IAD Handpump Project

DESIGN RULES FOR FATIGUE LIVE OF PVC RISING MAINS AND STAINLESS STEEL PUMPRODS OF HAND PUMPS

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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:

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IAD PROJECT

Design rules for fatigue life of PVC rising mains and stainless steel pumprods of hand pumps

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CONTENTS

1 INTRODUCTION

During the ten year water decade, declared by the UN, which will finish in 1990, several types of handpumps were introduced in third world countries for drinking water supply.After some years it appeared that, although these pumps seemed a simple piece of technology, many failures occurred in the field, such as breaking of pumprods and rising mains, corrosion etc. The Dutch government (Afdeling Internationaal Onderwijs en Onderzoek,(DPO), Bureau Onderzoek en Technologie (OT)) therefore funded the Inter Action Design (IAD) handpumpproject,to investigate the merites of handpumps.A well of 100 m.was made at SWNV at Nunspeet, where the SWN 81 and the Volanta pump are tested. The actual stresses in the pumprod and the rising main are measured with strain gauges. This is done for a range of depths; 20m, 40m, 60m, 80m.
The pumprods for both pumps are made of stainless steel AISI 304 and the rising mains of PVC.
For this paper the fatigue of stainless steel and PVC was studied and criteria were derived, in the form of design rules, for the conditions of the handpumps. The available measured loads of the SWN 81 pump are compared with these criteria.

2 NOMENCLATURE

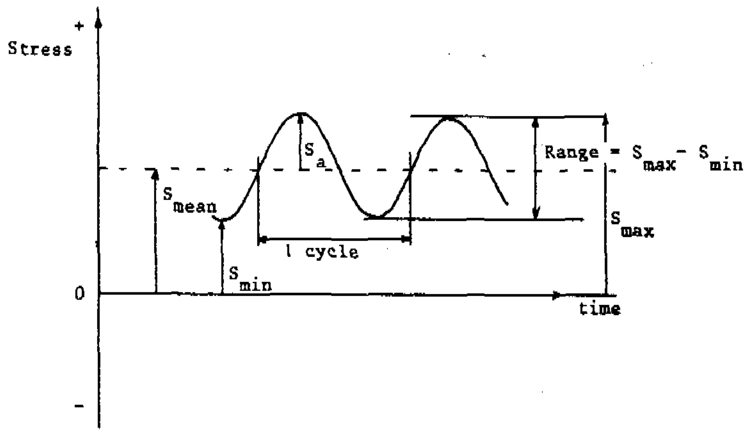

Fig. 2.1: nomenclature [12] [14]

S_a	The alternating stress, equal to half the stress range: $([S_{max}-S_{min}]/2)$
S_{mean}	$([S_{max}+S_{min}]/2)$
S_u	Ultimate strength = Tensile strength
S_y	Yield strength
S_f	Fatigue strength = The maximum alternating stress which a material will withstand without failure, for a given number of cycles.
	Fatigue limit = The stress at wich the S-N curve becomes horizontal (in air).
R	Stress ratio (S_{min}/S_{max})
Stress range:	Twice the S_a

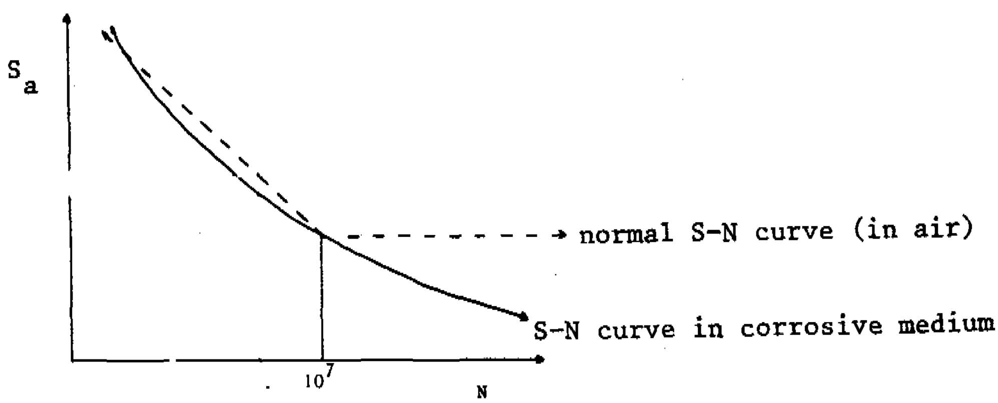

Fig. 2.2: Typical S-N curves

S-N curve: Curve obtained under load or stress control test condition with specimens. S is applied alternating stress, usually S_a, N is number of cycles or life to failure (failure is fracture).

K_t Stress concentration factor:
[maximum local stress/nominal local stress]
-The nominal stress is usually based on the net section

K_f Fatigue strength reduction factor:
[plain fatigue stress/notched fatigue strength]
-Plain fatigue stress = the fatigue strength of a specimen with no stress concentration
-Notched fatigue strength = fatigue strength with stress concentration

q Notch sensivity factor:
$([K_f-1]/[K_t-1])$
The value of q is always between 0 and 1

Design fatigue stress:
The admissible stress used to design the part such that it is able to withstand fatigue loading

Ratio X: [depth of flaw(notch or root depth)/wall thickness]

3 THEORETICAL BACKGROUND

In cases that structures are loaded with a cyclic load i.e. alternating load/unload for over two hunderd thousand cycles, fatigue has to be considered.
Fatigue is the effect that a material (mostly metal) fails under a considerable lower stress level when it is "fatigue" loaded than when it is under a continues static load.
For example, the reduced fatigue strength of mild steel is roughly 50% of the static strength.(in air)
There are several factors which determine the fatigue strength, of which the material itself is the most important one. The height of the stress variations in relation to the total number of cycles is the most determining relation.
PVC knows in addition to steel a static fatigue, which means that the static strength decreases also when the temperature raises or just after an elapse of time.(just by its own weight)
For polymeres such as PVC also the manufacturing procedure and the moleculair weight as wel as additions are of influence on the fatigue properties.
Notches influence to a large extend the fatigue limit of materials, a smooth surface without notches gives the highest resistance against fatigue.
Because of the different nature of steel and PVC, the fatigue characteristics will be described separately.
For the designer, the main tool to calculate the fatigue life are the S - N curves. S is the applied stress (S = Sa = the amplitude of the alternating stress) and N is the number of cycles to failure (fracture). In most cases constant amplitude S - N curves are plotted on semi- log paper.

4 STAINLESS STEEL

4.1 INTRODUCTION

There are several factors that influence the S-N curves, such as:

- the steel properties, due to chemical composition and treatment, annealed or cold worked.
- type of loading
- stress raisers (notches)
- corrosive conditions

Temperature influence is relatively small and not of importance for handpumps in most cases.
In the next chapters these factors are discussed.

4.2 STAINLESS STEEL PROPERTIES.

Stainless steel AISI 304 is an austenitic stainless steel (strength increases at low temperatures) and can be delivered as drawn wire.(up to 1/2"diam.)The strength capacities of the stainless steel are higly dependent on the percentage of cold working* of the metal.If it is not cold worked, i.e. annealed steel, the strength is a factor 3.5 lower than when it is 100% cold worked (100% cold deformed)
Therefore it is advised to use cold drawn rods supplied with thread ends manufactured by means of a cold rolling method, which also decreases the notch sensivity (for fatigue) If the percentage of cold working is not known it is advised to take the annealed characteristics to stay on the safe side.

			Stainless Steel AISI 304
Chemical composition			18.5 Cr 8.82 Ni
Static strength			
Tensile strength	N/mm2	annealed	580
		cold worked 60%	1140
yield stress	N/mm2	annealed	289
		cold worked 60%	1050
Fatigue limit , Rotating Bending *			
fatigue stress *	N/mm2	annealed	240
		cold worked 35%	480
		cold worked 98%	860
Fatigue limit , Direct(axial) at 10^8 cycles.			
fatigue stress, annealed			230
Fatigue limit , Torsion at 25.10^6 cycles.			
fatigue stress, cold worked 90%			190

* Tests under air temp., constant amplitude loading, rotating bending, unnotched smooth specimen.for 2*10^5 cycles

Table 4.1: Stainless Steel AISI 304 properties lit. [1]

For detailed tables of strength properties see Appendix A.
*" Cold working means"; "cold" deformation of the material, often expressed in percentage deformation.

4.3 TYPE OF LOADING

From measurements taken at the IAD pumptestrig, see chapter 7, it can be seen that the load during 1 cycle is more or less sinusoidal. The stress levels variing from zero (sometimes a small value below zero) to a maximum. For the measured values of the SWN 81 pump see appendix C.
The experiments done to determine the S - N curves may have different type of loadings:

a) Direct (axial) D loading, often between zero and a maximum level (R = 0)
b) Rotating Bending RB loading, which gives a sinusoidal load, with R = -1
c) Torsion T, which determines the fatigue life dependent on shear forces.

Rotating Bending gives only a slightly higher fatigue level then Direct loading, while the first type of loading resembles most the actual occurring load, see Appendix A. Therefore the S - N curves of Rotating Bending will be taken as criterion. From the actual measurements the max. and minimum peaklevels (over 1 rotation) will be taken as the actual stress range.
Whenever a load signal deviates from the sinesoidal form, e.g. with ripples (peaks) added to the sine, then the maximum and minimum occurring values of the load signal (over one rotation) may be taken as stress range, as long as the ripple values (top - trough value) remain in the order of 25-40 % of the overall maximum. See [12].
When these values are surpassed, more sophisticated methods should be used to calculate the fatigue load, such as the Rainflow Counting Method (R.C.M.) method, see [14].

<u>The effect of mean stress level.</u>

The maximum mean stress level during pumping with the SWN 81 is about 40 N/mm^2 (see Appendix C)
This is very low compared to the tensile strength of stainless steel AISI 304. Therefore the fatigue limit is practically not influenced by the mean stress level. The fatigue limit with a mean stress level of zero can further be used as criterion.

4.4 STRESS RAISERS (NOTCHES)

Notches, such as grooves from thread, generally decrease the fatigue strength. The measure is dependent of the material, treatment and notch dimensions. The following parameters are generally used; Kt,Kf, and q.

- Kt = stress concentration factor, which is a function of;
  - notch depth d , for example see fig 4.2
  - notch root radius r , when r decreases, Kt increases, see table 4.1
  - angle of notch (in degrees)

- Kf = fatigue strength reduction factor, which is a function of Kt and q, in which
q = Kf -1/ Kt -1 , the notch sensivity factor.
The notch sensivity factor is dependend on the material and the treatment, for example; for austenitic steels see fig 4.4.

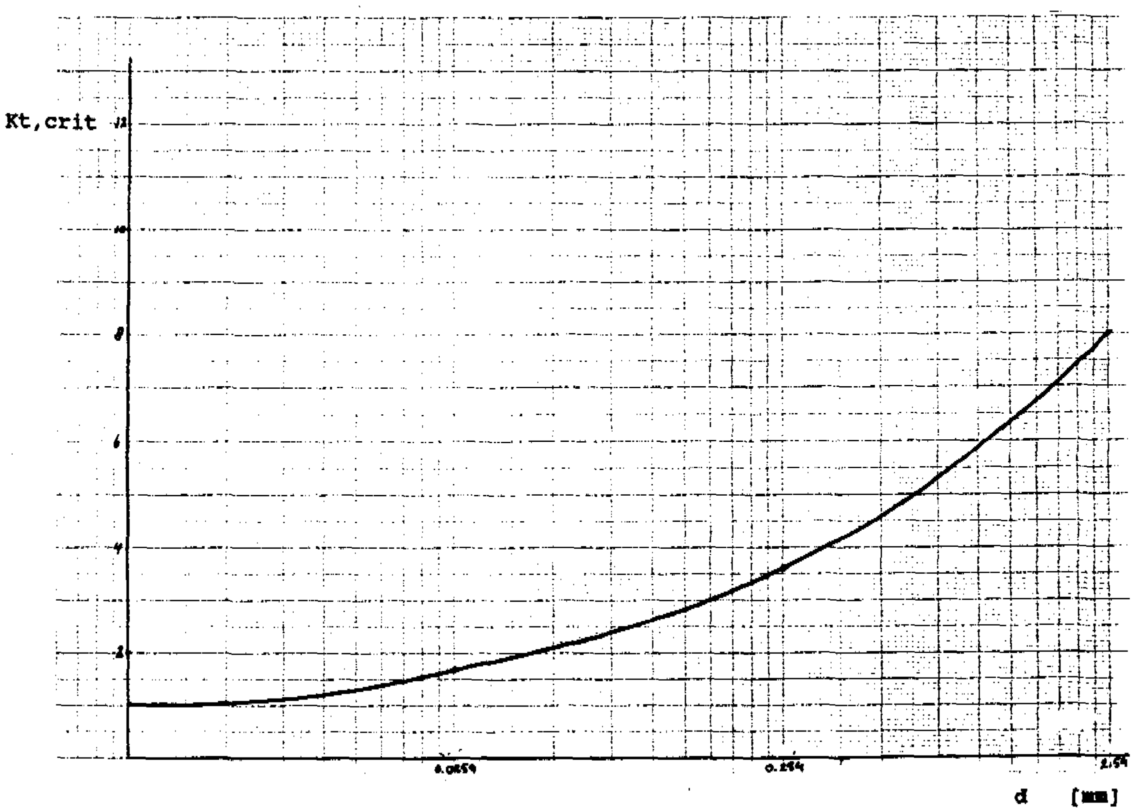

Fig. 4.2: Relation between $K_{t,crit}$ and notch depth d
lit. [2]

Kt crit = Kt at which cracks start to appear, $K_{t,crit}$ is independent of the root radius.

Steel/Thread	r [mm]	K_t	angle [^{o}]	depth [mm]	lit.
347	8.06	2		9.5	2
347	1.44	4		9.5	2
20/10 Ann	0.254	2.6	60	0.6	2
18/8	0.05	14	55	5	3
19/18/5	1.00	2.1	60		3
"	0.3	3.2	60		3
"	0.07	6.0	60		3
BSF thread	0.135	3.3	55	6.35	4
UNJF thread	0.152	3.1	60	6.35	4
S. Steel	0.10	4.4	60		2
Rolled thread		2.0			4

Table 4.2: K_t as function of root radius

In fig 4.3, it can be seen that q is decreasing when r is decreasing(opposite as for Kt.)

The following rules are advised for austenitic steel (Stainless steel AISI 304)

<u>For annealed stainless steel</u>

$q = 0.3$ for $Kt < 4$ (1)*

<u>For cold worked (90)% stainless steel</u>

$q = 0.7$ for $Kt < 4$ (2)*

$Kf = 1 + q(Kt - 1)$, see fig.4.4 (3)

* The values found in literature vary very much (as becomes clear when table 4.2 is compared with rule (1) and (3).
The values of q are determined as averages of values found in [1 and 2]

Condition	S_u [N/mm^2]	S_f [N/mm^2]		K_f	q
		Unnotched	Notched		
Annealed	571	241	290	0.8	0
Cold worked	911	482	344	1.4	0.25

Notch: radius 0.254 mm
depth 0.635 mm
angle 60°
K_t 2.6

Table 4.3: Influence of cold work on the notch sensitivity of 20/10 CrNi steel,lit. [2]

Austenitic stainless steel is less notch sensitive than almost any other metal. Table 4.3 shows that if the material is initially cold worked, the notch sensivity is increased. The annealed steel however shows a notched fatigue strength higher than the unnotched value. This is caused by the ability of this material to be strengthened by work hardening (which occurs during notching)

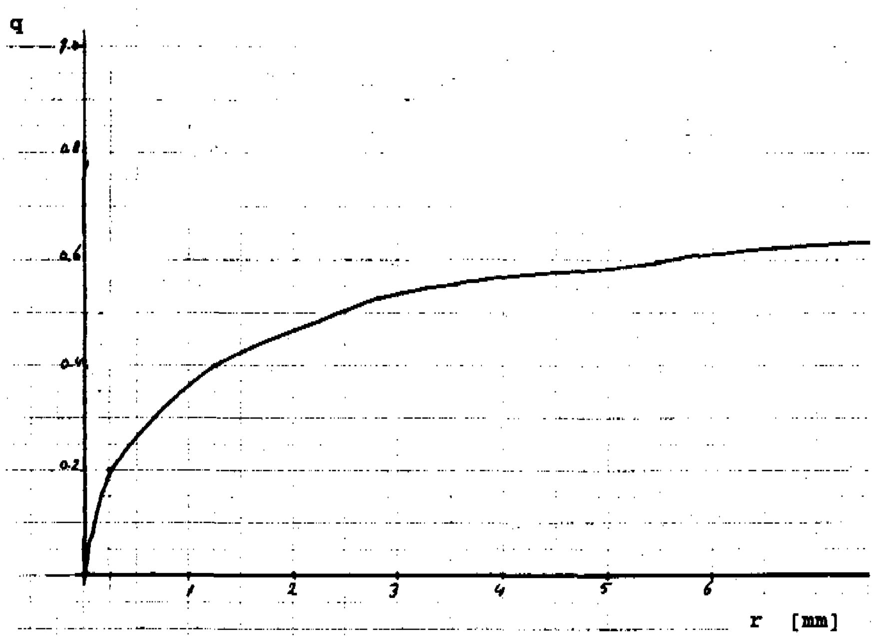

Fig. 4.3: Relation between notch sensitivity and notch radius for cold worked stainless steel, lit [2]

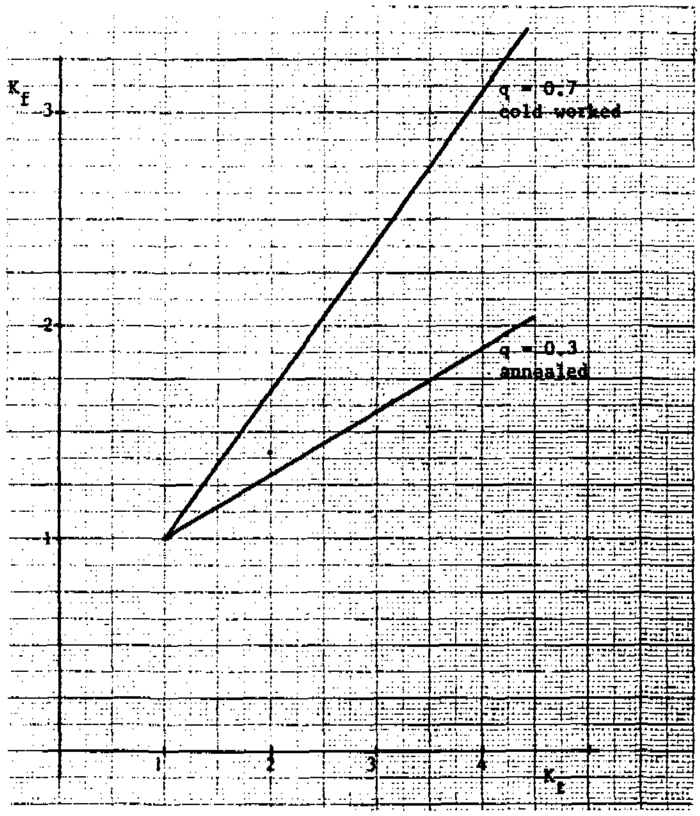

Fig. 4.4: K_f as function of K_t and parameter q for austenitic steel.

4.5 CORROSION FATIGUE

Corrosion of a metal results in formation of pits in the metal surface. The formation of pits results in a considerable loss in fatigue strength.
Stainless steel shows in a corrosive medium no obvious signs of corrosion. However, when measurements are done, it is found that the fatigue strength has been reduced.
This is caused by pits and later cracks, which arise by electro-chemical attack. These pits and cracks are similar to a non corrosive fatigue crack. The fatigue behaviour can be explained by the stress raising effect of these corrosion pits.
Tests carried out in corrosive environments show that the effect of corrosion and therefore the corrosion fatigue increases with the duration of the tests, it is a continues proces. S - N curves obtained from these tests show much less tendency to become horizontal and so it is not allowed to speak of a fatigue limit, but from a fatigue strength for a certain number of cycles. Also the testfrequency has proved to be of influence on the measure of corrosion fatigue. Therefore, when quoting corrosion fatigue strength, the endurance, the corrosive medium and the testfrequence should be mentioned.
It is usually not possible to make quantitative comparisons of the results of different investigations. Only some generalisations about the influence of corrosion should be made. The most important conclusion from corrosion fatigue investigations is that resistance to corrosion fatigue depends primarily on the resistance to corrosion.
Fig 4.5 shows the results of a fatigue tests in air and fresh water. The results for corrosion resistant steels with 5 % or more Cr show a great resistance to corrosion fatigue.(in comparison with mild steels)
The corrosion fatigue strength is approximately proportional to the tensile strength, see figure 4.5. Table 4.4 shows for stainless steels the fatigue strength for different corrosive mediums. Tests in water with a lower pH of 6.5-7 were not found in literature. Whith decreasing pH however the effect of corrosion fatigue increases.
In West Africa of more then 70% of the wells the pH is smaller then 6.5 ! See [13].
If the pumprod is connected to piston parts of other metals such as bronze, electro-galvanic corrosion will occur, which will decrease the diameter of the pumprod until it breaks. This effect should be avoided, see lit. [15].

Mode of testing	Corr. medium	Steel	$S_{f,corr}$	N	$S_{f,corr}/S_f$	lit.
Torsion	Fresh water	18/8 CW	81.8	$2.5.10^7$	0.43	2 213
Bending	Fresh water	304 AN	204	$2.0.10^7$	0.69	2 212
"	Fresh water	18/8 AN	171	1.10^8	0.63	2 213
"	Salt spray	18/8 CW		1.10^7	0.75	2 209
Direct	Salt spray	18/8 CW		1.10^7	0.70	2 209
	Corr. med.	S.Steel		1.10^7	0.60	5 203
Bending	See water	304 AN	103	1.10^8		6 84
"	See water	304 AN	193	1.10^7		6 229

TABLE 4.4: Fatigue strength of stainless steel in corrosive media

For handpumps with a stainless steel pumprod, even in clear fresh water, corrosion fatigue has to be taken into account. Since the S - N curve is continuesly decreasing, the pumprods cannot be designed for infinite life time, but for restricted lifetime, which is, due to rather large variations in fatigue strength (found during experiments) not so accurate.
In fig 4.6 the S - N curves for cold worked and annealed stainles steel in a corrosive medium are presented.

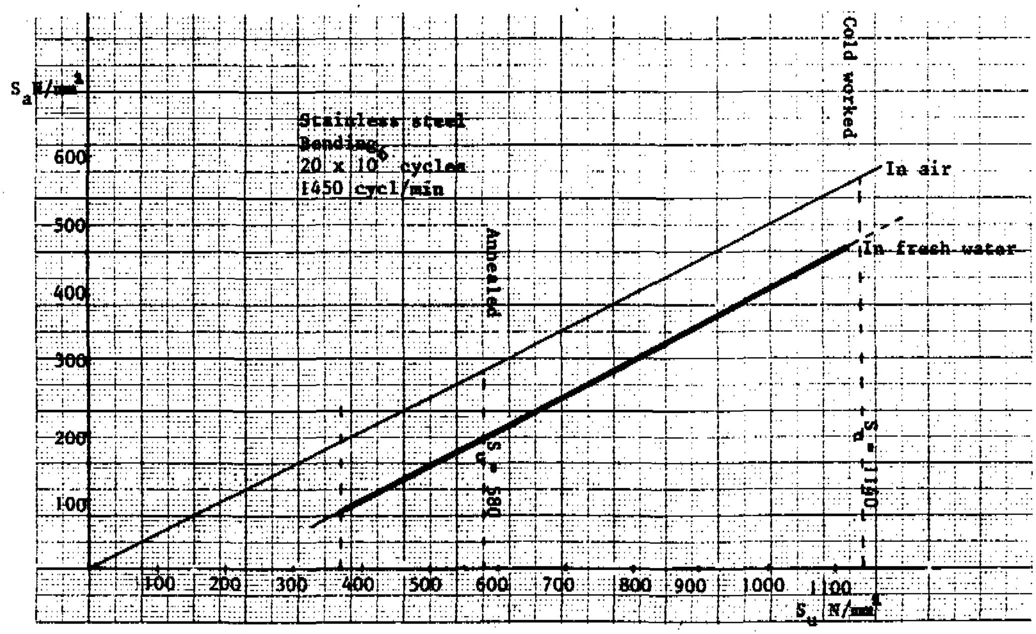

Fig. 4.5: The corrosive fatigue strength related to the tensile strength (S_u), lit. [2]

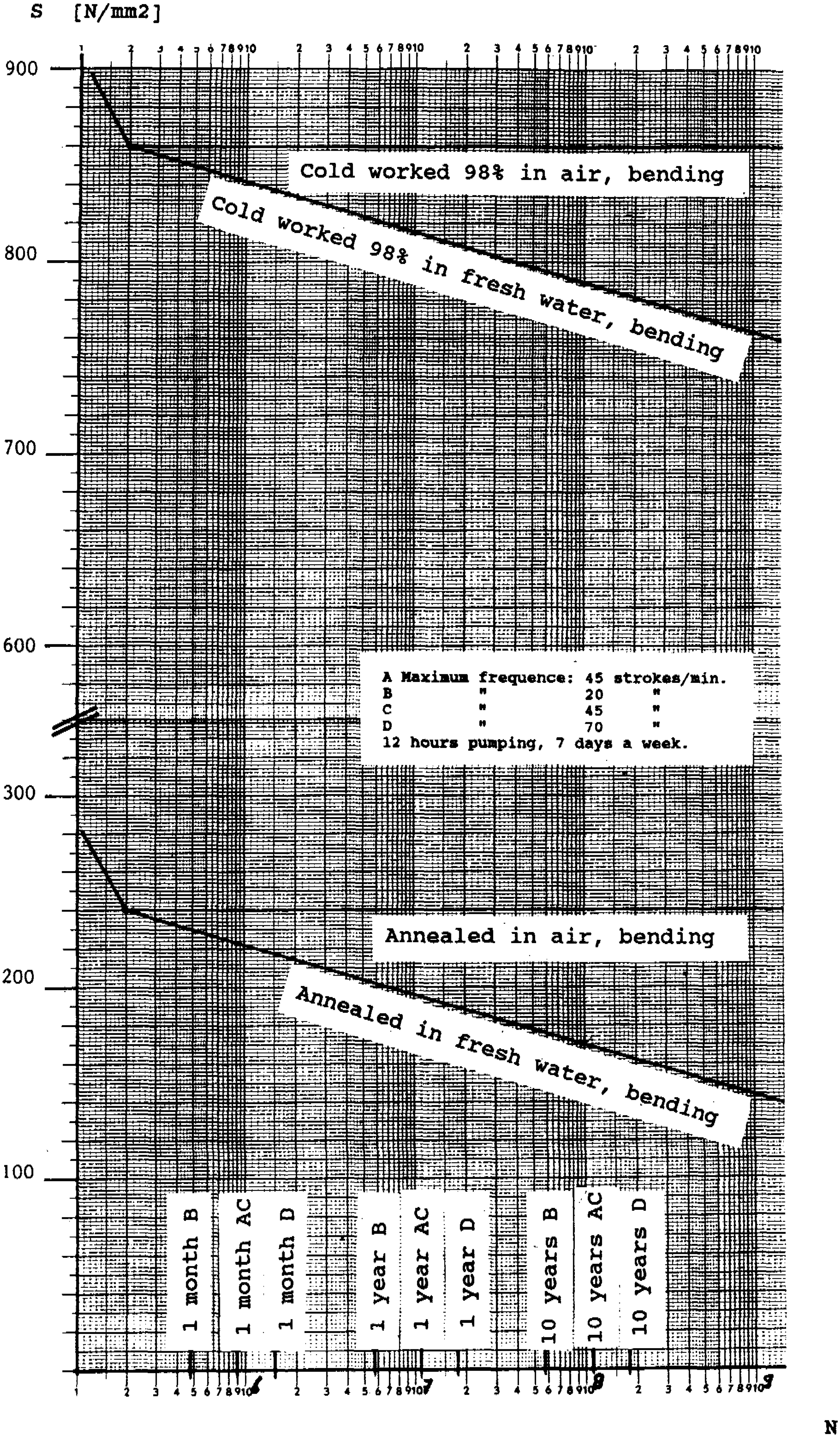

Fig. 4.6: S-N curves of stainless steel AISI 304

5 VINYL CHLORIDE POLYMERES PVC

5.1 INTRODUCTION

PVC rising mains are used because of their resistance against corrosion, even in acid media. In a considerable number of wells the pH is lower than 6.5.
Most is known of uPVC (unplastified PVC). The PVC used for the rising main of the SWN 81 handpump is "impact resistant PVC", which is a PVC with rubbery additives, causing a higher impact strength.Also hard PVC is found in literature.
In this paper the hard PVC plus the impact resistant PVC's will be indicated as "rigid PVC's"
Different samples of PVC may not have identical properties, depending partly on the molecular weight, which is indicated with a K value.
The data for uPVC below relate to suspension polymerised poly (vinyl chloride) homopolymer, stabilised with tri-basic lead sulphate,containing neither a filler nor an impact modifier.

5.2 PVC PROPERTIES

Property	UPVC	RIGID PVC	
		hard PVC	impact resist. PVC
S_u tensile [N/mm^2]	55	50-60	40
density	1.38-1.45	1.38-1.4	1.38
strain at fracture		15	60-70
compressive strength		80	45
bending strength		100-110	70-75
sharpy V		2-5	30-40
E modulus		3000	2400
Max. continues service temp. [^{o}C]	60		

Table 5.1: PVC properties, see [7[[8] [11]

5.3 TYPE OF LOADING

The PVC rising mains have a load pattern which is more or less sinusoidal with a minimum value for most time zero or sligthly negative and a maximum value.
To examine dynamic fatigue behaviour of PVC, in most cases square wave loading, or block load, is applied. The actual load pattern of a handpump cycle is not a blockload but can be considered as a blockload of which the maximum and minimum values are taken from the sinesoidal load.

5.4 STATIC FATIGUE

The strength is affected by time under load, temperature, and material properties.
Strenght under continues load:
When considering the performance of UPVC subject to the applied load it is necessary to know how yield stress and related phenomena are affected by 1) time 2)temperature and 3) molecular weight
Thermoplastics typically show a decrease in strenght with increase in either time under load or temperature, as can be seen from fig. 5.1.
Failure in every case is ductile and takes place essentially at yield.
Ductile behaviour is typical of uPVC at room temperature where the material deforms and yields under the impact loading, absorbing large amounts of energy.
Brittle behaviour is characterised by crack propagation at low strains, absorbing small amounts of energy.

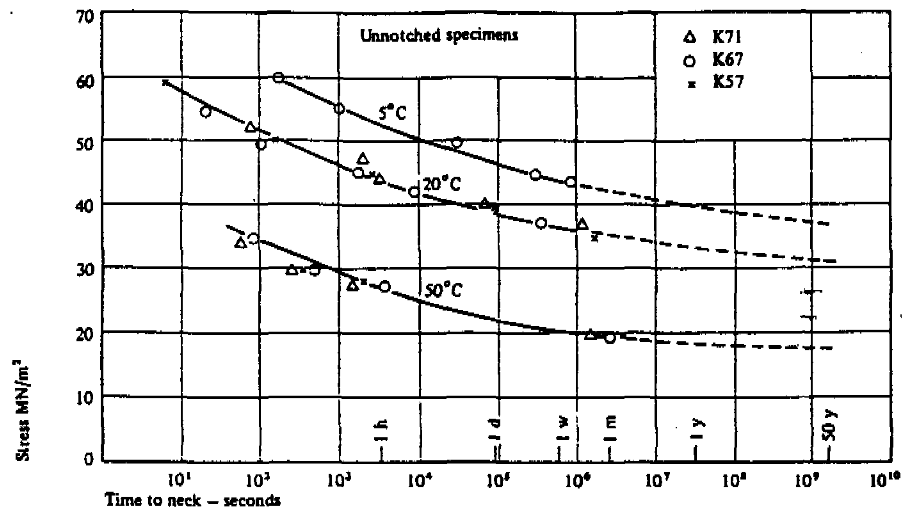

Fig. 5.1: Static fatigue of uPVC, see [8]

<u>Ductile strength criteria</u>(Static Fatigue)

Smooth pipes	Failure stress	22 N/mm2 at 40 degr.C after 1 year ,lit [8]
	Design stress	12,5 N/mm2 at 40 degr.C
	(50 years Safety	factor≈2)

<u>Influence of notches</u>

The static fatigue strengt does not decrease very much for moderate severe notches (Kt factor 4.2 and tip radius r =

In that case the fracture stress is reduced significantly, some 30% See ([8], figure 16).

5.5 DYNAMIC FATIGUE

The load frequency is of influence on the lifetime under cyclic load. An increasing frequency reduces the lifetime. The fatigue limit is however not frequency dependent. For uPVC the fatigue limit is about 16.5 N/mm2.
The recommended design stress (lifetime 50 years) for uPVC under intermittend loads is 6 N/mm2. This is based on the assumption that the component will fail by the propagation of a crack from a pre-existing flaw.(such as a thread, or when the pipes are glued.)
Only a few data are found in literature about dynamic fatigue of rigid PVC. The available material indicates that the fatigue strength for rigid PVC is about the same as for uPVC. For data about fatigue strength properties of PVC see Appendix B.

Brittle strength criteria of smooth PVC (Dynamic Fatigue)

Configuration	uPVC + rigid PVC S_f [N/mm^2]
smooth	16.5
glued/thread*	6.0

*This is valid for a ratio X; depth of flaw/wall thickness smaller than 0.4

Table 5.2: Dynamic fatigue criteria for uPVC and rigid PVC with smooth surfaces, lit. [8]

In figure 5.3 the S-N curve of smooth PVC is drawn.

Influence of crack like notches.

The table above is only valid for pipes with a smooth surface, without flaws with a very sharp notch.Threads normally have a notch with a root radius of more than 0.250 mm (250 mu) in which case table 5.2 is valid. However flaws or notches with a root radius in the order of 0.01 mm (or 10 mu)have a detrimental effect on the dynamic fatigue strength which goes down to a value of 2.5 N/mm^2.(for 10^7 cycles)
For example a
circumferential scratch made by a "scraper" used for measuring, reduces the fatigue level with a factor 6.6.

It is unrealistic to suppose crack like scratches present totally circumferential. However, during installation or transportation occasional cracks like scratches might be produced. **For this reason it is strongly recommended to reduce the design fatigue limit to 2.5 N/mm² for PVC, with regard to the scratch sensitivity of PVC.**

For a particular thread the fatigue limit can be determined with figure 5.2 in which the ratio X; depth of flaw/ wall thickness is set out against the fatigue strength Sf,ref[3]

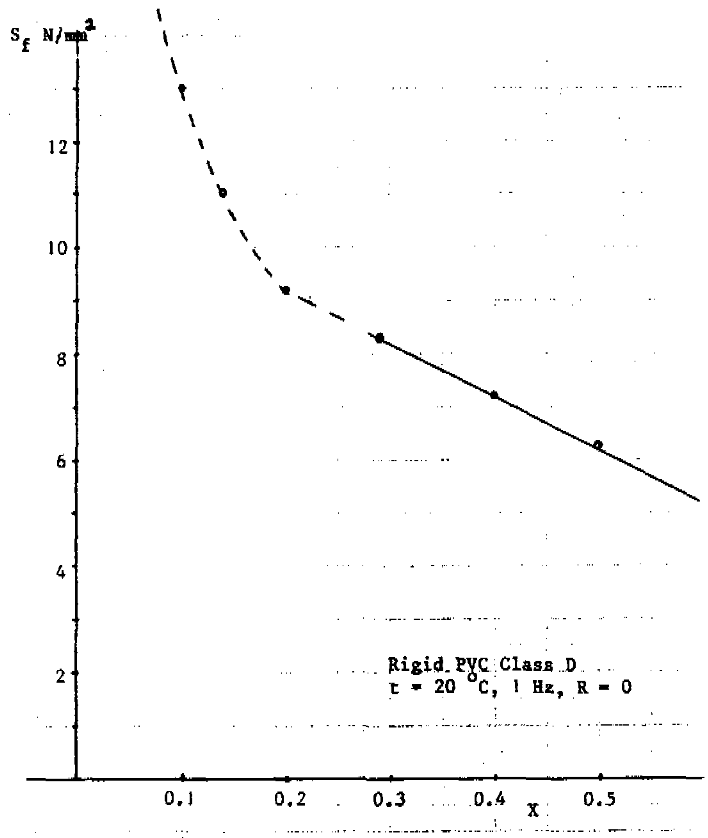

Fig. 5.2: Fatigue strength S_f against ratio X; flaw depth/wall thickness.

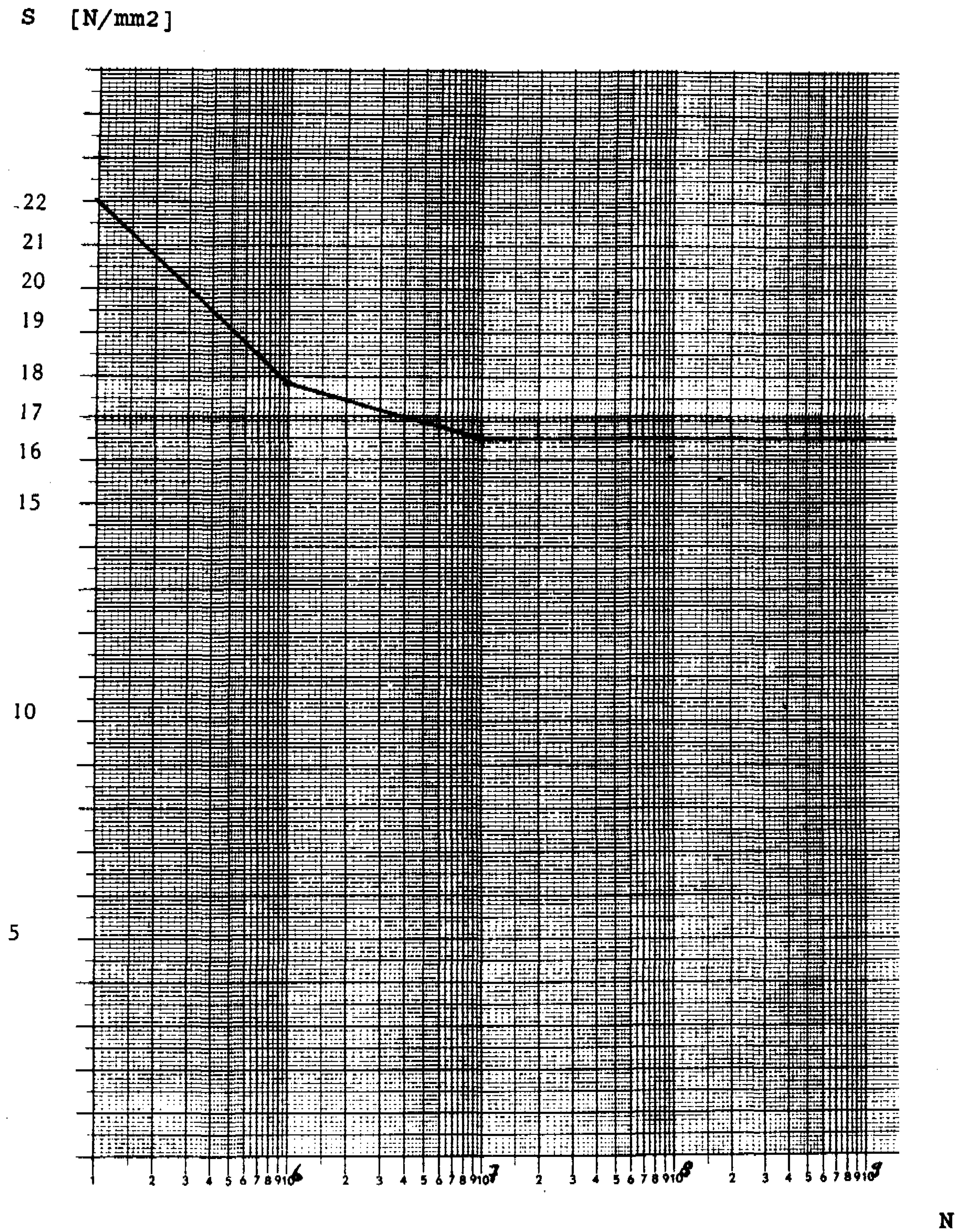

Fig. 5.3: S-N curve of smooth PVC (uPVC + rigid PVC)

6 DESIGN RULES, SUMMARISED

6.1 STAINLESS STEEL

6.1.1 Smooth stainless steel AISI 304

For pumprods normally submerged in fresh water, the fatigue strength is decreasing with increasing number of cycles. The ultimate fatigue strength of both annealed and 98% cold worked stainless steel AISI 304 is given in figure 4.6. The ultimate fatigue strength* of smooth stainless steel AISI 304 in fresh water is:

	2.10^5 cycles	1.10^8 cycles
annealed AISI 304	240 N/mm2	170 N/mm2
98% cold worked "	860	790

For a stainles steel that has been cold worked for a certain percentage, the fatigue strength can be found with linear interpolation.

*This is valid for alternating axial stresses (combined tension and bending) in the pumprod, which is normally the case. It is not valid for torsion.

6.1.2. Notched stainless steel AISI 304

The notches for which the pumprods generally have to be designed are notches formed by grooves of a thread.
As a rule of fist:

- For mechanically cut thread $K_t \approx 3$ (1)
- For rolled thread $K_t \approx 2$ (2)

- If for a certain thread the Kt is unknown, but the root radius is known (r), then with table 4.2 an estimate of K_t can be made. (3)

-annealed stainless steel AISI 304

$q = 0.3$ for $K_t < 4$ (4)

- cold worked (98%) stainless steel AISI 304

$q = 0.7$ for $K_t < 4$ (5)

- $K_f = 1 + q(K_t-1)$ see figure 4.4 (6)

-Safety factor

Seen the variety of values K_f found in literature, as well as the incompletenes of data about notches, it is preferable to take a Safety factor of 2 (instead of 1.5 which is recommended in [10] for thread under dynamic load.
Safety factor = 2 (7)

Summarised Design Procedure

To obtain the design strength of stainless steel AISI 304 with thread, the following procedure can be followed;
Data to be given: - the material, st st AISI 304
- the treatment, annealed or cold worked in percentage.
- the plain fatigue stress
- the type of thread with K_t value

In most cases K_t of tread is given in handbooks, if not, determine:
- K_t, using rules (1) (2) or (3)
- K_f, using rules (4) (5) or (6), or figure 4.4

- Choose a desirable lifetime for the pumprod, say 10 years. With figure 4.6 this gives a number of cycles of 1.10^8, supposing the pump is used as indicated.
With figure 4.6 for 10^8 the plain fatigue stress can be found for the steel used, using the lines for fresh water (taking the corrosion effect into account)
- ultimate fatigue strength = $\dfrac{\text{plain fatigue stress}}{K_f}$
- design fatigue strength = $\dfrac{\text{ultimate fat. strength}}{\text{Safety factor}}$ (2)

Suppose mechanically cut thread BSF (r = 0,135) on annealed stainless steel AISI 304 pumprods.

- K_t = 3.3 from (3)
- K_f = 1.7 from figure 4.4

-Choose a lifetime of 10 years, or 10^8 cycles.

-ultimate fat. strength = $\frac{170}{1.7}$ = 100

- design fat. strength = $\frac{100}{2}$ = 50 N/mm2

6.2 PVC

The brittle strength criteria for uPVC and rigid PVC for rising mains of hand pumps, protected against the sun are:

-<u>Ultimate fatigue limit:</u>

-smooth pipe	16.5 N/mm^2	(1)
-glued/thread*	6.0 N/mm^2	(2)

*For a thread with a ratio X < 0.4 and a notch (root) radius of at least 0.25 mm.

For the S-N curve of smooth PVC see figure 5.3

-For values of X > 0.4, the ultimate fatigue limit can be determined with figure 5.2. (3)

-A safety factor of 2.4 is recommended for both smooth and glued or threaded PVC. This because the possible occurrence of crack like notchs, with a root radius in the order of 0.01 mm.

- <u>Safety factor = 2.4</u> (4)

<u>Example calculation</u>

Rising main of rigid PVC (impact resistant PVC)

D_u = 47.5 mm
D_i = 36.0 mm

wall thickness	5.75 mm
A (area)	754 mm^2

Thread 1½" machined according NEN 3258 (see appendix D)

According NEN 3258:

-notch depth (d) = 1.479 mm
-X = 1.479/5.75 = 0.257 mm
-thus X < 0.4

root radius is r = 0.137*p
with p = 2.309
r = 0.31 mm
thus the root radius is larger then 0.250 mm

Therefore $rule_2$(2) can be used giving an ultimate fatigue limit of 6 N/mm^2.

<u>The design fatigue limit:</u>

(ultimate fatigue limit)/(safety factor):

$$6/2.4 = 2.5\ N/mm^2$$

<u>The maximum allowable</u> F_{max} becomes:

$$2.5*754 = 1885\ \text{Newton}$$

7 MEASUREMENTS ON THE SWN 81 PUMP

Materials:

pumprod:
stainless steel AISI 304 annealed
diameter 10 mm
thread, M10, mechanically cut, see Appendix F

rising main:
impact resistant PVC
diameter outside 47.5 mm
diameter inside 36.0 mm
thread 1.5" mechanically cut, see Appendix E

cylinder: ?

piston: ?

Measured configurations:

four different Heads have been measured, 20, 40, 60 and 80 m.

Measured data:

The position of the strain gauges is indicated in figure 7.1. For a typical stress signal see figure 7.2. For the method of elaboration of the measured data see Appendix C. The final results are shown in figure 7.3 and 7.4.

Actual measurements:

number of measurements: 128 hand driven
134 machine driven

period of measurements: 2-8-'88 - 22-9-'88

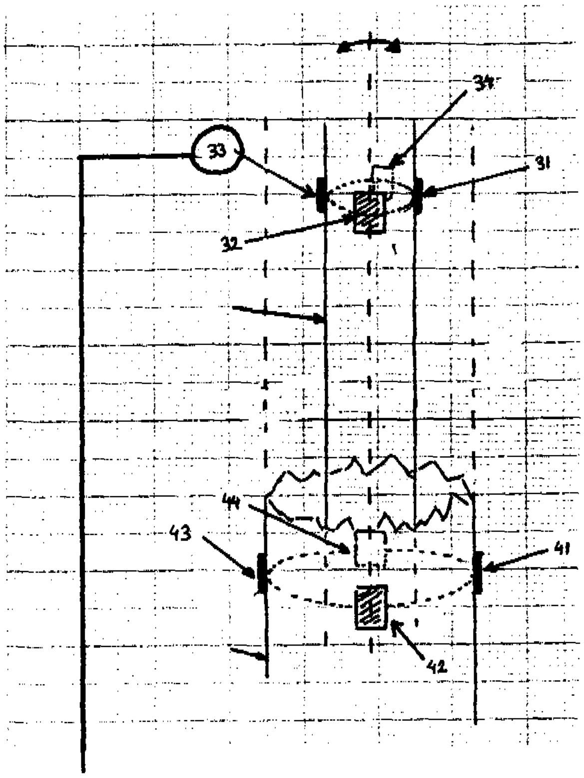

Fig. 7.1: Position of the strain gauges (upper end)

Filename: SOOHA601.DAT

Subfile : 17

Row nr. : 7 **Straingauge: 33**

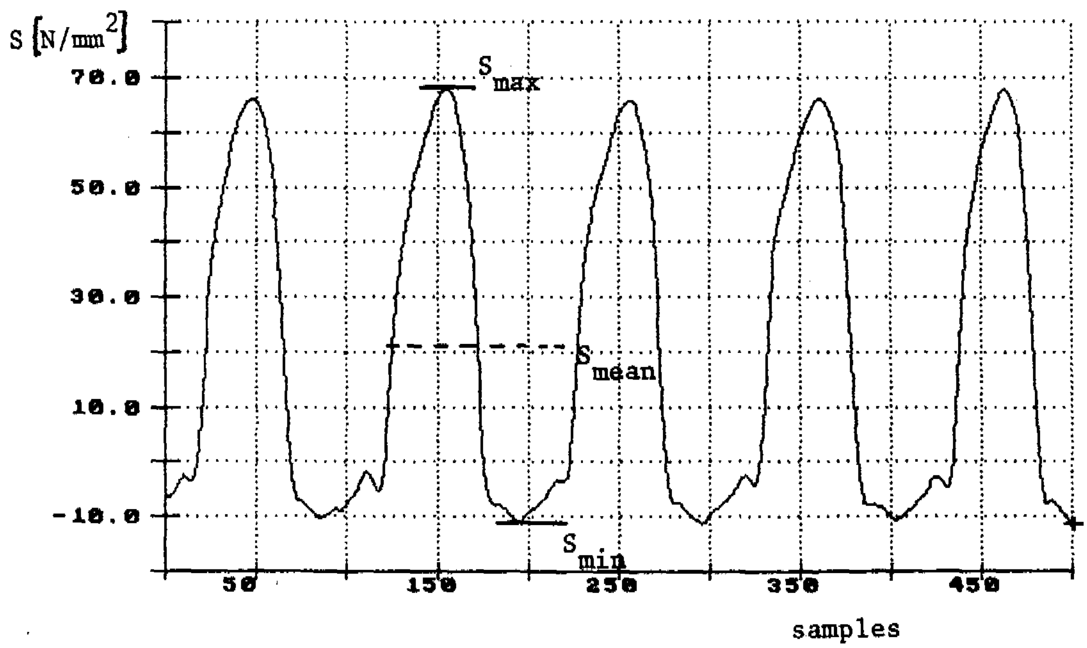

Fig. 7.2: Typical stress signal from transducer 33

The fatigue stress Sa in this case is:
Sa = (Smax - Smin)/2 ≈ 40 N/mm2

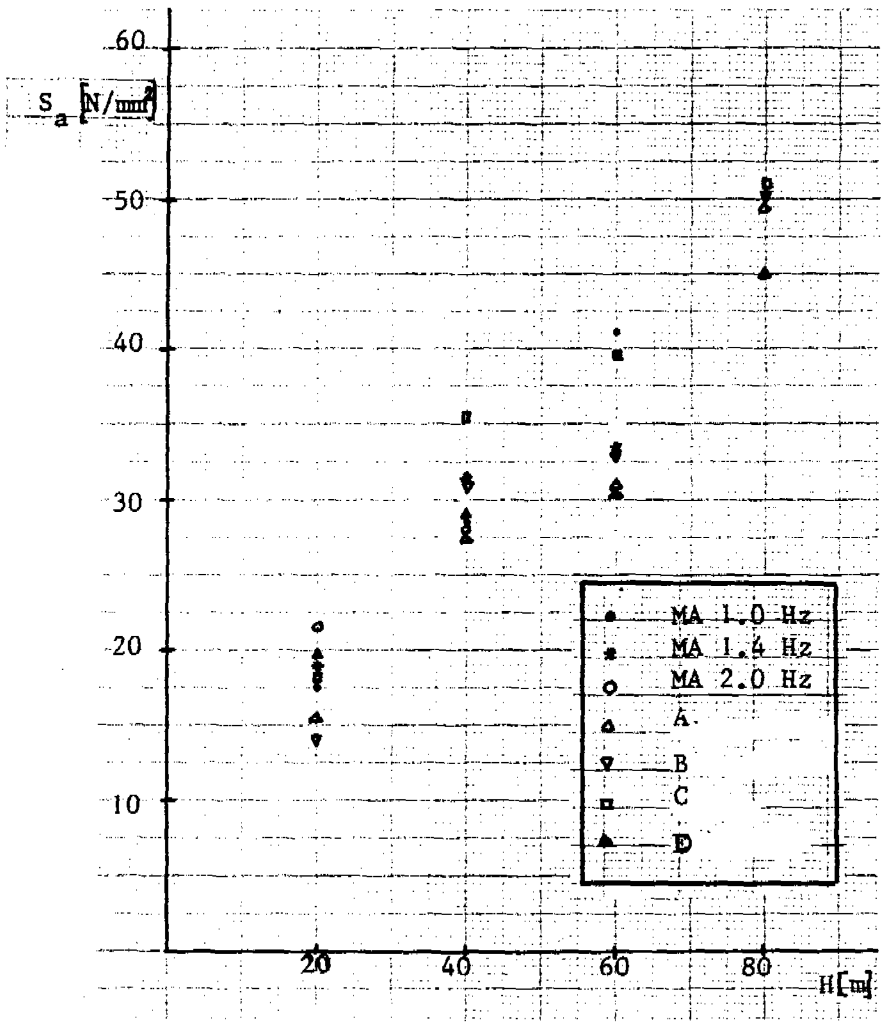

Fig. 7.3: Actual alternating stress measured on the stainless steel pumprod (upper position) for 4 different modes of handpumping plus 3 modes of machine pumping, as function of pumping head.

A   Steady pumping (normal)
B   Pumping against stops
C   Forced pumping (malen)
D   Pumping in natural frequency (jutteren)

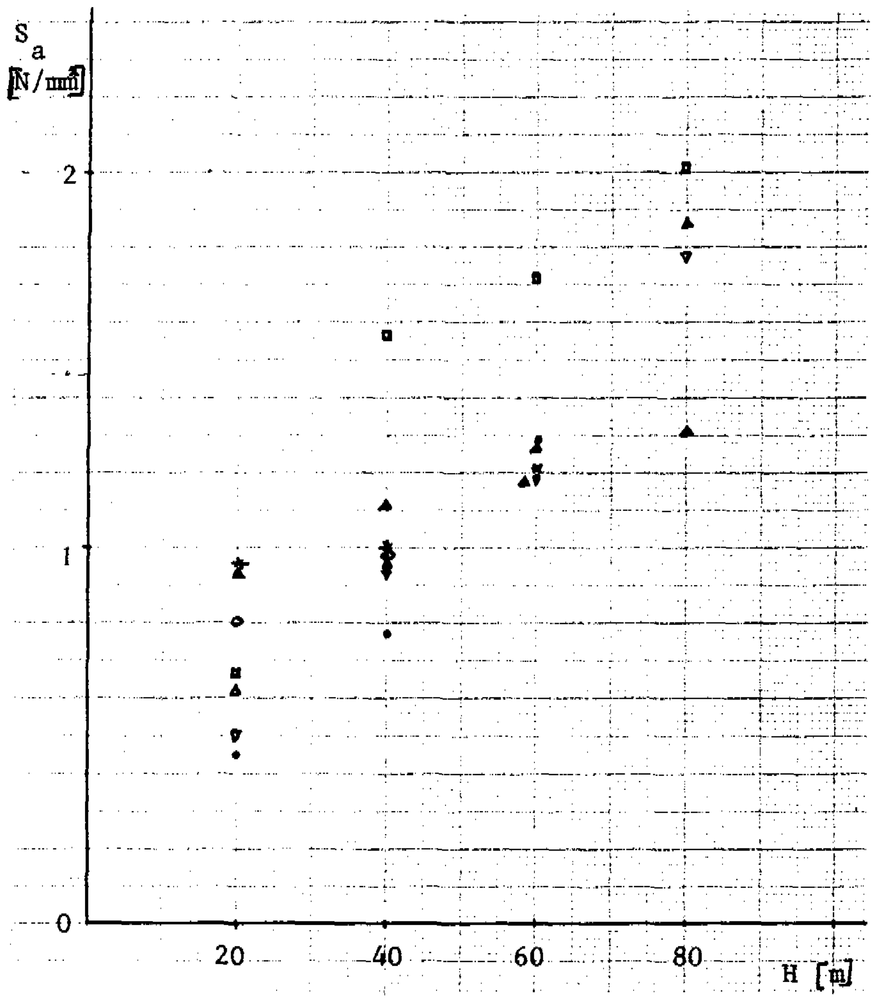

Fig. 7.4: Actual alternating stress measured on the PVC r ising main (upper position) for 4 different modes of handpumping plus 3 modes of machine pumping, as function of pumping head.
For legend see figure 7.3

COMPARISON OF THE ACTUAL MEASURED LOADS WITH THE DESIGN RULES

Pumprod:

annealed stainless steel AISI 304 with thread M10 mechanically cut:
rule (1) $K_t = 3$
fig. 4.4 $K_f = 1.6$
lifetime 10 years --> ultimate fatigue strength
170/1.6 = 106 N/mm^2

design fatigue strength 106/2 = 53 N/mm^2

From figure 7.3 it can be seen that the maximum occuring S_a is 51 N/mm^2. This value is below the design fatigue strength.

Conclusion:
The pumprod is strong enough for 10 years in fresh water (Ph = 7) for heads up to 80 m.

Rising main:

The pipe and thread have already been calculated in the example of chapter 6.2 giving a design fatigue limit of 2.5 N/mm^2. From the actual measured data in figure 7.4 it can be seen that the maximum occuring S_a is 2 N/mm^2. This is well below the design fatigue limit.

Conclusion:
The PVC rising main is strong enough for 10 years for heads up to 80 m.

8 CONCLUSIONS AND RECOMMENDATIONS

This study concentrates on stainless steel 304. In West Africa, about 70% of the wells contains water with a PH <6.5 which will increase the effects of corrosion fatigue lit. [13]. Therefore it is recommended to further investigate the fatigue properties of stainless steels with a higher resistance against corrosion fatigue,such as stainless steel AISI 316. (provided that costprice is acceptable at the end)

Data of fatigue life of stainless steels are not so abundently, for different corrosive media they are scarce. Data of fatigue life of specific sorts of PVC are very scarce. Further research experiments on fatigue life of rigid PVC's is recommended, although these experiments are not cheap.
Seen these remarks it has to be concluded that the design rules derived in this paper are provisional.

The measured loads on the SWN81 pump compared to the design rules showed that the pumprod and rising main were strong enough for a lifetime of 10 years for heads up to 80 m.

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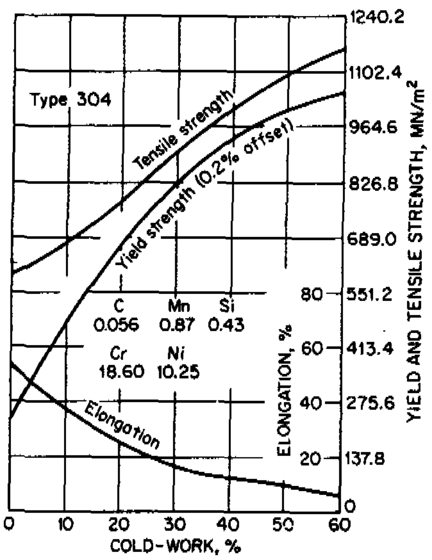
ANNEX A

FATIGUE DATA OF STAINLESS STEELS (Type 304 (or 18/8 steel))

Static properties:

Typical tensile– Su and yield Sy strength for annealed and cold worked stainless steel 304.



NR	MAT.	work	tensile Su		yield Sy	from ref.pag
1	304 sheet	AN	586		241	1 p 14–9
2	25° plate	AN	586		207	1 p 14–9
3	bars	AN	586		207	1 p 14–9
4	347 20°C	AN	650		275.8	1 p 20–26
5	304	AN	580		289.6	1 p 20–26
6	301	AN	758		276	1 p 20–26
7	303	AN	620		241	1 p 20–26
8	347	AN	655		276	1 p 20–26
9	18/12	AN	612			2 p 135
10	20/10	AN	571			2 p 153
11	347	AN	618			2 p 162
12	18/8	CW	1297	90%		2 p 213
13	304	CW	1451	98%	1019	2 p APX
14	18/8	AN	792		shear 310	16 p 281
15	s.s				240	16 p 343
16	18/8	AN	685			
17	304 20°C	AN	617			1
18	20/10	CW	911	35%		2 p 153
19	304	CW	1448	98%		1 p 20–11
20	304	AN	544			6 p 84
21	316	AN	579		290	

From this table the tensile strength can be calculated:

For annealed st.st. 304: Su = 580 N/mm²

*CW% = cold worked
AN = annealed
ss = stainless steel

Dynamic properties:

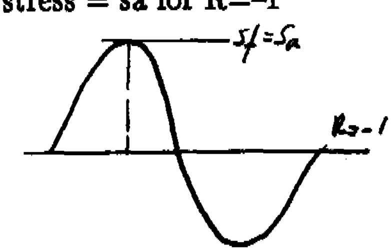
Fatigue limit s_f for smoothed specimes

NR	MAT.		s_f	mode of testing	from ref. page
14	18/8	AN	234	D	16 p 281 *
10	20/10	AN	241	RB	2 p 153
8	347	AN	268	B	1 p 20–33
7,6,5	304/303/301	AN	241	B	1 p 20–33
12	18/8	CW	190	T	2 p 213
22	18/8/1	AN	273	RB	2 p 213
23	ss	AN	294	RB	5 p 156
18	20/10	CW	482	RB	2 p 153
19	304	CW	862	RB	1 p 20–11
20	316	AN	269	RB	1 p 20–33

Mode of testing:

*D = Direkt, axiale
B(RB) = rotating bending
T = torsion

s_f = alternating stress = sa for R=–1



ANNEX B

FATIGUE DATA OF PVC

- General information:

μPVC	yield stress ;	55 MN/m²
rigid PVC	yield stress ;	50–60 MN/m²

Static fatigue

Material	Temp [°C]	Lifetime years	Notch K_t	Root radius [μm]	Sf_{st} [N/mm²]	From
μPVC K71/67/57	50	1			18	8 Fig. 14
"	20	1			33	8 Fig. 14
"	5	1			40	8 Fig. 14
"	50	50			17	8 Fig. 14
"	20	50			31	8 Fig. 14
"	5	50			37	8 Fig. 14
μPVC K67	50	1	<<	250	26	8 Fig. 15
μPVC k57	50	1	<<	250	18	8 Fig. 15
μPVC K71/67/57	20	1	<<	250	37	8 Fig. 15
μPVC K67/57	5	1	<<	250	45	8 Fig. 15
μPVC K67	20	50	<<	250	35	8 Fig. 15
μPVC K67	20	1	4.2	10	29	8 Fig. 16
μPVC K67	20	50	4.2	10	21	8 Fig. 16

Dynamical fatigue

Specimen: μPVC K67
Tested: R = 0 Sm = 17.5 N/mm²
uniaxial tested tension
20°C
load bending
time off load = tine under load $\tau = 1$ (8–22)

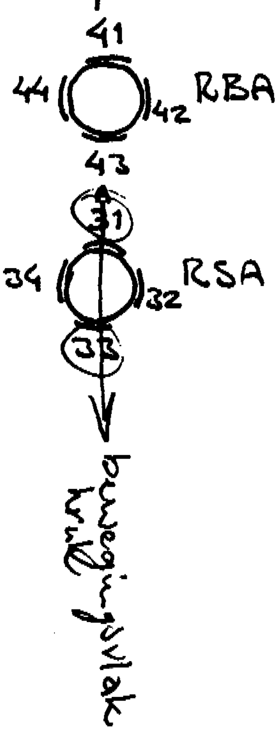
Testfreq. [Hz]	Notch K_f	Root radius μm	S_f [N/mm²]	N_f	From/note
5.10^{-3}			17.5	8.10^4	8 Fig. 17
0.5			17.5	9.10^5	8 Fig. 17
1			17.5	3.10^6	Extrapolated
	4.2	10	2.5	10^7	8 Fig. 25
	4.2	10	9.5	10^5	8 Fig. 25
	4.2	10	4	10^6	8 Fig. 25
			16.5	3.10^6	8 Fig. 25 well processed
			9.5	2.10^6	8 Fig. 25 poorly processed
	*	0.35 mm	12	3.10^5	rigid pvc class P ref.3 p690 ϕ = 50 mm
	*	0.70 mm	8	1.10^6	rigid pvc class P wall = 3.5 mm
	*	1.40 mm	6	2.10^6	rigid pvc class P
1			20.7	1.10^4	rigid vinyls ref.16 p533

DATAFILES IADHPP

Kodering S ØØ M A 8 Ø5. DAT

- S: S = SWN V = Volanta
- ØØ: nummer voor variant van opstelling ØØ = standaard
- M: M = mechanisch H = Handaandr.
- A: Kode voor opnemers-kombinatie
- 8: stijgbuislengte + 10
- Ø5: volgnummer in serie

Opnemers / rows:



1 t/m 4: RBA = axiaal gerichte rekstrook buiten aan boveneind stijgbuis

5 t/m 8: RSA = axiaal gerichte rekstrook aan boveneind op trekstang (31 en 33 in bewegingsvlak kruk)

9: ZVO = verplaatsing van zuiger t.o.v. cilinder

10: CVO = axiale verplaatsing cilinder

11: ZKO/ZKL = zuigerklep opnemer

12: VKO/VKL = voetklep opnemer

13: DRO = druk in cilinder, boven zuiger

14: HVO = krukhoekverdraaiing.

15: RBB55 = tangentiaal geplaatste rekstrook, onder op stijgbuis.

16: ——

Subfiles: ⓐ eerste 2 à 3 zijn zg. 'rust-bepalingen'.

ⓑ t/m 8 à 10 zijn scans bij pompen met de hand danwel mechanisch gedreven. Bij verschillende slag en/of frekwentie: zie schema.

ⓒ 9 (resp 11 bij handaandrijving) t/m 16 (resp 20) zijn naar technische eenheden omgerekende scans (dus bij handaandrijving 1 ⇒ 11; 2 ⇒ 12 enz mechanisch idem zo met uitzondering van SØØMA6Ø1.DAT.)

U 8

ANNEX C2   S 123

FILENAAM/PROEFNUMMER	TYPE PROEF	ONDERZOEKER
S00 HA601 .DAT	handpomptest SWN81 / 60 m.	rb

DATUM	TIJDSTIP
30.8.88	10.05

SAMPLE FREQ	SAMPLES/SC/KAN
100	500

WATERTEMP	BUITENTEMP
10°	17°

DOEL v/d PROEF / OMSCHRIJVING

OPSTELLING

SWN 81 + 60 m. stijgbuis ; opstelling nr: S 00601
standaard + gewicht 180 mm uitzwengel
aarding op: stand. bok. trekstang + habeskast ACDE
terugvoer putwater

ROW	KAN	OPNEMER	PLAATSING	GESEVENS CALIBR.
1	0	RBA41	59.5 m. boven cilinder	CALRBA 10
2	1	42	" " "	—
3	2	43	" " "	—
4	3	44		
5	4	RSA31	0.15 m. onder trekstanglager	CALRSA 10
6	5	32	" " "	—
→ (7)	6	(33)	" " " 22 Y	—
8	7	34	" " "	
9	8	ZVO	op habes-	CALZVO 04
10	9	CVO	kast	CALCVO 03
11	10	ZKO		—
12	11	VKO		—
13	12	DRO	in cilinder, boven zuiger	CALDRO 01
14	13	HVO		—
15	14	RBB55	0.15 m boven cilinder	CALRBB02/03
16	15	—	—	—

	SUBFILE	BESCHRIJVING	OPBRENGST kg/slag	SL.	LCI* mm.
x	1	rust: kruk horizontaal			
x	2	" : " tegen onderaanslag (zuiger in ODP)			
13 x	3	normaal pompen	3.5/30	17	
14 "	4		3.5/30	18	
15 x	5	tegen de aanslagen pompen	3.5/20	14	
16 x	6		3.5/20	13	
→ 17 x	7	malen	4.3/20	19.5	
18 x	8		5.1/20	25	
19 x	9	jutteren	0.7/20	35	
20 x	10		0.5/20	36	

	WATERNIVO	POMPELDIEPTE	ABSOLUTE Ø-BEPALING	
Voor proef:	-56.1 m.	5.0 m.	CALRBA 13	
Na proef:			CALRSA 22	
			CALRBB 06	

OPMERKINGEN / KONKLUSIES

bram pompt

* L.C.I = luchtbel conc. indikatie = [mm]

						S_{MAX}		S_{MIN}		S_{MEAN}
filename S00HA601.DAT										
nr. subfile :	13	chnl nr	1	max.		1.967	min.	-.347	mean.	.795
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nr. subfile :	13	chnl nr	4	max.		1.884	min.	.063	mean.	.937
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nr. subfile :	13	chnl nr	6	max.		48.784	min.	16.035	mean.	31.659
nr. subfile :	13	chnl nr	7	max.		52.473	min.	-9.998	mean.	19.648
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nr. subfile :	15	chnl nr	3	max.		1.938	min.	-.439	mean.	.730
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nr. subfile :	17	chnl nr	1	max.		2.270	min.	-1.167	mean.	.642
nr. subfile :	17	chnl nr	2	max.		1.874	min.	-1.615	mean.	.456
nr. subfile :	17	chnl nr	3	max.		1.913	min.	-.986	mean.	.618
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nr. subfile :	17	chnl nr	6	max.		58.043	min.	17.993	mean.	34.137
nr. subfile :	17	chnl nr	7	max.		68.034	min.	-11.352	mean.	21.005
nr. subfile :	17	chnl nr	8	max.		14.915	min.	-25.763	mean.	-7.515
nr. subfile :	19	chnl nr	1	max.		1.878	min.	.024	mean.	.881
nr. subfile :	19	chnl nr	2	max.		1.815	min.	-.550	mean.	.691
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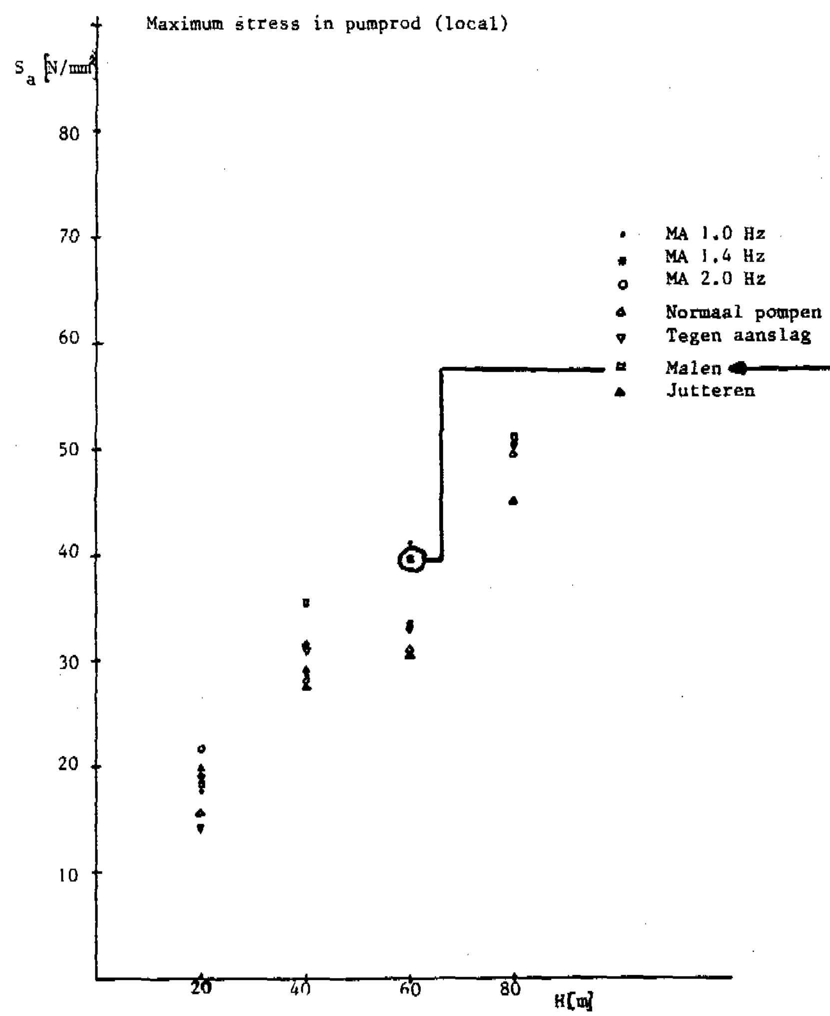
nr. subfile :	19	chnl nr	5	max.		42.026	min.	-10.973	mean.	13.337
nr. subfile :	19	chnl nr	6	max.		42.610	min.	26.349	mean.	34.343
nr. subfile :	19	chnl	7	max.		48.714	min.	-14.133	mean.	13.558
nr. subfile :	19	chnl nr	8	max.		-2.712	min.	-20.414	mean.	-12.232

$$S_a = \frac{S_{max} - S_{min}}{2}$$



filename SOOHA204.DAT

ANNEX C4

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nr.	subfile :	13	chnl nr	6	max.	26.349	min.	4.366	mean.	17.167
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nr.	subfile :	15	chnl nr	6	max.	26.876	min.	1.506	mean.	13.824
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nr.	subfile :	15	chnl nr	8	max.	4.972	min.	-12.279	mean.	-4.556
nr.	subfile :	17	chnl nr	1	max.	.883	min.	-.447	mean.	.254
nr.	subfile :	17	chnl nr	2	max.	.689	min.	-.757	mean.	.051
nr.	subfile :	17	chnl nr	3	max.	.317	min.	-.633	mean.	-.125
nr.	subfile :	17	chnl nr	4	max.	.557	min.	-.366	mean.	.092
nr.	subfile :	17	chnl nr	5	max.	10.818	min.	-9.028	mean.	1.232
nr.	subfile :	17	chnl nr	6	max.	26.123	min.	.753	mean.	11.994
nr.	subfile :	17	chnl nr	7	max.	26.988	min.	-10.374	mean.	6.582
r.	subfile :	17	chnl nr	8	max.	8.211	min.	-12.881	mean.	-5.555
nr.	subfile :	19	chnl nr	1	max.	1.031	min.	-.883	mean.	.142
nr.	subfile :	19	chnl nr	2	max.	.737	min.	-.791	mean.	.010
nr.	subfile :	19	chnl nr	3	max.	.357	min.	-.528	mean.	-.057
nr.	subfile :	19	chnl nr	4	max.	.538	min.	-.461	mean.	.073
nr.	subfile :	19	chnl nr	5	max.	13.931	min.	-2.490	mean.	4.941
nr.	subfile :	19	chnl nr	6	max.	30.941	min.	7.905	mean.	16.958
nr.	subfile :	19	chnl nr	7	max.	27.439	min.	-11.502	mean.	3.441
nr.	subfile :	19	chnl nr	8	max.	-6.102	min.	-14.689	mean.	-10.345

filename HA0HA404.DAT

ANNEX C5

nr. subfile :	13	chnl nr	1	max. 1.068	min. -.871	mean. -.077
nr. subfile :	13	chnl nr	2	max. 1.042	min. -.281	mean. .275
nr. subfile :	13	chnl nr	3	max. 1.149	min. -.163	mean. .368
nr. subfile :	13	chnl nr	4	max. 1.195	min. -.474	mean. .270
nr. subfile :	13	chnl nr	5	max. 30.741	min. -8.716	mean. 5.479
nr. subfile :	13	chnl nr	6	max. 35.760	min. 15.057	mean. 26.318
nr. subfile :	13	chnl nr	7	max. 39.843	min. -16.163	mean. 14.711
nr. subfile :	13	chnl nr	8	max. 1.281	min. -18.004	mean. -9.033
nr. subfile :	15	chnl nr	1	max. 1.023	min. -1.336	mean. -.153
nr. subfile :	15	chnl nr	2	max. 1.346	min. -.548	mean. .246
nr. subfile :	15	chnl nr	3	max. 1.115	min. -.282	mean. .297
nr. subfile :	15	chnl nr	4	max. 1.149	min. -.752	mean. .198
nr. subfile :	15	chnl nr	5	max. 24.515	min. -12.530	mean. 5.442
nr. subfile :	15	chnl nr	6	max. 33.275	min. 4.442	mean. 18.422
nr. subfile :	15	chnl nr	7	max. 46.45[illegible]	min. -15.787	mean. 14.731
nr. subfile :	15	chnl nr	8	max. 10.621	min. -15.217	mean. -4.666
nr. subfile :	17	chnl nr	1	max. .880	min. -1.800	mean. -.286
nr. subfile :	17	chnl nr	2	max. 1.968	min. -1.166	mean. .137
nr. subfile :	17	chnl nr	3	max. 1.551	min. -.938	mean. .263
nr. subfile :	17	chnl nr	4	max. 1.714	min. -1.131	mean. .090
nr. subfile :	17	chnl nr	5	max. 26.772	min. -10.273	mean. 5.533
nr. subfile :	17	chnl nr	6	max. 41.782	min. 7.302	mean. 21.140
nr. subfile :	17	chnl nr	7	max. 54.653	min. -16.088	mean. 16.449
nr. subfile :	17	chnl nr	8	max. 9.341	min. -14.162	mean. -4.663
nr. subfile :	19	chnl nr	1	max. 1.197	min. -1.617	mean. -.117
nr. subfile :	19	chnl nr	2	max. 1.221	min. -.728	mean. .209
nr. subfile :	19	chnl nr	3	max. .871	min. -.488	mean. .345
nr. subfile :	19	chnl nr	4	max. 1.541	min. -.707	mean. .282
nr. subfile :	19	chnl nr	5	max. 28.640	min. -8.405	mean. 10.503
nr. subfile :	19	chnl nr	6	max. 35.007	min. 16.111	mean. 24.249
nr. subfile :	19	chnl nr	7	max. 43.752	min. -14.208	mean. 9.220
nr. subfile :	19	chnl nr	8	max. -1.883	min. -16.874	mean. -10.362

filename S00HA803.DAT

ANNEX C6

nr. subfile :	13	chnl nr	1	max.	2.556	min.	-1.179	mean.	.834
nr. subfile :	13	chnl nr	2	max.	2.511	min.	-.778	mean.	1.021
nr. subfile :	13	chnl nr	3	max.	2.372	min.	-.118	mean.	1.245
nr. subfile :	13	chnl nr	4	max.	2.612	min.	-.492	mean.	1.077
nr. subfile :	13	chnl nr	5	max.	50.183	min.	-29.401	mean.	6.866
nr. subfile :	13	chnl nr	6	max.	57.480	min.	15.914	mean.	34.262
nr. subfile :	13	chnl nr	7	max.	88.576	min.	-10.217	mean.	33.290
nr. subfile :	13	chnl nr	8	max.	29.709	min.	-13.146	mean.	6.078
nr. subfile :	15	chnl nr	1	max.	2.847	min.	-.711	mean.	.862
nr. subfile :	15	chnl nr	2	max.	2.616	min.	-.314	mean.	1.076
nr. subfile :	15	chnl nr	3	max.	2.589	min.	.108	mean.	1.251
nr. subfile :	15	chnl nr	4	max.	2.824	min.	-.154	mean.	1.062
nr. subfile :	15	chnl nr	5	max.	51.714	min.	-30.609	mean.	4.265
nr. subfile :	15	chnl nr	6	max.	58.746	min.	11.005	mean.	34.616
nr. subfile :	15	chnl nr	7	max.	89.311	min.	-11.100	mean.	36.017
nr. subfile :	15	chnl nr	8	max.	21.168	min.	-7.799	mean.	6.908
nr. subfile :	17	chnl nr	1	max.	2.597	min.	-1.413	mean.	.583
nr. subfile :	17	chnl nr	2	max.	2.602	min.	-1.242	mean.	.704
nr. subfile :	17	chnl nr	3	max.	2.697	min.	-.345	mean.	.993
nr. subfile :	17	chnl nr	4	max.	2.834	min.	-.737	mean.	.899
nr. subfile :	17	chnl nr	5	max.	50.667	min.	-30.609	mean.	8.882
nr. subfile :	17	chnl nr	6	max.	67.772	min.	20.427	mean.	43.318
nr. subfile :	17	chnl nr	7	max.	94.603	min.	-9.262	mean.	39.011
nr. subfile :	17	chnl nr	8	max.	30.080	min.	-12.032	mean.	6.860
nr. subfile :	19	chnl nr	1	max.	2.383	min.	-.214	mean.	1.012
nr. subfile :	19	chnl nr	2	max.	2.611	min.	.055	mean.	1.109
nr. subfile :	19	chnl nr	3	max.	2.525	min.	.281	mean.	1.312
nr. subfile :	19	chnl nr	4	max.	2.309	min.	.284	mean.	1.229
nr. subfile :	19	chnl nr	5	max.	55.580	min.	-31.093	mean.	5.588
nr. subfile :	19	chnl nr	6	max.	50.671	min.	25.019	mean.	38.430
nr. subfile :	19	chnl nr	7	max.	78.652	min.	-11.320	mean.	30.956
nr. subfile :	19	chnl nr	8	max.	17.751	min.	-12.998	mean.	.836

ANNEX C7

filename S00MA205.DAT

nr. subfile :	14	chnl nr	1	max.	.633	min.	.015	mean.	.313
nr. subfile :	14	chnl nr	2	max.	.049	min.	-.752	mean.	-.336
nr. subfile :	14	chnl nr	3	max.	.638	min.	-.352	mean.	.205
nr. subfile :	14	chnl nr	4	max.	.775	min.	.038	mean.	.388
nr. subfile :	14	chnl nr	5	max.	6.926	min.	-13.386	mean.	-4.599
nr. subfile :	14	chnl nr	6	max.	15.282	min.	-2.936	mean.	6.337
nr. subfile :	14	chnl nr	7	max.	29.467	min.	-3.683	mean.	10.859
nr. subfile :	14	chnl nr	8	max.	.676	min.	-8.889	mean.	-2.333
nr. subfile :	15	chnl nr	1	max.	.623	min.	-.098	mean.	.253
nr. subfile :	15	chnl nr	2	max.	.252	min.	-.883	mean.	-.354
nr. subfile :	15	chnl nr	3	max.	.568	min.	-.322	mean.	.128
nr. subfile :	15	chnl nr	4	max.	.637	min.	-.038	mean.	.269
nr. subfile :	15	chnl nr	5	max.	9.106	min.	-12.841	mean.	-2.557
nr. subfile :	15	chnl nr	6	max.	18.519	min.	.000	mean.	9.362
nr. subfile :	15	chnl nr	7	max.	33.902	min.	-1.128	mean.	13.712
nr. subfile :	15	chnl nr	8	max.	6.102	min.	-3.842	mean.	2.234
nr. subfile :	16	chnl nr	1	max.	.766	min.	-.113	mean.	.272
nr. subfile :	16	chnl nr	2	max.	.194	min.	-.912	mean.	-.303
nr. subfile :	16	chnl nr	3	max.	.739	min.	-.613	mean.	.055
nr. subfile :	16	chnl nr	4	max.	.485	min.	-.304	mean.	.097
nr. subfile :	16	chnl nr	5	max.	6.460	min.	-12.763	mean.	-2.713
nr. subfile :	16	chnl nr	6	max.	19.046	min.	-.903	mean.	7.582
nr. subfile :	16	chnl nr	7	max.	35.931	min.	-2.105	mean.	12.858
nr. subfile :	16	chnl nr	8	max.	6.930	min.	-2.109	mean.	2.072
nr. subfile :	17	chnl nr	1	max.	.883	min.	-.319	mean.	.261
nr. subfile :	17	chnl nr	2	max.	.136	min.	-1.048	mean.	-.311
nr. subfile :	17	chnl nr	3	max.	1.201	min.	-.723	mean.	.161
nr. subfile :	17	chnl nr	4	max.	.500	min.	-.271	mean.	.229
nr. subfile :	17	chnl nr	5	max.	7.393	min.	-12.608	mean.	-2.590
nr. subfile :	17	chnl nr	6	max.	21.530	min.	.452	mean.	7.558
nr. subfile :	17	chnl nr	7	max.	37.811	min.	-1.579	mean.	12.923
nr. subfile :	17	chnl nr	8	max.	8.211	min.	-1.205	mean.	2.408
nr. subfile :	18	chnl nr	1	max.	.623	min.	-.108	mean.	.282
nr. subfile :	18	chnl nr	2	max.	.150	min.	-1.086	mean.	-.292
nr. subfile :	18	chnl nr	3	max.	.914	min.	-1.020	mean.	.137
nr. subfile :	18	chnl nr	4	max.	.652	min.	-.114	mean.	.280
nr. subfile :	18	chnl nr	5	max.	5.681	min.	-11.907	mean.	-3.656
nr. subfile :	18	chnl nr	6	max.	20.401	min.	-.452	mean.	7.410
nr. subfile :	18	chnl nr	7	max.	38.637	min.	.075	mean.	14.391
nr. subfile :	18	chnl nr	8	max.	8.437	min.	.226	mean.	2.671
nr. subfile :	19	chnl nr	1	max.	.761	min.	-.265	mean.	.288
nr. subfile :	19	chnl nr	2	max.	.121	min.	-1.057	mean.	-.277
nr. subfile :	19	chnl nr	3	max.	.995	min.	-1.216	mean.	.060
nr. subfile :	19	chnl nr	4	max.	.737	min.	-.338	mean.	.192
nr. subfile :	19	chnl nr	5	max.	7.393	min.	-11.440	mean.	-3.070
nr. subfile :	19	chnl nr	6	max.	20.853	min.	-2.785	mean.	6.502
nr. subfile :	19	chnl nr	7	max.	39.164	min.	-1.954	mean.	13.588
nr. subfile :	19	chnl nr	8	max.	9.491	min.	.527	mean.	3.848
nr. subfile :	20	chnl nr	1	max.	.957	min.	-.638	mean.	.237
nr. subfile :	20	chnl nr	2	max.	.223	min.	-1.159	mean.	-.303
nr. subfile :	20	chnl nr	3	max.	.713	min.	-1.166	mean.	-.001
nr. subfile :	20	chnl nr	4	max.	.847	min.	-.509	mean.	.096
nr. subfile :	20	chnl nr	5	max.	7.082	min.	-10.662	mean.	-2.491
nr. subfile :	20	chnl nr	6	max.	23.864	min.	-1.506	mean.	8.177
nr. subfile :	20	chnl nr	7	max.	42.847	min.	-1.052	mean.	14.891
nr. subfile :	20	chnl nr	8	max.	10.621	min.	.603	mean.	4.343

ANNEX C8

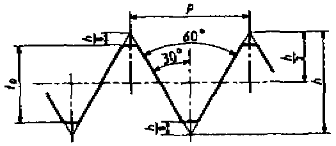
```
filename S00MA404.DAT
nr. subfile : 14 chnl nr 1 max. .925 min. -1.742 mean. -.469
nr. subfile : 14 chnl nr 2 max. 1.037 min. -.171 mean. .419
nr. subfile : 14 chnl nr 3 max. .967 min. .134 mean. .582
nr. subfile : 14 chnl nr 4 max. 1.067 min. -.310 mean. .413
nr. subfile : 14 chnl nr 5 max. 22.258 min. -18.055 mean. -2.944
nr. subfile : 14 chnl nr 6 max. 22.358 min. 2.409 mean. 12.437
nr. subfile : 14 chnl nr 7 max. 51.040 min. -4.285 mean. 20.197
nr. subfile : 14 chnl nr 8 max. 13.258 min. -3.239 mean. 4.051
nr. subfile : 15 chnl nr 1 max. 1.108 min. -1.304 mean. -.182
nr. subfile : 15 chnl nr 2 max. .986 min. -.221 mean. .375
nr. subfile : 15 chnl nr 3 max. 1.029 min. .062 mean. .539
nr. subfile : 15 chnl nr 4 max. 1.249 min. -.292 mean. .402
nr. subfile : 15 chnl nr 5 max. 20.235 min. -18.600 mean. -3.140
nr. subfile : 15 chnl nr 6 max. 21.831 min. 2.409 mean. 12.143
nr. subfile : 15 chnl nr 7 max. 53.596 min. -3.608 mean. 21.990
nr. subfile : 15 chnl nr 8 max. 14.162 min. -2.335 mean. 4.789
nr. subfile : 16 chnl nr 1 max. 1.175 min. -1.251 mean. .097
nr. subfile : 16 chnl nr 2 max. 1.429 min. -.544 mean. .321
nr. subfile : 16 chnl nr 3 max. 1.335 min. -.096 mean. .523
nr. subfile : 16 chnl nr 4 max. 1.117 min. -.588 mean. .353
nr. subfile : 16 chnl nr 5 max. 13.230 min. -18.133 mean. -4.105
nr. subfile : 16 chnl nr 6 max. 26.273 min. -.527 mean. 12.994
nr. subfile : 16 chnl nr 7 max. 61.715 min. -.301 mean. 25.299
nr. subfile : 16 chnl nr 8 max. 19.887 min. -2.260 mean. 6.637
nr. subfile : 17 chnl nr 1 max. .902 min. -1.613 mean. .528
nr. subfile : 17 chnl nr 2 max. 1.429 min. -.567 mean. .281
nr. subfile : 17 chnl nr 3 max. 1.221 min. -.153 mean. .501
nr. subfile : 17 chnl nr 4 max. 1.108 min. -.625 mean. .289
nr. subfile : 17 chnl nr 5 max. 18.989 min. -20.157 mean. -2.764
nr. subfile : 17 chnl nr 6 max. 26.574 min. .678 mean. 13.258
nr. subfile : 17 chnl nr 7 max. 62.166 min. -1.654 mean. 25.246
nr. subfile : 17 chnl nr 8 max. 20.640 min. -1.582 mean. 7.661
nr. subfile : 18 chnl nr 1 max. 1.157 min. -.983 mean. -.007
nr. subfile : 18 chnl nr 2 max. 1.226 min. -.272 mean. .327
nr. subfile : 18 chnl nr 3 max. 1.254 min. -.005 mean. .546
nr. subfile : 18 chnl nr 4 max. 1.341 min. -.556 mean. .354
nr. subfile : 18 chnl nr 5 max. 22.492 min. -20.857 mean. -2.666
nr. subfile : 18 chnl nr 6 max. 24.617 min. 3.613 mean. 14.152
nr. subfile : 18 chnl nr 7 max. 56.528 min. -2.706 mean. 24.355
nr. subfile : 18 chnl nr 8 max. 16.422 min. -2.034 mean. 6.289
nr. subfile : 19 chnl nr 1 max. 1.255 min. -1.023 mean. .008
nr. subfile : 19 chnl nr 2 max. 1.032 min. -.309 mean. .364
nr. subfile : 19 chnl nr 3 max. .976 min. .101 mean. .588
nr. subfile : 19 chnl nr 4 max. 1.423 min. -.570 mean. .370
nr. subfile : 19 chnl nr 5 max. 19.768 min. -20.935 mean. -3.290
nr. subfile : 19 chnl nr 6 max. 23.186 min. 4.818 mean. 14.102
nr. subfile : 19 chnl nr 7 max. 55.024 min. -2.631 mean. 24.813
nr. subfile : 19 chnl nr 8 max. 13.484 min. -.904 mean. 5.627
nr. subfile : 20 chnl nr 1 max. 1.224 min. -.777 mean. .080
nr. subfile : 20 chnl nr 2 max. .903 min. -.161 mean. .403
nr. subfile : 20 chnl nr 3 max. .957 min. -.062 mean. .578
nr. subfile : 20 chnl nr 4 max. 1.400 min. -.260 mean. .439
nr. subfile : 20 chnl nr 5 max. 16.732 min. -21.480 mean. -3.217
nr. subfile : 20 chnl nr 6 max. 22.132 min. 5.194 mean. 13.498
nr. subfile : 20 chnl nr 7 max. 54.348 min. -1.954 mean. 23.171
nr. subfile : 20 chnl nr 8 max. 11.827 min. -1.205 mean. 4.316
```

NED. MIJ. VOOR NIJVERHEID EN HANDEL | KON. INSTITUUT VAN INGENIEURS

NEDERLANDS NORMALISATIE-INSTITUUT

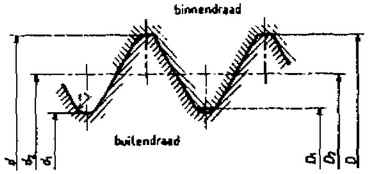
De metrische schroefdraden M1,7; M2,3 en M2,6 volgens deze norm worden internationaal door ISO [1]) niet aanbevolen.
Aanbevolen wordt de metrische schroefdraad M1,6; M2,2 en M2,5 (ISO) volgens NEN 81-II te gebruiken, die wèl internationaal is aanvaard.

Basisprofiel



p = spoed
h = 0,866 025 p
t_0 = 0,6495 p
60° = tophoek
30° = flankhoek

Maximummateriaalprofielen



d = buitenmiddellijn, d_1 = kernmiddellijn, d_2 = flankmiddellijn, r_1 = afrondingsstraal kern 0,1082 p = 1/8 h — buitendraad

D = buitenmiddellijn, D_1 = kernmiddellijn, D_2 = flankmiddellijn — binnendraad

Maten in mm

aanduiding	p	$d = D$	$d_2 = D_2$	d_1	D_1
M 1,7	0,35	1,7	1,473	1,246	1,256
M 2,3	0,4	2,3	2,040	1,780	1,795
M 2,6	0,45	2,6	2,308	2,016	2,036

Toleranties

Voor toleranties zie NEN 3223.

Aanduiding

Metrische schroefdraad volgens deze norm wordt aangeduid door vermelding van de nominale middellijn, voorafgegaan door de profielletter M.

Voorbeeld: M 1,7

[1]) International Organization for Standardization

Metrische schroefdraad M1,7, M2,3 en M2,6

Nominale maten

Metric screw threads M1,7, M2,3 and M2,6. Basic dimensions

NEN 81-I

6e druk, juni 1968
gewijzigd

UDC 621.882.082

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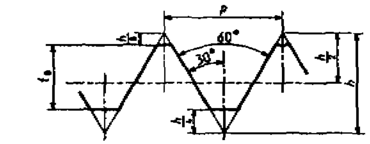
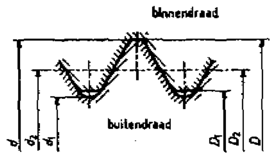
NEDERLANDS NORMALISATIE-INSTITUUT

Basisprofiel

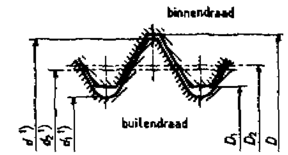


p = spoed
h = 0,866 025 p
t_0 = 0,541 266 p
60° = tophoek
30° = flankhoek

Maximummateriaalprofielen



zonder minimum-flankspeling
(passing H/h)



met minimum-flankspeling
(passing H/g)

d = buitenmiddellijn, d_1 = kernmiddellijn, d_2 = flankmiddellijn — buitendraad

D = buitenmiddellijn, D_1 = kernmiddellijn, D_2 = flankmiddellijn — binnendraad

Maten in mm

aanduiding	p	d [1]) = D	d_2 [1]) = D_2	d_1 [1])	D_1
M 1	0,25	1,000	0,838	0,693	0,729
M 1,1	0,25	1,100	0,938	0,793	0,829
M 1,2	0,25	1,200	1,038	0,893	0,929
M 1,4	0,3	1,400	1,205	1,032	1,075
M 1,6	0,35	1,600	1,373	1,171	1,221
M 1,8	0,35	1,800	1,573	1,371	1,421
M 2	0,4	2,000	1,740	1,509	1,567
M 2,2	0,45	2,200	1,908	1,648	1,713
M 2,5	0,45	2,500	2,208	1,948	2,013
M 3	0,5	3,000	2,675	2,387	2,459
M 3,5	0,6	3,500	3,110	2,764	2,850
M 4	0,7	4,000	3,545	3,141	3,242
M 4,5	0,75	4,500	4,013	3,580	3,688
M 5	0,8	5,000	4,480	4,019	4,134
M 6	1	6,000	5,350	4,773	4,917
M 7	1	7,000	6,350	5,773	5,917
M 8	1,25	8,000	7,188	6,466	6,647
M 9	1,25	9,000	8,188	7,466	7,647
M 10	1,5	10,000	9,026	8,160	8,376
M 11	1,5	11,000	10,026	9,160	9,376
M 12	1,75	12,000	10,863	9,853	10,106
M 14	2	14,000	12,701	11,546	11,835
M 16	2	16,000	14,701	13,546	13,835
M 18	2,5	18,000	16,376	14,933	15,294
M 20	2,5	20,000	18,376	16,933	17,294
M 22	2,5	22,000	20,376	18,933	19,294
M 24	3	24,000	22,051	20,319	20,752

Metrische schroefdraad (ISO)

Grove spoed

Nominale maten

ISO Metric screw thread. Coarse pitch. Basic dimensions

NEN 81-II

2e druk, juni 1968
gewijzigd

UDC 621.882.082

ANNEX D1

Deze norm is opgesteld door commissie 86 (Schroefdraad).

aanduiding	p	d 1) = D	d_2 1) = D_2	d_1 1)	D_1
M 27	3	27,000	25,051	23,319	23,752
M 30	3,5	30,000	27,727	25,706	26,211
M 33	3,5	33,000	30,727	28,706	29,211
M 36	4	36,000	33,402	31,093	31,670
M 39	4	39,000	36,402	34,093	34,670
M 42	4,5	42,000	39,077	36,479	37,129
M 45	4,5	45,000	42,077	39,479	40,129
M 48	5	48,000	44,752	41,866	42,587
M 52	5	52,000	48,752	45,866	46,587
M 56	5,5	56,000	52,428	49,252	50,046
M 60	5,5	60,000	56,428	53,252	54,046
M 64	6	64,000	60,103	56,639	57,505
M 68	6	68,000	64,103	60,639	61,505

Gebruik bij voorkeur de vet gedrukte middellijnen.

1) De waarden van d, d_1 en d_2 gelden alleen voor de buitendraad zonder minimum-flankspeling. Voor de buitendraad met minimum-flankspeling zijn de waarden kleiner, zie NEN 3222.

Toleranties

Voor toleranties, zie NEN 3222.

De grootte van de tolerantie wordt aangegeven door een getal (tolerantieklasse), de ligging van het tolerantieveld door een letter, waarbij voor de buitendraad kleine letters en voor de binnendraad hoofdletters worden gebruikt. Voor algemeen gebruik wordt de tolerantieklasse 6 aanbevolen. Kleinere toleranties worden met een kleiner getal aangegeven, grotere toleranties met een groter getal. Voor de ligging van het tolerantieveld van de buitendraad worden de letters e, g en h onderscheiden en voor die van de binnendraad de letters G en H. Voor algemeen gebruik wordt de passing 6H/6g aanbevolen, voor middellijnen 1 tot en met 1,4 mm echter 5H/6h.

Aanduiding

Metrische schroefdraad (ISO) met grove spoed volgens deze norm wordt aangeduid door vermelding van de nominale middellijn, voorafgegaan door de profielletter M. Aan deze aanduiding dient na een koppelteken, de tolerantieklasse en de ligging van het tolerantieveld te worden toegevoegd.

Voorbeeld: M 6 – 6g

Opmerking
Indien geen tolerantieklasse is aangegeven, geldt
- voor middellijnen van 1 tot en met 1,4 mm:
  voor binnendraad de klasse 5H,
  voor buitendraad de klasse 6h;
- voor middellijnen boven 1,4 mm:
  voor binnendraad de klasse 6H,
  voor buitendraad de klasse 6g.

Opmerkingen

1. De 1e druk van deze norm is verschenen in juni 1964.
   Wijziging t.o.v. de 1e druk:
   De schroefdraad M0,25 t.m. M0,9 is vervallen en vervangen door de miniatuurschroefdraad volgens NEN 1920.
2. Deze norm is in overeenstemming met ISO Recommendation R 68 – Screw threads, en met Draft ISO Recommendation 782 – ISO metric screw threads, basic dimensions, diameter range 1.6 to 300 mm, van de International Organization for Standardization (ISO).

De normen en de catalogus van normen, alsmede inlichtingen hierover en over de normalisatie in het algemeen, zijn verkrijgbaar bij het Nederlands Normalisatie-instituut, Polakweg 5, Rijswijk (ZH), telefoon (070) 90 68 00*, postrekening 25301.

UDC 621.882.082.22

Bevestigingspijpschroefdraad

(niet-afdichtend)

Nominale maten

Fastening pipe thread. Basic dimensions

NEDERLANDSE NORM

NEN 176

5e druk, september 1972

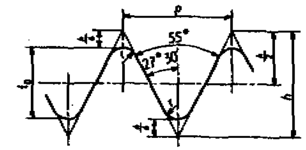
1. Onderwerp

Deze norm geeft de nominale maten voor de bevestigingspijpschroefdraad.

2. Toepassingsgebied

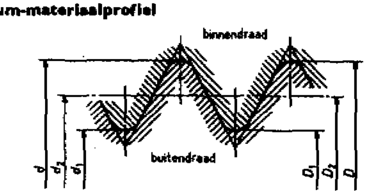
De norm is van toepassing op schroefdraad voor pijpvormige onderdelen en daarop aansluitende onderdelen met nominale doorlaten van 1/16 in tot en met 6 in, waarbij de afdichting niet op de schroefdraad plaats vindt.

3. Basisprofiel



h = 0,96049 p
t_1 = 0,64033 p
r = 0,13733 p
n = aantal gangen per inch
p = spoed = $\frac{25,4}{n}$

4. Maximum-materiaalprofiel



d = buitenmiddellijn, d_2 = flankmiddellijn, d_1 = kernmiddellijn } buitendraad

D = buitenmiddellijn, D_2 = flankmiddellijn, D_1 = kernmiddellijn } binnendraad

5. Nominale maten

Maten in mm, tenzij anders vermeld.

aanduiding	n	p	$d = D$	$d_2 = D_2$	$d_1 = D_1$
G 1/16	28	0,907	7,723	7,142	6,561
G 1/8	28	0,907	9,728	9,147	8,566
G 1/4	19	1,337	13,157	12,301	11,445
G 3/8	19	1,337	16,662	15,806	14,950
G 1/2	14	1,814	20,955	19,793	18,631
G 5/8	14	1,814	22,911	21,749	20,587
G 3/4	14	1,814	26,441	25,279	24,117
G 7/8	14	1,814	30,201	29,039	27,877
G 1	11	2,309	33,249	31,770	30,291
G 1 1/8	11	2,309	37,897	36,418	34,939
G 1 1/4	11	2,309	41,910	40,431	38,952
G 1 1/2	11	2,309	47,803	46,324	44,845
G 1 3/4	11	2,309	53,746	52,267	50,788
G 2	11	2,309	59,614	58,135	56,656
G 2 1/4	11	2,309	65,710	64,231	62,752
G 2 1/2	11	2,309	75,184	73,705	72,226
G 2 3/4	11	2,309	81,534	80,055	78,576
G 3	11	2,309	87,884	86,405	84,926

ANNEX D2

Basisprofiel cilindrische schroefdraad

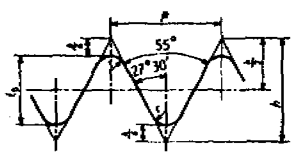


Fig. 1

p = spoed
n = aantal gangen per inch
h = 0,960 491 p
t_0 = 0,640 327 p
r = 0,137 329 p

Basisprofiel conische schroefdraad

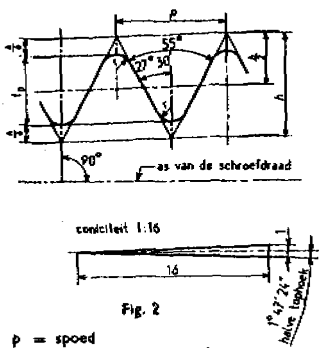


Fig. 2

p = spoed
n = aantal gangen per inch
h = 0,960 327 p
t_0 = 0,640 327 p
r = 0,137 278 p

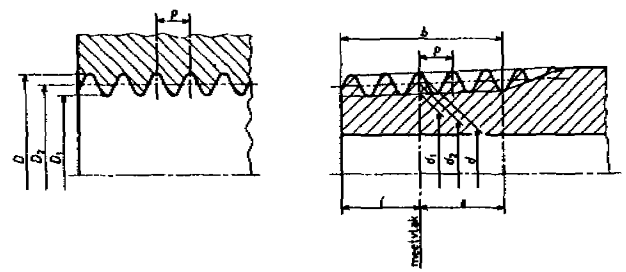


Fig. 3

a = nuttige inschroeflengte
b = bruikbare schroefdraadlengte
l = meetafstand
d = meetmiddellijn

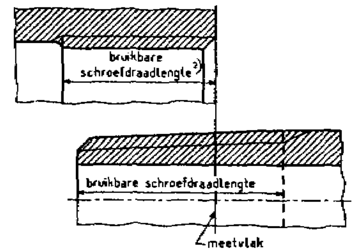


Fig. 4

Hoewel in bovenstaande figuur ter illustratie slechts één uitvoeringsvorm van binnen- en buitendraad is aangegeven, sluit dit andere uitvoeringsvormen niet uit.

n = aantal gangen per inch
p = spoed
t_0 = draaddiepte
d = buitenmiddellijn, d_1 = kernmiddellijn, d_2 = flankmiddellijn: conische buitendraad, in het meetvlak.
D = buitenmiddellijn, D_1 = kernmiddellijn, D_2 = flankmiddellijn: cilindrische binnendraad en conische binnendraad, in het meetvlak.

Maten in mm, tenzij anders vermeld.

1	2	3	4	5	6	7	8	9
nominale maat	n	p	t_0	middellijnen in het meetvlak			binnendraad	
				basiswaarden			maatafwijking[1]) op de ligging van het meetvlak	
in				$d = D$	$d_1 = D_1$	$d_2 = D_2$	mm ≈	aantal gangen
1/16	28	0,907	0,581	7,723	6,561	7,142	± 1,1	± 1 1/4
1/8	28	0,907	0,581	9,728	8,566	9,147	± 1,1	± 1 1/4
1/4	19	1,337	0,856	13,157	11,445	12,301	± 1,7	± 1 1/4
3/8	19	1,337	0,856	16,662	14,950	15,806	± 1,7	± 1 1/4
1/2	14	1,814	1,162	20,955	18,631	19,793	± 2,3	± 1 1/4
3/4	14	1,814	1,162	26,441	24,117	25,279	± 2,3	± 1 1/4
1	11	2,309	1,479	33,249	30,291	31,770	± 2,9	± 1 1/4
1 1/4	11	2,309	1,479	41,910	38,952	40,431	± 2,9	± 1 1/4
1 1/2	11	2,309	1,479	47,803	44,845	46,324	± 2,9	± 1 1/4
2	11	2,309	1,479	59,614	56,656	58,135	± 2,9	± 1 1/4
2 1/2	11	2,309	1,479	75,184	72,226	73,705	± 3,5	± 1 1/2
3	11	2,309	1,479	87,884	84,926	86,405	± 3,5	± 1 1/2
4	11	2,309	1,479	113,030	110,072	111,551	± 3,5	± 1 1/2
5	11	2,309	1,479	138,430	135,472	136,951	± 3,5	± 1 1/2
6	11	2,309	1,479	163 830	160,872	162,351	± 3,5	± 1 1/2

[1]) Voor verbindingen van cilindrische binnendraad met conische buitendraad gelden voor de middellijnen van de binnendraad toleranties die gelijk zijn aan 1/16 van de toleranties in de lengterichting, gegeven in kolom 9.

10	11	12	13	14	15	16	17	18	19
buitendraad									
l					b min.			a	
basis-waarde	maatafwijking		max.	min.	voor l =			≈	aantal gangen
	mm ≈	aantal gangen			basis-waarde	max. waarde	min. waarde		
4,0	± 0,9	± 1	4,9	3,1	6,5	7,4	5,6	2,5	2 3/4
4,0	± 0,9	± 1	4,9	3,1	6,5	7,4	5,6	2,5	2 3/4
6,0	± 1,3	± 1	7,3	4,7	9,7	11,0	8,4	3,7	2 3/4
6,4	± 1,3	± 1	7,7	5,1	10,1	11,4	8,8	3,7	2 3/4
8,2	± 1,8	± 1	10,0	6,4	13,2	15,0	11,4	5,0	2 3/4
9,5	± 1,8	± 1	11,3	7,7	14,5	16,3	12,7	5,0	2 3/4
10,4	± 2,3	± 1	12,7	8,1	16,8	19,1	14,5	6,4	2 3/4
12,7	± 2,3	± 1	15,0	10,4	19,1	21,4	16,8	6,4	2 3/4
12,7	± 2,3	± 1	15,0	10,4	19,1	21,4	16,8	6,4	2 3/4
15,9	± 2,3	± 1	18,2	13,6	23,4	25,7	21,1	7,5	3 1/4
17,5	± 3,5	± 1 1/2	21,0	14,0	26,7	30,2	23,2	9,2	4
20,6	± 3,5	± 1 1/2	24,1	17,1	29,8	33,3	26,3	9,2	4
25,4	± 3,5	± 1 1/2	28,9	21,9	35,8	39,3	32,3	10,4	4 1/2
28,6	± 3,5	± 1 1/2	32,1	25,1	40,1	43,6	36,6	11,5	5
28,6	+ 3,5	± 1 1/2	32,1	25,1	40,1	43,6	36,6	11,5	5

[2]) Onderdelen met binnendraad moeten zo zijn uitgevoerd en gedimensioneerd dat de pijpeinden kunnen worden ingeschroefd over een lengte als gegeven in kolom 16, waarbij de minimum bruikbare schroefdraadlengte (zie fig. 4) niet kleiner mag zijn dan 80% van de waarde in kolom 17.

ANNEX D3

Polyvinylchlorid (PVC)

Thermische Eigenschaften

Nr.	Eigenschaft	Einheit	Prüf-methode	PVC hart normal	PVC hart nachchloriert
1	Glasübergangstemperatur	°C	–	ca. 90	–
	obere Anwendungstemp.				
2	kurz	°C	–	70–80	bis 105
3	länger	°C	–	60–70	bis 90
4	Kältebruchtemperatur	°C	DIN 53372	–	–
5	Vicat-Erweichungspunkt 5 kg	°C	DIN 53460	70–90	105–110
	Formbeständigkeit in der				
6	Wärme Methode A	°C	ISO 75	60–72	102–104
7	Methode B	°C		62–78	114–116
8	spez. Wärmekapazität 20 °C	J/(g·K)	–	0,9–1,0	1,0
	lin. Wärmeausdehnungs-				
9	koeffizient	K^{-1}	–	$0{,}7–0{,}8 \cdot 10^{-4}$	$0{,}6 \cdot 10^{-4}$
10	Wärmeleitzahl	W/(m·K)	–	0,16	0,14
11	Entzündungstemperatur	°C	–	390 (FIT)	–
12		°C	–	455 (SIT)	–
13	Brennbarkeit	–	–	brennt in der Flamme, erlischt nach Entfernen der Zündquelle (schwerentflammbar). Flamme gelb-orange, in Gegenwart von Kupfer grün. Riecht stark nach Salzsäure.	
14	Verbrennungswärme	kJ/g	–	18	

Enthalpietabellen (Richtwerte für PVC hart und PVC weich) in J/g

	Temperatur in °C 20	40	60	80	100	120
PVC hart	0	20	42	68	96	125
PVC weich mit DOP (80:20)	0	26	57	87	118	153
PVC weich mit DOP (70:30)	0	30	60	92	124	160

p, v, T-Diagramm für Polyvinylchlorid hart (spez. Volumen in cm^3/g)*

Temperatur °C	Druck in bar 1	200	400	600	1000	1600	
35	0,70791	0,70468	0,70202	0,69925	0,69383	0,68546	
65	0,71270	0,70769	0,70498	0,70193	0,69563	0,68684	
85	0,71609	0,71045	0,70709	0,70316	0,69587	0,68747	PVC hart
120	0,72699	0,71710	0,71230	0,70627	0,69800	0,68849	
140	0,73381	0,72465	0,71812	0,71224	0,70113	0,68892	
160	0,72639	0,71578	0,70688	0,70212	0,70626	0,69393	
200	0,75485	0,74468	0,73506	0,72776	0,71653	0,70309	

* Abkühlgeschwindigkeit 2 K/s

Polyvinylchlorid (PVC)

Thermische Eigenschaften

Nr.	Schlagzähe Typen a_K 5–10	Schlagzähe Typen a_K 30–50	PVC weich, mit DOP 80/20	PVC weich, mit DOP 60/40	Copolymer mit VA
1	ca. 90	ca. 90	ca. 50	ca. 0	ca. 80
2	ca. 70	ca. 70	–	–	60–70
3	ca. 60	ca. 60	–	–	50–60
4	–	–	0 bis –5	–30 bis –35	–
5	ca. 80	ca. 75	ca. 42	–	70–80
6	bis 69	<68	–	–	–
7	bis 73	–	–	–	–
8	0,25	0,25	–	–	0,22
9	$0{,}8 \cdot 10^{-4}$	$0{,}8 \cdot 10^{-4}$	–	–	$0{,}8 \cdot 10^{-4}$
10	0,14	0,14	ca. 0,13	ca. 0,13	0,14
11	–	–	–	–	–
12	–	–	–	–	–
13	wie PVC hart		brennt stark rußend; flammhemmende Einstellungen z. B. durch Weichmachung mit Phosphorsäureestern		wie PVC hart
14	–		–		–

Elektrische Eigenschaften

Eigenschaft	Einheit	Prüf-methode	PVC (S) hart (ungefärbt)	PVC weich mit DOP 80/20	PVC weich mit DOP 60/40
Spez. Durchgangswiderst.	Ohm·cm	DIN 53482	$>10^{16}$	ca. 10^{15}	$5 \cdot 10^{13}$
Oberflächenwiderstand	Ohm	DIN 53482	ca. 10^{13}	ca. 10^{12}	ca. 10^{11}
Durchschlagfestigkeit (1 mm dicke Proben)	kV/mm	DIN 53481	40–50	32–34	24–26
Dielektrizitätszahl 50 Hz	–	DIN 53483	3,2–3,7	4,2	7,5–8,0
800 Hz	–	DIN 53483	3,0–3,5	3,6	6,2–6,4
10^6 Hz	–	DIN 53483	2,9–3,2	3,2	4,0–4,5
diel. Verlustfaktor 50 Hz	–	DIN 53483	0,011	0,08	0,08
800 Hz	–	DIN 53483	0,013	0,05	0,10
10^6 Hz	–	DIN 53483	0,015	0,03	0,12
Kriechstromfestigkeit	Stufe	DIN 53480	KA 2–36	–	–
	Stufe	DIN 53480	KC 300–>600	–	–

Optische Eigenschaften

Eigenschaft	Einheit	Prüf-methode	PVC (S) hart	PVC weich 80/20	PVC weich 60/40
Lichtdurchlässigkeit	–	–	opak bis glasklar	opak bis transparent	
Brechungszahl	–	DIN 53491	1,52–1,55	–	–

Polyvinylchlorid (PVC)

Mechanische Eigenschaften und Dichte

Nr.	Eigenschaft		Einheit	Prüfmethode DIN	PVC hart normal	PVC hart nachchloriert**
1	Dichte		g/cm³	53479	1,39	1,55
2	Streckspannung*		N/mm²	53455	55–70	75
3	Reißdehnung		%	53455	8–20	10–15
4	E-Modul (Zug)		N/mm²	53457	2800–3300	3000–3400
5	Grenzbiegespannung		N/mm²	53452	75–110	125
6	Biege-Kriechmodul	6 d	N/mm²	–	–	–
7	Kugeldruckhärte	30 s	N/mm²	53456	120–140	145–170
8	Shore-Härte		–	53505	D83–D85	D90
9	Schlagzähigkeit	23 °C	kJ/m²	53453	o. Bruch	o. Bruch
10		0 °C		53453	z.T. o. Bruch	o. Bruch**
11		−20 °C		53453	–	–
12		−40 °C		53453	–	–
13	Kerbschlagzähigkeit	23 °C	kJ/m²	53453	≥2	2 bis 3
14		0 °C		53453	z.T. ≥2	–
15		−20 °C		53453	–	–
16	IZOD-Kerbschlagzähigkeit		J/m	ASTM D256	35–85	–
17	Schlagzugzähigkeit	23 °C	kJ/m²	53448	–	–
18		0 °C		53448	–	–
19	Abriebfestigkeit n. Taber		mm³/1000 U	53754	250–360	–
20	Gleitreibungskoeffizient		–	–	ca. 0,6	–

Zugkriechmodul von PVC hart *(S-PVC, K-Wert ca. 60) bei 20 °C in N/mm²*

Temperatur °C	Prüfspannung N/mm²	Beanspruchungsdauer 1 h	100 h	1000 h	10000 h
20	10	3300	3100	2800	1900
	20	3200	3000	2600	1700
	30	3000	2600	2000	1400
	40	2400	1900	–	–
45	10	2200	1200	900	700
60	10	800	300	–	–

Biege-Kriechmodul von PVC schlagzäh (a_K = 8 kJ/m²) Randfaserspannung 10 N/mm²

Temperatur °C	Beanspruchungsdauer 1 h	100 h	1000 h	10000 h
20	2500	2300	2200	2100
40	2400	2000	1700	1200
60	2000	1200	500	–

* im allgemeinen bei PVC identisch mit der Zugfestigkeit
** einschließlich erhöht schlagzäher PVCC-Typen

Polyvinylchlorid (PVC)

Mechanische Eigenschaften und Dichte

Nr.	Schlagzähe Typen a_K 5–20*	Schlagzähe Typen a_K >20**	PVC weich, mit DOP 80/20	PVC weich, mit DOP 60/40	Copolymer mit VA
1	1,38	1,38	1,28	1,19	1,30–1,35
2	46–52	40–48	25–28	16–16	ca. 60
3	20–70	30–100	170–200	370–400	ca. 50
4	2200–2600	1800–2600	–	–	
5	80–85	70–80	22	3	
6	ca. 2000	ca. 2000	–	–	
7	95–100	80–100	–	–	ca. 90
8	D80–D81	D75–D81	A95–A97	A74–A76	
9	ohne Bruch	ohne Bruch	ohne Bruch	ohne Bruch	ohne Bruch
10	ohne Bruch	ohne Bruch	ohne Bruch	ohne Bruch	
11	ohne Bruch	ohne Bruch	ohne Bruch	ohne Bruch	
12	50 bis o. Bruch	ohne Bruch	–	–	
13	5–10	30–50	3–4	ohne Bruch	ca. 2
14	3–6	7–10	–	–	
15	2,5–3	4–6	2–2,5	ohne Bruch	
16	100–160	530–1300	–	–	
17	ca. 600	ca. 800	–	–	
18	200–300	ca. 600	–	–	
19	ca. 400	–	–	–	
20	–	–	–	–	

Zeitstandfestigkeit von PVC hart (S-PVC, K-Wert ca. 60) bei 20 °C in N/mm²

Temperatur °C	Belastungsdauer 0,1 h	1 h	10 h	100 h	1000 h
20	5–6	4,8–5	4,3–4,6	4,1–4,3	ca. 4

Schubmodul G in N/mm² und mechanischer Verlustfaktor tan δ in Abhängigkeit von der Temperatur

Temperatur °C	PVC hart (K-Wert 62) G	PVC hart (K-Wert 62) tan δ	PVC hochschlagzäh G	PVC hochschlagzäh tan δ	PVC weich (DOP) 70:30 G	PVC weich (DOP) 70:30 tan δ
−160	2100	0,007	–	–	2100	–
−120	2000	0,009	–	–	2000	0,01
− 80	1800	0,025	–	–	1800	0,015
− 40	1600	0,040	1300	0,040	1200	0,04
0	1300	0,030	1100	0,033	350	0.3
+ 20	1200	0,016	1000	0,02	70	0.5
+ 40	1150	0,012	900	0,02	<10	0.3
+ 60	1000	0,020	800	0,035	<2	0,12
+ 80	500	0,5	500	0,2	–	0,06
+100	4	0,3	<10	0,3	–	0,04

* erhöht schlagzäh; ** hochschlagzäh

SWN(81) trekstang Ø10

AUSTENITISCH ROESTVAST STAAL

Werkstofnummer: 1.4301 - AISI 304

Algemeen

Een chemisch bestendig staal, goed geschikt voor dieptrekwerk. Het is volkomen roestvast na blankbeitsen en slijpen resp. polijsten en kan toegepast worden bij temperaturen tot 300°C.
Het is daarom een roestvast staal dat in zeer veel gevallen toegepast kan worden, zoals in de levensmiddelenindustrie, in de chemische industrie, in de bouwindustrie, voor huishoudelijke apparaten en voor het vervaardigen van niet snijdende chirurgische instrumenten.

Chemische samenstelling

Koolstof C %	Silicium Si %	Mangaan Mn %	Chroom Cr %	Nikkel Ni %
≤ 0,06	≤ 1,0	≤ 2,0	17-20	9-11,5

Mechanische eigenschappen bij kamertemperatuur

Toestand	Trekvastheid N/mm²	Vloeigrens N/mm² min.	Rek L = 5d min. %	Brinell hardheid	Kerfslag waarde DVM min. J
Afgeschrikt	500-700	185	50	130-180	85

Sterkte-eigenschappen bij verhoogde temperaturen

Richtwaarden in N/mm² voor de 0,2% rekgrens en 1% rekgrens bij °C.

Rekgrens	50°	100°	150°	200°	250°	300°	350°	400°	450°	500°	550°
0,2%	175	155	140	127	118	110	104	98	95	92	90
1 %	210	190	170	155	145	135	129	125	122	120	120

Warmtebehandeling

Warmvervormen : 1150-750°C.
Afkoelen in lucht.
Afschrikken : 1000-1050°C.
Afkoelen in water of blaaswind.
Structuur na afschrikken : Austeniet.

Lasbaarheid

Aanbevolen laselektroden/lasdraden
Elektroden : V2A-4302 Ti
V2A NK-4316 Ti
V2A-4302 KHL
V2AX-4551 Ti
V2AX-4551 KHL
Lasdraden : Novonit 4316

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4 **Boormaten voor metrische schroefdraad (ISO) grof volgens NEN 81**

Tabel 2

Maten in mm

schroefdraad-middellijn	spoed	kernmiddellijn binnendraad (volgens NEN 3222, klasse 6H)		boormaat
		min.	max.	
M 1	0,25	0,729	0,785[2])	0,75
M 1,1	0,25	0,829	0,885[2])	0,85
M 1,2	0,25	0,929	0,985[2])	0,95
M 1,4	0,3	1,075	1,160[2])	1,1
M 1,6	0,35	1,221	1,321	1,25
M 1,8	0,35	1,421	1,521	1,45
M 2	0,4	1,567	1,679	1,6
M 2,2	0,45	1,713	1,838	1,75
M 2,5	0,45	2,013	2,138	2,05
M 3	0,5	2,459	2,599	2,5
M 3,5	0,6	2,850	3,010	2,9
M 4	0,7	3,242	3,422	3,3
M 4,5	0,75	3,688	3,878	3,7
M 5	0,8	4,134	4,334	4,2
M 6	1	4,917	5,153	5
M 7	1	5,917	6,153	6
M 8	1,25	6,647	6,912	6,8
M 9	1,25	7,647	7,912	7,8
M 10	1,5	8,376	8,676	8,5
M 11	1,5	9,376	9,676	9,5
M 12	1,75	10,106	10,441	10,2
M 14	2	11,835	12,210	12
M 16	2	13,835	14,210	14
M 18	2,5	15,294	15,744	15,5
M 20	2,5	17,294	17,744	17,5
M 22	2,5	19,294	19,744	19,5
M 24	3	20,752	21,252	21
M 27	3	23,752	24,252	24
M 30	3,5	26,211	26,771	26,5
M 33	3,5	29,211	29,771	29,5
M 36	4	31,670	32,270	32
M 39	4	34,670	35,270	35
M 42	4,5	37,129	37,779	37,5
M 45	4,5	40,129	40,799	40,5
M 48	5	42,587	43,297	43
M 52	5	46,587	47,297	47
M 56	5,5	50,046	50,796	50,5
M 60	5,5	54,046	54,796	54,5[1])
M 64	6	57,505	58,305	58
M 68	6	61,505	62,305	62

[1]) Dit is een niet-genormaliseerde boormaat.
[2]) M 1 t.m. M 1,4 klasse 5H.

5 **Boormaten voor metrische schroefdraad, internationaal niet aanbevolen, volgens NEN 81**

Tabel 3

Maten in mm

schroefdraad-middellijn	spoed	kernmiddellijn binnendraad (volgens NEN 3222)		boormaat
		min.	max.	
M 1,7	0,35	1,256	1,346	1,3
M 2,3	0,4	1,795	1,920	1,9
M 2,6	0,45	2,036	2,176	2,1

TABLE 1 Characteristics and Typical Applications of Certain Grades of Stainless Steel Wire

302 and 302 HQ	Good corrosion resistance, a basic general-purpose type. Can be cold-worked to high tensile strength. Good cold-heading properties. For fasteners with simple head design, springs, food processing equipment.
304	Low carbon variation of 302. Work hardens rapidly. High corrosion resistance, i.e., nitric acid. Good cold-heading properties; for fasteners with simple head design, circuitboard nests, safety lock wire.
305	Lower work-hardening rate than 302, 304; good for severe cold-heading in multiple stage and for thread rolling. Work hardens rapidly. Resists corrosion in severe atmosphere, nitric acid, foodstuffs. For instruments, low magnetic parts.
316	Higher corrosion and pitting resistance than 304. Good strength at high temperatures. Work hardens rapidly. Good cold-heading properties. For fasteners in chemical processing industries, screens for marine use.
321 and 347	Stabilized to permit use in 800–1500°F (425–815°C) range. Work hardens rapidly at room temperature. Has superior resistance to intergranular corrosion. Used for aircraft fasteners, rocket engine parts, furnace parts.
410	A general-purpose, low-cost alloy used where corrosion is moderate. Cold-worked with good results. Heat-treatable. Used for sheet metal screws, bolts, fasteners, springs, pump parts.
430	Good corrosion, heat resistance. Excellent cold-working results. Economical where corrosion is mild. Low work hardening. For all types of fasteners, particularly for recessed heads. Can be upset as much as 3½:1. Resists mild acids and water. For decorative parts.
431	Best corrosion resistance of standard chromium types. Heat treatable for high mechanical properties. For marine and aircraft fasteners.