling "  "

F8:   R [ 6 ] R [ 7 ] + 2. / 63.6⑧ *
      S [ 3 ] * INTEG 1E-5 * STORE W
      F9

F9:   R TRANS 1. / STORE R
      S TRANS 1. / STORE S
      T TRANS 1. / STORE T
      3333.3333  G =

F10   0 A = 0 B = 0 C = 0 D = 0 E = 0 G =
      0 H = 0 I = 0 STORE R  0 STORE S
      0 STORE T  0 STORE W          (z.o.z)
```