Voluntary Closing Hook Prosthesis

Jasper Feijtel
December 1998
T-851

Faculty of Design, Engineering & Production
Mechanical Engineering and Marine Technology
Man-Machine Systems & Control

TU Delft
Delft University of Technology

Titel: Voluntary Closing Hook Prosthesis

Auteur: J. Feijtel

Datum: december 1998

Verslag nummer: T-851

Aantal pagina's: 45

Instelling: Technische Universiteit Delft
Faculteit Ontwerp, Constructie & Produktie
Werktuigbouwkunde & Maritieme Techniek
Mens-Machine Systemen

Begeleiders: Ir. Just L. Herder
Ir. Dick H. Plettenburg
Ing. André A. M. Sol

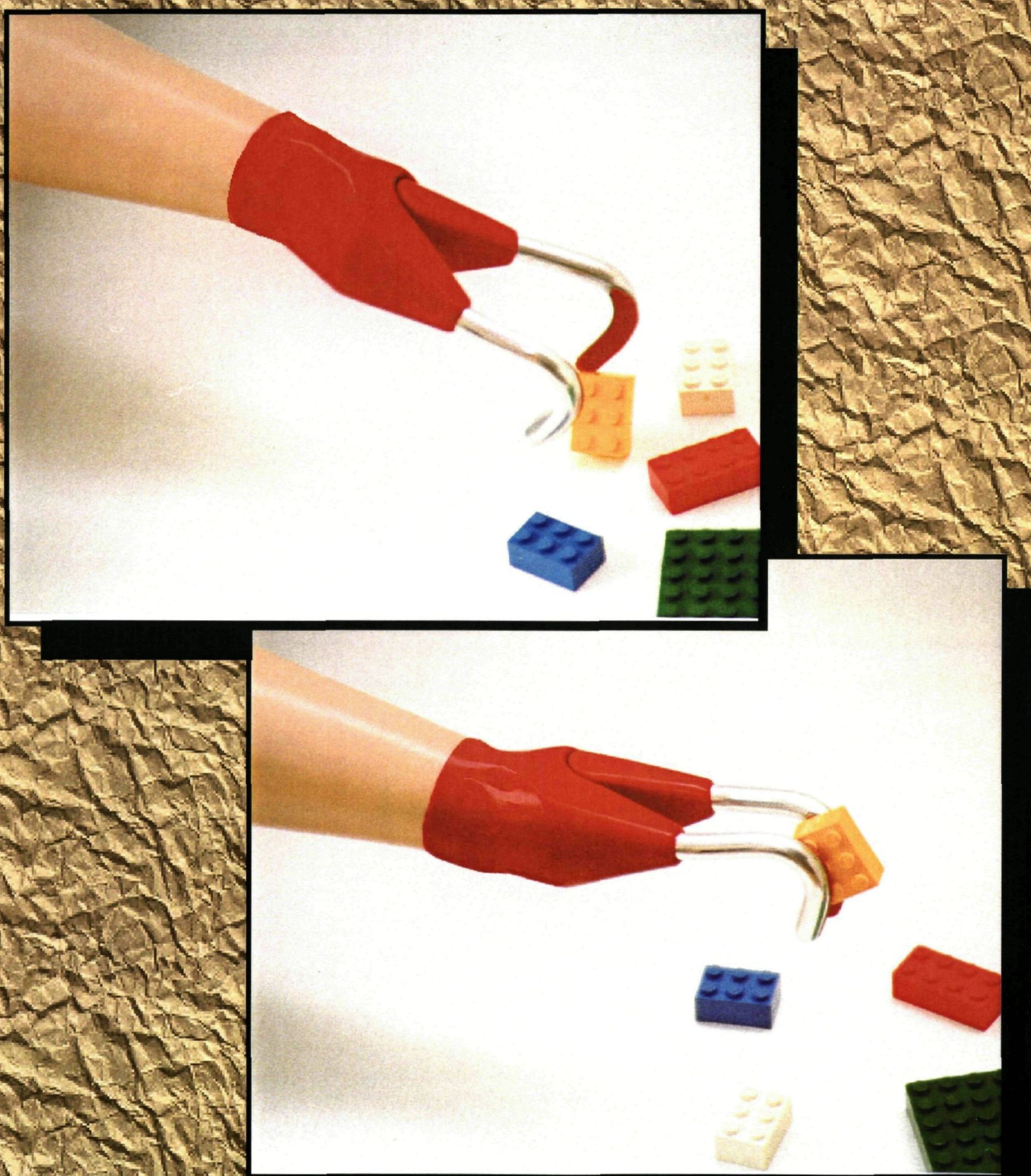
Abstract:

The Wilmer Rotational Instant Seizing Tentacle (WRIST) is a Voluntary Closing (VC) hook prosthesis for transradial amputees, developed by the WILMER Group at the Delft University of Technology in the Netherlands. Dissatisfaction with the currently used body-powered arm prostheses, expressed by patients and members of the WILMER group, led to a study devoted to the design of a new kind of VC arm prosthesis. This research resulted in a prototype of the WRIST which is neither elbow nor shoulder controlled.

The WRIST consists of a two-fingered hook connected to a socket by a hinge. The distance between the hook fingers is related to the manually adjustable hook-socket angle in a way that dorsal flexion of the hook results in grasping. This provides the concept with some unique features: any pinching force can be locked to prevent fatigue, the hook can be closed at all times, and the system does not require a harness or operating cables. This improves cosmetics and comfort as well as functionality.

Key words: body powered prostheses, children, transradial amputations, voluntary closing hook prostheses.

VOLUNTARY CLOSING HOOK PROSTHESIS



Jasper Feijtel

CONTENTS

The Author

Name : Jasper Feijtel
Student no. : 239562
No. of exam : T-851
Guidance : Just L. Herder
Dick H. Plettenburg
André A. M. Sol

Personal note

The author would like to thank: all members of the WILMER group for lending a hand, especially Just, Dick and André, for their unbridled enthusiasm and support, John and Ad for their excellent job in making the WRIST components, my parents, my sister Nadja, Arina, Evert, Ad, Gemma, Sherriff and Astrid for being there when I needed them.

Voluntary Closing Hook Prosthesis

Jasper Feijtel, Dick H. Plettenburg, Just L. Herder, André A. M. Sol
WILMER group, Man-Machine Systems & Control, Department of Design, Engineering & Production
Delft University of Technology, The Netherlands

Abstract—The Wilmer Rotational Instant Seizing Tentacle (WRIST) is a Voluntary Closing (VC) hook prosthesis for transradial amputees, developed by the WILMER Group at the Delft University of Technology in the Netherlands. Dissatisfaction with the currently used body-powered arm prostheses, expressed by patients and members of the WILMER group, led to a study devoted to the design of a new kind of VC arm prosthesis. This research resulted in a prototype of the WRIST which is neither elbow nor shoulder controlled.

The WRIST consists of a two-fingered hook connected to a socket by a hinge. The distance between the hook fingers is related to the manually adjustable hook-socket angle in a way that dorsal flexion of the hook results in grasping. This provides the concept with some unique features: any pinching force can be locked to prevent fatigue, the hook can be closed at all times, and the system does not require a harness or operating cables. This improves cosmetics and comfort as well as functionality.

Key words: body powered prostheses, children, transradial amputations, voluntary closing hook prostheses.

This material is based upon work supported by the WILMER Group of the Delft University of Technology, Delft, The Netherlands.

Address all correspondence and requests for reprints to:
A.A.M. Sol, WILMER Group, Delft University of Technology, Department of Design, Engineering & Production, Man-Machine Systems & Control,
Mekelweg 2, 2628 CD Delft, The Netherlands; email: a.a.m.sol@wbmt.tudelft.nl

BACKGROUND

The WILMER Group is a small section of the Laboratory for Man-Machine Systems & Control at the Delft University of Technology which is primarily concerned with the development of prosthetics and orthotics. The use of Thalidomide by pregnant women, as a tranquilizer or soporific in the late 50's, caused an increase in newborns with severe limb deformations. This increase resulted in a demand for better prostheses for children. In an attempt to fulfill this demand the WILMER Group specialized in child prosthetics about 30 years ago. In this period WILMER has been in touch with several Dutch rehabilitation centers and the parents of their young patients to find out what a better prosthesis should be like. This co-operation resulted in a list of wishes and demands concerning a new arm prosthesis, which formed the basis for further developments (1).

In these developments of body powered child prosthetics, the WILMER group shows a preference for Voluntary Closing hook prostheses. A hook is preferred over a hand with a cosmetic glove because it is more functional, more efficient with operating energy and less vulnerable. Voluntary Closing (VC) is preferred over Voluntary Opening (VO) because the VC principle is superior in two ways: it provides feedback of the pinching force and it has a correct physiological coupling of force (muscle force corresponds with pinching) (2). These two advantages highly improve controllability and acceptance of the prosthesis by the patient.

Despite of the superior principle of VC most prostheses currently used are VO. This is due to two major drawbacks of most VC models: pinching is fatiguing because it requires a continuous muscle force, and the hand prosthesis is opened at rest which makes it less appealing and less practical. To overcome these problems a new concept, named the WRIST (Wilmer Rotational Instant Seizing Tentacle), was developed at the Delft University of Technology.

PRODUCT DESCRIPTION

Working Principle

The WRIST is a body powered VC hook prosthesis, developed for transradial amputees, that has a rather unconventional way of controlling. It is neither elbow nor shoulder controlled so no harness or operating cables are required.

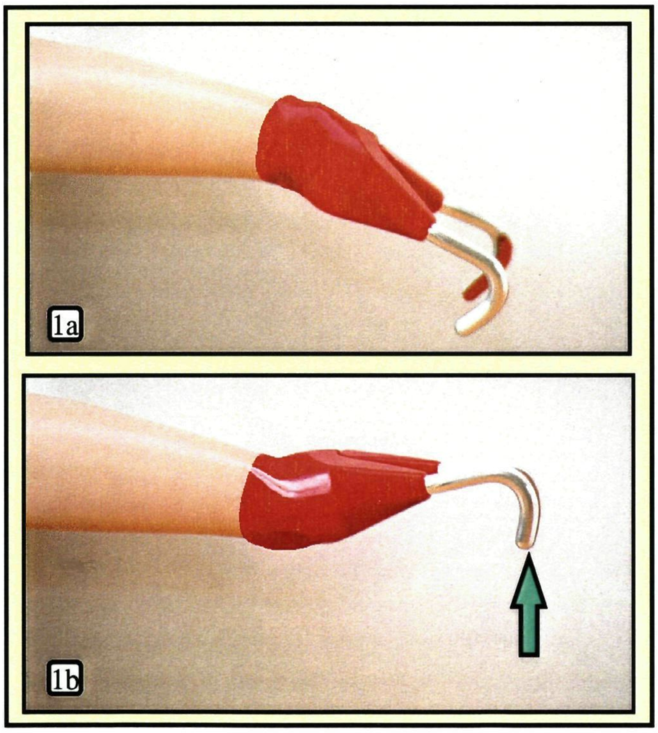


Figure 1.
Photograph of the Wrist in two positions (the cover is available in various colours to provide the hook with the looks of a toy (3)).

1a: The WRIST in its rest position.

1b: The WRIST will grasp and pinch when it is rotated about the hinge.

The basis of the WRIST is formed by a two-fingered hook connected to a socket by a hinge. The inside mechanism provides a linear relationship between the hook-socket angle and the distance between the hook fingers. This mechanism forces the hook to grasp and pinch when it is rotated about the hinge (**fig. 1a-b**). For a better understanding of the principle **figures 2a** and **2b** show a simplified cross sectional view of the WRIST. A wedging mechanism (for one way clutching) makes it possible to lock any desired pinching force by means of friction (4). A two-position switch, activated by further rotation of the hook, is used to unlock the pinching force and let the fingers return to the open position. In fact the mechanism is a bit more complex, as illustrated in **appendix A**.

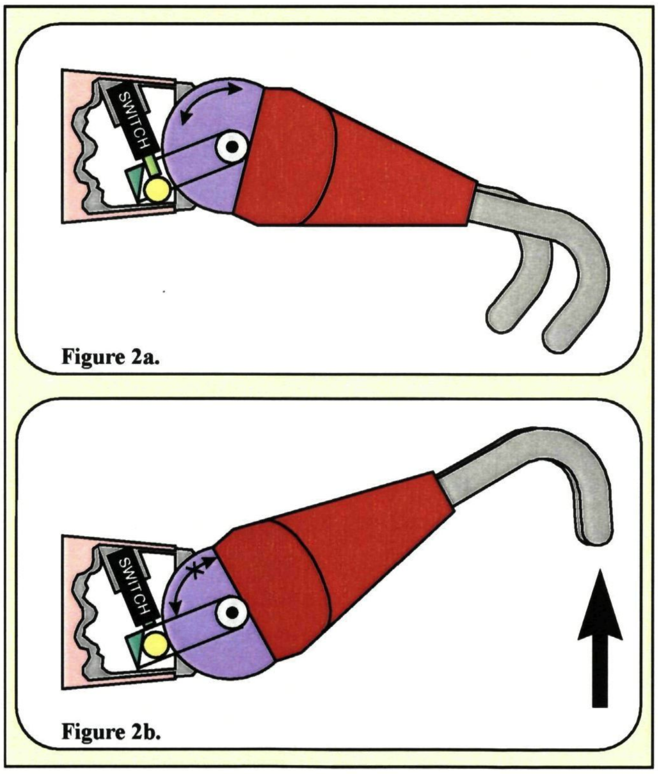


Figure 2.

2a: A simplified cross sectional view of the WRIST. The WRIST in its rest position (analogous to fig. 1a). The switch (out) prevents the yellow cylinder from wedging, so the hook can rotate freely in both directions.

2b: The WRIST will grasp and pinch when it is rotated about the hinge (analogous to fig. 1b). The switch is in, so the wedging mechanism prevents the hook from rotating clockwise and the pinching force will be retained.

Operating Principle

The animation of **figure 3** shows how to operate the WRIST in 7 steps. One operating cycle can be divided into 3 phases: phase 1: grasp an object, phase 2: hold the object, and phase 3: release the object.

In the first phase the sound hand places an object between the two hook fingers and imposes a rotation of the hook about the hinge. The hook will close, grasp the object between the fingers and pinch it (**fig. 3a-c**).

This pinching force, proportional with the operating force provided by the sound hand, will be retained automatically by a locking device as soon as the operating force is removed. The object can now be held without any muscle effort and with total freedom of movement (**fig. 3d**).

To unlock the grasp and release the object held, the sound hand has to provide the same operating force the hook was locked with, and it will open again (**fig. 3e-g**).

The operating force, in the example of figure 3 provided by the sound hand, can be a reaction force as well. For instance by pushing the hook on a table the fingers will close, grasp and hold the object in between in one simple movement. To let go of the object all that is needed is a second push on the table and the hook will open again. This makes it possible for the patient to actively grasp an object without any action from the sound hand. Independence of the patients amputated side will improve the acceptance of the prosthesis and stimulate the use of it, and keeping the sound hand free enables the patient to execute two-handed tasks which will increase his capability.

Properties

With its unconventional working principle and its automatic locking device the WRIST distinguishes itself from other VC arm prostheses. It lacks their main drawbacks and is provided with some unique features:

- the absence of operating cables and harness improves cosmetics and comfort.
- Any desired pinching force can be locked to prevent fatiguing.
- The hook can be closed when not in use to improve cosmetics and functionality.

The first mentioned feature is probably the most important of all. The presence of a harness (shoulder control), upper-arm shell (elbow control) and operating cable in conventional body powered arm prostheses can cause irritation of the skin, transpiration, damage to clothing and limitation of freedom of movement. Even of more importance, according to the young patients and their parents, are the looks of the prosthesis (1). Absence of harness and shell will improve the appearance of the patient and will contribute to a more natural pattern of movement.

The second feature of locking the pinching force not only prevents fatiguing, but retains the patient's freedom of movement as well. Unlike most elbow and shoulder controlled prostheses the WRIST has a pinching force that is independent of shoulder and elbow flexion, so the patient can hold an object without taking on any specific posture. For safety reasons the hook fingers are locked by means of a spring so the object can always be pulled out of the hook in case of an emergency.

The third and last feature takes care of the opened hook at rest. The hook can be closed at all times which makes it more appealing and a lot easier, for instance, to put on a sweater.

Additional information concerning the WRIST is provided by **table 1**.

Weight (without socket)	150 grams
Wrist Flexion	- 20° to + 30°
Operating Force:Pinching Force	1:1
Range of Pinching Force	0 to (10–20)* [N]
max. Hook Opening (adjustable)	45 mm
Axial Wrist Rotation	unlimited

* depending on object size

Table 1: technical specifications of the WRIST.

Notes:

—In the process of designing the first prototype, weight has not been a consideration. The weight mentioned in Table 1 can be reduced by approximately 50 % in a second version.

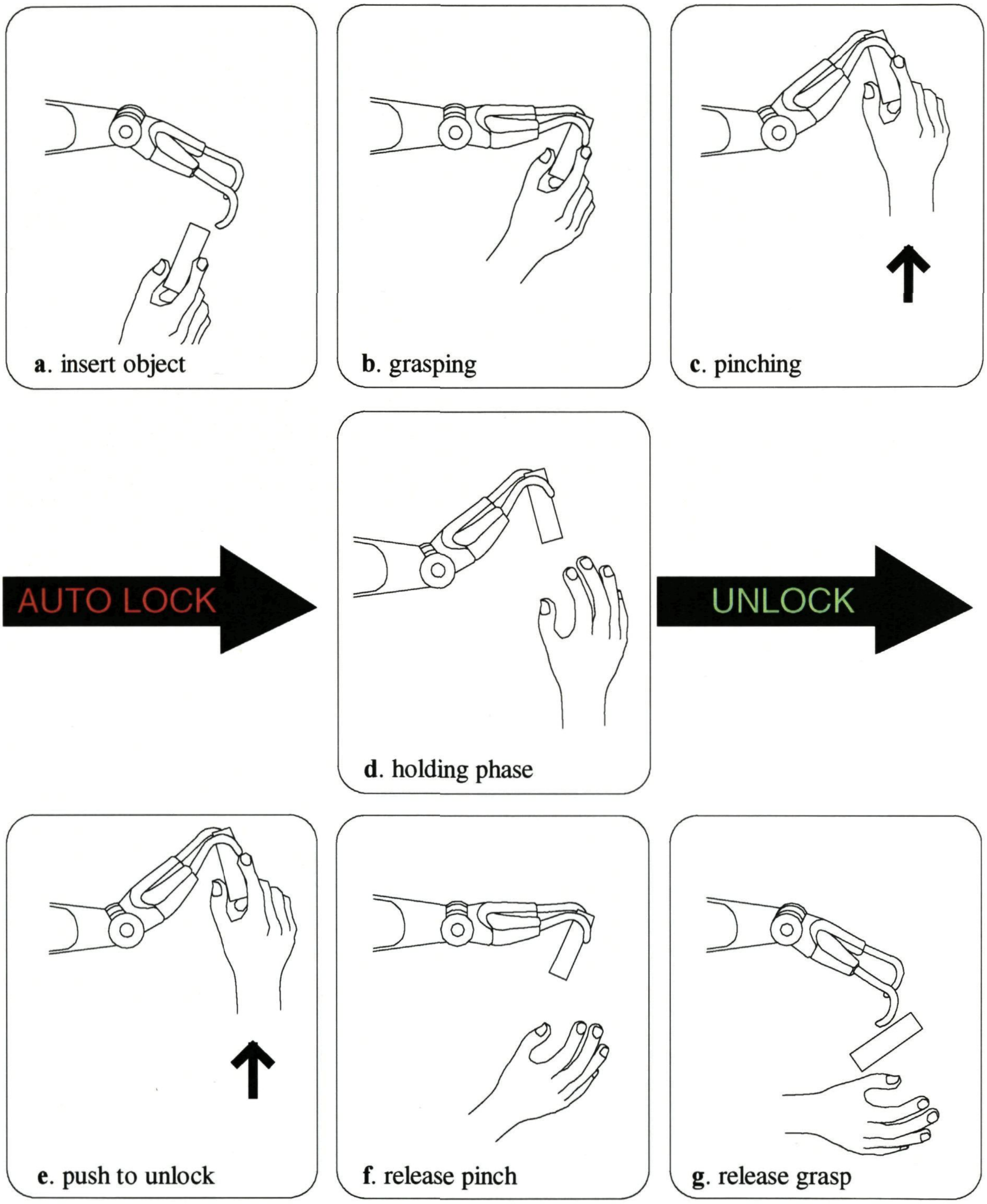


Figure 3.
Operating principle of the WRIST divided into 3 phases:

- phase 1: grasp an object (a-c).
- phase 2: hold the object (d).
- phase 3: release the object (e-g).

—The flexion angles of the wrist are measured between the central hook axis and the central socket axis (0° corresponds with the neutral position of the wrist).

DISCUSSION

The intention of the WRIST project was to design a hook prosthesis that would possess all the good qualities of a VC arm prosthesis and lack its disadvantages. In other words: it should have a correct physiological coupling and provide sufficient feedback of the corresponding pinching force, and, to overcome the disadvantages, it should have a lock to prevent fatigue in holding tasks and to close the hook when not in use.

The result of the project is a VC hook prosthesis, equipped with an automatic locking device, that has a rather unconventional way of controlling. This concept not only evades the VC drawbacks, but lacks the harness as well. As for the correct physiological coupling and provision of feedback: those are inherent in VC.

For the patient and his prosthesis to become a unity, this feedback is essential. The VC principle of the WRIST provides the patient with a sensation of the pinching force he is applying. This force can be estimated by the feedback received from all used muscles and skin receptors when operating the prosthesis. The quality of this feedback decreases with an increase of the amount of friction provided by the mechanism. Although the WRIST hardly suffers from friction, no exact numbers can be given at this moment. Due to the complexity of the system, combined with the absence of suitable measuring-instruments, this information is not available yet. This research will be continued in a proceeding project.

The WRIST VC hook prosthesis is a potentially useful addition to the current range of arm prostheses. It is functional, easy to use, appealing and it lacks the main disadvantages that most VC prostheses have, that is, in theory. So far all the positive results are obtained by testing under laboratory conditions. The next logical step will be clinical testing to get an actual proof of the practical use of the WRIST. In these trials the following aspects will be of interest:

- Acceptance of appearance.
- Comfort (passive and active).
- Functionality.
- Ease of operation.
- Frequency of use (in various tasks).
- Reliability (durability, frequency of repairs).

These criteria, looked at in general and compared with other prostheses, will have to reveal every possible weakness and shortcoming of the first prototype. On the basis of these data the concept can be altered and a second version can be developed. Small adjustments to the personal preferences of the patient can easily be made: maximum hook opening, range of pinching force and the closed position of the hook can be altered by means of setting screws. Adjustments of the ratio operating force - pinching force, range of wrist flexion and maximum pinching force are a bit more time consuming because they require the replacement of two original parts.

The amount of adjustments can be minimized if the testing is done on patients within the target group. The WRIST has been designed for patients with a unilateral below-elbow arm defect. Although the original concept was developed for young children, it is suitable for all ages. The possibility to actively grasp with the prosthesis enables the use by bilateral amputees as well. The practical use for above-elbow (transhumeral) amputees is potential, but has to be proven by clinical testing.

If the results of the clinical trials are positive, and the practical use of the WRIST proves to be sufficient, the WILMER group will consider the commercial possibilities.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the contribution and support of the members of the WILMER research group at the Delft University of Technology.

REFERENCES

1. Plettenburg DH. Basic requirements for upper extremity prostheses: the WILMER approach. Proceedings of the 20th Annual International Conference of the IEEE Engineering in Medicine and Biology and Society, Vol. 20, No. 5, 1998. p. 2276-2281. ISBN: 0-7803-5164-9.

2. Radocy B. Voluntary Closing Control: A successful new design approach to an old concept. Clinical Prosthetics and Orthotics, Vol. 10, No. 2, 1986. p. 82-86.

3. Plettenburg DH, Cool JC. The WILMER cosmetic prosthetic prehensor for children. Proceedings of the 7th World Congress of the International Society for Prosthetics and Orthotics, Chicago, 1992. p. 62.

4. Chironis NP. Mechanisms & mechanical devices source book. McGraw-Hill, Inc. USA, 1991. p. 309-315.

APPENDICES

A WORKING PRINCIPLE

B DESIGN CALCULATIONS

C AUTOCAD® DRAWINGS

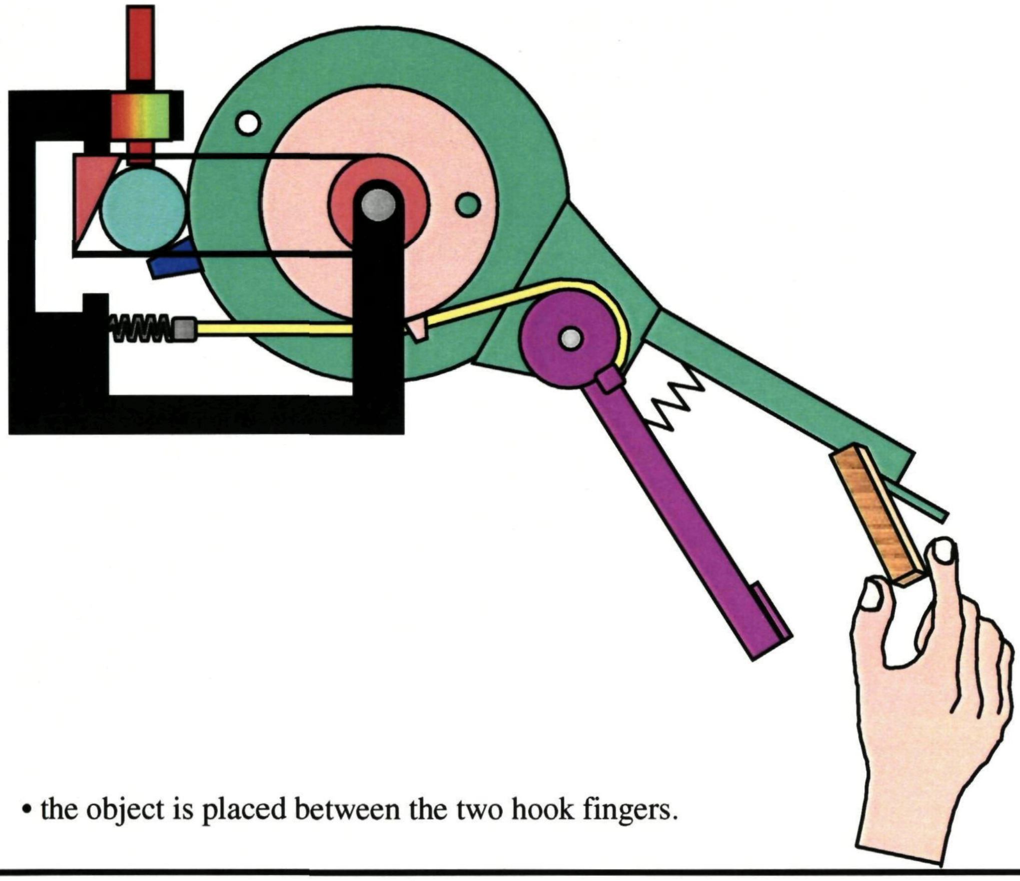
APPENDIX A

WORKING PRINCIPLE

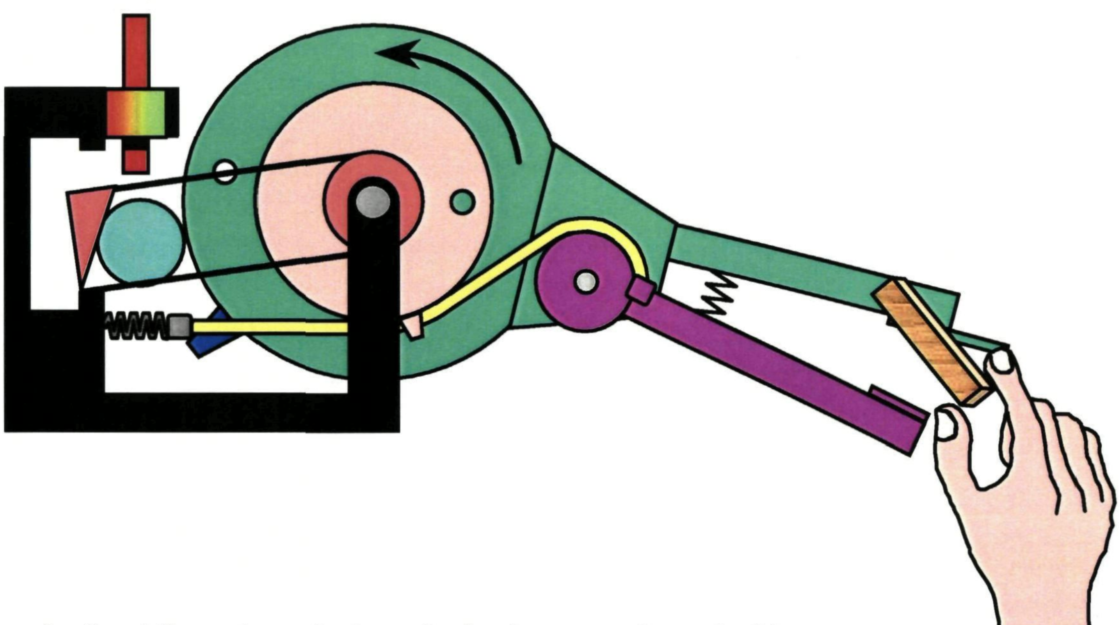
This appendix contains a more detailed overview of the WRIST working principle. One operating cycle is divided into 9 steps analogous to the 7 steps of **figure 3**. Step 1-4 correspond with **3a-c**, step 5 with **3d** and the last four steps, 6-9, correspond with **3e-g**.

Size and appearance of the hook and parts of its mechanism as shown in the following pictures do not correspond with the actual design of the WRIST, but have been altered for the sake of clarity. The principle of the mechanism however is exactly the same with the exception of the position of the two hook fingers. They have been rotated by 45° about their axes and are now pointing away from the reader, whereas in the actual design the finger tips point downwards. The reason for this visual simplification is that the real working of the pulley string mechanism can not be shown in a 2-dimensional picture because the two pulley axes are perpendicular.

Note: the switch used in the mechanism is a two-position push-push mechanical switch as used in, for instance, a ball-point pen or as a power switch in electric devices.



1 • the object is placed between the two hook fingers.



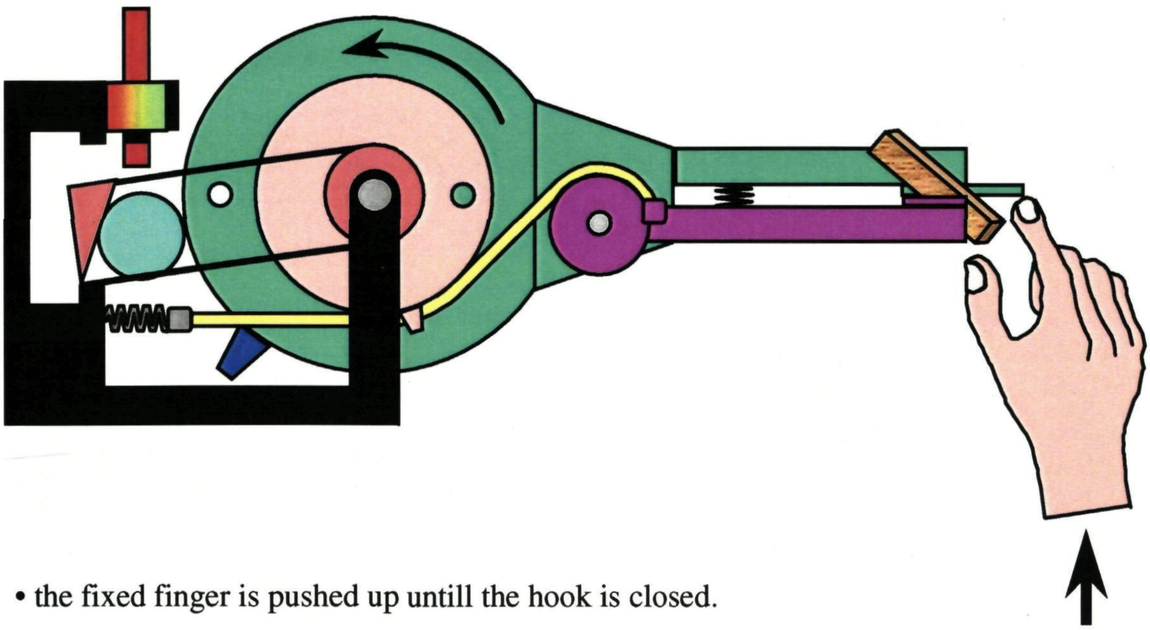
2

• the fixed finger is pushed up, the hook rotates about the hinge.

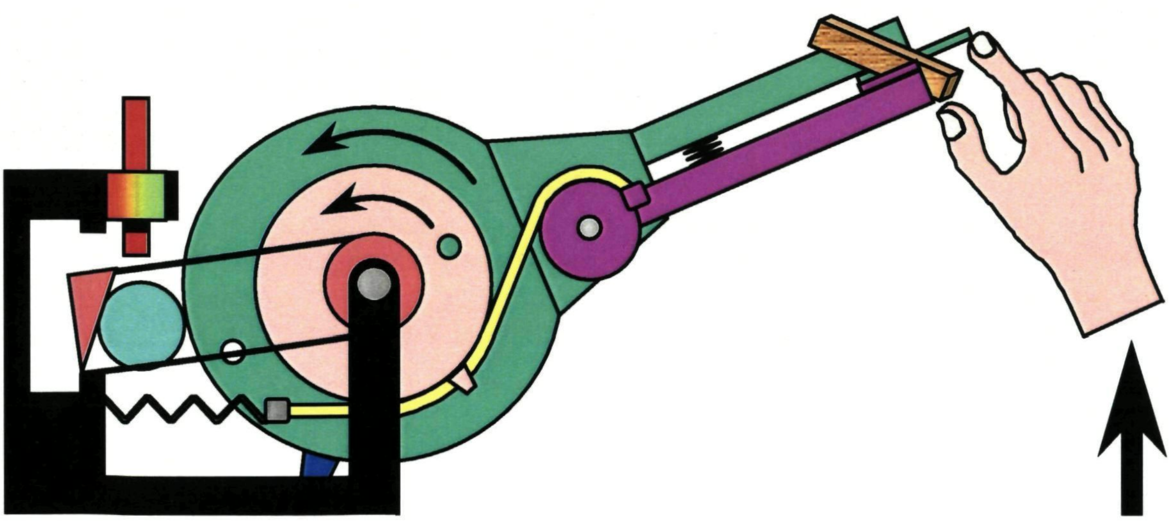
• the free finger rotates towards the fixed finger.

• the blue cylinder is released by the blue pin.

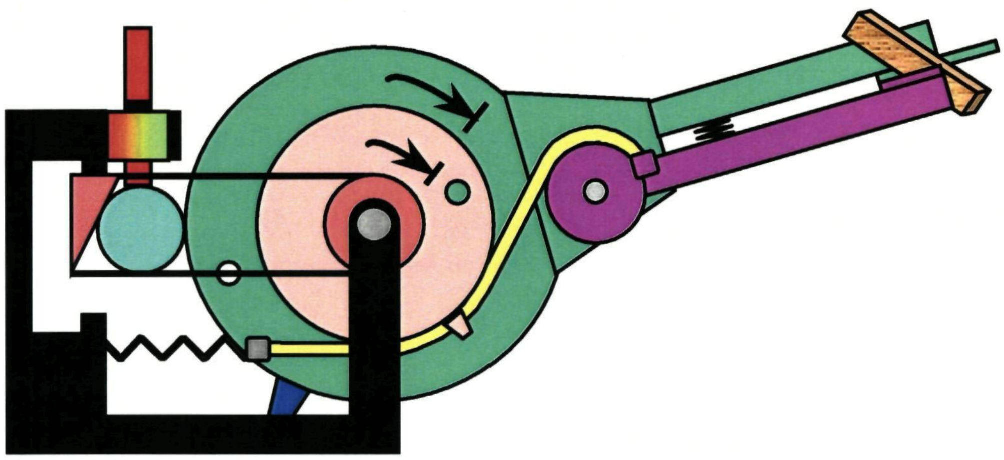
• the switch is released by the blue cylinder.



3 • the fixed finger is pushed up untill the hook is closed.

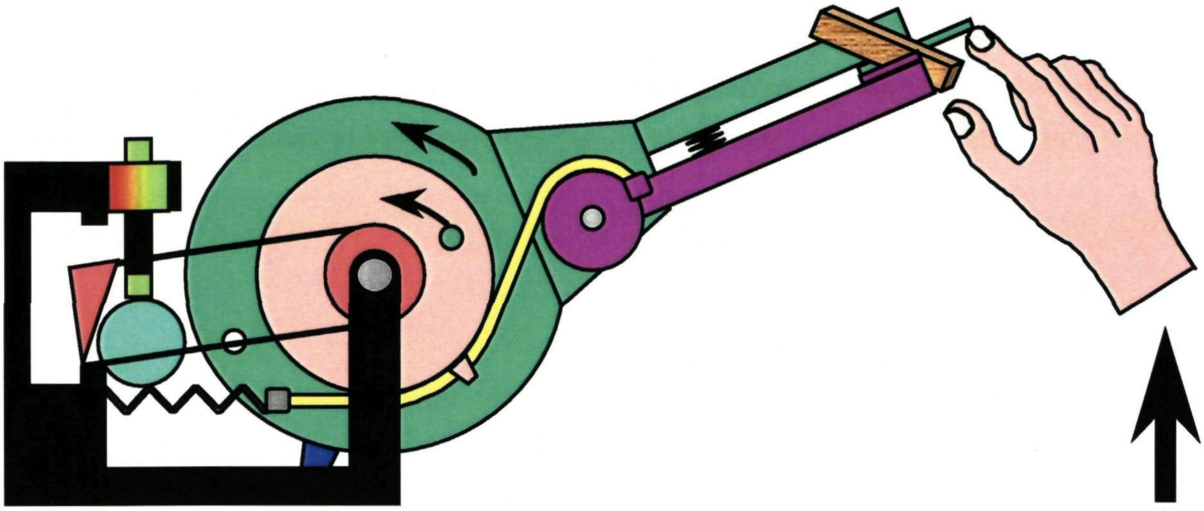


4 • the operating hand is building up pinching force.



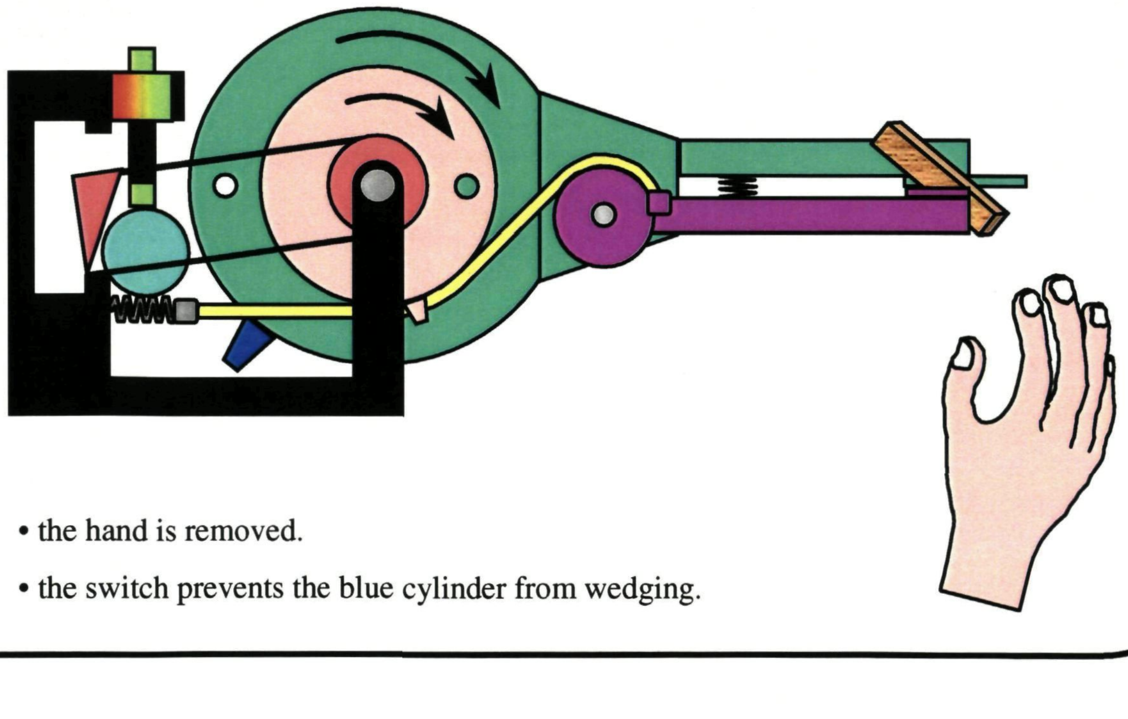
- the hand is removed when the desired pinching force is reached.
- the wedging mechanism prevents the hook from rotating clockwise.
- the switch is pushed in by the blue cylinder.
- the pinching force is retained by a spring.

5



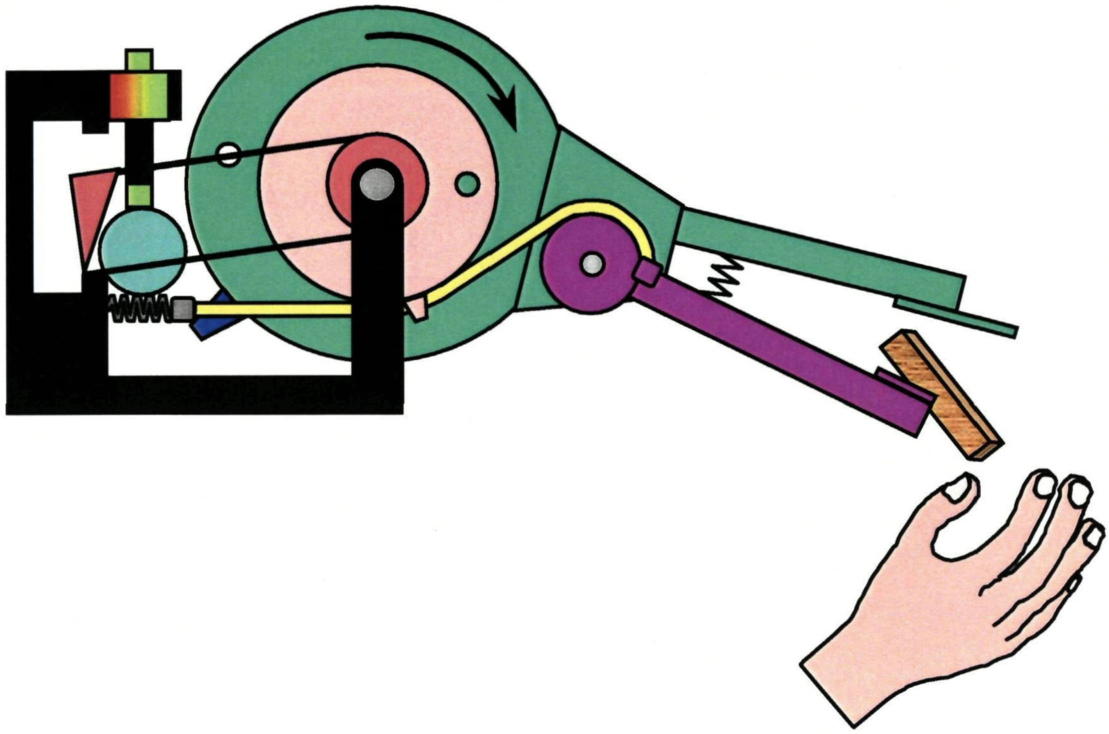
6

- the fixed finger is pushed up with the same operating force it was locked with.
- the cylinder is pushed down by the switch.

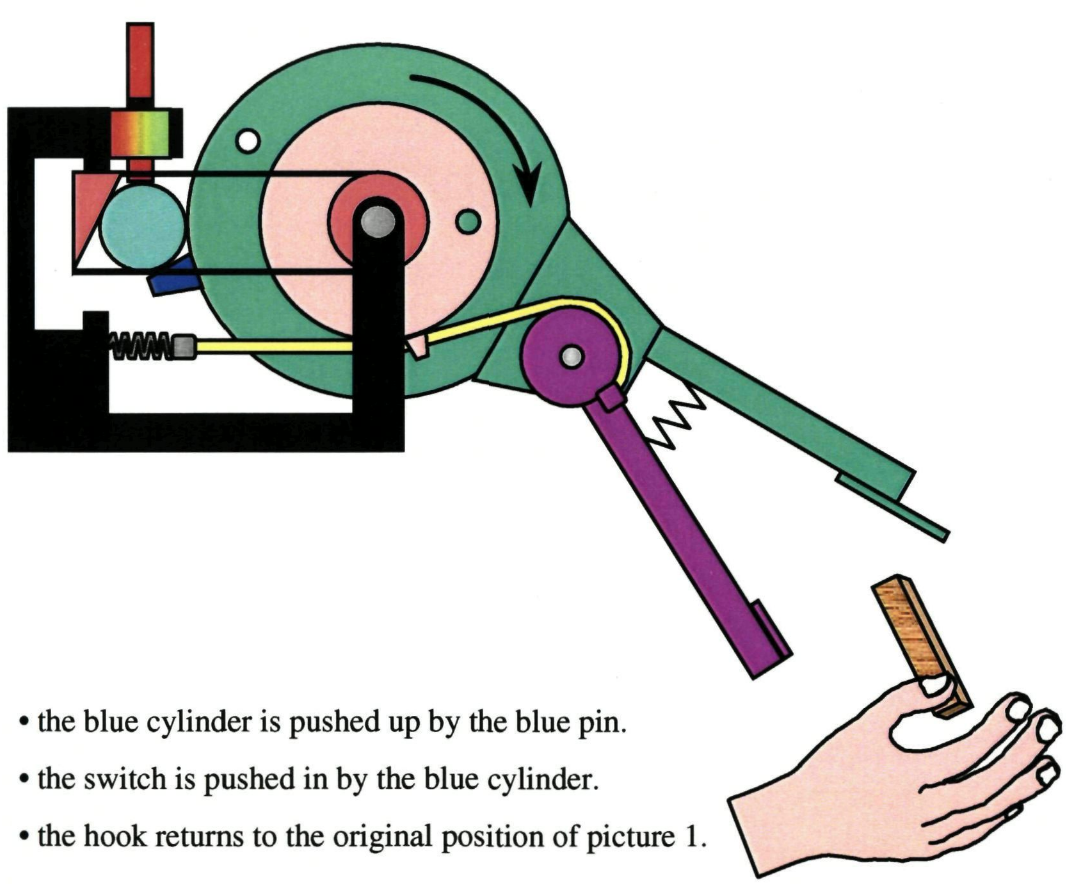


7

- the hand is removed.
- the switch prevents the blue cylinder from wedging.



8 • the hook opens and the object is released.



• the blue cylinder is pushed up by the blue pin.

• the switch is pushed in by the blue cylinder.

9 • the hook returns to the original position of picture 1.

APPENDIX B

DESIGN CALCULATIONS

This appendix contains the most important considerations and calculations that have been made in the process of designing the WRIST VC hook prosthesis. If necessary, calculations will be accompanied by references to the subjoined illustration (**fig. B1**).

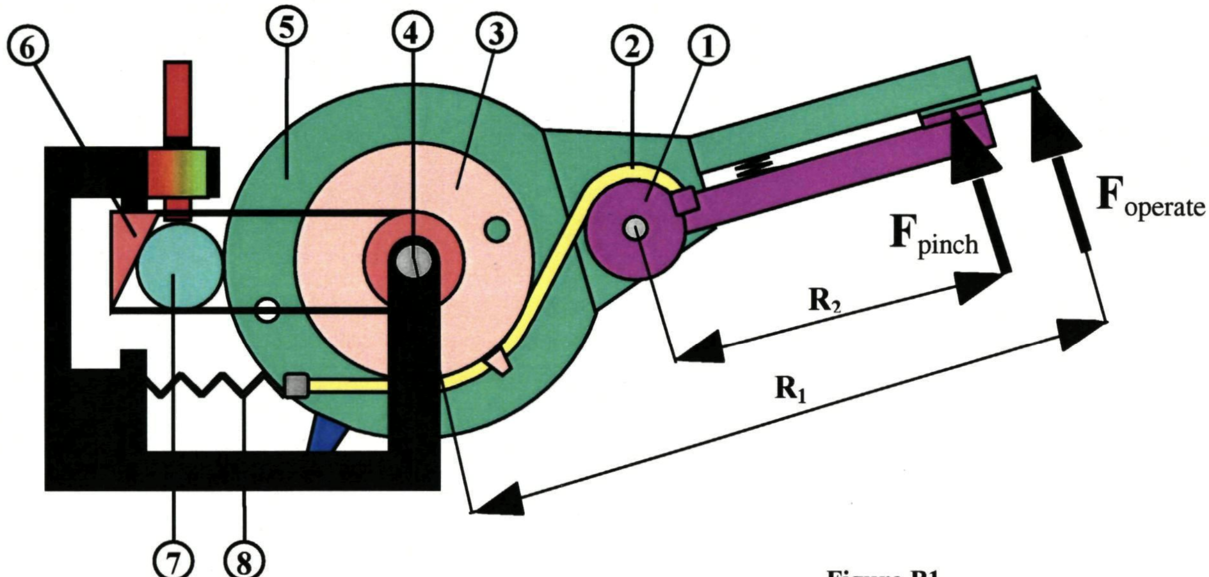


Figure B1.
Simplified illustration of the WRIST mechanism.

1. Small pulley
2. String
3. Large pulley
4. Glycodur® bearings
5. Wedging wheel
6. Wedging surface
7. Wedging roll
8. Spring

A. Considerations in the design process.

Several important decisions were made in the development of the WRIST mechanism and its components. There is a complex relation between: the ratio Operating Force-Pinching Force (OF-PF), the range of wrist rotation and the maximum hook opening. For instance: to keep the operating forces small, a low ratio OF-PF is desired and can be realized by making the large pulley (3) smaller. On the other hand, a lower OF-PF ratio means a larger range of wrist rotation, which is not desired because a large dorsal flexion is less appealing and less practical. Both the OF-PF ratio and the range of pinching force can be kept small by decreasing the maximum hook opening, which will exclude large objects from being grasped.

Literature does not provide unique information concerning the maximum operating force of young children and acceptable wrist rotation or maximum hook opening. Previous research done at the Delft University of Technology proved a hook opening of 45 [mm] and a maximum pinching force of 10 [N] to be sufficient (ref. B1). This taken as a starting point leaves only the OF-PF ratio or the rotation range to be determined. In order to minimize this ratio, the range of rotation has been chosen as large as acceptable by means of a model of the WRIST. The result is a range of 50° (hook closes in the range of -20° to +5° and remains closed in the range of +5° to +30°) which corresponds with a OF-PF ratio of 1:1. Due to the lack of relevant information gained from literature and the great diversity among the patients its hard to determine whether this ratio is acceptable or not. Clinical testing will have to decide if this ratio needs to be adjusted to a specific patient by changing the radius of the large pulley.

Notes: -The maximum hook opening can be reduced by means of a setting screw in favour of a smaller range of wrist rotation.

-The maximum pinching force depends on the size of the object pinched and equals 10 [N] when no object is inserted up to 20 [N] when the size of the object is 45 [mm].

B. Calculation of the Pulley Radii Ratio.

The maximum hook opening of 45 [mm] corresponds with a 37° angle between the two hook fingers. The hook closes in a wrist rotation range of: +5° - (-20°) = 25°. So the desired radius ratio large pulley : small pulley is 37 : 25 (1.48 : 1). This resulted in a large pulley radius of 7 [mm] and a small pulley radius of 4.5 [mm] (these radii, combined with a 0.75 [mm] string radius, equal a ratio of 1.48 : 1).

C. Calculation of the Operating Force to Pinching Force Ratio.

To calculate this ratio, the moments have to be in equilibrium. (All dimensions are in [mm], all forces in [N], all moments in [N/mm] and R_{xyz} = radius of xyz).

$$M_1 = M_2$$

$$F_{operate} * R_1 = F_{pinch} * R_2 * \frac{R_{large\ pulley}}{R_{small\ pulley}}$$

$$F_{operate} * 94 = F_{pinch} * 65 * \frac{7 + 0.75^{\#}}{4.5 + 0.75^{\#}}$$ (# radius of the string is 0.75 [mm]).

$F_{operate} = 1.02 * F_{pinch}$ $\Rightarrow$(ratio **Operating Force:Pinching Force** is approx. **1:1**).

D. Calculations of the Forces on the Wedging Mechanism.

The components of the wedging mechanism (5,6,7) suffer from high contact forces and are therefore made of tempered steel. The subjoined illustration (**fig. B2**) shows the principle of the mechanism and the forces that are present.

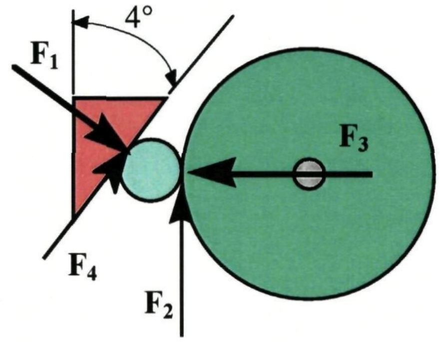


Figure B2.
Illustration of the principle of a wedging mechanism and the forces present.

Equilibrium of forces:

$F_1 * \sin(4) - F_4 * \cos(4) = F_2$

$$\mathbf{F_2} = F_{operate\ max.} * \frac{R1}{R_{wedging\ wheel}} = 20 * \frac{94}{17.5} = \mathbf{107}\ [N]$$

Equilibrium of moments $\Rightarrow M_2 = M_4 \Rightarrow \mathbf{F_2 = F_4}$

$F_1 * 0.07 = 107 * (1 + 0.998) \quad \Rightarrow \mathbf{F_1 = 3076}\ [N]$

$\mathbf{F_3} = F_1 * \cos(4) + F_4 * \sin(4) = 3076 * 0.998 + 107 * 0.07 = \mathbf{3076}\ [N]$

Conclusions
The load of force F_3 is distributed over the two **Glycodur® bearings (4)** (F_2 is negligible). The bearings can each take a load of 3000 [N] (guaranteed), so the **safety factor** is at least: 2 * 3000 / 3076 = **1.95**.

F_1 and F_3 are the most crucial loads the wedging mechanism is subjected to. The next formula (Hertz) is used to check whether the material of the wedging roll is not over stressed by these forces.

$$\sigma = \sqrt{\frac{F * E_r}{L * 2 * \pi * R_r * (1-\mu^2)}} \quad , \; R_r^{-1} = R_1^{-1} + R_2^{-1} \quad , \; E_r = \frac{2 * E_1 * E_2}{E_1 + E_2}$$

In which: $F = F_3 = 3076$ [N]
$E_1 = E_2 = 200*10^3$ [N/mm^2]
$L = 8$ [mm]
$R_1 = 4$ [mm]
$R_2 = 17.5$ [mm]
$\mu = 0.3$
so: $E_r = 200*10^3$ [N/mm^2]
$R_r = 3.26$ [mm]

This results in a stress σ of:
σ = **2031 [N/mm^2]**, which is less than the **maximum admissible stress** of tempered steel: σ_{max} = **3000 [N/mm^2]**, so the material is not over loaded.

E. Calculations for the determination of the SPRING (8).

Data:
Range of Pinching Force = 0 to 10 [N] (20 [N] max., depending on object size)
Wrist Flexion range = -20° to +30° (hook closes in the range -20° to +5°, and remains closed in the range +5° to +30° (adjust.)).

The Pinching Force of 10 [N] corresponds with a String Force of:

$F_{string} = 10 * R_2 / R_{small\ pulley} = 10 * 65/ 5.25 = 124$ [N]

So the spring has to built up a force of 124 [N] in a range of 30° - 5° = 25°.
25° corresponds with a spring prolongation of : $X_{spring} = 25°/ 360° * C_{large}$
(C_{large} = Circumference of large pulley).

$X_{spring} = 25°/ 360° * 2\pi * 7.75 = 3.4$ [mm]

So the **desired spring stiffness** is:

$K_{spring} = 124/ 3.4 =$ **36 [N/mm]**.

The spring used is a bit smaller due to the restricted space inside the mechanism.
Used spring stiffness K_{spring} = 31 [N/mm].
Note: the spring used in the mechanism is in fact a compression spring as opposed to the tensile spring shown in the illustration. This spring can not be overloaded because it can withstand full compression, after which it will restrict its own movement.

F. Calculations for the determination of the STRING (2).

In the calculations of the spring (**E**) the load on the string:

$F_{string} = 124 * K_{spring\ used} / K_{spring\ desired} = 107$ [N]

corresponds with a hook rotation of 25°. F_{string} max. is reached when the size of the object pinched equals the maximum hook opening and the hook is rotated to its maximum (+30°). A hook rotation of : 30°- (-20°) = 50° corresponds with a **max. String Force** of:

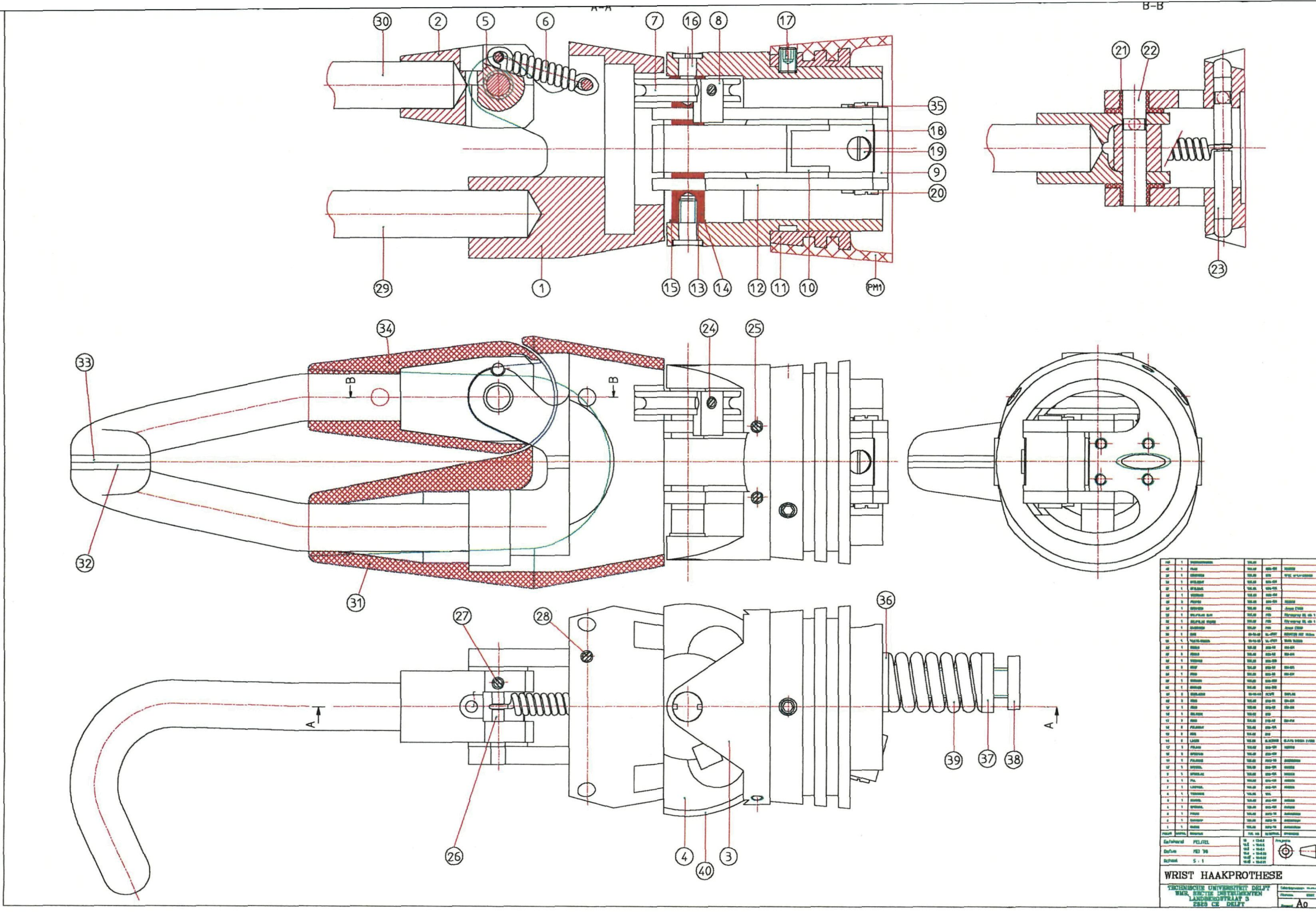
$F_{string\ max.} = 107 * 50° / 25° = \mathbf{214}$ **[N]**

The string used is a 1.5 [mm] Dynema string that can take a max. load of 2000 [N]. The (virtual) **safety factor** of 2000/ 214 = **9.3** is high, but has to deal with additional forces when the object held is twisted and forces the hook fingers apart.

REFERENCE

B1. Lunteren A van, Lunteren-Gerritsen GHM van. Field evaluation of below-elbow prostheses for children. Delft University of Technology, Faculty of Mechanical Engineering & Marine Technology, Laboratory for Measurement & Control; 1992. Report n-400.

AUTOCAD® DRAWINGS



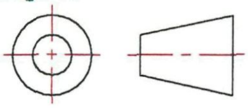
A-A
B-B
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
PM1
B
A
Getekend PELITEL
Datum MEI '98
Schaal 5 : 1
Projectie
WRIST HAAKPROTHESE
TECHNISCHE UNIVERSITEIT DELFT
WMR, SECTIE INSTRUMENTEN
LANDBERGSTRAAT 3
2628 CE DELFT
A0

PM1	1	ONDERARMKOKER	TEK.NR		
40	1	MAAN	TEK.NR	RVS-431	HARDEN
39	1	DRUKVEER	TEK.NR	RVS	SPEC art.nr.D22350
38	1	STELBOUT	TEK.NR	RVS-431	
37	1	STELRING	TEK.NR	RVS-431	
36	1	VEERRING	TEK.NR	RVS-431	
35	2	PASPEN	TEK.NR	RVS-431	HARDEN
34	1	DUIMHOES	TEK.NR	PUR	James C1080
33	1	GRIJPVLAK DUIM	TEK.NR	PUR	Vibraspray 80, dik 1 mm
32	1	GRIJPVLAK VINGER	TEK.NR	PUR	Vibraspray 80, dik 1 mm
31	1	BASISHOES	TEK.NR	PUR	James C1080
30	1	DUIM	09-16-27	AL-51ST	INKORTEN MET 12.5mm
29	1	VASTE-VINGER	09-16-27	AL-51ST	WARM BUIGEN
28	1	M2X2.5	TEK.NR	RVS-A2	DIN-551
27	2	M2X3.5	TEK.NR	RVS-A2	DIN-551
26	1	VEERAS2	TEK.NR	RVS-303	
25	2	M2X7	TEK.NR	RVS-A2	DIN-551
24	1	M2X3	TEK.NR	RVS-A2	DIN-551
23	1	VEERAS1	TEK.NR	RVS-303	
22	1	DUIMAS2	TEK.NR	RVS-303	
21	2	DUIMLAGER	09-16-18	PCTFE	ERIFLON
20	2	M2X5	TEK.NR	RVS-A2	DIN-551
19	1	M2X3	TEK.NR	RVS-A2	DIN-551
18	1	ROLVEER	TEK.NR	RVS	
17	3	M3X5	TEK.NR	RVS-A2	DIN-916
16	2	POLSBOUT	TEK.NR	RVS-431	
15	2	RING	TEK.NR	RVS	
14	6	LAGER	TEK.NR	GLYCODUR	GLY.PG 040504 F/VBO 55
13	1	POLSAS	TEK.NR	RVS-431	HARDEN
12	2	SPERHUIS	TEK.NR	RVS-431	
11	1	POLSRING	TEK.NR	7075-T6	ANODISEREN
10	1	SPERROL	TEK.NR	RVS-431	HARDEN
9	1	SPERVLAK	TEK.NR	RVS-431	HARDEN
8	1	PAL	TEK.NR	RVS-431	HARDEN
7	1	LOOPWIEL	TEK.NR	RVS-431	HARDEN
6	1	TREKVEER	TEK.NR	RVS	
5	1	DUIMROL	TEK.NR	RVS-431	HARDEN
4	1	SPERWIEL	TEK.NR	RVS-431	HARDEN
3	1	FRAME	TEK.NR	7075-T6	ANODISEREN
2	1	DUIMROMP	TEK.NR	7075-T6	ANODISEREN
1	1	BASIS2	TEK.NR	7075-T6	ANODISEREN
POS.NR	AANTAL	BENAMING	TEK. NR.	MATERIAAL	OPMERKING

Getekend	FEIJTEL
Datum	MEI '98
Schaal	5 : 1

10 = 10±0.5
$10.\tilde{0}$ = 10±0.2
$10.\bar{0}$ = 10±0.1
10.0 = 10±0.05
$10.0\tilde{0}$ = 10±0.02
$10.0\bar{0}$ = 10±0.01

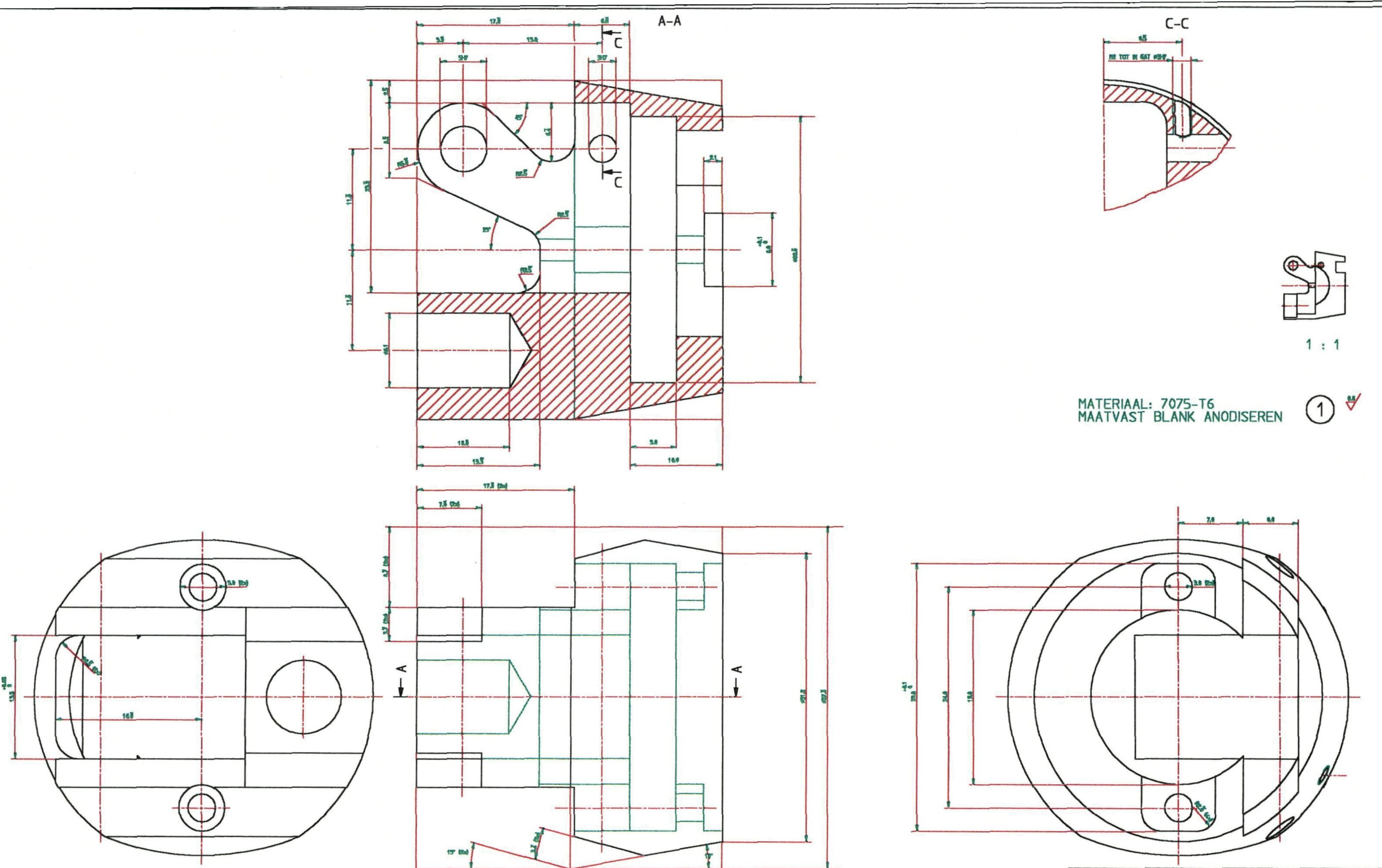
Projectie



WRIST HAAKPROTHESE

TECHNISCHE UNIVERSITEIT DELFT
WMR, SECTIE INSTRUMENTEN
LANDBERGSTRAAT 3
2628 CE DELFT

Tekeningnummer: **-**-**
Filename: WRIST
Formaat A0



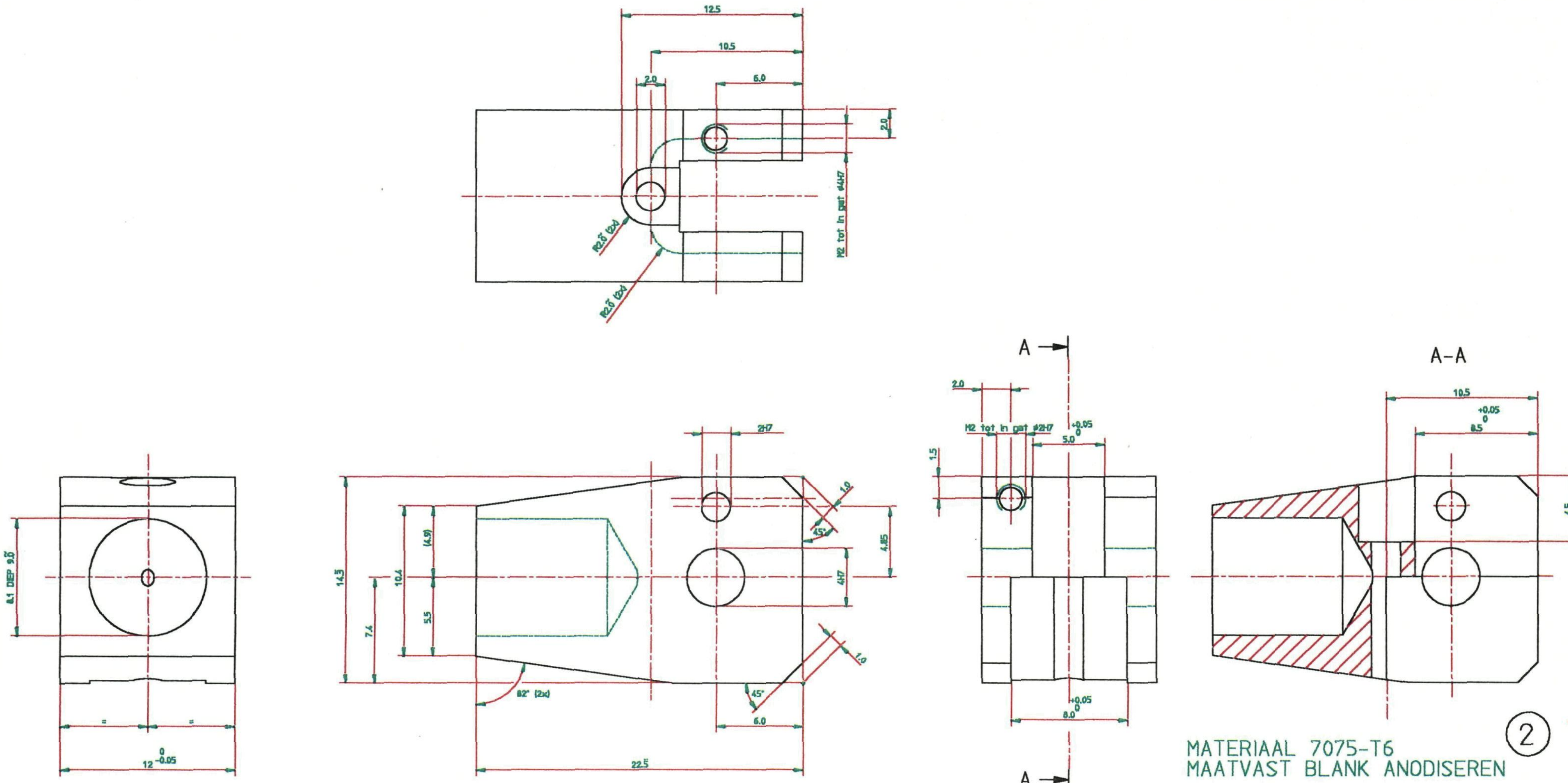
Getekend	FELITEL
Datum	MRT '98
Schaal	5 : 1 (1 : 1)

Projectie

BASIS2

TECHNISCHE UNIVERSITEIT DELFT
WMR, SECTIE INSTRUMENTEN
LANDBERGSTRAAT 3
2628 CE DELFT

Formaat A1



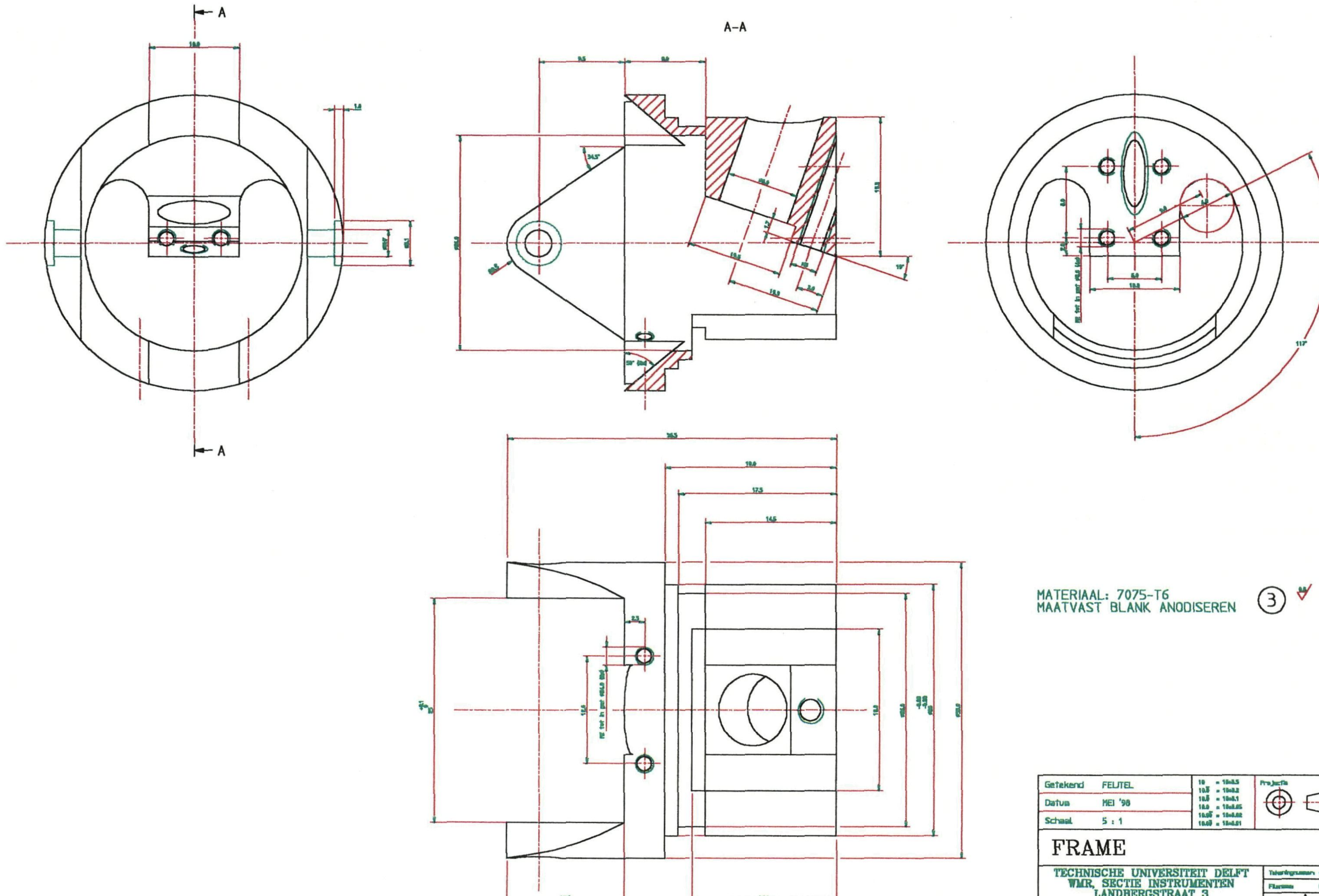
MATERIAAL 7075-T6
MAATVAST BLANK ANODISEREN

Getekend	FEIJTEL	10 = 10±0.5 10.0 = 10±0.2 10.0 = 10±0.1 10.0 = 10±0.05 10.00 = 10±0.02 10.00 = 10±0.01	Projectie
Datum	APR '98		
Schaal	5 : 1		

DUIMROMP

TECHNISCHE UNIVERSITEIT DELFT
WMR, SECTIE INSTRUMENTEN
LANDBERGSTRAAT 3
2628 CE DELFT

Tekeningnummer: --.--.--
Filename: DUIMROMP
Formaat A2



MATERIAAL: 7075-T6
MAATVAST BLANK ANODISEREN

(3)

Getekend	FEIJTEL
Datum	MEI '98
Schaal	5 : 1

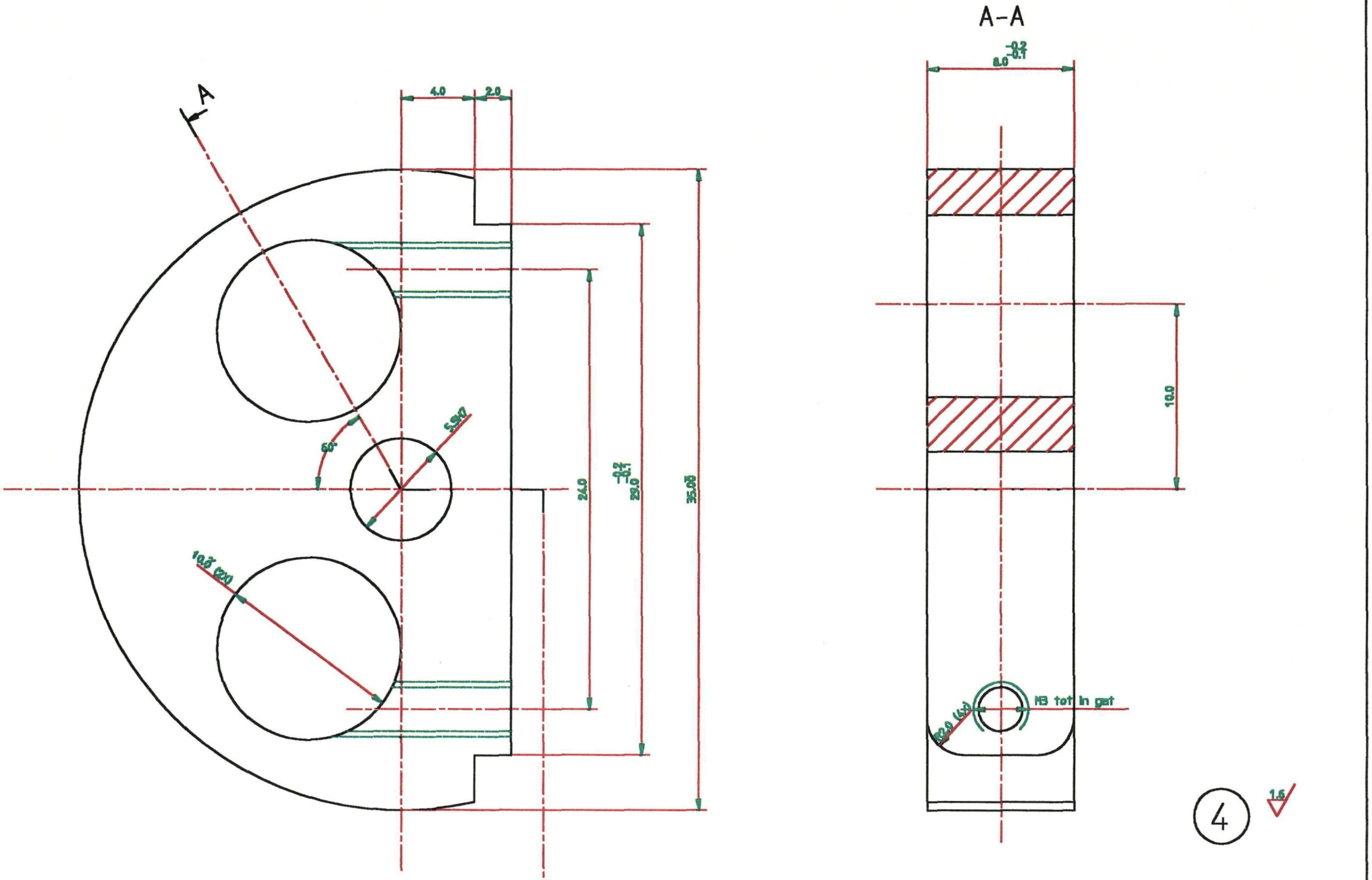
Projectie

FRAME

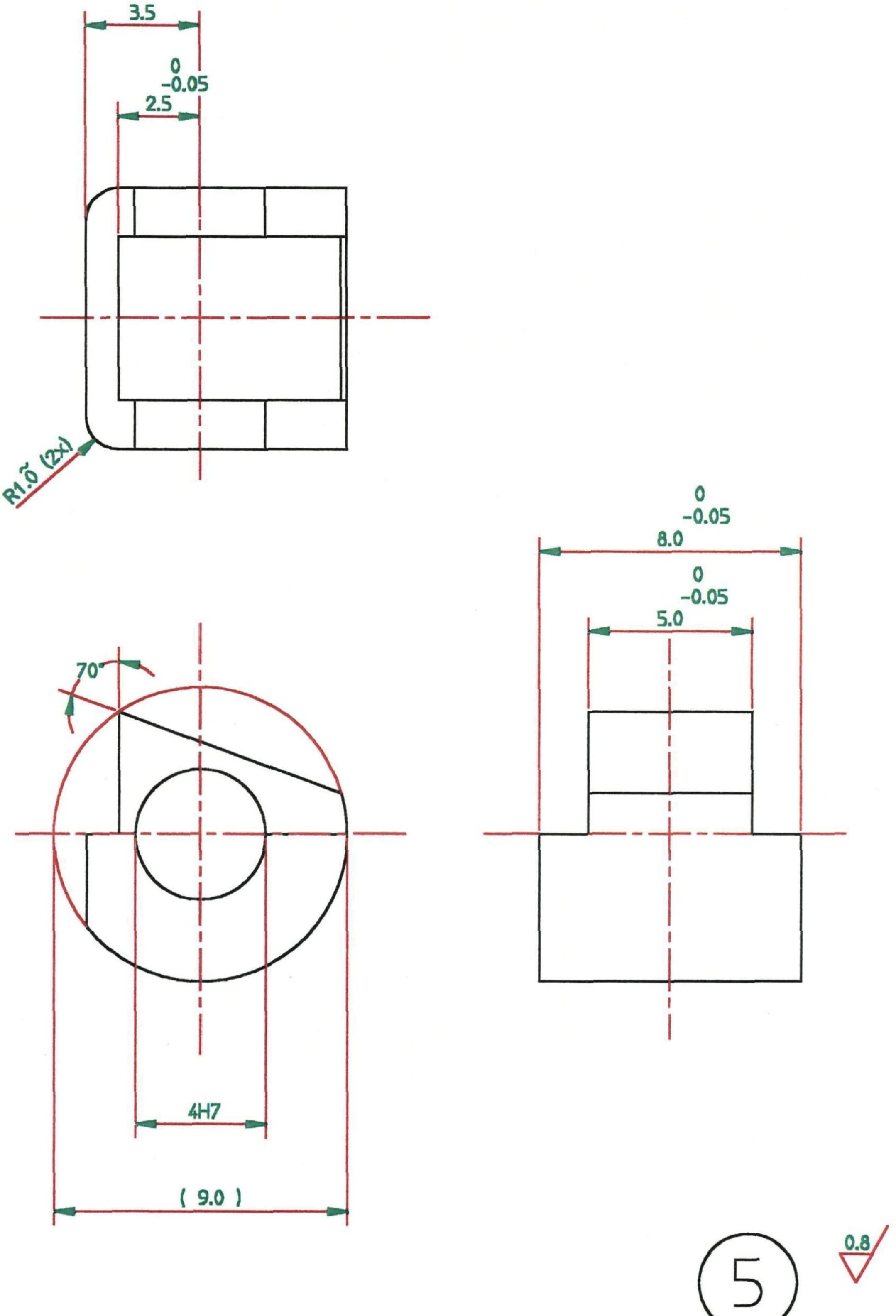
TECHNISCHE UNIVERSITEIT DELFT
WMR, SECTIE INSTRUMENTEN
LANDBERGSTRAAT 3
2628 CE DELFT

Filename: FRAME

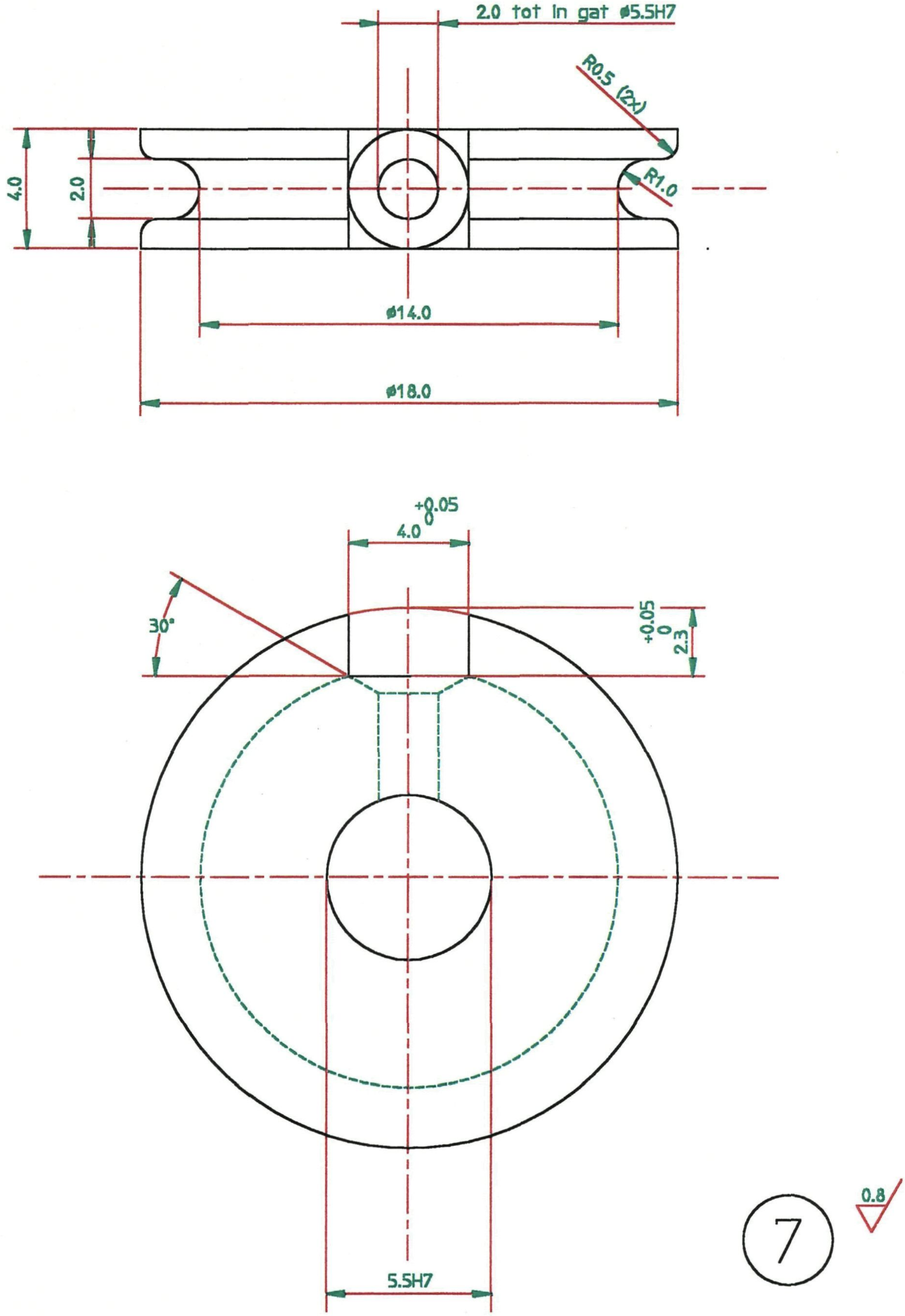
Formaat: A1



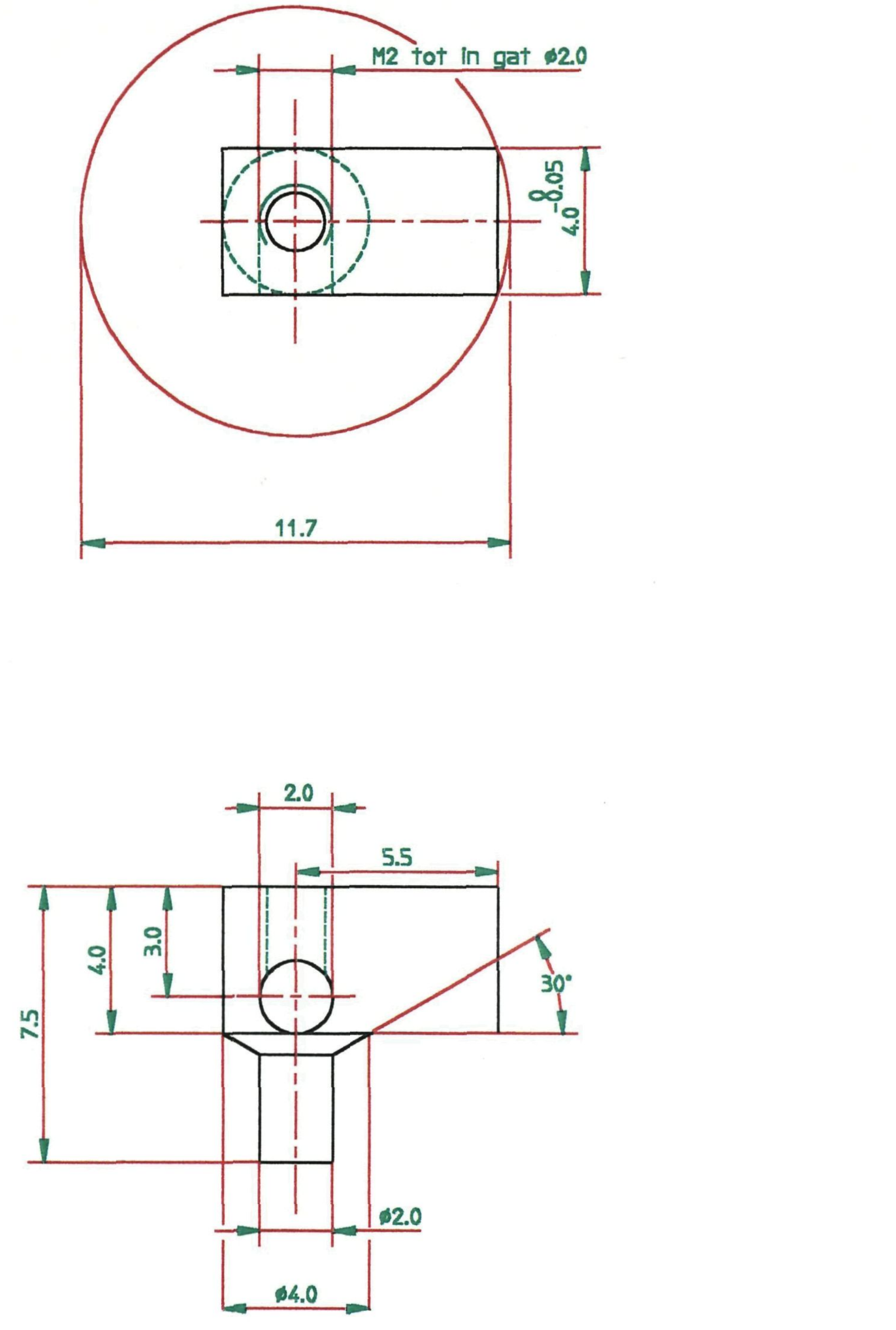
TECHNISCHE UNIVERSITEIT DELFT WbMR, SECTIE INSTRUMENTEN LANDBERGSTRAAT 3 2628 CE DELFT	SPERWIEL	Get.: FEIJTEL Dat.: MRT '98 File: SPERWIEL Schaal: 5 : 1	Gecont.	Mat.: RVS 431 GEHARD Nr.: --.--.--



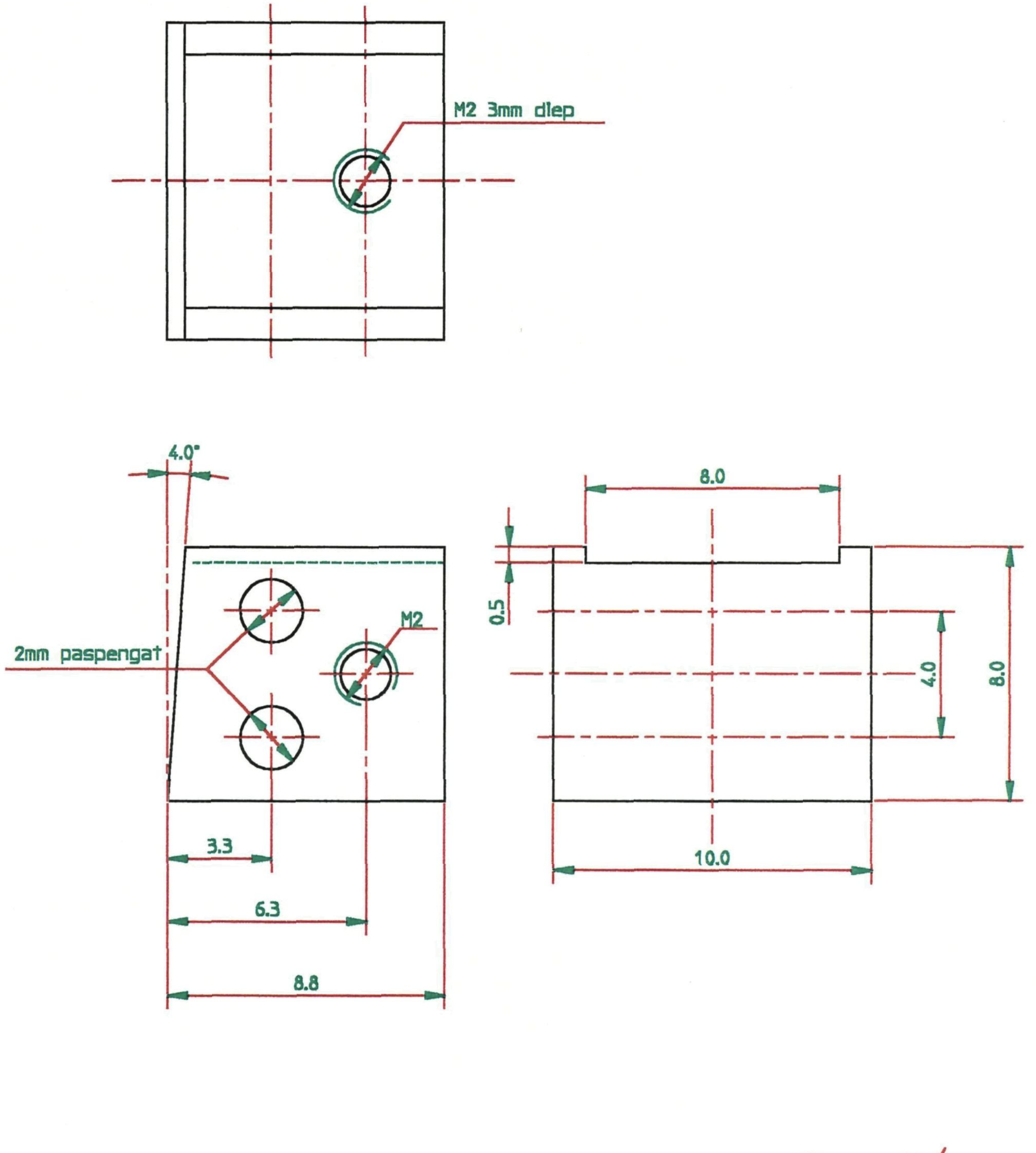
TECHNISCHE UNIVERSITEIT DELFT WMR, SECTIE INSTRUMENTEN LANDBERGSTRAAT 3 2628 CE DELFT	DUIMROL	Get.: FEIJTEL Dat.: APR '98 File: DUIMROL Schaal: 5 : 1	Gecont.	Mat.: RVS 431 GEHARD Nr.: **-**-**



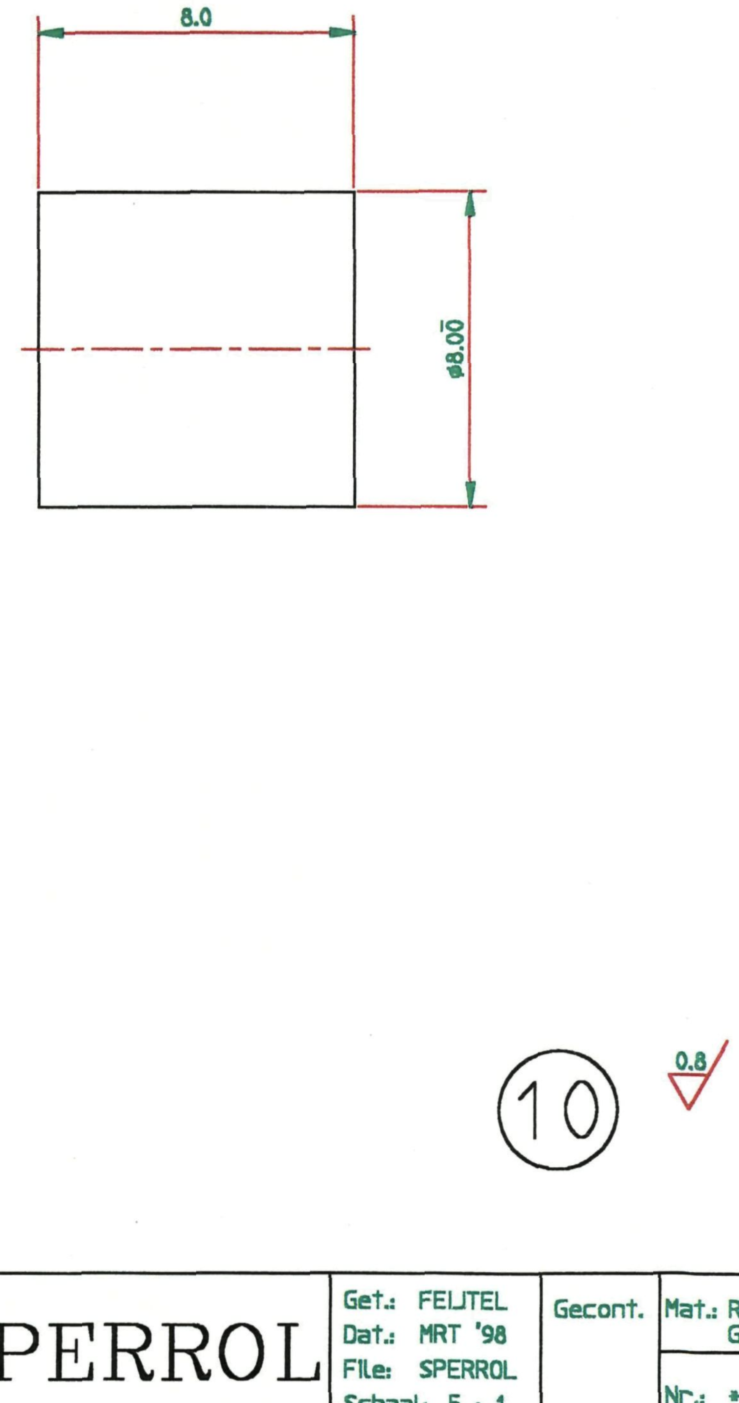
TECHNISCHE UNIVERSITEIT DELFT WMR, SECTIE INSTRUMENTEN LANDBERGSTRAAT 3 2628 CE DELFT	LOOPWIEL	Get.: FEIJTEL Dat.: APR '98 File: LOOPWIEL Schaal: 5 : 1	Gecont.	Mat.: RVS 431 GEHARD Nr.: **-**-**



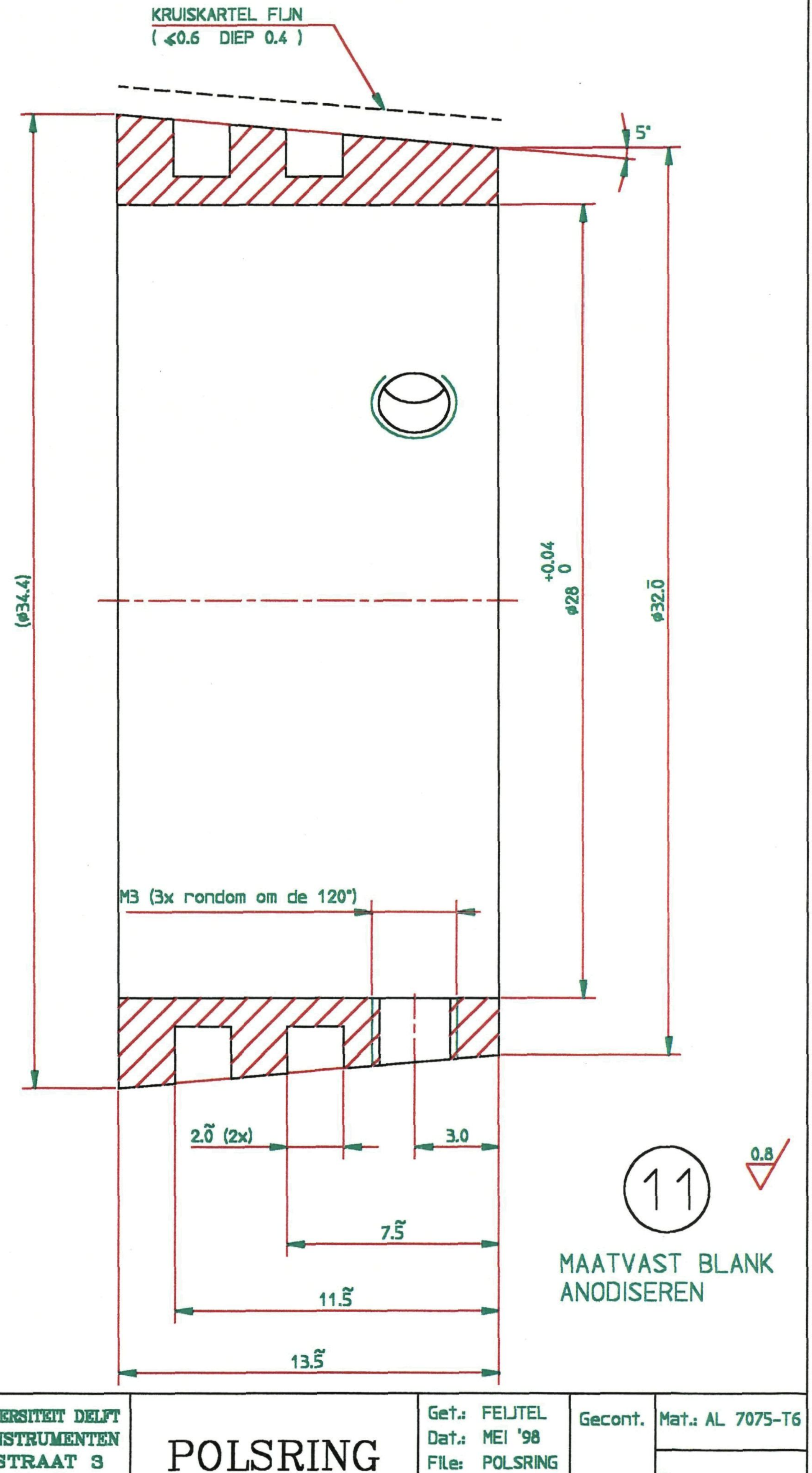
TECHNISCHE UNIVERSITEIT DELFT WMR, SECTIE INSTRUMENTEN LANDBERGSTRAAT 3 2628 CE DELFT	PAL	Get.: FEIJTEL Dat.: APR '98 File: PAL Schaal: 5 : 1	Gecont.	Mat.: RVS 431 GEHARD Nr.: **-**-**



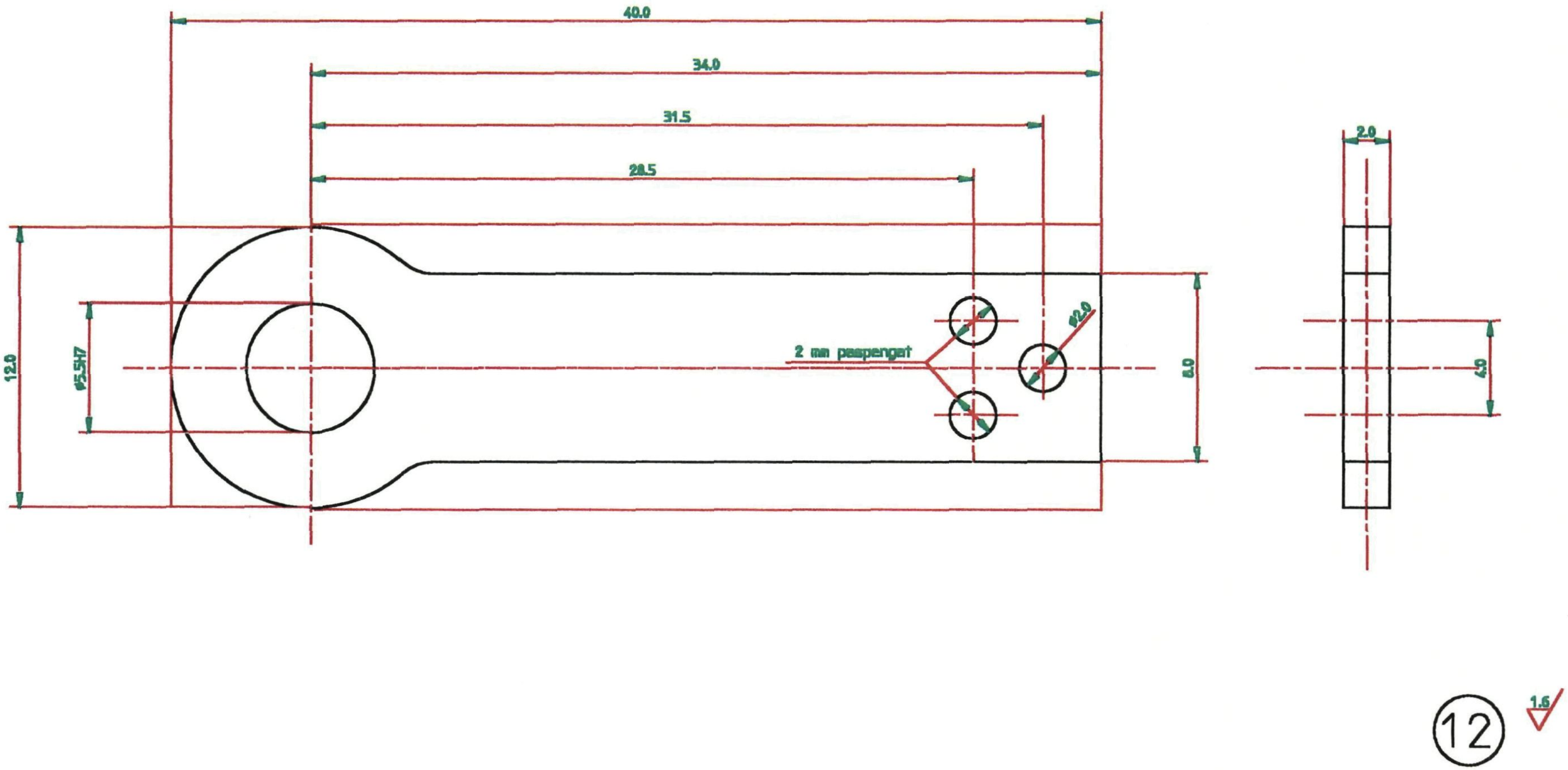
TECHNISCHE UNIVERSITEIT DELFT WMR, SECTIE INSTRUMENTEN LANDBERGSTRAAT 3 2628 CE DELFT	SPERVLAK	Get.: FEIJTEL Dat.: MRT '98 File: SPERVLAK Schaal: 5 : 1	Gecont.	Mat.: RVS 431 GEHARD Nr.: **-**-**



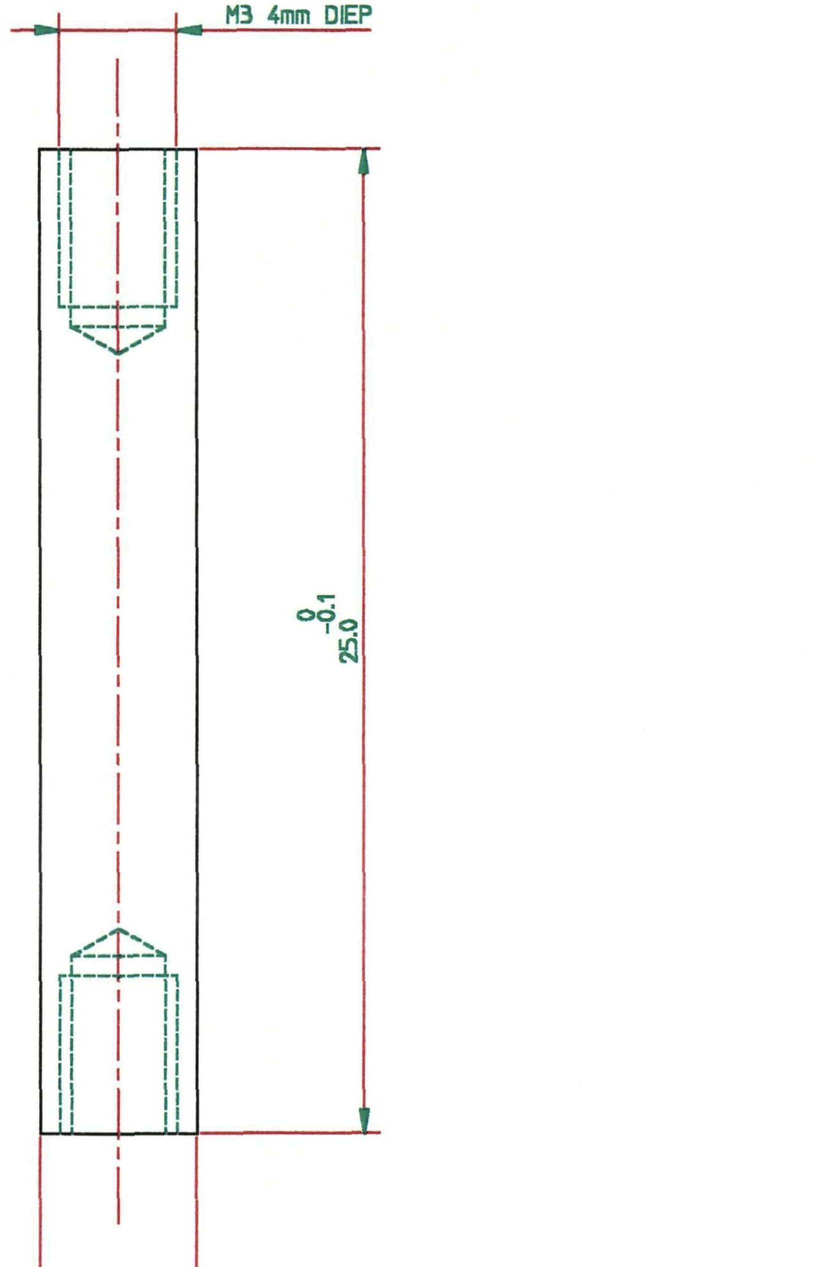
TECHNISCHE UNIVERSITEIT DELFT WMR, SECTIE INSTRUMENTEN LANDBERGSTRAAT 3 2628 CE DELFT	SPERROL	Get.: FEIJTEL Dat.: MRT '98 File: SPERROL Schaal: 5 : 1	Gecont.	Mat.: RVS 431 GEHARD Nr.: **-**-**



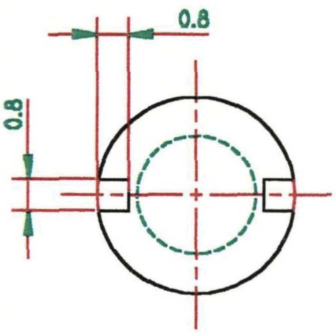
TECHNISCHE UNIVERSITEIT DELFT WMR, SECTIE INSTRUMENTEN LANDBERGSTRAAT 3 2628 CE DELFT	POLSRING	Get.: FEIJTEL Dat.: MEI '98 File: POLSRING Schaal: 5 : 1	Gecont.	Mat.: AL 7075-T6 Nr.: **-**-**

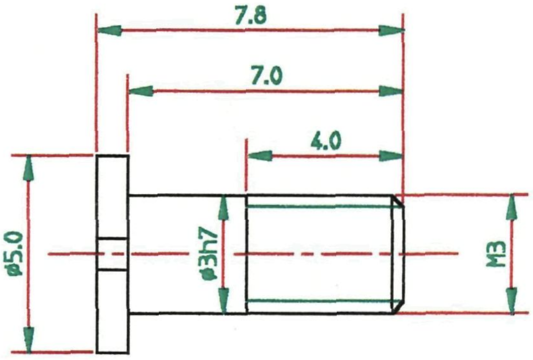


TECHNISCHE UNIVERSITEIT DELFT WMR, SECTIE INSTRUMENTEN LANDBERGSTRAAT 3 2628 CE DELFT	SPERHUIS	Get.: FEIJTEL Dat.: MRT '98 File: SPERHUIS Schaal: 5 : 1	Gecont.	Mat.: RVS 431 Nr.: ##-##-##



TECHNISCHE UNIVERSITEIT DELFT WMR, SECTIE INSTRUMENTEN LANDBERGSTRAAT 3 2628 CE DELFT	POLSAS	Get.: FEIJTEL Dat.: APR '98 File: POLSAS Schaal: 5 : 1	Gecont.	Mat.: RVS 431 GEHARD Nr.: **-**-**

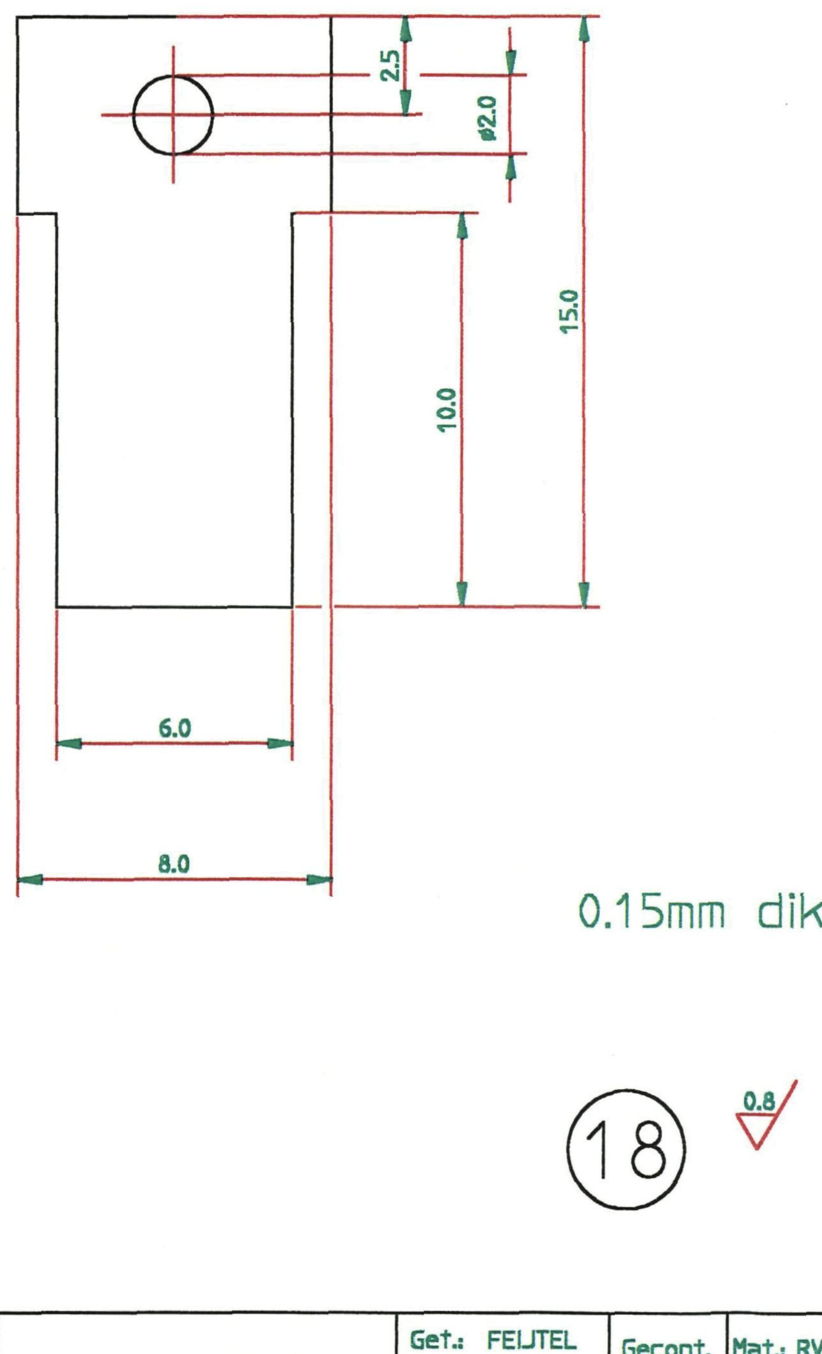




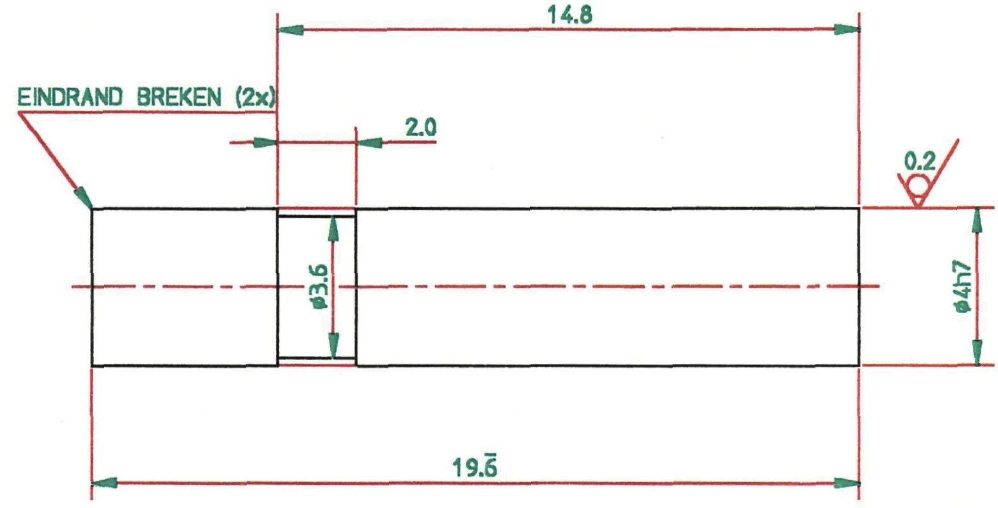
(16)

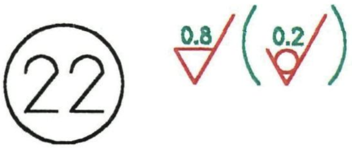
0.8

TECHNISCHE UNIVERSITEIT DELFT WMR, SECTIE INSTRUMENTEN LANDBERGSTRAAT 3 2628 CE DELFT	POLSBOUT	Get.: FEIJTEL Dat.: MEI '98 File: POLSBOUT Schaal: 5 : 1	Gecont.	Mat.: RVS 431 Nr.: **-**-**



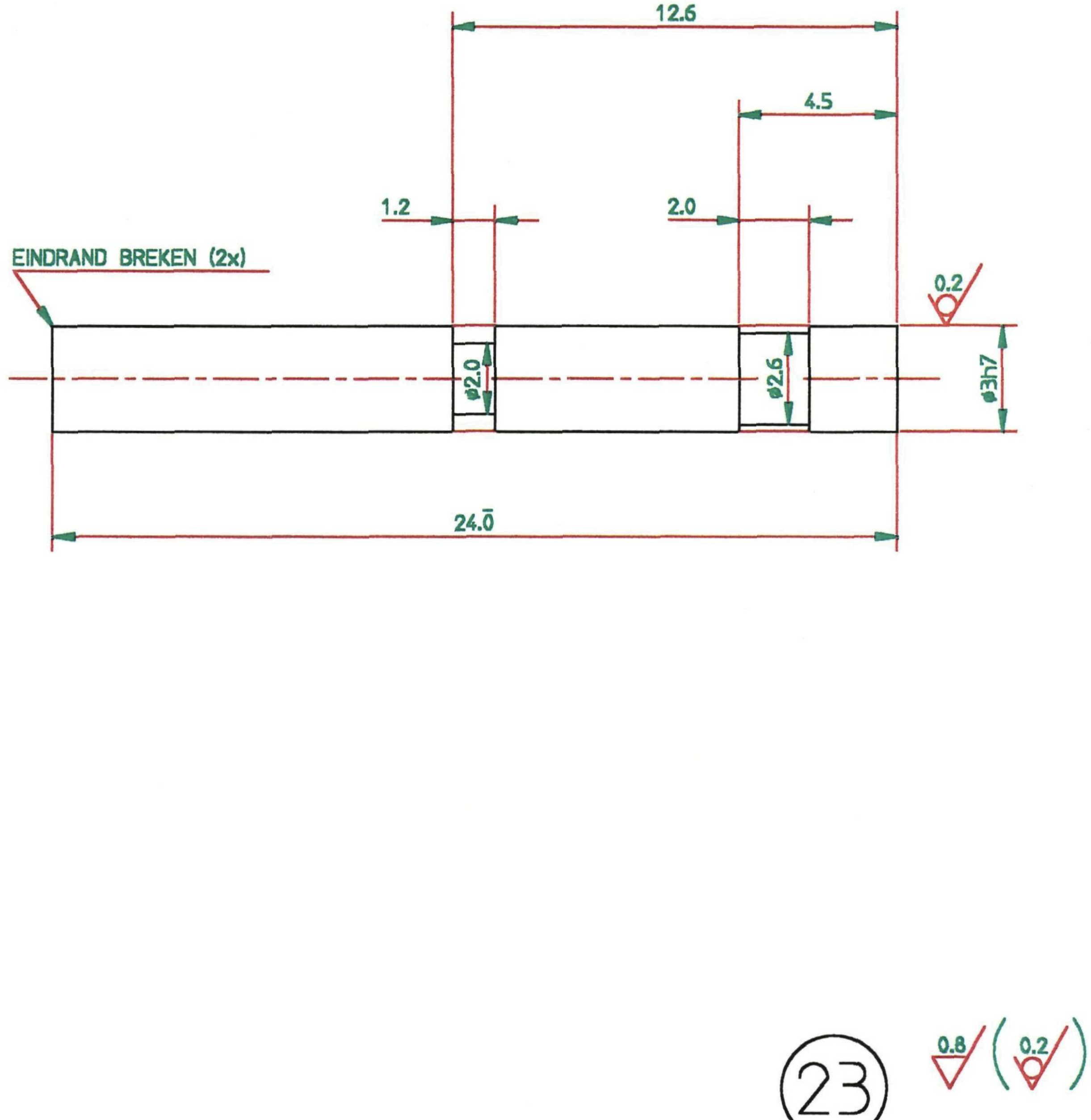
TECHNISCHE UNIVERSITEIT DELFT WMR, SECTIE INSTRUMENTEN LANDBERGSTRAAT 3 2628 CE DELFT	ROLVEER	Get.: FEIJTEL Dat.: MRT '98 File: ROLVEER Schaal: 5 : 1	Gecont.	Mat.: RVS 431 Nr.: **-**-**





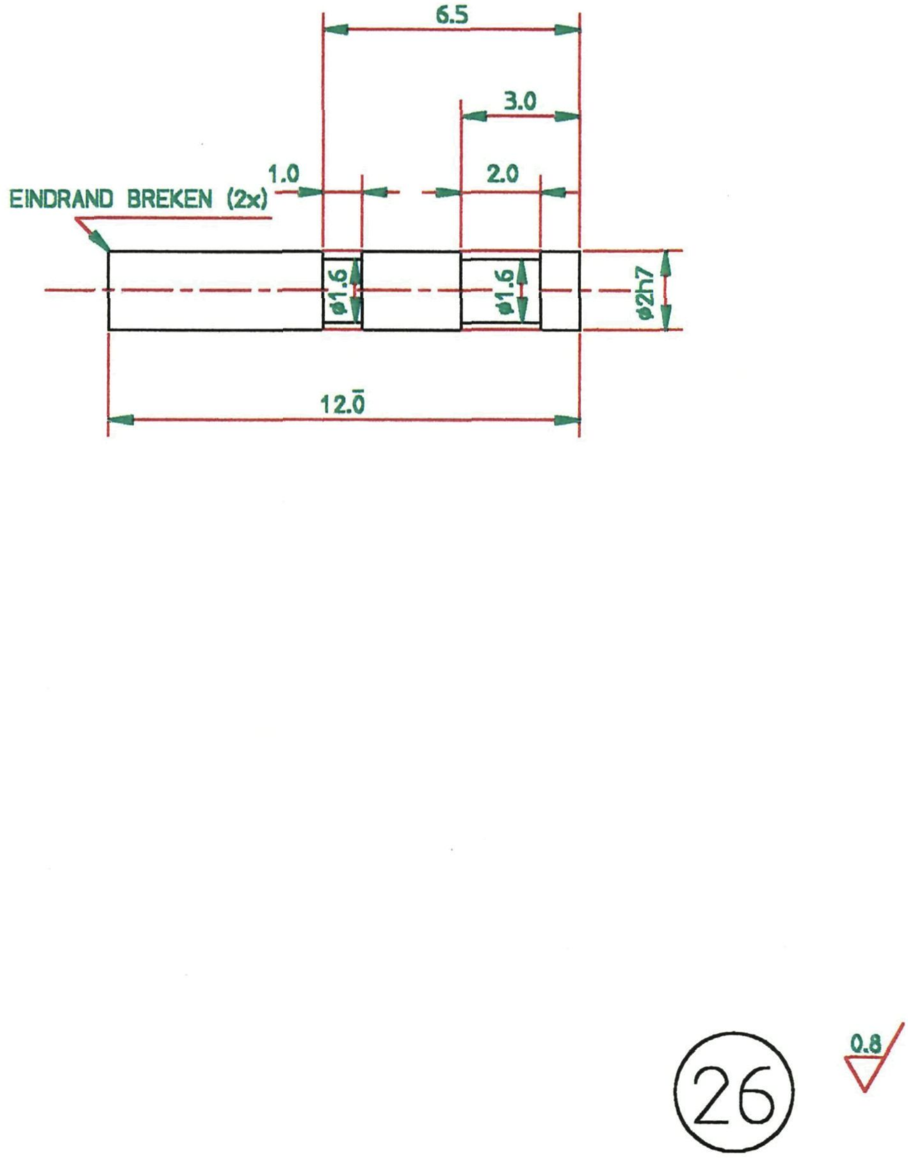
VLAK 0.2 ONBEWERKT LATEN

TECHNISCHE UNIVERSITEIT DELFT WMR, SECTIE INSTRUMENTEN LANDBERGSTRAAT 3 2628 CE DELFT	DUIMAS2	Get.: FEIJTEL Dat.: MEI '98 File: DUIMAS2 Schaal: 5 : 1	Gecont.	Mat.: RVS 303 Nr.: **-**-**

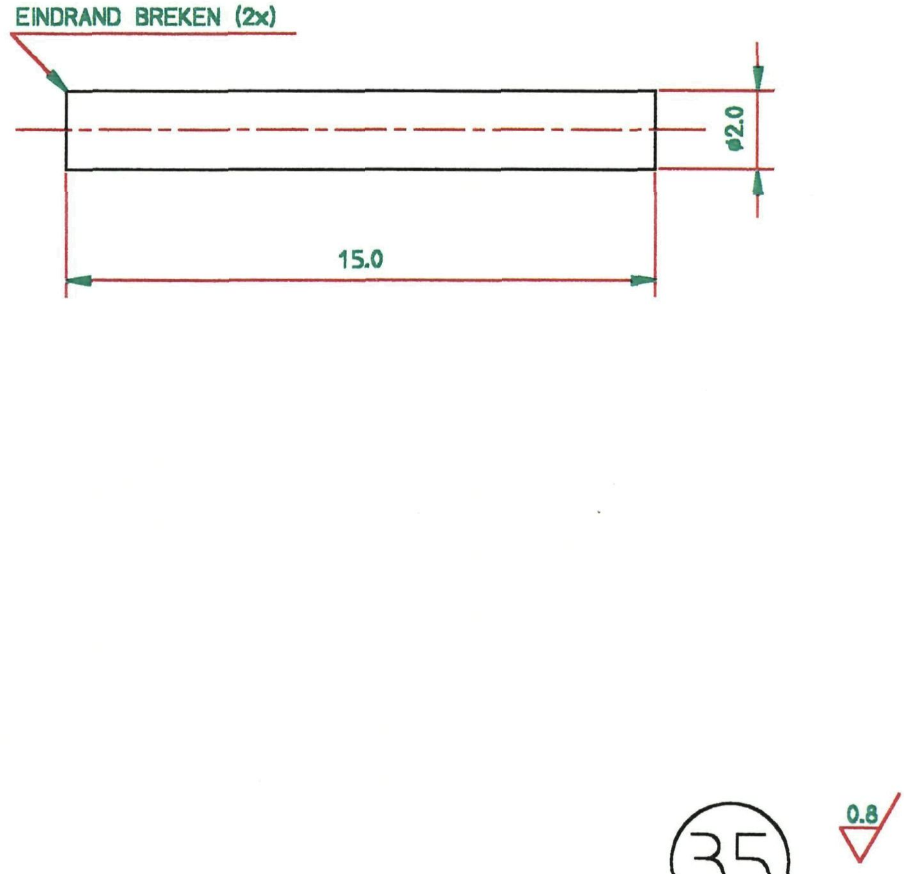


VLAK 0.2 ONBEWERKT LATEN

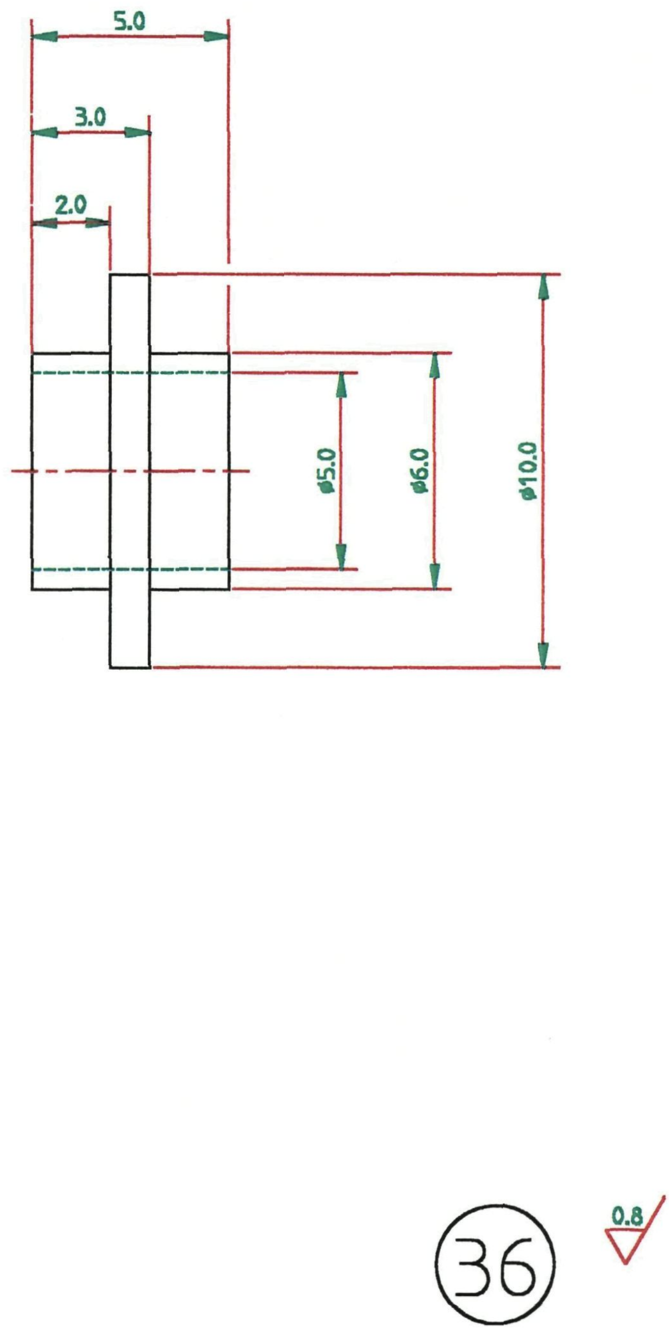
TECHNISCHE UNIVERSITEIT DELFT WMR, SECTIE INSTRUMENTEN LANDBERGSTRAAT 3 2628 CE DELFT	VEERAS1	Get.: FEIJTEL Dat.: MEI '98 File: VEERAS1 Schaal: 5 : 1	Gecont.	Mat.: RVS 303 Nr.: **-**-**



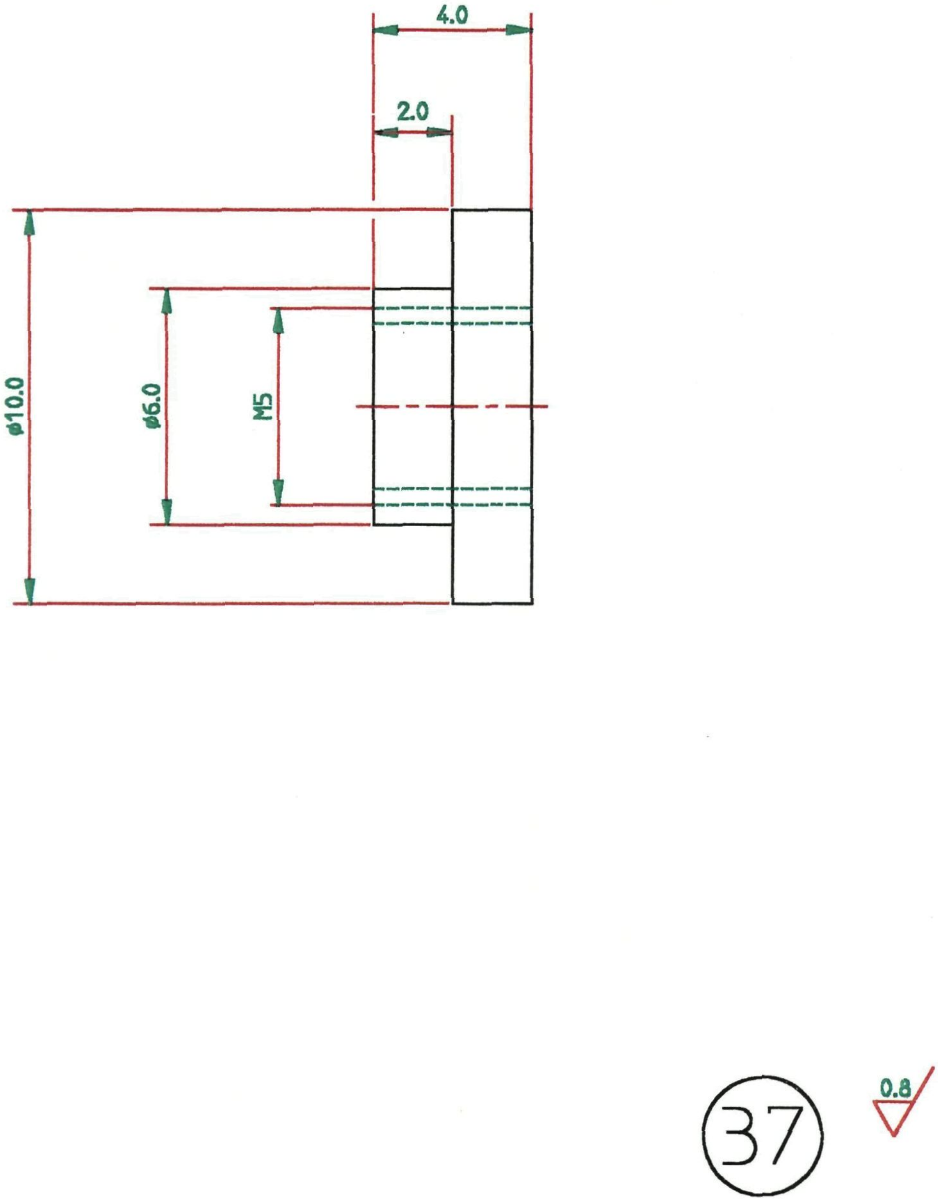
TECHNISCHE UNIVERSITEIT DELFT WMR, SECTIE INSTRUMENTEN LANDBERGSTRAAT 3 2628 CE DELFT	VEERAS2	Get.: FEIJTEL Dat.: MEI '98 File: VEERAS2 Schaal: 5 : 1	Gecont.	Mat.: RVS 303 Nr.: **-**-**



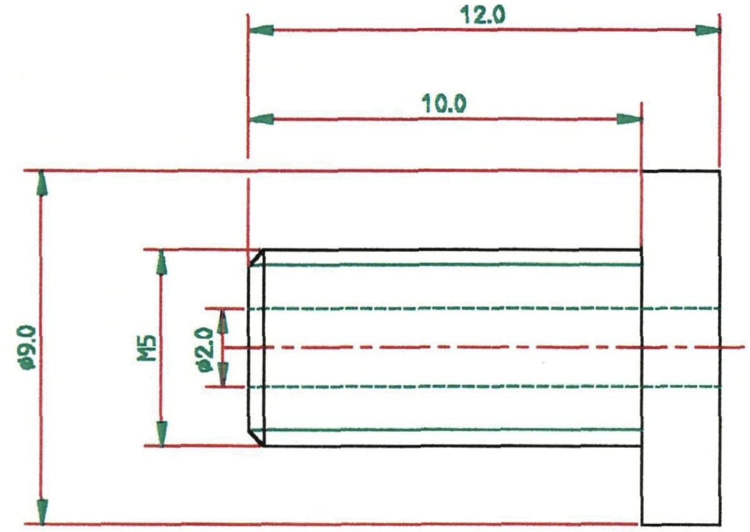
TECHNISCHE UNIVERSITEIT DELFT WMR, SECTIE INSTRUMENTEN LANDBERGSTRAAT 3 2628 CE DELFT	PASPEN	Get.: FEIJTEL Dat.: MEI '98 File: PASPEN Schaal: 5 : 1	Gecont.	Mat.: RVS 431 GEHARD Nr.: **-**-**

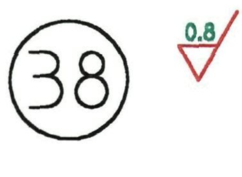


TECHNISCHE UNIVERSITEIT DELFT WMR, SECTIE INSTRUMENTEN LANDBERGSTRAAT 3 2628 CE DELFT	VEERRING	Get.: FEIJTEL Dat.: MRT '98 File: VEERRING Schaal: 5 : 1	Gecont.	Mat.: RVS 431 Nr.: **-**-**

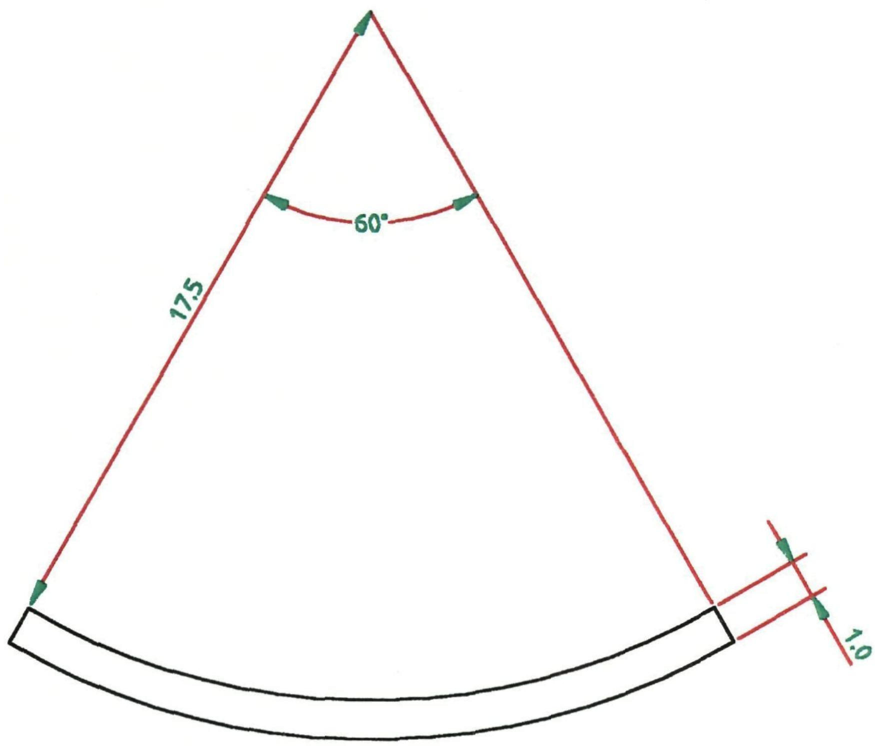


TECHNISCHE UNIVERSITEIT DELFT WMR, SECTIE INSTRUMENTEN LANDBERGSTRAAT 3 2628 CE DELFT	STELRING	Get.: FEIJTEL Dat.: MRT '98 File: STELRING Schaal: 5 : 1	Gecont.	Mat.: RVS 431 Nr.: **-**-**





TECHNISCHE UNIVERSITEIT DELFT WMR, SECTIE INSTRUMENTEN LANDBERGSTRAAT 3 2628 CE DELFT	STELBOUT	Get.: FEIJTEL Dat.: MRT '98 File: STELBOUT Schaal: 5 : 1	Gecont.	Mat.: RVS 431 Nr.: **-**-**



8mm breed

40

0.8

TECHNISCHE UNIVERSITEIT DELFT WMR, SECTIE INSTRUMENTEN LANDBERGSTRAAT 3 2628 CE DELFT	MAAN	Get.: FEIJTEL Dat.: MRT '98 File: MAAN Schaal: 5 : 1	Gecont.	Mat.: RVS 431 GEHARD Nr.: **-**-**