A study on the further development of the test protocol for the base slip test of leaning ladders

Final Report

21-07-2016

Contract n° 2014 86 01

Written by:

Netherlands Food and Consumer Product Safety Authority

Ministry of Economic Affairs

18 Jul 2016

Justice and Consumers

EUROPEAN COMMISSION

Produced by Consumers, Health, Agriculture and Food Executive Agency (Chafea) on behalf of

Directorate-General for Justice and Consumers
Directorate E — Consumers Unit E.3 (Consumer Markets)

European Commission
B-1049 Brussels

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Luxembourg: Publications Office of the European Union, 2016

ISBN 978-92-9200-718-8

doi:10.2818/915338

CONTENT

1 Abstract

The base slip of leaning ladders is a serious risk to the user. This risk is not covered in the EN 131-2:2010+A1:2012. In the Commissions view the European ladder standard needs improvement and therefore published a tender in 2014 with the aim to study the further development of the CEN TC93/WG10 test protocol for the base slip test of leaning ladders.

The product safety laboratory of the Netherlands Food and Consumer Safety Authority started the study in January 2015. The main parameters were studied and the protocol was improved. Three separate laboratories executed the tests according the protocol independently to judge the applicability of the protocol and variability of the results. The laboratories managed to execute tests under equal conditions.

The results show a large deviation and therefore the protocol in its actual form cannot be used as a standard test to distinguish the safe from the unsafe ladders concerning the resistance against base slip. No explanations were found for the large deviation. Therefore, more research is needed. It is not certain if the protocol can be further improved. It is recommended to continue with the development of an alternative method.

2 Introduction

Ladders are inherently dangerous products: some would even call them 'the deadliest DIY danger'[1] .Yet ladders are extremely common. Almost every household in Europe has at least a ladder or a step stool (the 3-steps ladder). According to the European Commission, the ladder standard needs a thorough improvements, in particular, the requirements for stability[2]. A group of ladder experts volunteered in a Ladder Working Group of the GPSD Committee. This group prepared a report[3] in which it identified that the EN 131-2 should include stability requirements and methods of assessing the stability of the ladder during conditions of use.

Most leaning ladder accidents are caused by base slip[4]: the bottom of the ladder slides away from the wall. These accidents are quite often the most serious ones, as they are more likely to happen the higher the user climbs on the ladder. A ladder only stands if there is friction between the top of the ladder and the wall and - more importantly - between the foot of the ladder and the ground. The friction between the foot of the ladder and the surface on which the ladder is standing is influenced by many factors; therefore it is not easily reproducible in a test lab. To further develop the test protocol for the base slip test of leaning ladders, as defined in contract 2014 86 01 by Consumers, Health and Food Executive Agency (CHAFEA), the Netherlands Food and Consumer Safety Authority (NVWA) started working on the program in January 2015.

This report describes the main activities that were done and the results that were obtained during the whole project. Chapter 3 describes the test environment of the NVWA laboratory, choice of samples and how the specific tasks were approached. Chapter 4 describes the findings and analysis of each task. Finally, chapter 5 describes the general conclusions and recommendations.

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[1] 'Ladders, deadliest DIY danger', 18 March 2001, http://news.bbc.co.uk/2/hi/uk_news/1227441.stm
[2] Tender specifictions , Ares(2014)69818 - 14/01/2014
[3] http://ec.europa.eu/chafea/documents/consumers/tenders/2013/eahc_2013_cp_07_annex-11_en.pdf
[4] Extension-ladder safety:Solutions and knowledge gaps, H. Hsiao et. Al., 19 March 2008

3 Methods and materials

3.1 General preparations

3.1.1 *Test setup*

In the Product Safety Laboratory of the NVWA a 6 meter high free wall, perpendicular to the floor, was prepared for the base slip tests. Against this wall, plates with specific surface conditions can be fixed at locations where a leaning ladder rests against the wall with its top feet.

On the floor, plates with specific surface conditions can be fixed at the location where the leaning ladder stands with its feet. The plates can be attached to the floor to prevent movement during the base slip test. Additionally, a heavy beam is provided at the end of slide path to prevent the ladder from slipping outwards excessively. Also, a stand is provided to position the ladders against the wall with its feet off the floor.

To apply the horizontal force during the test on stainless steel a contraption was build that leads the weight of a water bucket to the base of the ladder via a steel cable. Instructions in protocol CEN/TC 93/WG 10/N64 were the basis for building the contraption. Means to attach one end of the steel cable to the ladder were designed and realised. To lead the weight of the water bucket to the ladder base stainless steel highly flexible cable was used running over smooth running pulleys. On top of the contraption water was stored in a container. During tests the water flows down through a hose into the bucket below. The hose contains two valves. One to adjust and set the right water flow and a second to start and stop the flow. At the end of the hose the water exits horizontally to avoid that the water flow exerts a dynamic force on the bottom of the bucket.

Figure 1 - Impression of the base slip test site. Right, the vertical test wall with one of the samples on stainless steel. Left, the contraption that guides a thin steel wire along pulley's to transfer the weight of a bucket filled with water horizontally onto the lowest step of the ladder. In de middle a top view at the feet standing on stainless steel.

During the tests the temperature of the test site was monitored constantly and controlled to be 20 ± 2 C°. Previous to the tests the samples were stored lying flat on the floor in the vicinity of the test site. The polymers of the feet were able to relax at least 17 hours before testing.

3.1.2 Samples

To select the samples for the tests, past Joint Market Surveillance Actions[5] were taken as a starting point. The base slip results of these projects were reviewed and ten ladder models were selected having good, average and bad base slip results in the projects. The ladders have various properties: straight ladders and ladders with a wide base, both with stabilizer bar and flared beams, single part ladders, assembled ladders, telescopic and multi hinged. Additionally, all kinds of foot constructions are included like rounded standing surface, flat standing surface, stabilizer bar feet, telescopic ladder feet and wooden standing surface. The samples origin from various manufacturers and brands. European member states involved in the projects above were contacted and the internet was searched to find the selected ladders.

Seven ladders of the selection were purchased matching the models. Three samples were purchased as close to the specifications as possible. Of all samples two pieces were purchased; one as spare in case of backup is needed.

Table 1 - Ladder samples

	Ladder	Type	NVWA ID
1	DIRKS 2x12	push up ladder	87044297
2	Van Eldik 1x13	single straight ladder (wood)	87044319
3	HYMER 2x11	push up ladder	87044327
4	HYMER 2x16	rope operated ladder	87044335
5	ALPE 3x11	push up ladder	87044343
6	Hailo 3x9	push up ladder	87044351
7	Altrex 1x12	single straight	87044378
8	Zarges 1x12	single straight ladder	87044386
9	Jinmao 4x3	hinged ladder	87044394
10	ASC Group 1x13	telescopic ladder	87044408

An impression of the ladder are attached in Appendix 1.

3.2 Review of the TC93 / WG10 protocols (task 1.1)

The purpose of this task was to indicate what aspects of the two CEN TC93/WG10 protocols, if any, should be amended.
In the NVWA's view a protocol needs to be valid and practically executable. Validity means that the protocol describes a test that is valid for the parameters to determine. Practically it means it has to be possible for any lab to execute the test without expensive and sophisticated means. Different laboratories should be able to execute the test in the same way. Hence, it must be easy to purchase the required equipment. The protocol should be unambiguously described.
With this thought the protocols devised by the CEN TC93/WG10 (see Appendix 2) were critically and analytically reviewed. All NVWA team

[5] Final Technical Report Ladders – Joint Action 2012 GPSD – D11.2LD – January 2015

members reviewed both protocols and listed advantages and shortcomings from their own point of view. Additionally, they formulated improvements. Then, the lists were shared within the team. Comments of each other's review were discussed. Expertise, experience, previous results and findings and theory was involved. Also practical considerations were made.
Based on the result of this critical and analytical review the TC93/WG10 protocols were amended. The amended protocols were used for a first series of tests. The amended subjects are described in more detail in the next paragraphs.

3.3 First series of tests (task 1.2)

The purpose of this task was to obtain results that enable a choice for the vertical weight to use in the next task.
A first series of 57 tests were done on stainless steel according to CEN/TC 93/WG 10/N64 amended in task 1.1. All 10 samples were tested with 50 kg, 100 kg, and 150 kg load at an angle of 70°. The aim of this test was to gain data on base slip performance on stainless steel and determine the load for the tests on float glass in a second series of tests in task 1.3.

3.3.1 *Preparations*

Stainless steel plates were prepared. The steel plates were attached to the floor with the polish grain perpendicular to the sliding direction. Stainless steel plates with the same Rz[6] roughness were mounted to the wall, cleaned once before each set of tests with ethanol and a dry cotton cloth. A test set-up was built as sketched in Figure 2.

3.3.2 *Way of testing*

In principle protocol CEN/TC 93/WG 10/N64 was taken as basis for testing the ladders. For the purpose of this task the tests were executed with loads of 50 kg, 100 kg and 150 kg. During the transition from one to the next load the ladders were stored flat on the floor for at least 17 hours. The feet and plates only were cleaned between each transition.
The tests were started with the series of the 50 kg load, naturally with unused feet, than with 100 kg and at last with 150 kg. Along the tests the feet became more 'used'. To have a reasonable comparison with the results of 100 kg and 150 kg, with used feed, the tests with a load of 50 kg was repeated with used feet.
During the tests the mass of the bucket with water that caused the ladder base to slip over 40 mm and the test duration were recorded as main results. Additionally, some characteristic dimensions were noted as well. During the tests the temperature of the feet and stainless steel plates were monitored. At first constantly while the test was running. Later, only before and after the test.

[6] Rz roughness of a surface according to DIN is defined as the average distance between the highest peak and lowest valley of the surface in each sampling length.

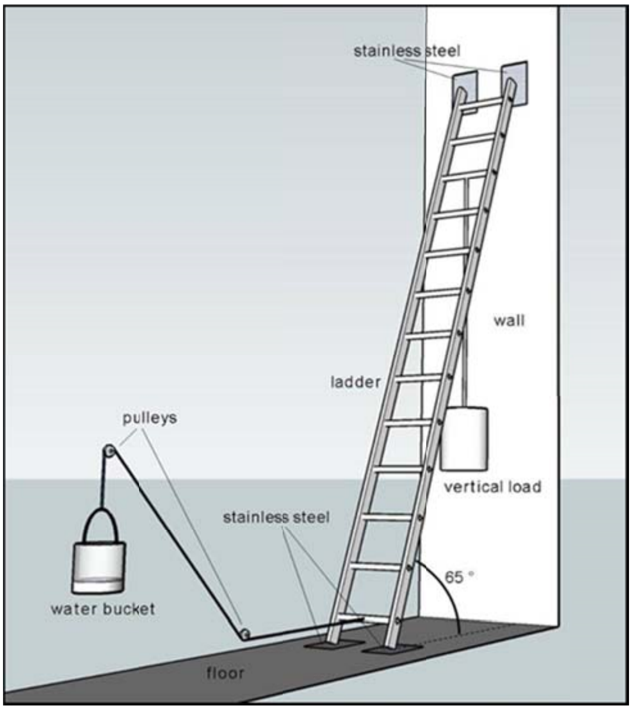


Figure 2 - Test set-up on stainless steel.

3.3.3 *Considerations*

To achieve improvement of the protocol some considerations were made.

Influence of ladder length: The base of a ladder leaning against a wall will not slide away as long as the horizontal force component at the feet can be compensated by the friction force. The horizontal force component depends on where the load is on the ladder. The higher the load is on the ladder, the larger the horizontal force component is at the feet. During the base slip tests, the ladder length is set to a test length and a load is applied on the third rung from the top (maximum climbing height). For example, if the test length is 4 meter the load is approximately at a rate of 80% of the ladder length from the bottom. However, the test length is a practical one and in many cases not the maximum length at which the ladder can be used. In case of the same ladder extended to 8 meter the third rung from the top is approximately at a rate of 90% of the ladder length from the bottom and so is the load at maximum climbing height. This means that the horizontal force component at the feet is proportionally larger when the ladder is loaded at a longer length then the test length. In case of the example above the horizontal force component at the feet is 90/80 = 1.125 times larger.

As mentioned before as long as the horizontal force component is smaller than the maximum friction force the base of the ladder will not slip away. The maximum friction force is fixed and determined by the vertical load and the friction coefficient between the polymer feet and the stainless steel. The maximum friction force is independent of the ladder length and independent of the position of the load on the ladder.

During the base slip test, the horizontal pulling force is increased steadily to initiate a base slip. If the horizontal pulling force is larger than the maximum friction force minus the actual friction force under the test condition the ladder base will start sliding. Since the horizontal force component increases with the ladder length under test the horizontal pulling force to initiate the ladder base to slip will decreases with the ladder length under test. In other words, a ladder tested at a shorter length than its maximum length gains a favourable base slip performance.

It is to consider whether the protocol should compensate for this fact. A suggestion is to apply the vertical load higher on the ladder when it is tested at a shorter length than its maximum length.

Another phenomenon that depends on the ladder length is that styles of a longer ladder tend to bend more under load. The angle of the feet will change during the test before sliding. Assuming a 10 meter ladder at 70° bends 50mm in the middle. It can be calculated that this would result in ~0,5° reduction of the angle at the feet. It is to consider to test longer ladders at a compensated angle.

Diameter of the steel cable: Using a 4 mm steel cable to transfer the weight of the water to the ladder base, half a kilogram is lost on 15 kg due to bending around the sheaves. Using a 2 mm cable only 150 grams is lost on 15 kg. Hence, a thin cable is preferred.

Cleaning Cloth: The cotton cloth was used to clean the feet with ethanol instead of a clean-room certified dry hygiene wipe. Inspections through a microscope revealed that no fluff was left behind on the feet after cleaning with a cotton cloth. Fibres from fabric left behind on the steel after cleaning could influence the resistance against sliding of ladder feet during testing.

Blocking of the ladder: Blocking has been done manually, by holding the ladder back, standing in front of it, with both hands at the styles without bending the ladder. A mechanical solution needs to be highly sophisticated to not introduce unintentional movement, blocking or impulses. It needs a good thought to find a solution for blocking without human intervention.

Vertical load: A hoisting strap was used to attach the vertical load to the third rung. A strap distributes the load along the rung and it will lead the load through the cross section centre of the rung. A strap can be positioned in advance and tightened to the rung in a way that is fixed exactly in between styles. The load should be applied exactly in between the styles to avoid pressure difference on the feet causing different base slip performance between both feet. It can be calculated that a 10 mm displacement out of the middle on a 400 mm wide rung under 100 kg load causes a 5 kg difference between feet.

Water flow: For the tests a water flow of 3 ± 0,2 litres per minute was chosen. Past Joint Market Surveillance Actions showed that 3 litres is a good rate to distinguish different base slip behaviour. At small flow rates tests would take unacceptably long. High flow rates would turn the test into a test with a dynamic character while the base slip test is preferred to be a static test. The acceptable deviation on the flow has been decreased from ±0,5 to ±0,2 litres per minute, meaning from 17% to 7% deviation, achieving less deviation between tests and laboratories.

Cable attachment: An L-shaped beam, or any rectangular shaped beam, is preferred to a beam with a circular cross section. If not attached rigidly to the ladder, the latter introduces an upwards force component that is not representative for real use. A rectangular beam is more easy to mount rigidly to the styles and will not introduce this upwards component. It is also important to align the cable attachment point exactly in between the styles. Any misalignment causes a different pulling force on each ladder side. Assuming a ladder with 400 mm between the styles, it can be calculated that a

cable misalignment of 10 mm from middle causes a difference of 0,5 kg pulling force between the stiles when the bucket with water weighs 10 kg.
Total Alignment: The contraption for the base slip was set up in a way to meet the following conditions:

- The pulley sheaves need to be aligned with each other in an imaginary plane that is upright to the floor and perpendicular to the vertical wall. The steel cable runs through this plane to the ladder.
- The centre line of the ladder needs to be aligned with this imaginary vertical plane. To do so a line was drawn on the test wall that is exactly vertical. It helps aligning the top side of the ladder.

If this is correctly done the vector of the vertical load propagates exactly through this imaginary vertical plane.
Choice of ladders to be tested repeatedly: To reveal data on the repeatability of the tests in an early stage of the project three ladders were tested four times instead of once. These three ladders performed good, average and bad in past Joint Market Surveillance Actions.

Table 2 – The three ladders that were tested repeatedly

	Ladder	Type	NVWA ID
1	DIRKS 2x12	push up ladder	87044297
6	Hailo 3x9	push up ladder	87044351
8	Zarges 1x12	single straight ladder	87044386

Stainless steel Rz 5 µm: The instructions for the stainless steel treatment of protocol CEN/TC 93/WG 10/N64 were followed to achieve a Rz roughness of 2 µm on stainless steel plates. It was a laborious job with unsatisfying result. Therefore the plates as used during the last Joint Market Surveillance Action on ladders were used with an Rz of 5 µm were used. It is likely to expect that ladders are more resistant against sliding on 5 µm than on 2 µm. The relative difference between the ladders however will still be revealed by the results. Testing on 5 µm instead of 2 µm will still enable to fulfil the aim of this task. Some time was spent to find an alternative. Electrolytical polishing was found as an alternative surface treatment for stainless steel. An orientation on this technique and consultation with several companies revealed that the surface of stainless steel becomes very homogeneous after the treatment. One company confirmed a Rz of 2 ± 0,2 µm to be feasible and agreed upon delivering electrolytically polished plates. Additionally, mechanically polished stainless steel plates with a Rz of 2 ± 0,2 µm ordered at a company with professional polishing experience.

3.4 Second series of tests (task 1.3)

The purpose of this task was to obtain results from tests on float glass at two angles, each tests once repeated.
A second series of 200 tests were done on float glass according to CEN/TC 93/WG 10/N99 amended in task 1.1. All 10 samples were tested with 50 kg at an angle of 65° and 70°. Each test was executed twice. The aim of this task was to gain data on base slip performance on float glass.

3.4.1 *Preparations*

Float glass of 10 mm thick produced according to EN 572-2 was fixed to the floor. Stainless steel plates with a Rz surface roughness of 5 µm, as used in task 1.2, were mounted to the vertical wall on the spot where the top part of the ladder touches the wall.

The samples used for this task were the same as used for task 1.2.

3.4.2 *Way of testing*

The amended protocol CEN/TC 93/WG 10/N99 was taken as basis for testing the ladders, see Figure 3. As a result of the previous task a load of 50 kg was used.

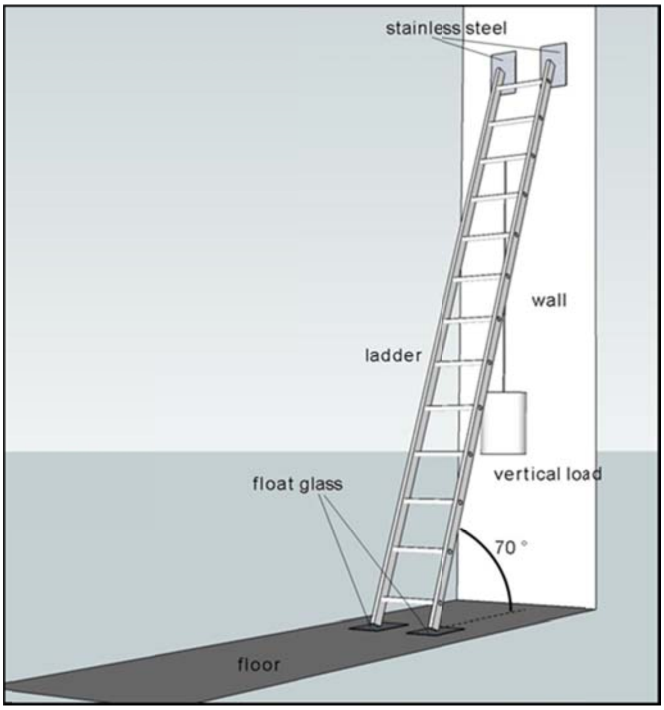


Figure 3 - Test set-up on float glass.

3.4.3 *Considerations*

Test duration: In these tests the time that the feet need to slip 40 mm is recorded. To avoid endless tests, some choices were made to limit the durations of the tests. If no displacement could be observed the test was stopped after 5 minutes. If any displacement could be observed the test was stopped when the feet displaced 40 mm or when 15 minutes elapsed. In the case of reaching 40 mm the duration was noted and in case of elapsing 15 minutes the displacement was noted.

Vertical wall surface: Glass is preferred as the support material on the vertical wall because of minimal friction. However, stainless steel plates are chosen to put on the wall to support the top part of the ladder in this task. Generally, the horizontal force against the wall in real is small compared to the vertical load and so is the friction. The friction with the stainless steel plates on the wall is assumed to be much smaller than the friction on the glass base and therefore of negligible influence. Glass plates on the wall can break during tests. Descending shards pose a risk to the laboratory staff. For this practical reason stainless steel was used. Glass may be used in future, but it has to be considered how to apply glass on the vertical wall without posing risk at the staff.

Top wheels: As a derogation from instruction in CEN/TC 93/WG 10/N99 no wheels were mounted at the top of the ladder. Although additional wheels provide minimal friction with the wall it is preferred to test the ladder as delivered. Adding top wheels by a laboratory for testing purposes has a number of disadvantages:

- It is likely that the construction of the ladder (top) has to be changed to mount the wheel construction, which can be a considerable amount of extra work and make the ladder less suitable for other tests.
- It is likely to expect that testing laboratories design different constructions to apply the wheels. This would result in different test circumstances amongst the testing laboratories resulting in different results. To define a standard construction in the protocol is almost undoable because it has to suit a lot of different ladders.
- An additional construction with wheels at the ladder top changes the weight and weight distribution of the ladder. The centroid shifts upwards resulting in an increased horizontal force that consumes part of the capability of remain standing. An increased weight also changes its dynamic behaviour of sliding. These effects of adding wheels to the top have relatively more influence on short ladders that on long ones.
- If the ladder slides away completely it is likely that the wheel construction is damaged and a new wheel construction has to be build and mounted. Apart from the effort this can make correct interval timing of tests impossible.
- Wheels rolling at the top and the construction around it will induce vibrations which will differ from the vibrations when the original ladder top would slide along the wall. These vibrations are likely to have influence on the sliding process at the bottom.
- Testing with wheels is not testing the ladder as it was supplied and therefore not representative for the use in practice.
- A manufacturer can claim that the ladder failed the test due to the fact that top wheels are added. The testing laboratory will not be able to refute this because the original ladder (without top wheels) is not tested. See also the next point!
- An innovative ladder manufacturer could design a ladder in such a way that the top helps to improve slip resistance. Instruct to add top wheels to the ladder for testing would not encourage this innovation.

Adding the fact that in the big majority of cases the friction at the top will have little influence compared with the friction on the floor, it is strongly preferred to work with a smooth surface on the wall instead of mounting a wheel construction on the ladder.

3.5 Complementary tests (task 1.4)

The purpose of this task was to evaluate the results of task 1.2 and task 1.3 and to decide what complementary tests should be done.
Test of the electrolytically polished and mechanically polished surface treatment that were outsourced were yet to be used for the base slip to complement the results of previous task. Additionally, the choice of the 50 kg on float glass in task 1.3 needed a verification. To complement the tests of previous tasks 69 tests were done.

3.5.1 *First series of complementary tests*

The mechanically polished stainless steel with an Rz of 2 ± 0,2 µm looked smooth and homogeneous. However, a pale circular pattern could be noticed. The roughness was within the specifications. The electrolytically polished with Rz of 2 ± 0,2 µm has a smooth, homogeneous and shiny looking surface. The Rz roughness of both was within specification. Base slip results with these plates would complement the results of previous tasks. For task 1.3 the vertical load was chosen to be 50 kg. This choice would be verified with tests using 150 kg load on float glass. Complementary tests were planned as follows:

1. As in 1.2 (stainless steel) with 150 kg 70° only, on the stainless steel as used for the tests in task 1.2 (Rz = 5 µm) repeated 4x. (reference)
2. As in 1.2 (stainless steel) with 150 kg and 70°, only on electrolytically polished stainless steel (Rz = 2 µm) repeated 4x.
3. As in 1.3 (float glass) with 150 kg and at 70° only, on float glass as used for the tests in task 1.3 repeated 2x.

Apart from the specific settings all other settings were replicated from task 1.2 and 1.3. The tests were done on the three samples that were tested repeatedly in task 1.2 and 1.3.

Table 3 - samples that were tested repeatedly

	Ladder	Type	NVWA ID
1	DIRKS 2x12	push up ladder	87044297
6	Hailo 3x9	push up ladder	87044351
8	Zarges 1x12	single straight ladder	87044386

The samples were used in the condition as they were after task 1.3. In between the tests of task 1.3 and the complementary tests of task 1.4 the ladder were stored lying flat on the floor at 20 ± 2 °C.
Analysing the results of the complementary tests listed above it turns out that the electrolytically polished stainless steel plates with Rz 2 µm were accidentally exchanged with mechanically polished plates of Rz 2 µm. Therefore more tests had to be done to gain the necessary data on electrolytically polished steel. This data was needed to judge applicability of electrolytically polished plates that were assumed to have a more homogenous micro structure than mechanically polished plates.

3.5.2 *Second series of complementary tests*

It was decided to order more sets of electrolytically polished plates at the same company and a second company. This would enable to compare base slip

results of plates from different sources and reproducibility of plates from the same source. Additionally, it would gain more data to compare the base slip behaviour with mechanically polished stainless steel.
On theoretical bases the roughness of the floor is a significant parameter. The results of previous tests and past projects on base slip show that the roughness of the stainless steel needs to be defined and prepared with care. Once delivered, five sets of plates were ready to support a second series of tests.

Table 4 - Stainless steel plates available for the second series of complementary tests.

	surface treatment	Rz[7] [µm]	supplier	remark
1	electro polish	0,7	Company D	2nd batch (June ’15)
2	electro polish	1,4	Company G	
3	electro polish	1.9	Company D	1st batch (April ’15)
4	mech. polish	1.9	Company V	professional
5	hand polish	3,5	NVWA	Acc. to instructions in CEN/TC 93/WG 10/N64

All plates are of stainless steel type AISI 304 (1.4301) with a dimension of 300 x 200 x 2 mm. The specifications of the Rz roughness for the suppliers to achieve was 2,0 ± 0,2 µm.

3.6 Draft final base slip protocol (task 1.5)

The purpose of this task was to provide recommendations for the best form of the protocol based on the findings of previous tasks.
Based on results and experience of previous tasks the protocols were developed further into a new protocol. In the NVWA’s view a protocol needs to be designed in such way that it firstly can be repeated by any laboratory. All significant parameters need to be known and controllable. The protocol must be written unambiguously. Further, a protocol needs to include a test method that gains results that enables to distinguish the good from the bad ladders. A test method in which all ladders pass is not a good test considering the risk of the users. On the contrary, a test method in which all ladders fail would not be accepted by the producers. Therefore a reasonable compromise has to be found: requirements that take away the main risks that occur during reasonably foreseeable use but take into account what is possible with the present state of technique as well.
Results so far did not provide sufficient information to decide which surface specifications for the stainless steel should be specified in the protocol: stainless steel treated by mechanical polishing or treated by electrolytical polishing. Mechanically polished stainless steel with Rz 3.5 µm gains distinctive results. However, realising equal surfaces between laboratories is still a challenge as is measuring Rz according to the same standard. Electrolytically polishing gains a homogeneous surface conditions but 2 µm turns out to be too smooth. What other roughness is feasible is not known let alone how it influences the base slip performance. Additionally, the process of electrolytical polishing process for base plates needs to be studied to find stable parameter settings. After a discussion within the team and consultation

[7] roughness values are the average of 5 measurements across the surface.

with the expert group it was decided to proceed with mechanically polished plates.

3.7 Base slip test with the new protocol (task 1.6)

The purpose of this task was to perform base slip tests according to the new protocol as defined in task 1.5 .
For this task 160 test were done according to the new protocol with new ladders.

3.7.1 Preparations

Samples: The samples for this task are the same as used in the previous tasks, but new. Before testing they were stored lying horizontally with the feet unloaded. The polymer feet were assumed relaxed.

Test set-up: The new test set-up was prepared on the same test site as used in the first tasks. The equipment and aids were adapted to the requirements in the new protocols. Also the area around the test set-up was temperature conditioned to meet the protocols requirement during the tests.

Way of testing: The tests were done according to the new protocol. Practically, the tests per sample included:

- 3 preconditioning tests on stainless steel at 65° with 150 kg
- 3 preconditioning tests on stainless steel at 70° with 150 kg
- 5 tests on stainless steel at 65° with 150 kg
- 5 tests on float glass at 70° with 50 kg.

Steel plates: New stainless steel plates were purchased. The plates (300 x 200 x 2 mm) are polished mechanically by a professional grinding and polishing company. The plates were purchased in one batch of 16 plates. Once received, the surface conditions of all plates were identified by measuring the Rz roughness. See Appendix 2. Based on this data, 8 plates were selected as floor plates. The Rz of these plates are within the smallest range of Rz roughness, being Rz 3.3 ± 0,5 µm. The other 8 plates were selected as wall plates.

3.8 Final protocol base slip test (task 1.7)

The purpose of this task was to prepare a final version of the base slip protocol including a pass/fail criterion.
The findings and experience of task 1.6 were evaluated within the project team. Based on that the protocol was amended. The protocol has still two parts. Part one is on stainless steel plates at 65° 150 kg. This part also includes preconditioning tests. The second part is on float glass plates at 70° with 50 kg.

3.9 Round robin (task 2.1)

The purpose of this task was to organise a round robin in three separate laboratories.
To judge the practicability of the new protocols of task 1.7 and the value of the results, 324 tests with 9 samples were executed by three different laboratories.

3.9.1 Samples

To execute the round robin samples were chosen from the selection of task 1. The results of task 1.6 were used as basis for the choice. The samples for the round robin were selected with the intention to gain a wide range of results during the round robin. If all ladders would remain standing the results would not gain distinctive results to give a profound picture of the performance of the base slip test. Furthermore, to involve that the load needs to be applied on different rungs, as indicated in item 34 of the stainless steel protocol, the same Dirks ladder as in task 1 was purchased only with 3 parts of 16 rungs. (11,45 m fully extended).

Table 5 - round robin samples

	Ladder	Type	NVWA ID	Performance in previous tasks
1	DIRKS 3x16	push up ladder	87044297	Good results on both steel and glass
2	Hailo 2x9	push up ladder	87044351	Bad results on steel and good on glass
3	Zarges 1x12	single straight ladder	87044386	Moderate on steel and bad on glass

Choosing samples of task 1 enables comparison between results throughout the project giving extended data on the reproducibility.

3.9.2 Laboratories

Three laboratories participated in the Round robin. The laboratories were selected out of a list of 6 options. Capability, availability and price were subjects that counted during the selection.

Table 6 - round robin laboratories

	Laboratory	Location - Country	Information
1	Vinçotte	Vilvoorde - Belgium	www.vincotte.be/en_be/labo/
2	INAIL	Monte Porzio Catone - Italy	www.inail.it/cs/internet/multi/english.html
3	NVWA	Zwijndrecht - Netherlands	english.nvwa.nl/

Two of the selected laboratories are accredited for ladder tests according to EN 131 and have proven experience in testing ladders. The other selected laboratory has significant and proven experience with the base slip test of leaning ladders. All three selected laboratories are working in the non-profit area, fully or partly.
All laboratories were visited by the NVWA during one of the tests. During this visit the execution of the test was witnessed and the equipment and protocol requirements were inspected.

3.10 Round robin – analysis (task 2.2)

The purpose of this task was to analyse the results of the round robin of task 2.1 to judge the variability of the results.
Results were collected form the three laboratories. The raw data from the laboratories were converted into performance graphs per sample, per floor

material . The graphs were structured in an overview table per ladder, per floor material.

The results have been analysed and discussed within the project team of the NVWA. The external laboratories were asked for their opinion on the results.

4 Results and analysis

4.1 Review of the CEN TC93 / WG10 protocols (task 1.1)

As a results of the critical and analytical review the advantages, shortcomings and improvements of CEN/TC 93/WG 10/N64 and CEN/TC 93/WG 10/N99 were listed in two tables. The improvements of the review were implemented in the protocols and resulted in amended versions of CEN/TC 93/WG 10/N64 and CEN/TC 93/WG 10/N99.
Aspects that were reconsidered amongst others:
- multiple choices
- indistinct phrases
- tolerances of significant parameters
- timing of and in between tests
- specifications

The full list of comments, shortcomings and improvements of both protocols is attached in Appendix 4.

4.2 First series of tests (task 1.2)

The results of the base slip tests on stainless steel are showed in Figure 4. The base slip tests were performed with a vertical load of 50, 100 and 150 kg. The results of the tests show that some samples have most trouble coping with 50 kg and some samples with 150 kg; respectively 6 and 4 out of 10.

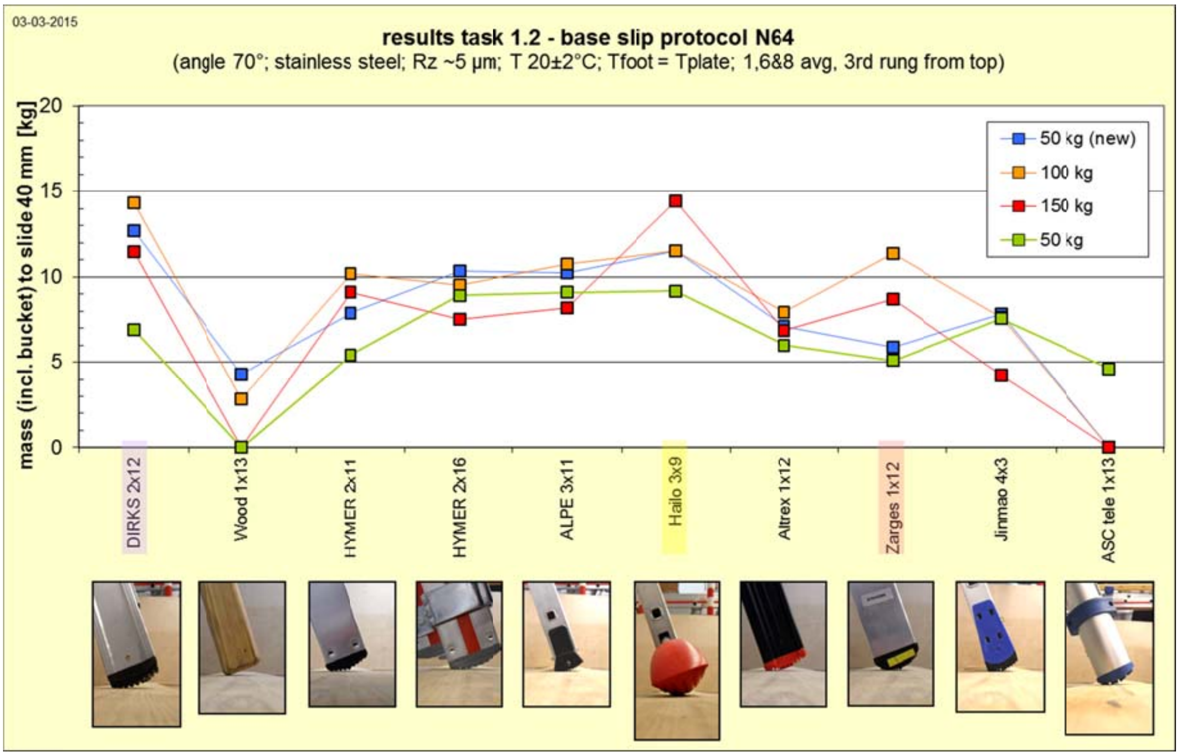


Figure 4 - Results on stainless steel at 70°. Most samples have trouble coping with 50 kg and 150 kg. With new feet the base slip resistance is better than with 'used' feet.

From the results of 50 kg, new and used, it turns out that the base slip performance with 50kg is worse after tests with 100kg and 150kg. The telescopic and the wooden ladder have a remarkable bad base slip resistance. The Hailo performs best. Under all loads it has the highest base slip resistance.

The results of the Altrex stand out because it performs almost equal under all loads.
Other findings of the base slip tests on stainless steel at 65° are:

- there is a clear distinction between the results of good and bad performing ladders.
- that the deviation between tests decreases the more the feet wear. The standard deviations of the horizontal force at 50 kg with new feet (3,8 kg) is consistently higher than 50 kg with used feet (2,8 kg). It also seems that the higher the load the larger the deviation; 4,4 kg at 100 kg load and 4,8 kg at 150 kg load.
- that the 2σ deviation of the results of the repeated tests is around 20%.
- that the water flow rate, calculated from duration and mass, turns out to be still quite variable throughout the tests. In the used test site the flow rate depends on the height of the water in the container. The used container is rather narrow causing the water level to ascend quickly in between tests. Using a wide container will result in less fluctuation of the water level during the test series.
- that the values in Figure 4 that are averages of five tests (Dirks; Hailo; Zarges) all perform better. The difference between the loads is larger.

A few checks on the room temperature showed that the temperature does not change significantly during and in between the tests. Also, no significant differences of temperature between feet and steel were noticed. Throughout all tests of task 1.2 the temperature in the vicinity of the test site was 20 ± 2 °C.

Intermezzo
When a mass m is pulled by a horizontal force F_{pull} causing the mass to slide upon another material a counter force $F_{friction}$ will arise caused by friction between the two materials. See Figure 5. According to the classical friction theory of Coulomb the proportion of the friction force is linear to the vertical force $F_{vertical}$. The ratio between $F_{vertical}$ and $F_{friction}$ is defined as the friction factor. According to the classical friction theory this factor is constant for most materials.

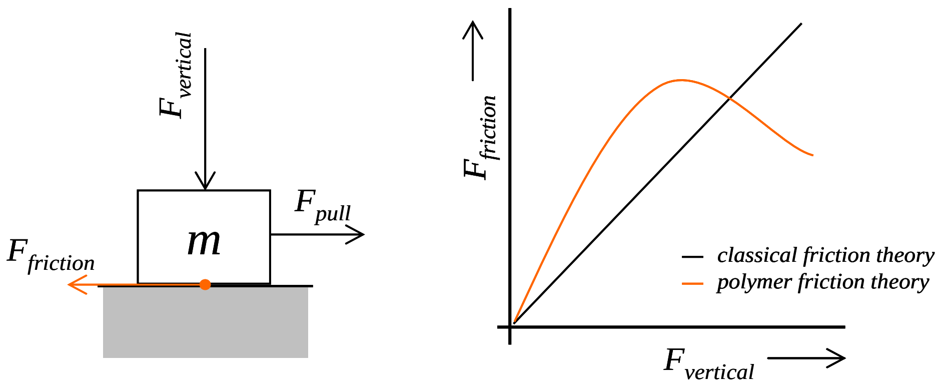


Figure 5 - When a mass m made of polymers is pulled along a surface by a pulling force the counter force coursed by friction between the two materials is not directly proportional to the vertical load.

If the mass m is made of polymers the proportion of the friction force $F_{friction}$ is non-linear[8] to the vertical force $F_{vertical}$. (indicatively illustrated by the orange

[8] Elastomeren Fäderung elastische Lagerungen, 1982, from Battermann & Köhler, published by Verlag Wilhelm Ernst & Sohn, ISBN 3-433-00939-2.

graph in Figure 5) Because of this effect it will occur that at an increasing vertical force the friction will decreases at a certain point. The friction factor is not constant. Another effect that influences the base slip behaviour is that the contact area depends on the load, Figure 6. An increasing vertical load leads to a larger contact area, as the figure below illustrates, and hence more resistance against sliding.

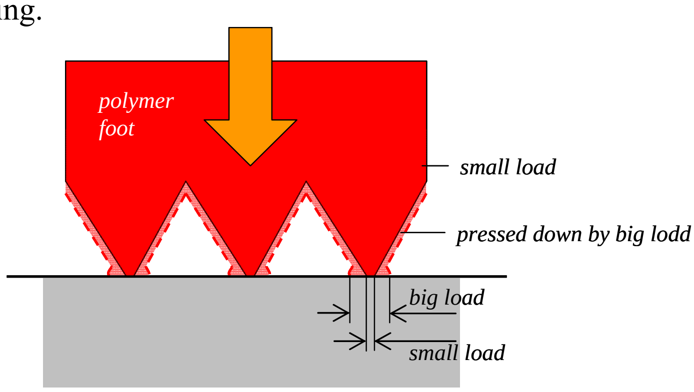


Figure 6 - Deformation of a polymer foot under load. The contact area between polymer and base material varies with the load.

According to anthropometric data[9] , the 5th percentile of the European adults body mass is approximately 50 kg. Under less load polymers would deform too little for an optimal resistance against base slip, posing a risk to the light user with minimal clothes and no carry. The 95th percentile of the European adults body mass is approximately 130 kg. Under high load the polymers would deform enough to achieve an optimal resistance against base slip. However, the resistance against sliding deteriorates when polymers are under high load, posing a risk to the heavy user with clothes and carry. These considerations argue for 50 and 150 kg to choose as weights for testing ladders in the most risky conditions. Besides, 150 kg is set as maximum load in the EU standard.

Testing with 50 kg on glass would then represent the worst case at the low end. Tests that would represent the worst case on the high end would be 150 kg on stainless steel. Testing with 150 kg on glass is not preferred because of the 'suction-cup'-effect. Vacuum spots under highly deformed feet would cause indistinct sliding performances. It is likely to expect that test with 50 kg on glass gain more distinctive results. Applying 150 kg on glass probably all samples will directly slide away.

Both the non-linear friction factor and the load dependent contact area strongly affect the base slip behaviour of a ladder. However, both effects also make it challenging to accurately predict base slip behaviour of leaning ladders.

Considering the above theory and findings in this task the load to apply on a glass base in the tests series of task 1.3 was recommendation to be 50 kg. However, it needs to be considered to include two loads in the eventual protocol.

[9] http://dined.io.tudelft.nl/en

4.3 Second series of tests (task 1.3)

This task produced three kinds of results:

- No displacement within 5 minutes.
- Less than 40 mm displacement within 15 minutes.
- 40 mm displacement in less than 15 minutes.

To enable comparison between these different results, the values were converted to the duration to slide 40 mm. The formula is

$$t_{(40\,mm)} = \frac{40\,mm}{s[mm]} \cdot t[minutes]$$

where:
s = the sliding distance that was recorded within
t = the time that was recorded

Table 7 - calculated examples

recorded distance [mm]	recorded time [minutes]	$t_{(40\ mm)}$ [minutes]
0	5	infinite
30	15	20
40	7	7

The data were plotted in graphs, see Figure 7. Plotting the sliding time of ladders that remained standing and ladders that slid within minutes did not result in a clear graph. Therefore times for ladders that remained standing were sized down to 2 hours; a value of two hours means the ladder remained standing under the test conditions. However, it still results a graph in which most lines are tangled at the bottom of the graph when the scale of the y-axis is set to a maximum of 2 hours. Therefore a second graph was plotted with the y-axis' maximum set to 10 minutes. One has to keep in mind that in this graph the "2:00:00h"-ladders are not displayed. Lines and bullets of the same colour display the same test conditions. Continuous lines display the first tests and dashed lines the second test at the same condition. Appendix 5 contains the graphs in larger sizes.

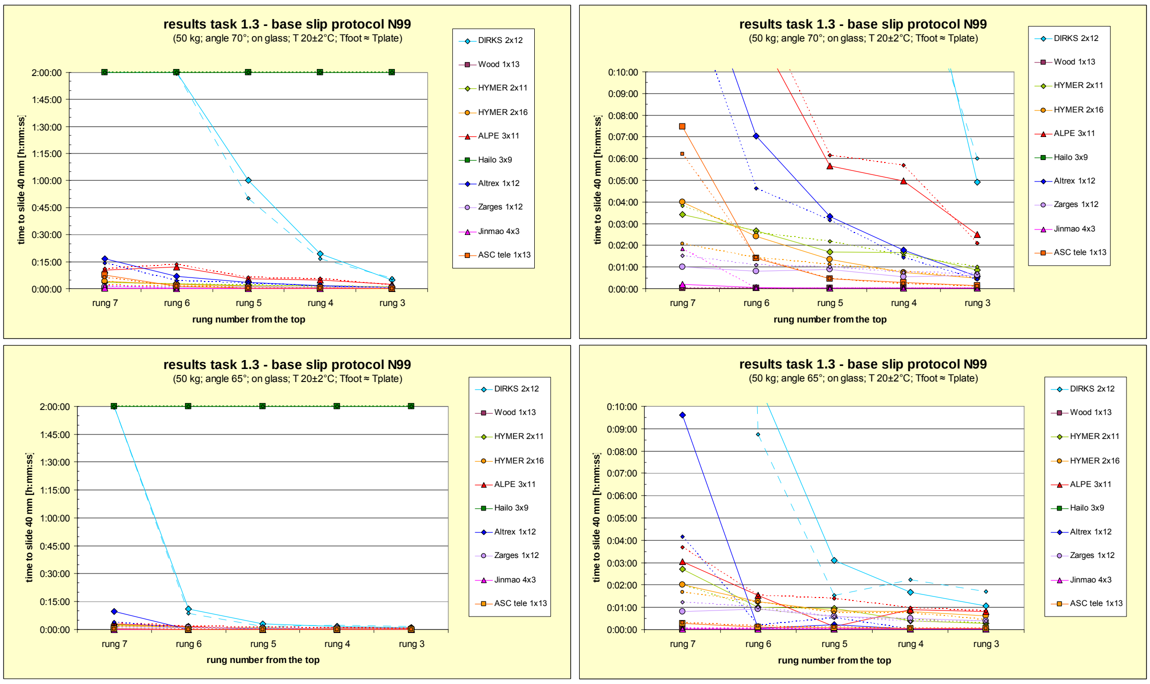


Figure 7 – Results on float glass with 50 kg. Most results are packed at the bottom of the graphs.

Only one ladder remains standing at all test conditions. One ladder slides immediately at all test conditions. Comparing the results of 65° and 70° it stands out that the samples are more resistant against sliding at 70° than at 65°. Generally, the samples slide quicker the more close the load is to the top. If it is counted how many samples slid 40 mm in less than 1 minute with the load on a certain rung the next overview can be drawn.

Table 8 - Number of ladders that slid 40 mm in less than 1 minute.

	7th rung from top	6th rung from top	5th rung from top	4th rung from top	3rd rung from top
angle 65°	4	5	8	8	8
angle 70°	2	3	4	5	7

These findings confirm what theoretically was expected. At a 65° angle most results are very close to each other. This makes it very difficult to distinguish the good ladders from the bad. In particular at the higher rungs.

In order to compare the base slip performance of the ladder on stainless steel and float glass under the same test conditions data of task 1.2 and 1.3 are plotted in one graph. See Figure 8.

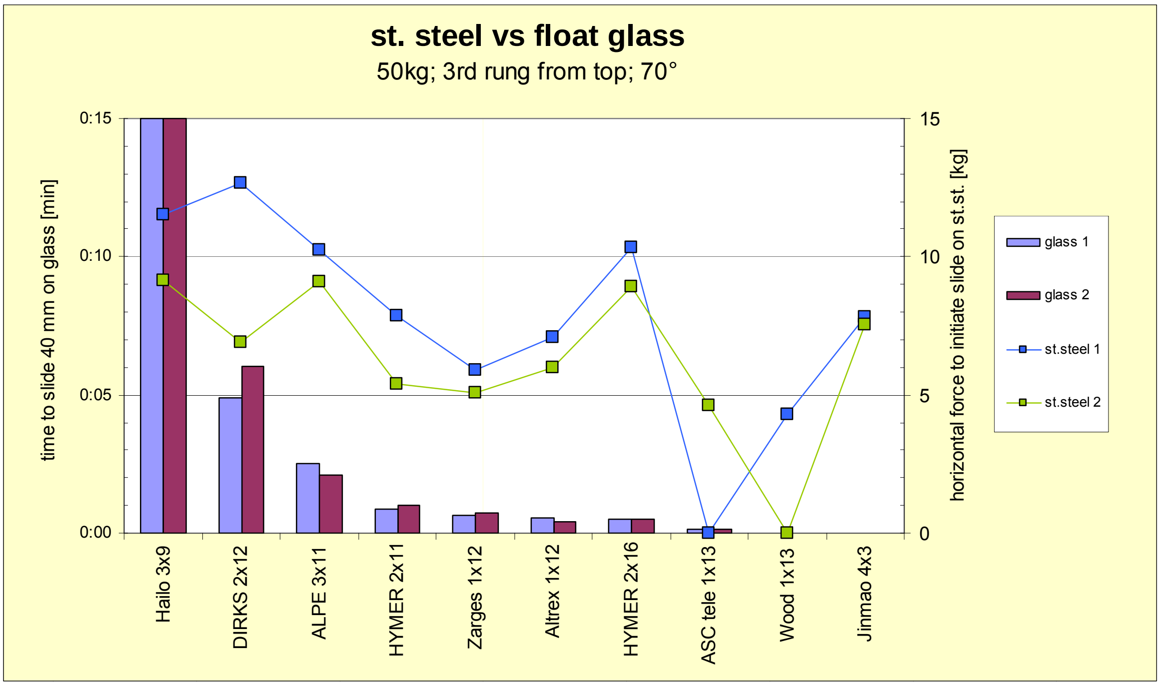


Figure 8 – Base slip results on both stainless steel and float glass to compare base slip performance.

Figure 8 shows that a good base slip performance during the tests on stainless steel does not guarantee a good base slip performance during the tests on float glass. While the Jinmao performs bad on float glass it performs average on stainless steel. The same counts for the Hymer 2x16. While the Dirks performs well on float glass it performs average on steel. From this results it needs to be considered to include two base materials in the eventual base slip protocol.

4.4 Complementary tests (task 1.4)

4.4.1 *First series of complementary tests*

The graph in Figure 9 is based on the graph in Figure 4. The data points of 50 kg and 100 kg of task 1.2 were removed leaving only the data points of 150 kg load. Data points of the complementary tests are added. The data points show the mass, including water bucket, to slide the base of the ladder to 40 mm.

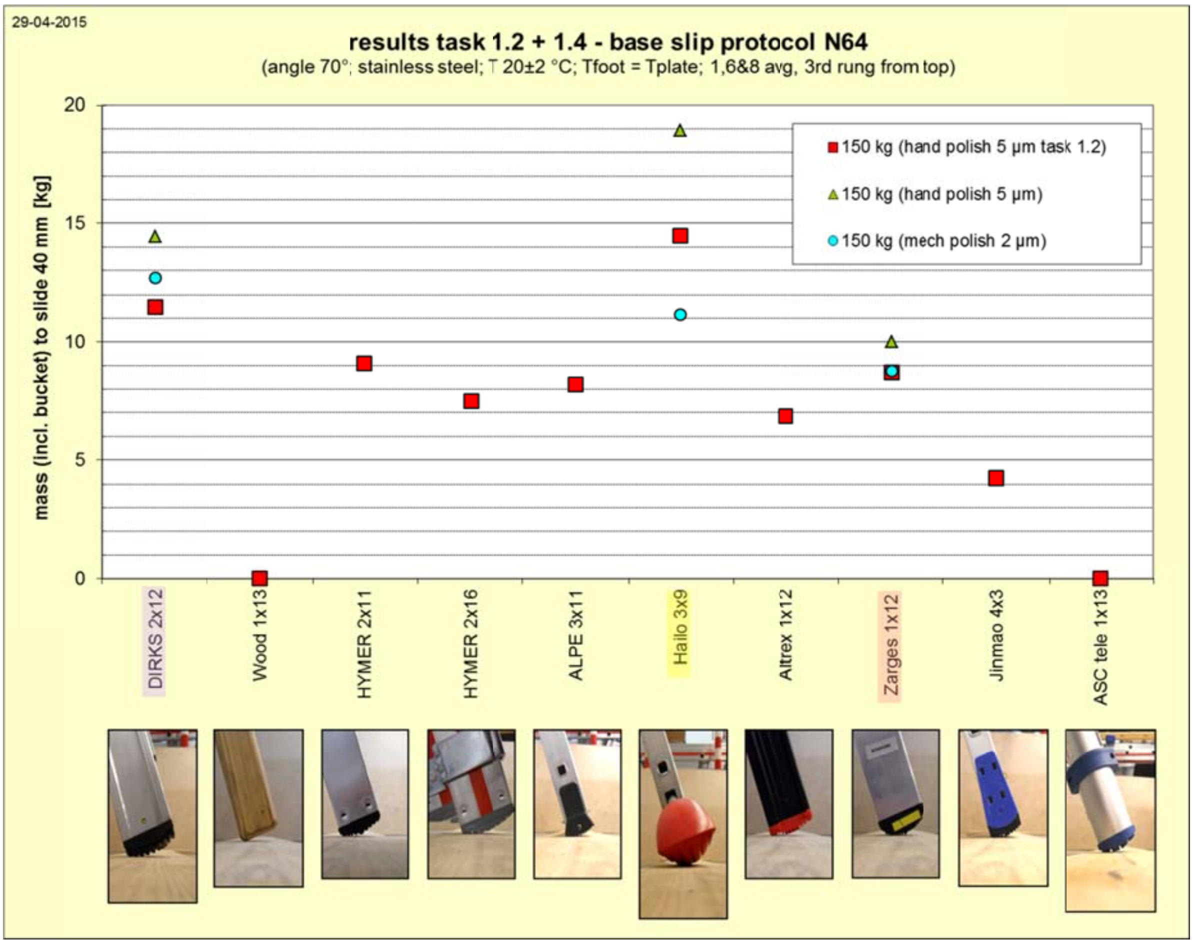


Figure 9 - Results of the first series of complementary tests compared with results of previous tests.

When analysing the results of the first series of complementary tests on stainless steel the results show

- that ladders are less resistant against base slip on mechanically polished stainless steel with an Rz of 2 µm than on manual polished stainless steel with an Rz of 5 µm. Apparently a surface with higher roughness gains more slip resistance;
- that when the results on hand polished 5 µm plate are combined with the results of task 1.2, gained under the same conditions, the deviation is within about ± 13 %, even though one test is with newer feet and the other with more used feet;
- that the higher the slip resistance the more deviation in test results;
- that in this tests ladders with more used feet perform better. In contrary to the results of task 1.2 with 50 kg.

The graph in Figure 10 is based on Figure 7 showing only the results of the three samples that were tested repeatedly on float glass. The light coloured graphs are the results from task 1.3 with 50 kg load. The dark coloured graphs are the results of the complementary tests with 150 kg. Each test has executed twice directly after another. The first is shown by the continuous lines and the second by the dashed lines. In some cases the dashed and continuous lines are on top of each other and difficult to see. Tests that gained no displacement of the feet would need infinite time to reach 40 mm. To plot a clear graph these values were manually changed to 12:00 hours. In other words, the values on 12:00 represent no base slip at all under the specific test conditions.

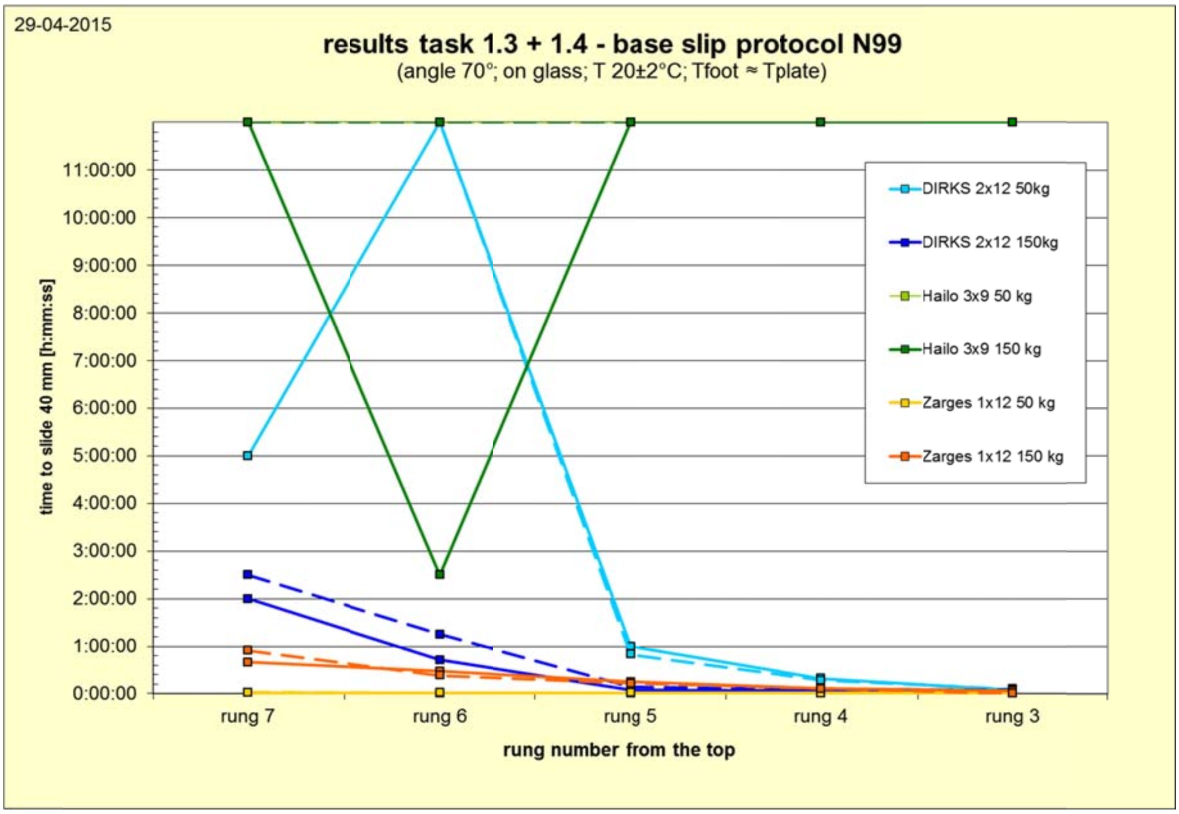


Figure 10 – Results on float glass with a load of 50 kg (light colour) and 150 kg (dark colour).

When analysing the complementary tests on float glass the results show

- the DIRKS and Hailo samples perform better with 50 kg and the Zarges performs better with 150 kg.
- that the tests reproducibility seems reasonably good; the results of the first test (continuous line) and the second test (dashed line) under the same conditions are reasonably close to each other.
- that the higher the slip resistance the more deviation in test results.
- generally, with one incidental exception, the results show that 40 mm displacement of the feet is reached in shorter time when the vertical load is at a higher rung. This matches with theoretical calculations.
- the values of rung 6 for the Dirks and Hailo are odd.

The results of this task confirm that involving two loads, i.e. 50 kg and 150 kg, in the final base slip protocol is preferable. It is not obvious that a higher load is always the worst scenario. Probably due to the non-linear behaviour of polymer feet. Additionally, the results show that the surface condition of the stainless steel should be defined and prepared with great precision. The same roughness value not obviously gains the same result under the same test conditions. Furthermore, the results indicate that a reproducibility of +/-13% on stainless steel can be achieved, although through the limited number of tests the statistic reliability/accuracy is limited.

4.4.2 *Second series of complementary tests*

Five series of plates were available for the second series of tests. The surface condition was characterised with roughness measurements. The results of the roughness measurements are showed in Figure 11.

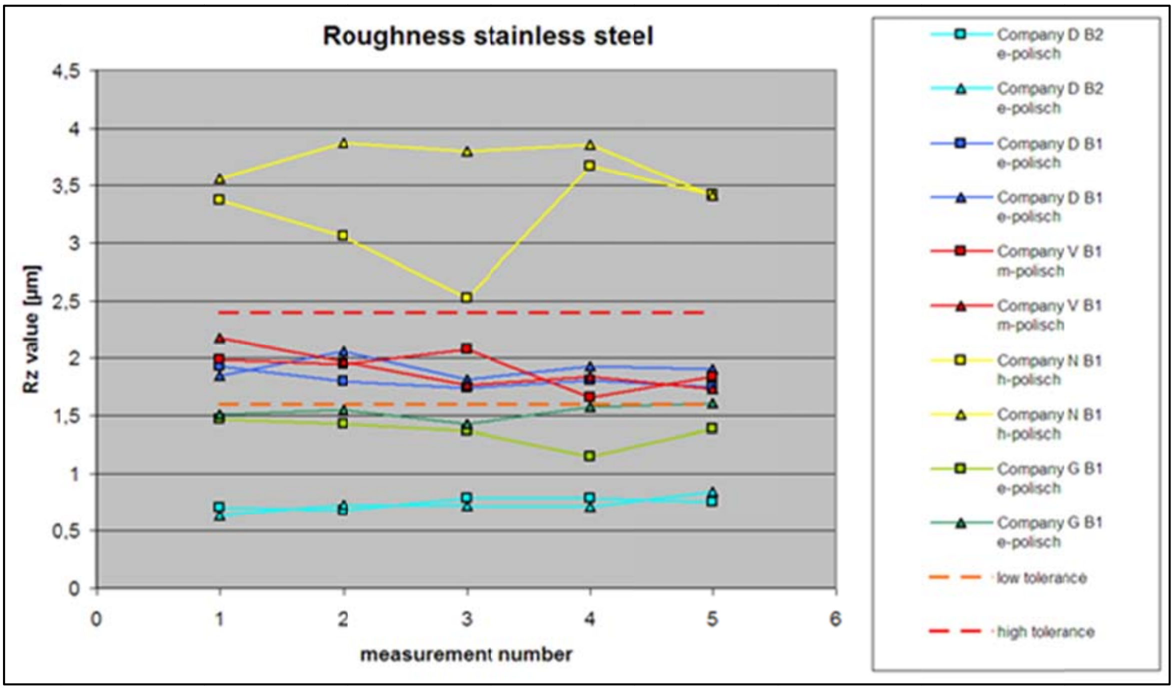


Figure 11 – Results of the roughness measurements on the stainless steel plates for the second series of complementary tests.

Of each different plate two specimen were examined. Across the surface 5 measurements were done. In the graph a tolerance range is showed. This tolerance range is specified in CEN/TC 93/WG 10/N64.
The roughness measurements show that purchasing electrolytically polished plates from different suppliers does not guaranty the same roughness. Even two batches from the same supplier do not guaranty the same roughness. The roughness deviation of the electrolytically polished surfaces is within ± 0,4 µm from the average. Also the roughness deviation of the mechanically polished surface, done by a professional company, is within ± 0,4 µm from the average Polishing according to CEN/TC 93/WG 10/N64 has a roughness deviation of ± 0,8 µm from the average. However, 3 out of 5 average values deviate from the specified Rz of 2 µm.
To gain base slip results tests were done according to the new protocol on stainless steel with 65 ° and 150 kg vertical load. The graph in Figure 12 shows the time in which the ladder feet reached 40 mm on the five different stainless steel surfaces.

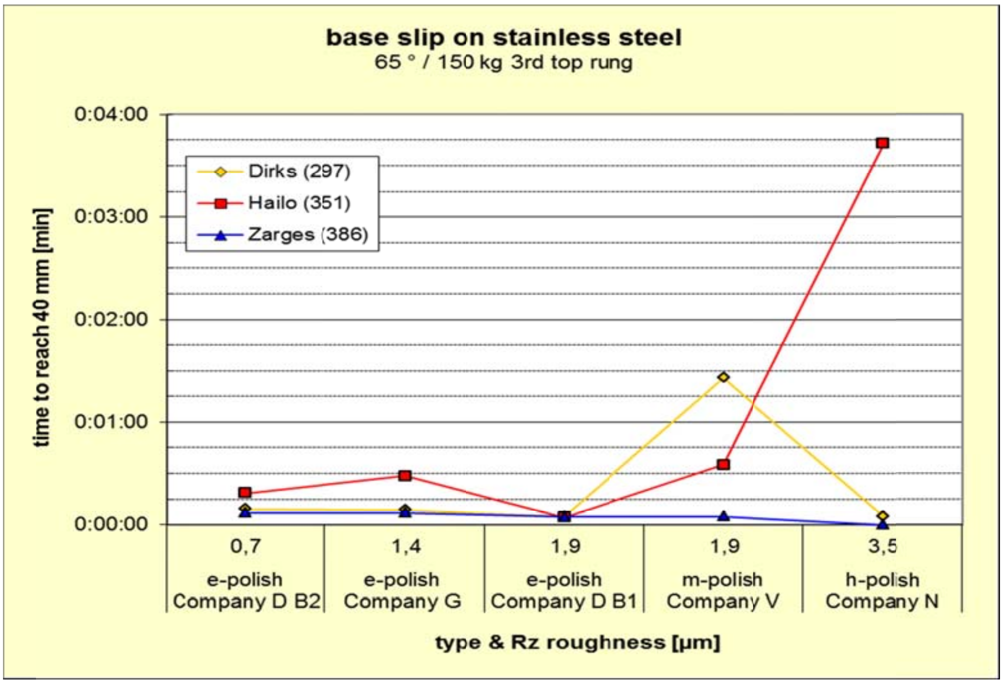


Figure 12 - Base slip performance on stainless steel with different surface conditions.

The graph in Figure 13 shows the horizontal force applied on the bottom rung that was needed initiate the ladder base to slide 40 mm. The lines on the bottom of the graph are of ladders that slid 40 mm without a horizontal force on the bottom rung. The Hailo only slid with additional horizontal force.

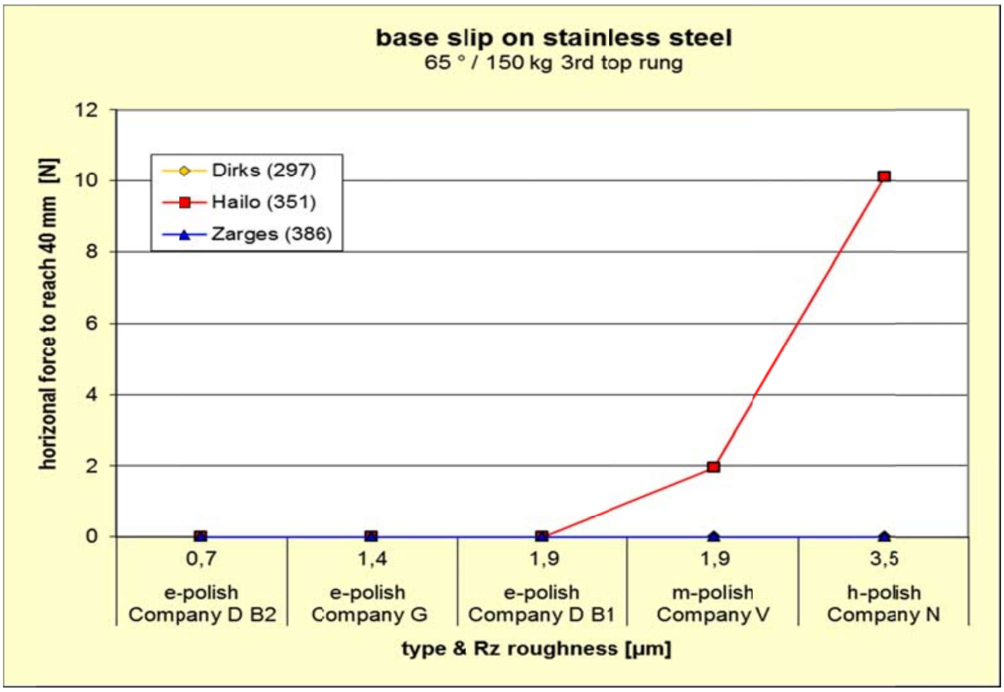


Figure 13 - Base slip performance on stainless steel with different surface conditions.

The above base slip test results show that samples slid easily. Especially on the plates that are electrolytically polished. Over 50 % of the ladders reached 40 mm within 10 seconds without an additional horizontal force. The results are most indistinctive, accept for mechanically (m-polish) and manual polished (h-polish) steel.

Comparing the results on both electrolytically and mechanically polished surface of Rz 1,9 µm it can be seen that the mechanically polished plates gain slightly more friction with the feet than the electrolytically polished plates. This demonstrates that even if the Rz value of two different treated plates is the same, the base slip behaviour can be different.

4.5 Draft final base slip protocol (task 1.5)

Both protocols, CEN/TC 93/WG 10/N64 and CEN/TC 93/WG 10/N99, have advantages and disadvantages. Neither of these protocols is preferred above the other. The results in previous tasks show that testing on at least two floor materials is preferable because ladders perform differently on different materials. The polymer expert of the KIWA institute in Rijswijk (NL) who was consulted by the NVWA confirms: “A good performance on one material does not automatically mean a good performance on another material. Sufficient performance on both materials are important for safety”. Also testing at two angles is better, preferably at 70° and 65°. This will prevent that ladders are optimized for one angle and perform poor at any other angle that can be expected during use. Concluding from the results in task 1.2 a vertical load 50 kg and 150 kg would cover the performance with a small load (minimal contact) and a heavy load (stressed polymers). Pulling at the base with a horizontal force represents a force exerted by a user cleaning or drilling at the top of the ladder. To apply this pulling force a well-defined and reproducible test protocol is necessary. A protocol without pulling at the base is easy to perform with a uniform floor condition.

The new protocol has two parts. One on stainless steel at 65° with 150 kg and a horizontal pulling force to initiate base slip. A second on float glass at 70° and 50 kg without additional pulling force. The protocols have to be executed sequentially, starting on stainless steel. The stainless steel protocol contains preconditioning test to wear the feet before testing. Both the protocols contain four clear sections: equipment/requisites, preparation, testing and PASS/FAIL criteria.

Most significant changes compared to the CEN TC93/WG10 protocols:

document structure: each protocol part has four sections. The first section describes the equipment and requisites that are necessary. The second section describes the preparations. The third part describes the test procedure. And the fourth and last section describes the pass/fail criterion. With this arrangement a more clear document was achieved.

timing: timing is more specified to control the relaxing and loading of the polymer feet. In this way, the condition of the polymer feet is more consistent.

specifications instead of solutions: describing solutions in a protocol would compel laboratories to purchase or build new equipment when not available. It is possible that laboratories, in that case, decide to use own equipment deviating from the protocol. Specifications enables the laboratories to use their own equipment and experience to achieve what is required for the tests. For example: the attachment of the cable to the lowest rung.

less choices: to achieve that the tests are executed in a same way between laboratories no choices are left to make. For example: the material of the vertical wall.

more and defined tolerance: for all significant parameters better defined tolerances are formulated. For example: the weight of the water bucket.

stainless steel roughness: Precious tasks revealed that 2 µm gains indistinctive results at 65°. Furthermore it is not clear yet what roughness and treatment is most suitable. The Rz roughness of the stainless steel was temporarily specified 3,3 ± 0,5 µm to be achieved by mechanical polishing.

4.6 Base slip tests with new protocol (task 1.6)

The results of task 1.6 on stainless steel show that 7 out of 10 ladders slid with only the load of the empty bucket (1,85 kg). Time records show that these 7 ladders slid directly after removing the blocking beam at the feet. Three ladders remained standing after removing the blocking beam at the feet and slid to 40 mm with an additional amount of water. These ladders were tested five times. The standard deviations calculated from the five individual results are 7% (Dirks), 4% (Alpe) and 24% (Zarges).
Roughness measurements on the stainless steel plates after the tests show that the Rz value has changed during the tests. Measurements on the same spots as before the tests and on wear marks reveal an average Rz value of 2.6 µm and 2.9 µm for the two floor plates used during the tests of this task. Before the tests the average Rz value of these plates were respectively 3.4 µm and 3.3 µm. The average Rz value decreased more than 13% during the tests. Theoretically this causes the ladders last in row to slide more easily that the first ladders. The test results is analysed based on the order in which the ladders were tested however there is no trend that shows that the ladders first in row perform clearly better than the ladders last in row.
Figure 14 shows the results of task 1.6 together with the results of task 1.2 (red squares). The ladders tested in task 1.6 need much less horizontal force to slide. And also, more ladders slid without additional water. It is remarkable that the Hailo ladder is being less capable of remain standing compared to the previous result.

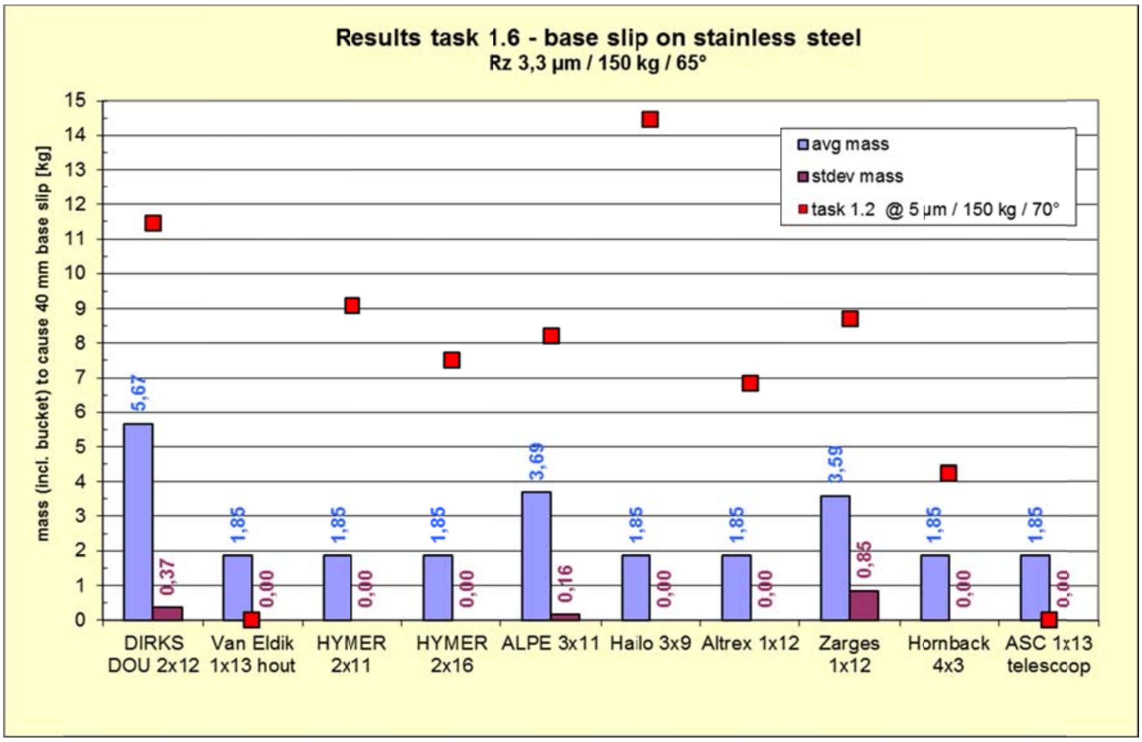


Figure 14 - Results on stainless steel of task 1.6 compared with results of task 1.2.

Judging the results of the base slip tests on stainless steel it has to be kept in mind that the results of task 1.2 were obtained at an angle of 70° and on a surface with a Rz of 5 µm. It is obvious that the ladders perform worse because the test conditions of 65° and Rz of 3,3 µm are more severe. The reason for testing at 65° is because this angle was indicated in the past as the angel of reasonable foreseeable use that causes most accidents with severe injuries.

Only 4 out of 10 results on stainless steel are odd and cannot be explained with the actual knowledge. It can be calculated that the horizontal force has decreased by circa a factor two for the Dirks, Alpe, Zarges and de Hornbach. For the Van Eldik and ASC it is obvious that the performance is still bad under more severe test conditions. It is questionable why the other four ladders directly slip in task 1.6 while they performed moderate in task 1.2. The Hailo in particular which performed outstanding on stainless steel in task 1.2. The deviations from the 5 individual test results of one sample on stainless steel are acceptable but not excellent (4% to 24%). The final protocol 'base slip on stainless steel' may need to be amended to achieve greater distinctiveness in the test results; now 70% directly fails. Due to tight schedule of the project it was impossible to amend the protocol before the round robin. Carrying out the round robin is most valuable when making a smart choice of ladders to be tested.

Figure 15 shows the results of task 1.6 on float glass. 2 ladders directly slid after removing the blocking beam at the feet. 6 ladder slid slowly after removing the blocking beam. Two ladders remained standing. The standard deviation calculated of five individual test values are 223% (Dirks), 46% (Hymer 2x11), 91% (Hymer 2x16), 56% (Altrex), 20% (Zarges) and 0% (ASC). To enable comparison with the results of task 1.6 the values of task 1.3 were converted to values in millimetres per minute (red bars). The comparison shows that most ladders perform better in task 1.6 then in task 1.3. In both tasks, the Hailo performance is superb as well as the Dirks. The performance of the Van Eldik and the Hornbach in both tasks is worse.

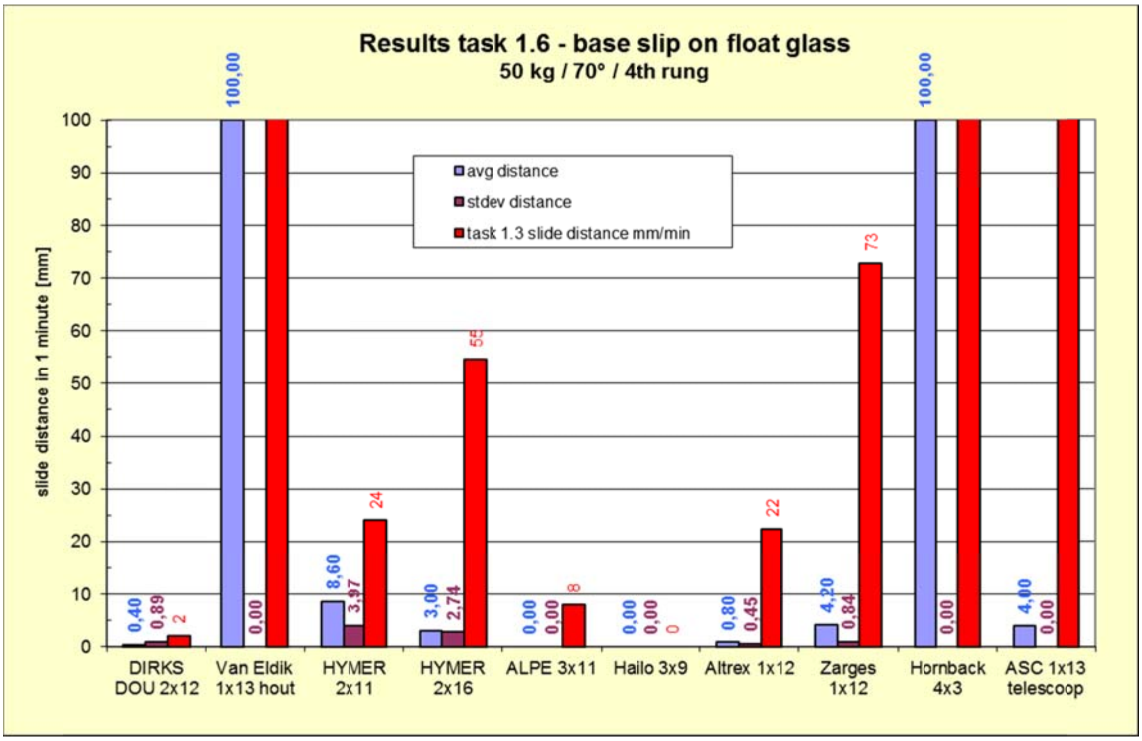


Figure 15 - Results on float glass of task 1.6 and task 1.3.

What stands out most in the results of the tests on float glass is that 6 ladders perform significantly better in task 1.6 than in task 1.3. It is not possible to indicate a cause with the actual knowledge. The base slip behaviour of the other 4 ladders is comparable to results of task 1.3. The deviation of the five individual results of some samples on float glass are alarming. If 5 successive tests with one sample have such deviation on a smooth and homogeneous underground the reproducibility can be questioned. However, the measurements of such small movements do have large uncertainties too.

On float glass only 4 out of 10 results are comparable to the results of task 1.3. The other results are surprisingly different to the results of task 1.3. The findings on float glass show that the reproducibility between tests of task 1.6 as well as the reproducibility between task 1.3 and 1.6, carried out under the same conditions but different ladders of the same brand and type, are questionable. The results are contradictory to the theorem that base slip tests on glass are reproducible because of the smooth and uniform nature of a glass surface. There is no logical explanation for this result. However, the deviation of the results can be caused by the measurement of small displacements.

A plausible reason for the unexpected differences between previous test results and the test results of task 1.6 is that the tests in task 1.6 are executed with new ladders. Product models can differ from one to the other and in this particular case it would concern difference in feet shape and feet material. Visual inspection of the feet after the tests did not reveal any reliable evidence. However, when viewing ladder feet used in task 1.2 and 1.3 with ladder feet used in task 1.6 closely, a few minor difference in colour and shape were detected of the spots where the feet interacted with the floor plates. But these observations are too undefined to determine them as the cause of the differences.

Generally, performing the base slip test according to the actual protocol on steel and glass obtains uncertain results. Some results are explainable and encouraging but some results are doubtful and require to reconsider parts of the protocol. However, once the test setup is ready and all aids are at hand the protocol is easily executable according to operators that performed the tests so far.
Based on the above roughness value of the stainless steel should be reconsidered. A higher Rz roughness could lead to more friction between the feet and the steel plates. As a result the horizontal force to cause base slip of 40 mm will increase and in turn leads to more distinctive results and a larger range to define a PASS/FAIL criterion. However, the best value of roughness is unknown. To determine the Rz value more research will be necessary.

4.7 Final protocol base slip test(task 1.7)

4.7.1 *Final protocols*

The experience and results of task 1.6 led to some amendments of the protocols. Main amendments/comments after task 1.5 are:

- size of the bucket – during task 1.6 it turned out that a bucket of 20 litre is too small. It was enlarged to 30 litre. During the preconditioning tests on stainless steel at 70° the pulling force exceeded 20 kg.
- attachment of the steel cable to the ladder – until now an additional bar with an attachment point for the steel cable was fixed to the ladder base at a 50 mm height. If not fixed well it could introduce additional force components that influence the results of the base slip. Due to the variety of ladders a uniform way to fix the bar to each ladder is undoable. Therefor it was decided to always attach the cable to the lowest rung. This improves the uniform way of testing amongst laboratories.
- pass / fail criterion – what the findings of task 1.6 mean for the protocol is partly uncertain. A reasonable PASS/FAIL criterion could not be derived with confidence. Therefore the PASS/FAIL criterion are left blank for tests on stainless steel. Also the time frame for the determination of the displacement is still 1 minute, despite of the rather small displacements found in task 1.6.
- content – some motivations were added and some parts were revised to enhance the readability.

The parts and parameters of the protocol that are now uncertain will become definite after the analyses of the results of the round robin. The protocols ready for use in the round robin is attached in Appendix 6.

4.7.2 *PASS / FAIL criterion*

If the base slip results on stainless steel are valued with the criterion that was established in task 1.5, (>7 kg = PASS) all ladders fail in task 1.6. However, measuring with a criterion derived from a less severe test in not suitable. If this criterion is reduced by a factor 2 (>3,5 kg = PASS) than three ladder pass the test on stainless steel. 3,5 kg is about twice the weight of the empty bucket. Valuing the performance on float glass with the criterion of tasks 1.5 (<40 mm/min = PASS) is reasonable because the test conditions were the same. With this criterion 7 samples pass the base slip test on float glass. Combining both values the preliminary verdicts on stainless steel and float glass three

ladders pass both tests: Dirks, Alpe and Zarges. As a result, a minority of the ladders PASS the test. This is less than initially intended in task 1.5. Before, the criteria were chosen to let pass half the ladders.
The results of task 1.6 show that there is not much space to define a criterion. In other words, there is only a 3.85 kg range between the maximum result and the weight of the empty bucket. An increased Rz roughness of the plates to create more friction with the feet could result in a larger amount of additional water to cause 40 mm base slip. The results of the tests in task 1.6 on glass are alarming and raise questions about the tests on glass in general. 6 out of 10 samples performed better than task 1.3. This needs to be cleared before a suitable PASS/FAIL criterion can be formulated. The round robin planned in phase 2 of the project will deliver additional information to judge the protocols. It is expected that the results of task 1.6 can be verified with the results of the round robin. This verification will lead to improvements of the main parameters in the protocol and the PASS/FAIL criterion as well.

4.8 Round Robin Task 2.1

Each laboratory (Inail, Vinçotte and the NVWA) that participated in the round robin recorded the results in a template provided by the NVWA. See Appendix 7. For the analysis, the individual results were transferred into graphs.

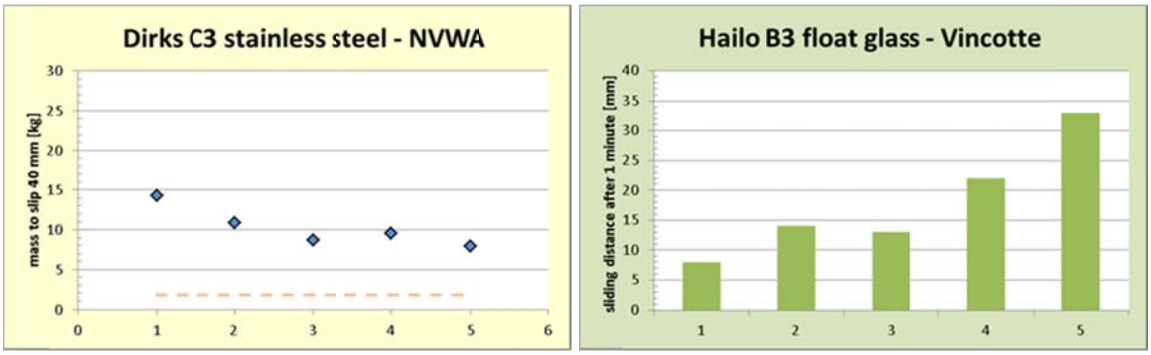


Figure 16 – Examples of graphs with results of the round robin. Left, the result of sample Dirks C3 on stainless steel obtained by the NVWA. Right, the results of sample Hailo B3 on float glass obtained by Vinçotte.

Each individual graph, see Figure 16, shows the results of the successive tests per sample produced in one round, one ground (stainless steel or float glass), at one of the laboratories. The graphs show the results of one test sequence on stainless steel (yellow) or on float glass (green). All graphs are arranged in a table as exampled in Figure 17.

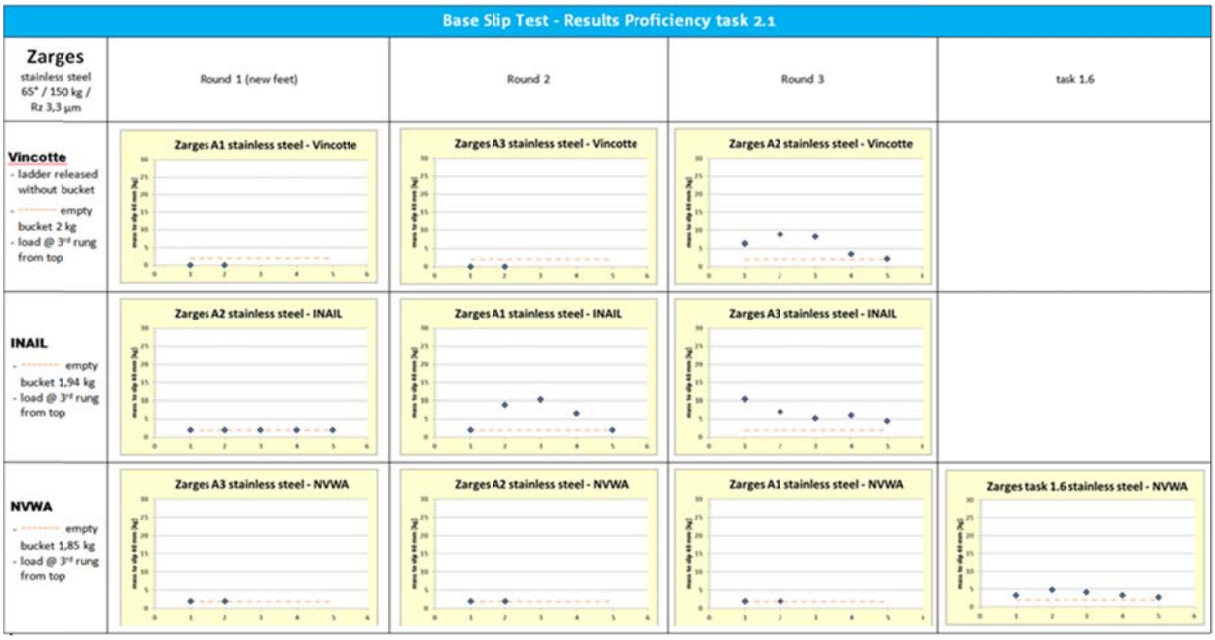


Figure 17 – Example of table with results. The result graphs are arranged in columns of rounds and rows of laboratories. In the left top corner the sample type and the conditions of the test.

All results are included in Appendix 8. Each individual table in this Appendix contains all results of one ladder type, indicated in the top left corner. The graphs of the individual samples in the table are arranged in columns per round and in rows per laboratory. In the first column additional information is provided of specific test conditions.
Additionally, details on the test performance in the laboratories need to be mentioned. These details mainly concern deviations from the protocol. The deviations from the protocol are mentioned in particular because these could explain differences of trends in the results.

Vinçotte:

- released the ladder without the bucket attached to the wire. Once the ladder remained standing after unblocking the feet, the bucket was attached gently to the cable. The protocol instructs to attach the cable with bucket before unblocking the feet of the ladder;
- executed the tests on float glass five minutes after the tests on stainless steel. The protocol indicates to wait 17 hour before starting the tests on float glass;
- used 150 kg for the tests on float glass during the first round. The protocol describes to use 50 kg;
- measured the feet displacement with a tape ruler taking the distance from the feet to a fixed reference on the floor. The protocol does not describes a specific way of measuring;
- mentioned that the left foot of the Hailo B2 kept slipping systematically more than the right foot on float glass;
- mentioned that the explanations throughout the protocol are sometimes confusing.

INAIL:

- continued testing when the first two tests resulted in a direct base slip. In such case, the protocol indicates to terminate the test sequence;
- applied the load on the Dirks samples at the third rung from the top on stainless steel and the 4th on float glass. Indicted by its maximum length the protocol instructs to apply it on the 2nd rung from the top on stainless steel and the 3rd from the top on float glass;
- positioned the samples with priority to stability. The protocol indicates to align it to a vertical centre line on the wall;
- executed the tests on float glass five minutes after the tests on stainless steel. The protocol indicates to wait 17 hour before starting the tests on float glass;
- measured feet displacement with use of an indicator attached to the feet pointing at a scale on the floor. The protocol does not describes a specific way of measuring.

NVWA:

- measured feet displacement with use of an indicator attached to the feet pointing at a scale on the floor. The protocol does not describes a specific way of measuring.

Apart from the deviations it was witnessed during a visit of the NVWA that the laboratories performed the tests with great care. Most of the protocol instructions were met during the performance of the tests. The samples were configured to the same test length at all laboratories according to the registered ladder lengths.

4.9 Analyses of the Round Robin Results Task 2.2

4.9.1 *Preconditioning tests*

The purpose of the preconditioning test is to wear the new feet on the spots that will be used in the actual tests. Although the results of the preconditioning tests are not judged, the results could have a correlation to the performance in the actual tests. So, the results of the preconditioning tests are plotted in graphs as well. See Appendix 9.
Overall, the graphs clearly show, as expected, that ladders have a better base slip performance at an angle of 70° than at 65°. Remarkably, the Dirks C3 solely needs additional water to initiate a base slip at 65°. The performance on the Hailo at an angle of 70° is disappointing compared to the performance in task 1.2 where it showed excellent base slip performance under the same test conditions.

4.9.2 *Results on stainless steel*

Base slip on stainless steel was performed with a Rz roughness of 3,3±0,5 µm, at a slope of 65° and a load of 150 kg. It was recorded how much weight, applied horizontally to the bottom rung, was needed to initiate a base slip of 40 mm.

Zarges on stainless steel

During the preconditioning tests the Zarges samples do not show any resistance against base slip at 65°. All Zarges samples show an immediate base slip during the first tests in round 1, see Figure 18. After certain tests they all start to perform reasonable (max. 10 kg) during the intermediate tests followed by a decrease of performance. During task 1.6 the Zarges needed 2 to 5 kg to initiate a base slip at comparable circumstances. In task 1.2, a weight of 8,7 kg led to a base slip on stainless steel with an Rz of 5 µm.

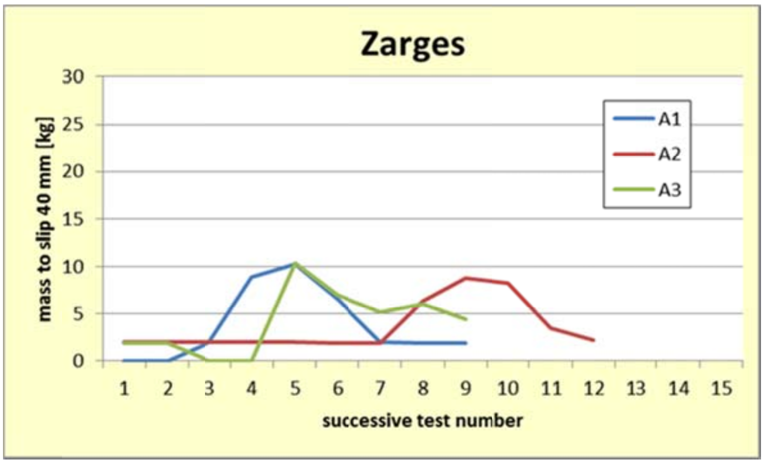


Figure 18 - Round robin results of the Zarges samples on stainless steel plotted as a continues sequence independently of the laboratories and rounds.

Hailo on stainless steel

During the preconditioning tests the Hailo samples do not show any resistance against base slip at 65°. All Hailo samples show immediate base slip during all tests Figure 19. Remarkably, the Hailo performed as best during the second series of tests of task 1.4. Under the same condition (65°, 150 kg and Rz 3,3 µm) it was the only sample that needed an additional horizontal force to initiate a base slip. It reproduces the result of task 1.6 where the Hailo did not performed well. In contrary to the results of task 1.3 where the Hailo performed excellent.

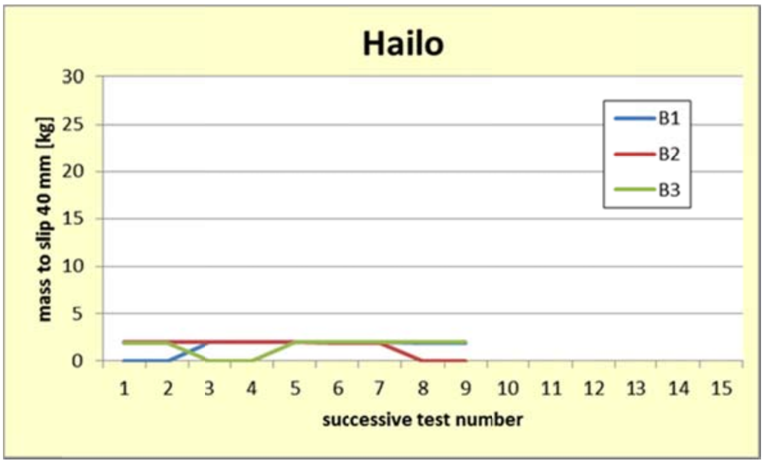


Figure 19 - Round robin results of the Hailo samples on stainless steel plotted as a continues sequence independently of the laboratories and rounds

Dirks on stainless steel

During the preconditioning tests two of the Dirks samples do not show any resistance against base slip at 65°. The one that was preconditioned at the NWA (C3) needed an average weight of 13 kg to initiate a base slip. The Dirks samples all perform differently, see Figure 5. All samples show a moment of reasonable performance during the sequence of all tests. However, they peak at another moment along the test sequence. As mentioned, INAIL applied the load on a rung lower than the other laboratories. In fact, their test was less severe which could lead to a systematically better performance of the Dirks samples at the INAIL laboratory. No such effect can be observed in the results. The maximum values to initiate a base slip are significantly higher than in task 1.6 (5,7 kg). For C2 (red) and C3 (green) even higher than in task 1.3 (11,5 kg) achieved on an Rz of 5 µm.

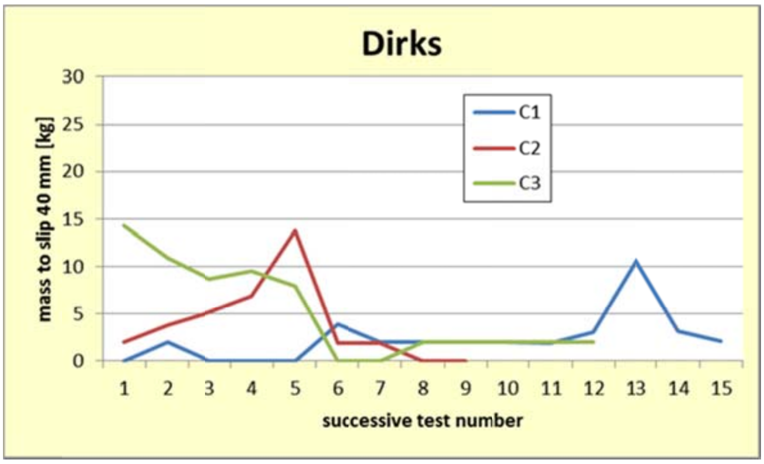


Figure 20 - Round robin results of the Dirks samples on stainless steel plotted as a continues sequence independently of the laboratories and rounds.

General

Viewing the results on stainless steel in general, none of the ladders show a steady base slip performance throughout the rounds and throughout the laboratories. No systematic base slip behaviour can be noticed. None of the laboratories stands out with systematically good or bad performance. Feet wear during time and the roughness of the plates decreases. Due to these effects one expect deterioration of the base slip performance along the round robin. The appearance of the results cannot be related to these phenomena.

Table 9 - Averages and standard deviation calculated with all results per ladder type

Stainless Steel	Zarges (A1-A2-A3)	Hailo (B1-B2-B3)	Dirks (C1-C2-C3)
Average [kg]	3.7	1.5	3.6
Standard deviation [kg]	3.2	0.8	4.0

Compared to the results of task 1.6 the results of the round robin are more or less equal. Weights to initiate base slip in task 1.6 are in the same order as the averages in Table 1. The results of task 1.6 were obtained under the same conditions as the round robin. Compared to task 1.2 the results of the round robin are clearly worse. The obvious reason is that the tests in task 1.2 were executed at an angle of 70° and on an Rz of 5 µm. It stands out that the standard deviation is approximately the same value as the average.

4.9.3 *Results on float glass*

Base slip on float glass was performed at a slope of 70° and a load of 50 kg. It was recorded how much feet displacement occurred after one minute.

Zarges on float glass

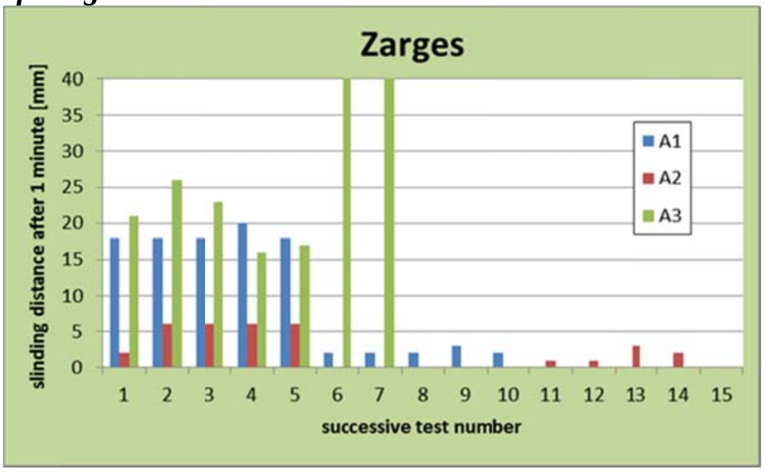


Figure 21 - Round robin results of the Zarges samples on float glass plotted as a continues sequence independently of the laboratories and rounds.

During the preconditioning tests at 70° the Zarges samples show a resistance against base slip between 10 and 15 kg. During the actual tests the Zarges samples show reasonable base slip resistance on glass, see Figure 21. Except for two tests, the samples slip less than 26 mm within a minute. It stands out that after 5 tests the performance gets significantly better. A1 (blue) was accidentally tested with 150 kg during the first 5. These 150 kg results are equal to the results of the Zarges that was tested under the same circumstances during task 1.4. All other results of the Zarges samples are of the same scale to the results in task 1.6. and remarkably better than in task 1.3 where the Zarges slipped over 40 mm in one minute.

Hailo on float glass

During the preconditioning tests at 70° two Hailo samples show no resistance against base slip. One sample (B3) shows a resistance between 8 and 12 kg. The first two results of B1 (blue) were obtained with 150 kg load, accidentally. Omitting these two, it seems that the performance of B2 (red) and B3 (green) worsens after more tests, see Figure 22. However, B1 (blue) performs constant through time. For comparison, the Hailo performed excellent on glass in task 1.6. The Hailo remained standing with 150 kg during tests on glass in task 1.3.

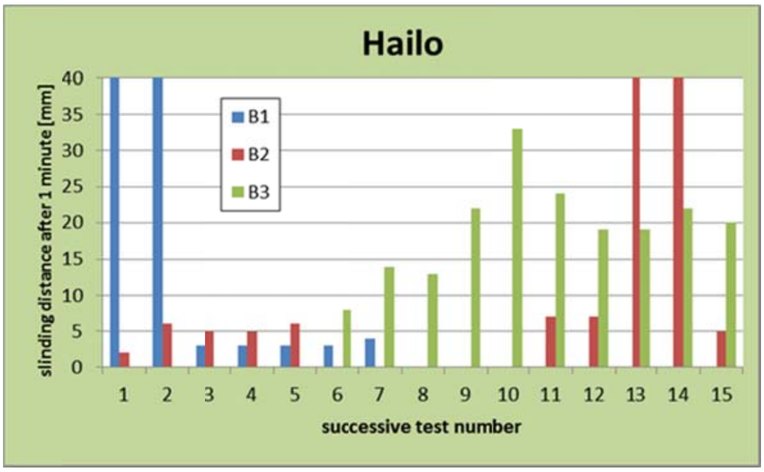


Figure 22 - Round robin results of the Hailo samples on float glass plotted as a continues sequence independently of the laboratories and rounds.

Dirks on float glass

During the preconditioning tests at 70° the Dirks samples show an excellent resistance against base slip. At the NVWA C3 repeatedly slipped not at all with a full bucket. Throughout the round robin the Dirks samples perform reasonably well, see Figure 23. Except for the first two tests of C1 (blue) that was accidentally tested with 150 kg and test 6, 7 and 8 of C3 (green). The Dirks performed one of the best on float glass in task 1.3 and excellent in task 1.6.

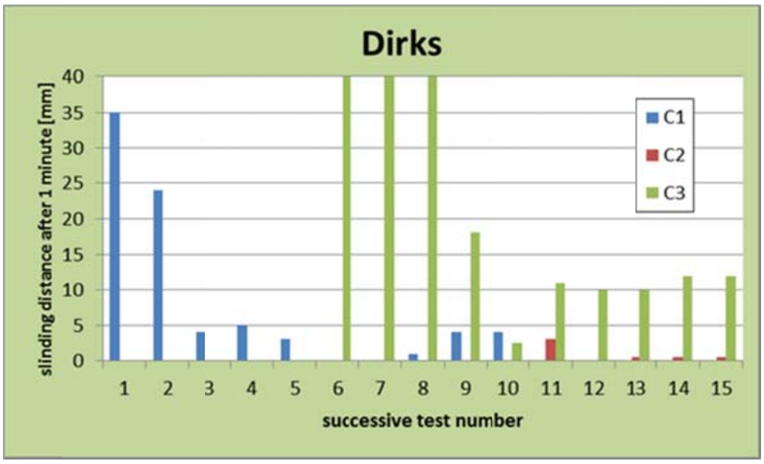


Figure 23 - Round robin results of the Dirks samples on float glass plotted as a continues sequence independently of the laboratories and rounds.

General

Viewing the results on float glass generally, the ladders perform reasonably well on float glass. Most base slip results are less than 40 mm within 1 minute. Before continuing with the tests on float glass, the NVWA waited 17 hours after the stainless steel tests. The other two laboratories directly continued with the float glass tests with a pause of 5 minutes. After 17 hours polymer feet are assumed completely relaxed and can theoretically expect to have a better resistance against deformation. This would result in a better resistance against base slip than with un-relaxed feet. However, the results show no remarkable difference in the first round between the NVWA and the other laboratories.

Table 10 - Averages and standard deviation calculated with all results per ladder type.

Float Glass	Zarges (A1-A2-A3)	Hailo (B1-B2-B3)	Dirks (C1-C2-C3)
Average [mm]	10.5	14.5	9.2
Standard deviation [mm]	21.8	26.6	22.4

Compared to the results of task 1.6 and 1.3 the results obtained during the proficiency are less excellent. It stands out that the standard deviation is approximately twice the value of the average.

4.9.4 Comments on the protocol by the laboratories

After the tests laboratories gave some suggestions and considerations.

Vinçotte:
- Recommends to add in section 3 of the float glass protocol that the vertical test load is 50 kg. Because all other loads are 150 kg, including the one for the preconditioning tests on float glass, it is easy to make a mistake.
- Mentions that it is challenging to maintain the tight time frame of the test. They also questioned the significant influence of the time variance.

INAIL:
- The procedure is generally good.
- Especially for long ladders (e.g. combination ladder) handling of the ladders, relevant to the time tight, is feasible but difficult.
- It is necessary to employ minimal three persons.
- In order to adjust the ladders (from 65° to 70°) it is necessary to have the length of the testing surface (stainless steel and float glass) as minimum 50 cm.
- Testing with stainless steel should be performed at 70° (as for float glass) instead of 65°.
- In addition to the pulley diameter range, I suggest to test efficiency of single pulleys and so to fix a minimum pulley efficiency 0,95. This means efficiency of two pulleys placed in series equal to 0,9.
- Increase the range of roughness e.g.: average between 2,4 µm and 5,0 µm; no single measurement less than 2,4 µm or greater than 5,0 µm.

NVWA:
- It is challenging to finish all the actions within the given time. Just a bit longer would be more convenient.

The purpose of the round robin is to experience the practicality of the protocols and to obtain results to judge the variability and consistency of the base slip test. Therefore three laboratories have tested three ladders, five times during three rounds. All results have been collected and analysed.
Calculating the average with all results on stainless steel of one ladder type gives 3,6 kg, 1,5 kg and 3,7 kg for the Zarges, Hailo and Dirks respectively. About 1,5 kg above the weight of the bucket. The weights, that were recorded to initiate a base slip on stainless steel, vary from 0 kg to 15 kg max. The weight only exceeds 10 kg only 5 times, about 20% of all test. Calculating the standard deviation between all results on stainless steel of one ladder type

reveals that the base slip test on stainless steel, executed by the labs, gives a standard deviation about the size of the average.
The average of the results is very low. It is just half a minute of water flow added to the bucket weight to initiate a base slip. This is to critical to define a pass/fail criterion. The standard deviations is very large. Too large to reliably judge the base slip performance of ladders on stainless steel.
Calculating the average with all results on float glass of one ladder type gives values of 10,5 mm, 14,5 mm and 9,2 mm for the Zarges, Hailo and Dirks respectively. Most tests on float glass show less than 40 mm displacement within one minute. Only at 4 (~15%) of test sequences (5 tests in a row) ladders completely slip. Calculating the standard deviation between all results on float glass of one ladder type reveals that the base slip test on float glass, as executed by the labs, gives a standard deviation about twice the size of the average.
The average of the results is acceptable. It is a distinctive displacement that can be measured well. The standard deviation is too large and unsuitable to reliably judge the base slip performance of ladders on float glass.
The scheme of the round robin was designed to match result with variation in time, location and product. Through time the feet and the floor plates wear. Feet become more used and the Rz roughness of the floor plates becomes less. In task 1.4 it was concluded that ladders with more used feet perform better. Based on this, it can be expected that ladders perform better through time. From the results of task 1.4 on stainless steel it was concluded that the smaller the Rz the less resistance against base slip the ladders have. Because of the intensively use of the floor plates the Rz will decrease along the rounds. It can be expected that the resistance against base slip deteriorates during the rounds of the round robin. No such trend can be noticed from the results. A reason for this could be that these effects are contrary to each other.
With testing at different laboratories the location changes per round. Although each laboratory built the test site and executed the tests with great care, particular differences could lead to different result. The results of the round robin do not show a consistent level of results related to the laboratories. Even known differences cannot be correlated to the results. Although the test set-up and execution of the test seem equal, it could be that the crucial parameters are highly sensitive and influence the result at the slightest difference.
Involving three pieces of each ladder type in the round robin could reveal product deviation. In particular a difference in feet due to the manufacturing process or a difference in mounting could lead to different result. Looking at the results, none of the ladders show a typical performance throughout the round robin, e.g. one systematically better than the other. Although, they all produce uncertain results.

From the experience of the laboratories and the observations during the inspections of the NVWA it can be concluded that all three laboratories generally achieved to set-up and execute the base slip tests as meant in the protocol. However, they experienced the protocol as complex and in particular the timing requirement of the protocol was challenging. Furthermore, some details were not as clear as expected, evidenced by use of the wrong weight and wrong rung. Apparently, it was difficult for the laboratories to extract essential details from the protocol despite of the framed explanations. As a result some tests were executed differently from one lab to the other but not that different to explain the differences in results. Some laboratories expressed their doubts about parameters and tolerances. The timing not only turns out to be a logistic issue but it was also questioned whether it has so much influence. Furthermore, it is suggested by one laboratory to enlarge the roughness tolerance of the stainless steel.

5 General conclusions and recommendations

To further develop the test protocol for the base slip test of leaning ladders 486 tests were done with 29 ladder samples throughout the project. Main parameters such as floor material, angle and vertical load were varied. Also other parameters were studied as vertical load position, roughness, steel cable attachment, flow rate, temperature, ladder alignment and cleaning. Requirements and tolerances for the parameters were defined. The CEN TC93/WG10 protocols were revised to improve the readability and practicability to achieve an unambiguously preformed test. Three separate laboratories have executed the test according to the new protocol.

Although the instructions in the protocol lead to equal test set-ups and test conditions, the obtained results deviate largely. Results obtained on stainless steel in task 1.4 turned out to be 20% lower than in task 1.2. On float glass, 8 of 10 samples slid 40 mm within one minute in task 1.3 while 8 of 10 samples slid less than 10 mm in one minute in task 1.6. The Hailo ladder remained standing during tests on stainless steel in task 1.6 while it directly slid in most of the tests during the round robin. The results of the round robin are inconsistent.

The NVWA has not found a provable explanation for these findings. Only assumptions can be made. One assumption is that the friction behaviour of the polymer of the feet is sensitive to variations on micro scale. The tolerances set to the main parameters in the protocol are too coarse to control these variations. This assumption is supported by the polymer expert of the KIWA institute in Rijswijk (NL).

Given the large deviation of the results, the method is not suitable for indicating whether or not a ladder is safe or unsafe concerning the base slip in its actual form. Given the similarity of the test set-ups and the execution of the test at the separate laboratories it can be concluded that the instructions in the protocol are suitable to achieve uniform test conditions in separate laboratories. This proves that the deviation of the results is caused by the protocol itself and not by different ways of testing in separate laboratories.

There are two possibilities for continuing the development of a base slip test for leaning ladders.

1) **Improve the test protocol**. Firstly, tolerances need to be tightened to control the variations on micro scale. However, tightening the tolerances could lead to requirements that are difficult to meet for test laboratories. Secondly, a test surface needs to be specified that leads to a uniform test condition. This involves characterisation of surface by identifying the right parameters, a reproducible process to treat a surface and a measurement method to measure the surface parameters. Suggestions are to characterise the surface conditions by more than one roughness indicator, e.g. Rz and Ra. Furthermore, in the field of tribology it is common to test with uniform surface conditions. Sand blasting is a process that is used in this field to produce specific surface conditions. It needs to be studied to find out whether this process is applicable for base slip test. The advantage of further developing the protocol is that one can build on the experience and knowledge gained up till now. A disadvantage of putting more effort in improving the protocol is that the outcome is uncertain.

2) **Develop an alternative test method**. It needs to be a method that obtains a stable result that enables to distinguish the safe from the unsafe ladders concerning the base slip. The method needs to be simple and easy to reproduce by separate laboratories. The polymer expert of the KIWA institute in Rijswijk (NL) suggests the following test. A ladder is set-up against a wall at a certain angle. Its bottom feet are standing on a sheet of material with a defined surface condition. The sheet of material is fixed to a small trolley that can roll nearly frictionless along a track perpendicular to the wall.

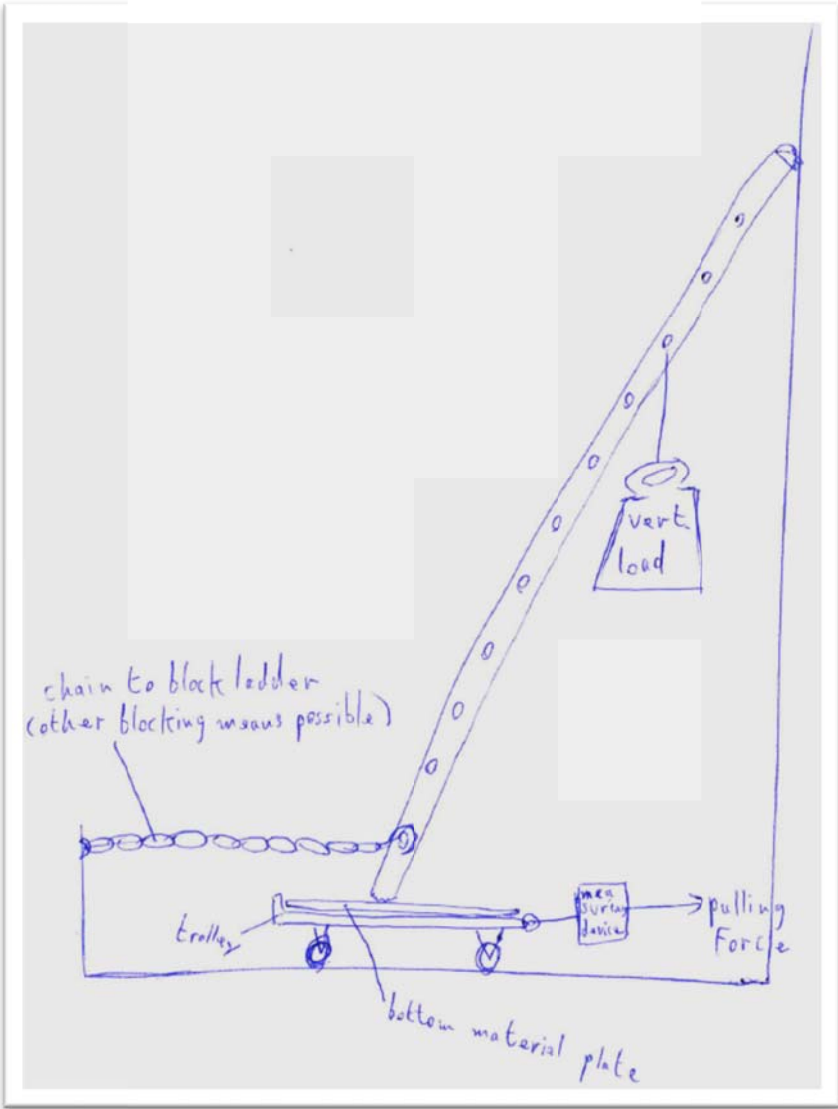


Figure 24 - sketch of an alternative base slip test method

After a vertical load is applied on the ladder the trolley is pulled in the direction of the wall until the trolley moves. The force that is needed to start the trolley moving could be a value for the base slip safety of the ladder.

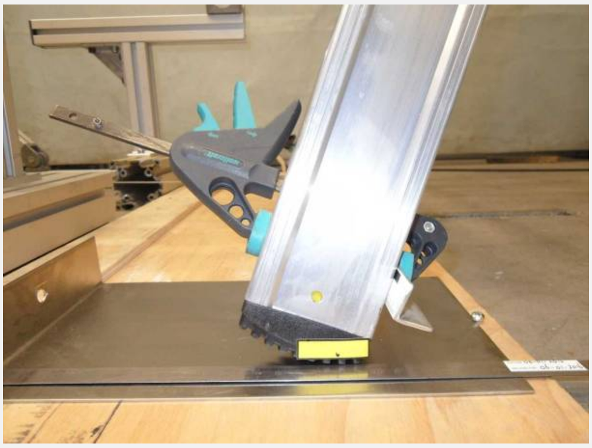
The setup of this method is very simple and easy to build. However, still a test surface needs to be specified as addressed under 1). It needs to be studied whether or not the recorded value is suitable for indicating the base slip resistance of ladders reliably.

The advantage of developing a new base slip method is that a method with less deviation can be found. A disadvantage is that one has to start from scratch, costing extra time and budget.

Given the effort that already was put into the studied method it is recommended to continue with option 2.

Appendix 1. Samples

DIRKS DOU 2x12 - NVWA87044297



65°

70°

Van Eldik 1x13 - NVWA87044319

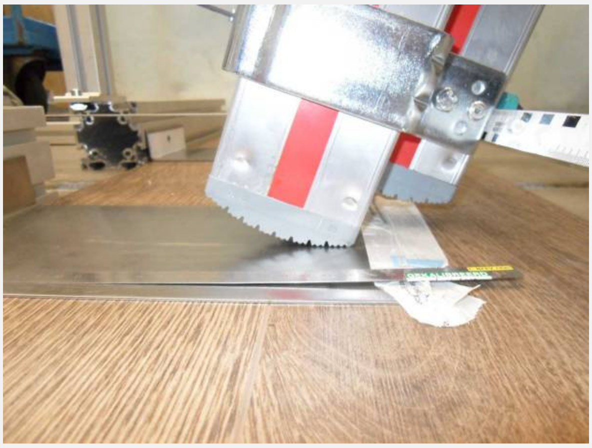
65°

70°

HYMER 40046 / 2x11 - NVWA87044327

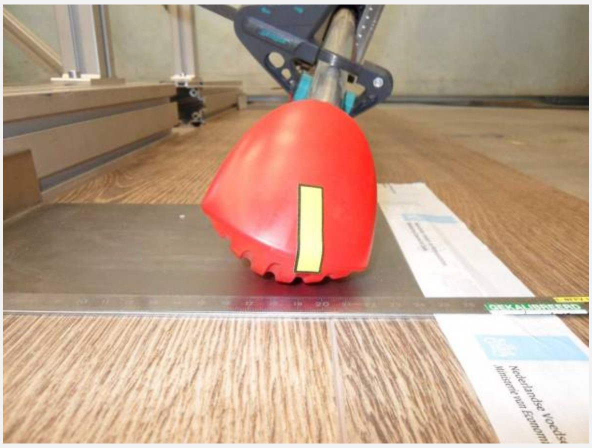
65°

70°

HYMER 4051/2x16 - NVWA87044335	
	
	
 65°	 70°

ALPE 36RL3x11VS - NVWA87044343	
	
	
 65°	 70°

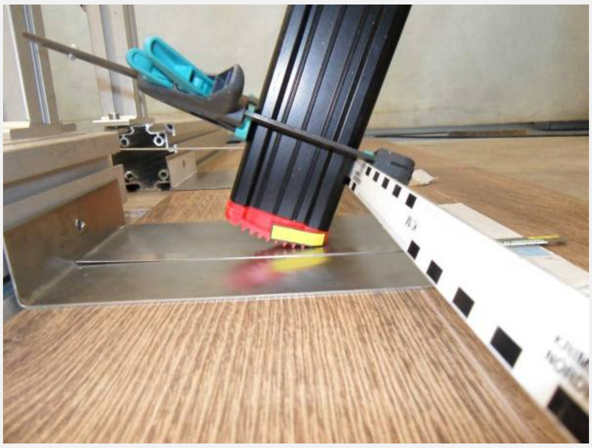
Hailo ProfiLOT 9309-501 3x9 - NVWA87044351

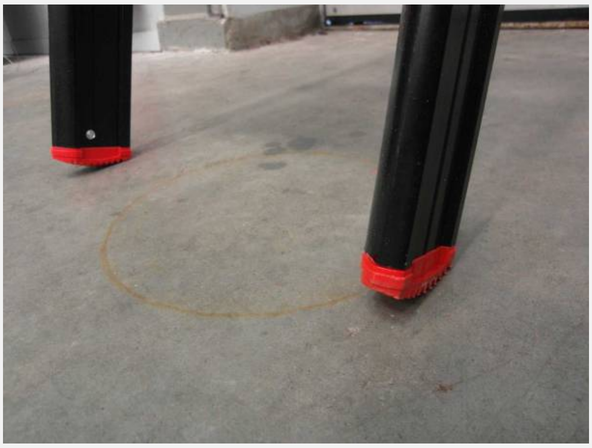


65°

70°

Altrex Nevada NZER 1036 1x12 - NVWA87044378

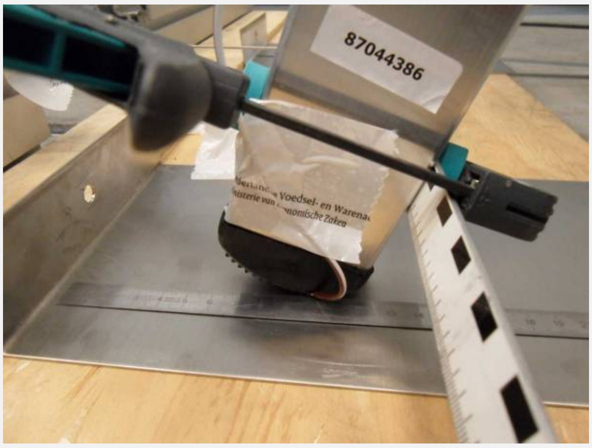




65°

70°

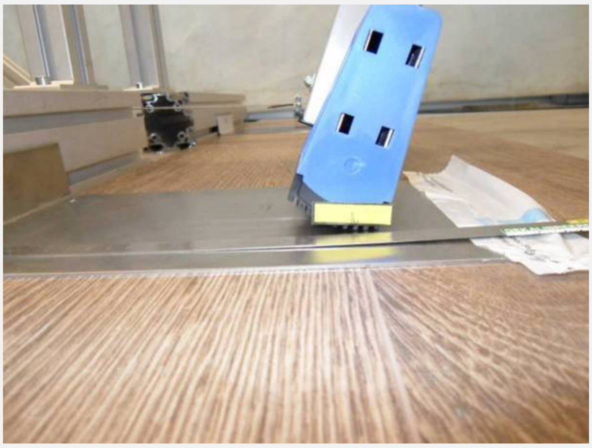
Zarges Z600 1x12 - NVWA87044386

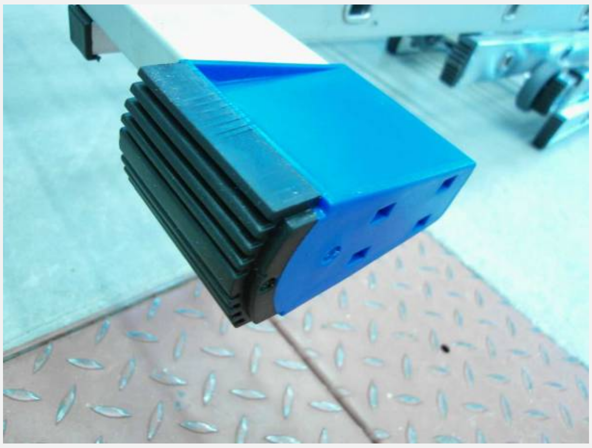


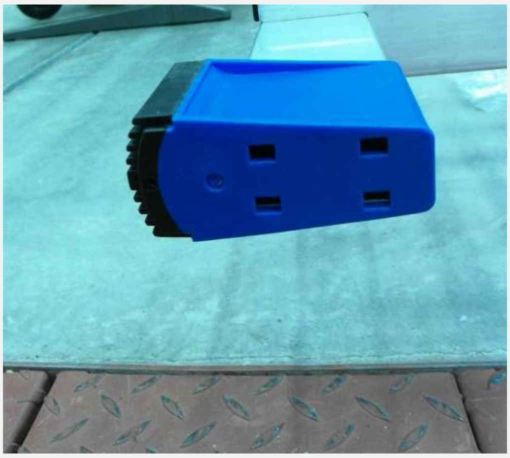
65°

70°

Hornbach Jinmao FE4X3A - NVWA87044394



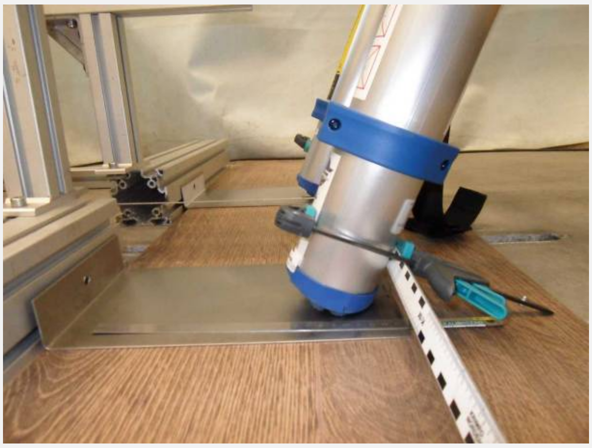


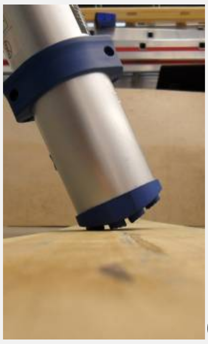


65°

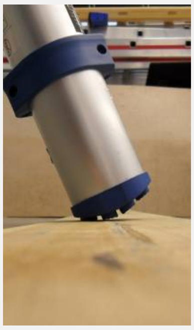
70°

ASC Group telescopic 1x13 - NVWA87044408





65°



70°

Appendix 2. CEN TC93 / WG10 base slip protocol

CEN/TC 93/WG 10/N 64

TG1 012a (Short)
BASE SLIP TEST (BASED ON TG1 012A v8 but with background text removed)
SHORT Draft v8b
11/06/2012

Ladders to be tested - Single AND multi-section ladders with a maximum extended length (l_1) of 4000 mm (+200 mm)[1].

1.0 PREPARATION

1.1 Floor surface – stainless steel (minimum thickness – 2 mm). Prepare the surface and measure the roughness with a roughness meter. See Annex 1

1.2 Surface at the top of the ladder (top surface) shall be one of the following:

- smooth stainless steel
- smooth glass
- the smooth side of high pressure laminate (HPL conforming to EN 438-S333)
- rollers attached to the top of the ladder (rollers should be strong enough to resist the load, be in good condition and free-running).

The top surface shall be cleaned before the test using the same method for the floor material

[1] +200 mm tolerance is included so that ladders just over 4000 mm long are tested. For ladders longer than this, a correction factor added to a test on a ladder with l_1 less than or equal to 4000 mm shall be used

Page 1 of 9

1.3 A vertical force F_1 of 150 kgf +/- 1 kgf shall be applied as in Figure 1[2]. F_1 shall be applied at the mid-point of the 3[rd] rung from the top by suspending a weight

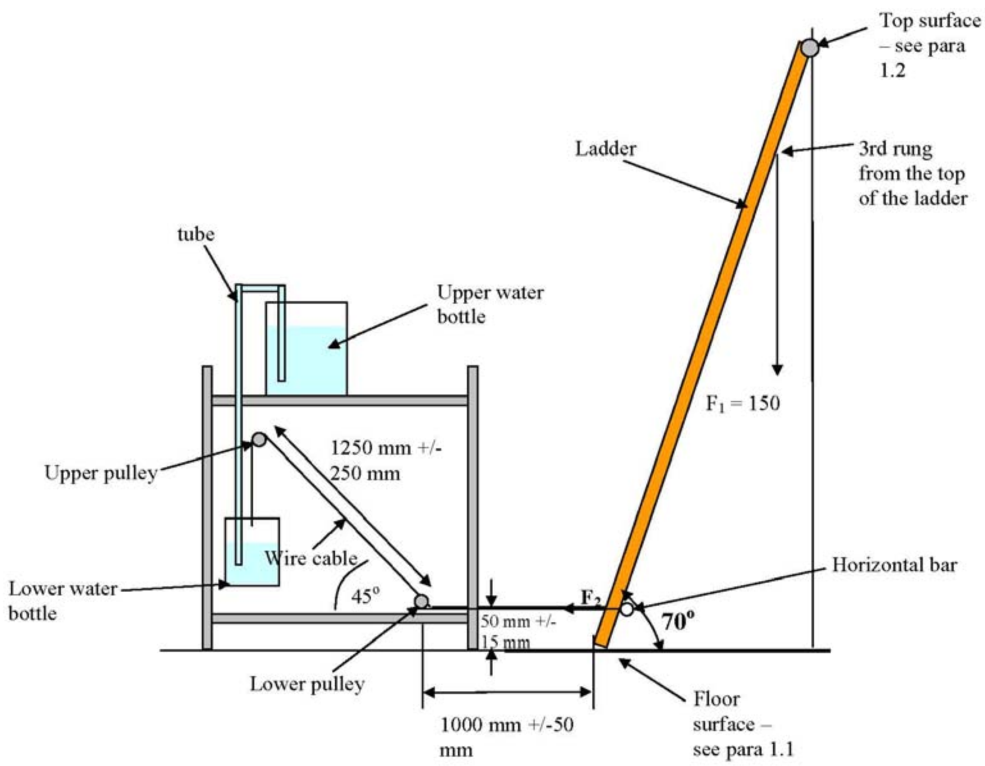


Figure 1 Test Equipment Layout

1.4 A horizontal force F_2 shall be applied to the ladder using a horizontal bar between the stiles at the base of the ladder 50 mm above the floor (Figure 1).

- The bar shall be stiff but not weigh more than 0.75 kg (e.g. aluminium or steel tube).

[2] CEN TC93/WG10 considered doing two sets of tests with a vertical load of 50 kgf AND 150 kgf. To keep the test straightforard, we decided to carry out tests at only one load., and we chose 150 kgf. Although the ladder will slip at a lower horizontal (F_2) load for a 50 kgf vertical load, we chose the higher load as it places a greater demand on the ladder feet. Also, work in CEN TC93/WG10/TG1 014 showed that the coefficent of friction tended to reduce for the higher vertical loads.

Page 2 of 9

- The bar shall be attached to the stiles. For example - cable ties, light clamps, adhesive tape.
- The force shall be applied at the centre of the bar using a wire cable. The cable shall be an unsheathed 4 mm diameter, low stretch, stainless steel (A4-AISI 316 1.4401 and manufactured in accordance with DIN 3053[3])

- Water shall be added using one of the following methods:
  - a siphon tube (Figure 1)
  - pouring it from a beaker
  - installing a valve in the upper water bottle connected to a hose that passes into the lower water bottle.

  Water shall be added at a rate **no greater than 3 litres/minute (+/- 0.5 litres/minute)**.

  If pouring the water from a beaker, DO NOT add the water at a rate greater than 3 litres/45 seconds, **and wait until the full minute has passed before adding further water**.

  The water shall be added gently to prevent the water container from swinging (this adds dynamic forces).

- The distance between the ladder foot and the lower pulley wheel shall be 1000 mm (+/- 50 mm).

- Between the first and second pulleys, the wire rope should be at an angle of 45° (+/- 5°), and the length should be 1250 mm (+/- 250 mm).

- Pulley wheels shall have a sheave diameter of 35 mm – 45 mm, and comply with EN 12278 *Mountaineering Equipment – Pulleys – Safety Requirements and Test Methods*

1.5 Air temperature shall be measured close to the ladder feet (within 100 mm) at a height no greater than 10 mm from the steel surface. Temperature shall be 20°C +/- 2.0 °C before testing, and remain within this range during the test

1.6 Ladder feet shall have been unloaded and off the ground for at least two hours (e.g. lying in a horizontal position) before the first test

1.7 The ladder feet shall be new, in good condition and not 'scuffed' or damaged in any way

1.8 The steel surface shall be cleaned with pure industrial grade ethanol, and a clean-room certified dry hygiene wipe[4]. Remove the ethanol with another clean-room certified dry hygiene wipe.

1.9 The ladder feet shall also be cleaned with a clean-room certified dry hygiene wipe.

1.10 Wait at least 20 minutes before testing.

1.11 Place the ladder against the wall at an angle (α) of 70°, as shown in Figure 2

[3] If the ladder has a stability bar at the base, the wire cable can be attached to this, but ensure the cable is no greater than 50 mm above the ground

[4] Industrial ethanol is 96% by volume. Read the safety data sheet before use. Pure ethanol is highly flammable, and should be used in a well ventilated area. Also avoid skin contact

Page 3 of 9

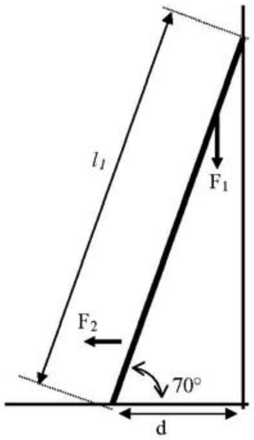


Figure 2 Angle of the Ladder Against the Wall

Obtain the correct angle by

- measuring the length of the ladder (l_1)
- multiplying the length by 0.342 (i.e. cosine 70°) to give distance d in Figure 2
- mark this distance on the floor,
- lean the ladder against the wall with the feet at this distance from the wall. The angle should be close to 70°. This may not be the case if wheels have been used (para 1.3). So the ladder angle may need to be adjusted.
- confirm the angle is correct by measuring it with an inclinometer accurate to within +/-0.5° and record the result **(see Test Sheet in Annex 2)**. For multi-section ladders, measure the angle half way along each section and record the result
- check the ladder is not leaning to one side by measuring the angle on one side of the stile using the inclinometer. The angle shall be 90°+/-1.0° before testing
- Check the cable is horizontal and the pulley wheels are rotating freely, and the cable is pulling in a direction parallel to the ground as shown in Figure 1. There should be no more than 30 mm difference in height between the cable at the lower pulley wheel, and the cable at the ladder foot[5].
- If the pulleys swivel, ensure they are in line with the cable. Do a visual check from above to ensure the wire rope is pulling at 90° i.e. at a right angle with the base of the ladder.

1.12 To ensure the plate does not slip, place weights on each side where they will not interfere with the test

[5] 30 mm difference in height over 1000 mm gives an angle of $\tan^{-1}(30/1000) = 1.72°$. This ensures there is no significant difference between the true horizontal force (F_2), and the force measured using the water canister. The true force will be less than the measured force by a factor of cosine(1.72°) = 0.9996 which is negligible.

Page 4 of 9

2.0 BASE SLIP TESTS

Do not stand on the steel plate as grit from shoes could affect results. Also do not stand on the ladder during tests

2.1 Position the ladder as stated in para 1.11

2.2 Place a steel rule next to one of the ladder feet at right angles to the wall (for measuring slip distance)

2.3 Block the base of the ladder[6] to prevent it slipping, and apply F_1 at the mid-point of the 3rd rung from the top of the ladder - para 1.3

2.4 Wait two minutes

2.5 Record the temperature – para 1.5

2.6 Apply a horizontal load F_2, of 5 kgf, then release the blocks at the base of the ladder[7]

2.7 Add water at 3 litre/minute (+/- 0.5 litre/min) – see para 1.4.

2.8 Observe the ladder feet and monitor the movement against the steel rule

2.9 Ensure the steel plate does not move. Mark the floor next to the edge of the plate to check for movement. If movement occurs, apply more weights to the plate - para. 1.12

2.10 When the ladder has slipped 40 mm, stop the test

2.11 If the water is added through a siphon tube or hose pipe, stop the siphon or switch the tap off within 5 seconds of the test finishing.

2.12 Raise the ladder feet off the ground. Start measuring the time. There should be only be a 10 to 15 minutes pause between tests

2.13 Clean the ladder feet with a clean-room certified dry wipe

2.14 Weigh the water container and attachments to give F_2 (kgf).

2.15 The test shall be repeated four times starting at para 2.1 each time. The feet shall be placed at a different position on the plate each time.

2.16 Remove the used feet and replace with new feet. Carry out a further four tests as described above.

2.17 Report all eight values of F_2 in kgf. Use the Test Sheet in Annex 2

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[6] If you don't do this, when the vertical load is applied, the vibrations may cause the ladder to move. The ladder can be blocked with weights placed against the base of the stiles. Or the ladder can be blocked by pushing on the stiles with your arms.

[7] If the ladder slips 40 mm or more, stop the test, lift the ladder feet off the ground for 10 minutes, then repeat the test. Record that the ladder slipped 40 mm for a 5 kgf pre-load. Repeat the test. If the ladder slips 40 mm again for a 5 kgf pre-load, the test is concluded (fail)

Page 5 of 9

2.18 Report the mean and standard deviation values of all eight values. All in kgf. Use the Test Sheet in Annex 2

Note: at CEN TC93 WG10 meeting 6, (Rome Nov 2011) we discussed where the pass/fail criteria should be for the value of F_2. An F_2 – 1 standard deviation of 20 kgf was suggested. This can be adjusted depending on additional preliminary data that WG10 receives

Annex 1 - Preparation of Test Surfaces. This information is taken from clause 6 of EN ISO 13287 *Personal Protective Equipment – Footwear – Test Method for Slip Resistance* (the work of CEN TC161)

Stainless steel plate (thickness 2 mm minimum) such as number 1.4301, type 2G (cold rolled ground) conforming to EN 10088-2 2005 to be used

Surface roughness shall be measured, using a calibrated surface micro-roughness meter on the stainless steel. An example of one is shown below.

The roughness meter shall measure Rz in accordance with BSENISO 4287 1998 + A1 2009 *Geometrical Product Specification (GPS) – Surface Texture: Profile Method – Terms, definitions and surfacetexture parameters*

The meter shall have a full independent calibration carried out periodically in accordance with an audited quality management system, and if possible, using manufacturer's recommendations.

As we have observed some variations in roughness meters, the meter shall have the following parameters:

- Tip diameter to be 0.5 microns (to ensure the depth to which the stylus can go to within the troughs of the surface does not vary – a thinner stylus could go deeper, a thicker stylus would measure a more shallow depth)

- At each location measurements shall be made with a sampling length of 0.8 mm taking five sampling lengths per location (evaluation length 4.0 mm)

Measurements to be made at twenty random locations, and in the direction parallel to the sliding movement. R_Z[8] shall be measured in each case. The average of the twenty measurements should be between 2.0 μm and 2.5 μm.

No single measurement shall be less than 1.6 μm, or greater than 3.6 μm

The plate shall be thoroughly cleaned with industrial grade ethanol (see para 1.8) and cleaned with clean-room certified hygiene wipes to remove all residual grit from the surface.

More information on micro-roughness meters can be found on pages 1 and 2 of
http://www.hse.gov.uk/pubns/web/slips01.pdf

and

http://www.hse.gov.uk/slips/sat/satmeters.htm

When the roughness parameter does not conform to the above specifications, the steel surface shall be prepared with silicon carbide abrasive paper or cloth for polishing in a succession of reducing grit sizes. The polishing direction of each operation shall be perpendicular to the preceding operation with the final direction being in the test direction. The preparation shall continue until the roughness parameter falls within the above roughness range.

The silicon carbide paper could be mounted on a rigid block with a flat face 100 mm x 70 mm and mass 1200 +/- 120g (can be achieved using a steel block 22 mm thick)

Note: grit sizes 100 to 600 are a typical range that may be needed. The grit paper is less abrasive for increasing numbers.

[8] Rz calculated from BSENISO4287 (1998) measures the maximum peak and max trough in each of the five 0.8 mm sample lengths, and adds them together (the maximum peak may not be adjacent to the maximum trough. One could be at one end of the sample length, and the other could be at the other end). It then takes the mean of these five maximum values. This is Rz

Annex 2 Leaning Ladder – Base Slip Test Sheet

Date		**Ladder Angle (°)**			
Temp		**Single section, or lower section of a multi section ladder**	**Second section (multi section ladder only)**	**Third section (multi section ladder only)**	**Side angle (check for vertical)**
Information on Ladder and Foot type					
Ladder length (mm)					
Stile width (mm)					
Stile depth (mm)					
Ladder weight (kg)					

Sample 1	**F_2 when foot has slipped 40mm minimum (kgf)**	**Comments**
Test No.		
1		
2		
3		
4		
Mean		

Sample 2	**F_2 when foot has slipped 40mm minimum (kgf)**	**Comments**
Test No.		
1		
2		
3		
4		
Mean		
Total Mean ($\bar{x}$)		
Standard Deviation[9]		
Total Mean – 1 standard deviation		

[9] Standard deviation calculated from $sd = \sqrt{\frac{\sum_{i=1}^{8}\left(x_i - \bar{x}\right)^2}{8-1}}$ where x_i is the individual measurement, and $\bar{x}$ is the mean **of the 8 measurements** $\bar{x} = \sqrt{\frac{\sum_{i=1}^{8} x_i}{8}}$

Page 9 of 9

CEN/TC 93/WG 10/N 99

WG10 Revised Base Slip Test
November 2012

The following revision to the base slip test was proposed at the meeting of TC93 WG10 in Brussels on the 14th November 2012.

1. The feet of the ladder shall be new.
2. The air temperature shall be measured at the base close to the ladder feet (within 100 mm) at a height no greater than 10 mm from the supporting surface. The temperature shall be 20°C +/- 2.0°C before testing, and remain within this range during the test.
3. The ladder is fitted with wheels (rollers) at the top on the inside of the stiles. The wheels shall be suitably strong to resist the loads without deformation and be free running and have a diameter of nominally 80mm and with the circumference of the wheel towards the supporting surface projecting no more than 10mm from the rear surface of the ladder (see fig 1).
4. The surface of the upper wall shall be firm and smooth and either smooth stainless steel, smooth glass, smooth high pressure laminate (HPL) conforming to EN438-S333. The top surface shall be cleaned before the test using the same method for the base surface.

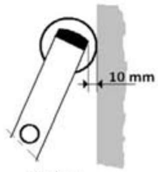


Figure 1

5. The base of the ladder is supported on a sheet of float glass meeting the relevant requirements of EN572 Part 2:2012. The glass shall be of a suitable thickness to support the weight of the ladder.
6. Prior to carrying out the test, the glass shall be cleaned using pure industrial grade ethanol[1], and a clean-room certified dry hygiene wipe. After cleaning remove the ethanol with another clean-room certified dry hygiene wipe.
7. Prior to carrying out the test the feet of the ladder feet shall be cleaned with a clean-room certified dry hygiene wipe.
8. Wait 20 minutes.
9. Check that the temperature at the base of the ladder is within the required limits.

TEST at 75 Degrees

10. Position the ladder at an angle of 75° with its feet on the glass supporting surface and the rollers at the top resting against upper supporting surface. Confirm the angle is correct by measuring it with an inclinometer accurate to within +/-0.5°
11. Block the base of the ladder to prevent outwards movement.
12. Establish a datum at the base of the ladder as the origin of measurement for outwards movement of the feet of the ladder.
13. Add a 1471N (150kg) vertical load to the 7th rung down from the top of the ladder.
14. Wait 2 minutes.
15. Remove the block from the base of the ladder and wait one minute
16. If the ladder feet move outwards more than 40mm in less than one minute with respect to the origin for measurement, then record the test as a failure.
    If the ladder feet do not move outwards more than 40mm in less than one minute with respect to the origin for measurement, then record the amount of movement and record the test as a pass.

[1] Industrial ethanol is 96% by volume. Read the safety data sheet before use. Pure ethanol is highly flammable, and should be used in a well-ventilated area. Also avoid skin contact

Page 1 of 3

CEN/TC 93/WG 10/N 99

WG10 Revised Base Slip Test
November 2012

17. If the ladder passes the test remove the vertical load and wait 10 minutes and then repeat steps 10, 11 & 12.
18. Add a 1471N (150kg) vertical load to the 6th rung down from the top of the ladder.
19. Repeat steps 14, 15 & 16

20. If the ladder passes the test remove the vertical load and wait 10 minutes and then repeat steps 10, 11 & 12.
21. Add a 1471N (150kg) vertical load to the 5th rung down from the top of the ladder.
22. Repeat steps 14, 15 & 16.

23. If the ladder passes the test remove the vertical load and wait 10 minutes and then repeat steps 10, 11 & 12.
24. Add a 1471N (150kg) vertical load to the 4th rung down from the top of the ladder.
25. Repeat steps 14, 15 & 16.

TEST at 70 Degrees

26. Repeat steps 6 to 16 but at step 10 position the ladder at 70°

27. If the ladder passes the test remove the vertical load and wait 10 minutes and then repeat steps 10 (with the ladder positioned at 70°) 11 & 12.
28. Add a 1471N (150kg) vertical load to the 6th rung down from the top of the ladder.
29. Repeat steps 14, 15 & 16.

30. If the ladder passes the test remove the vertical load and wait 10 minutes and then repeat steps 10 (with the ladder positioned at 70°) 11 & 12.
31. Add a 1471N (150kg) vertical load to the 5th rung down from the top of the ladder.
32. Repeat steps 14, 15 & 16.

33. If the ladder passes the test remove the vertical test load and wait 10 minutes and then repeat steps 10 (with the ladder positioned at 70°) 11 & 12.
34. Add a 1471N (150kg) vertical load to the 4th rung down from the top of the ladder.
35. Repeat steps 14, 15 & 16.

TEST at 65 Degrees

36. Repeat steps 6 to 16 but at step 10 position the ladder at 65°

37. If the ladder passes the test remove the vertical load and wait 10 minutes and then repeat steps 10 (with the ladder positioned at 65°) 11 & 12.
38. Add a 1471N (150kg) vertical load to the 6th rung down from the top of the ladder.
39. Repeat steps 14, 15 & 16.

40. If the ladder passes the test remove the vertical load and wait 10 minutes and then repeat steps 10 (with the ladder positioned at 65°) 11 & 12.
41. Add a 1471N (150kg) vertical load to the 5th rung down from the top of the ladder.
42. Repeat steps 14, 15 & 16.

43. If the ladder passes the test remove the vertical load and wait 10 minutes and then repeat steps 10 (with the ladder positioned at 65°) 11 & 12.
44. Add a 1471N (150kg) vertical load to the 4th rung down from the top of the ladder.
45. Repeat steps 14, 15 & 16.

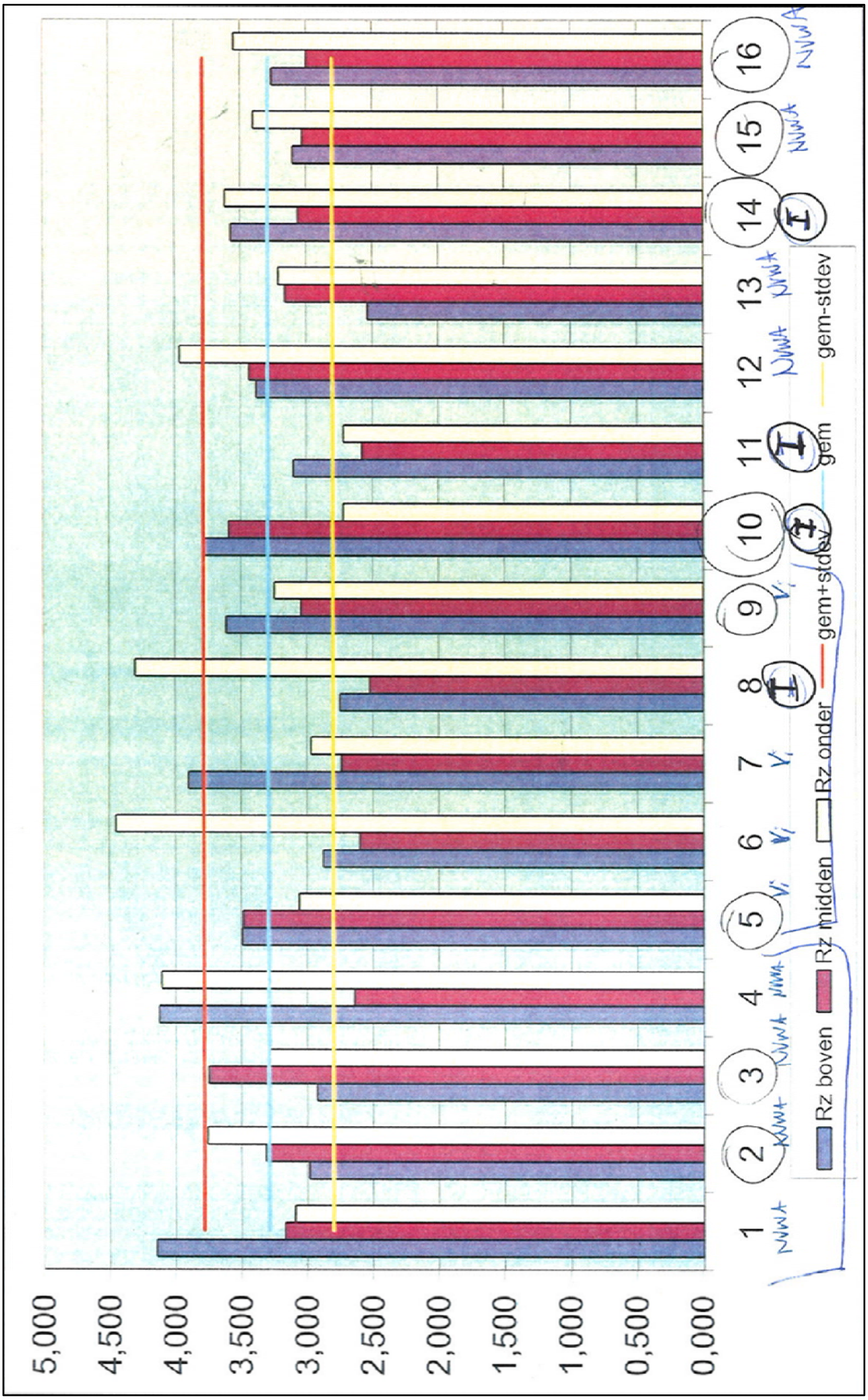
CEN/TC 93/WG 10/N 99

WG10 Revised Base Slip Test
November 2012

46. Repeat the entire test steps 1-45 on a second ladder. ________________________________ ends

Appendix 3. Selection of floor plates

Floor plates: 2 – 3 – 5 – 9 – 10 – 14 – 15 – 16
Wall plates: 1 – 4 – 6 – 7 – 8 – 11 – 12 - 13



Appendix 4. Critical Analytical review task 1.1

Task 1.1 – critical analytical review			../N64 stainless steel
item	advantage	shortcomings	improvement
1.2 vertical surface.	More choice in material.	Choices will lead to deviations amongst the laboratories.	Only one unambiguous option, we suggest same specs as bottom material.
footnote 1.		Correction factor not stated in the document. Sentence not clear.	State correction factor.
1.3 + 1.4 (especially last 3 bullets)+ fig. 1 test equipment layout.	Describes in detail, easy to understand.	Very restrictive, not always practical/available.	Deviation should be allowed where influence on result is negligible.
1.4 cable for horizontal force.	Clear.	Very restrictive.	To be optimized within program. Specify significant parameters; flexibility, no stretch. Needs to be easily availability.
1.4 attaching horizontal force.		Way described produces a vertical lift component with much influence.	Device a solution without vertical lift.
1.4 speed of. adding water	Easy to realise.	Not univocal.	Try to find a better method with a flow meter/constant rate.
1.5 measuring temperature of air.	One measurement.	Not the value of the contact materials, essential for behaviour of elastomer molecules are foot and bottom temperature.	Measure temperature of feet and bottom material (usually some difference) and monitor them during testing.
1.6 feet shall be unloaded for at least 2 hours before testing.	Clear prescription.	According to our specialist material is distressed only after 17 hours.	Require at least 17 hours.
1.8 clean-room certified dry hygiene wipe.		Infinite choices available.	State the requirements and leave purchase free. Cloth needs to be dry, not leave fluff behind, absorbing debris (grease/oil).

Task 1.1 – critical analytical review			../N64 stainless steel
item	**advantage**	**shortcomings**	**improvement**
1.10 wait 10 minutes.	Some time for temperature to recover.	Not sure whether enough or unnecessary much.	Measure temperature after cleaning. All ethanol needs to be evaporated before proceeding
1.11 positioning ladder under 70 degrees.	2 methods are given on top of each other.	Confusion, method with length less accurate, calculating is complication with more risk of mistakes.	Measure angle only.
1.11 exact position.	Check 90 degrees clear.	Ladders not always perfect in plane.	If difference between styles one style 70 degrees, other one less. Or, mark a vertical line on the test wall that intersects the horizontal axis of the test set-up. The horizontal axis needs to be perpendicular aligned to the wall.
1.12 blocking base plate.	Weights might prevent slipping.	Not sure, very restrictive.	Simply prescribe: plate shall be prevented from slipping.
2.1 fail criteria are missing.		Judgement difficult.	Introduce fail criteria in line with CEN/TC 93/WG 10/N99.
2.1 till 2.18	Step by step.	Wording not always clear.	Improve wording.
2.2 measuring movement with steel rule.	Clear method.	Very restrictive.	Leave measuring equipment open.
2.5 record temperature after timing		Disturbs timing effect.	Measure temperature in advance.
2 timing of the steps in the protocol	Some timing described.	Lacks in timing, we know from elastomer theory that timing is essential factor, not always practical timing.	Duration in combination with pressure essential for elastomers. Therefore specify duration per step. Ideal duration to determine in project.
2.15 and 2.17		Seems to contradict: 2x4 versus 2x5 times.	Choose 2x5 times more data for average and stdev.

Task 1.1 – critical analytical review			../N64 stainless steel
item	**advantage**	**shortcomings**	**improvement**
2.6 starting load	Clear.	Might be much for some products already: no measurement possible.	Start with smaller weight.
2.16 replace feet	Exactly same conditions.	Often not available or not good replaceable.	Continue with same feet.
Footnote 6 blocking of ladder base	Block with weights or pushing arms on style.	Pushing arms on style can cause vibrations and forces on feet.	Allow blocking at base only.
Footnote 7 pre-load		5 kgf to high, possibly initiates premature sliding .	Pre-load of 2kgf preferred.
2.15 positioning	In beginning always clean plate.	Not practical, excludes (small) effect of possible positioning in same place.	Use same place.
2.18 report 8 values			If 2x5 chosen report 10 values.
2.18 details roughness	Some clear prescriptions.	Not always clear.	To be investigated and discussed, mention direction of roughness!
2.18 roughness	Wide range is easy.	Wide range is inaccurate.	Roughness has important influence on result. The more specific the Rz requirement the less deviation expected. Specify narrower range.
2.18 roughness direction.	Clear prescription.	Not accurate.	Sliding orientation perpendicular to grain direction less sensitive to alignment than parallel to grain direction. Do all preparation perpendicular on test direction: small deviations in direction will then have negligible influence on results.

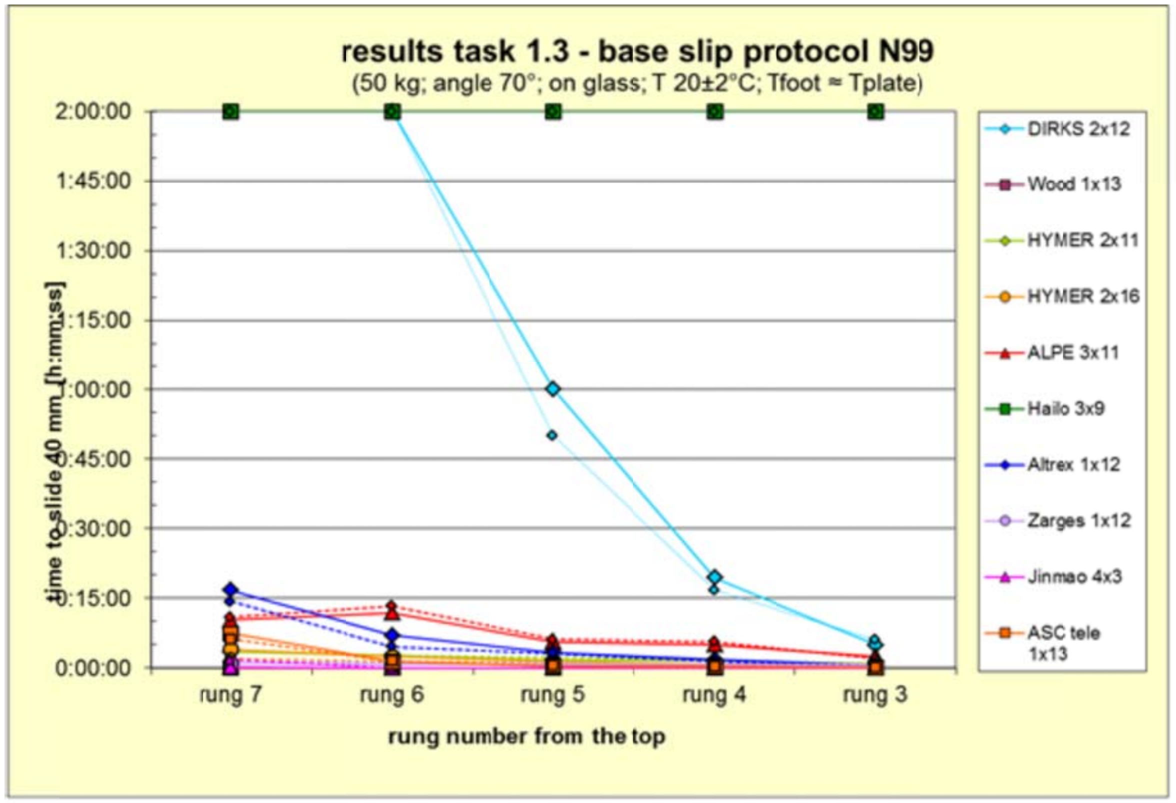
Task 1.1 – critical analytical review			../N64 stainless steel
item	**advantage**	**shortcomings**	**improvement**
Annex 1 Tip diameter of 0,5 micron seems wrong.		Not possible.	Check (actions started) and correct if desirable.
Annex 1 whole procedure.	In principle performable by anyone.	Source of deviations.	NVWA experience: difficult to achieve homogeneous roughness. Laborious process. Roughness well defined standard in industry achieved by grinding technique. Proposal: require Stainless Steel plate with specific Rz produced by grinding.
Annex 1 stainless steel.	Steel type example.	Steel type is example and not mandatory; causes deviation. Hardness determines sensitivity for deformation of surface structure e.g. roughness.	Change wording; choose generally available type.

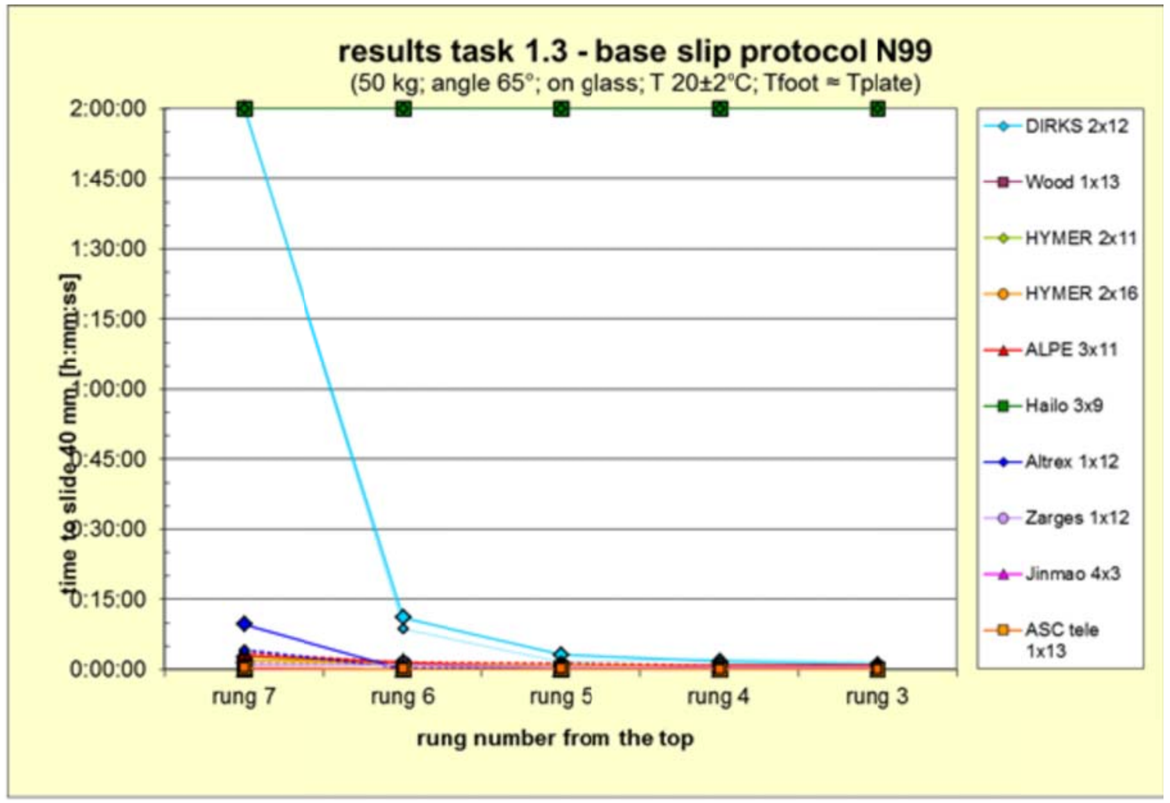
Task 1.1 – critical analytical review			../N99 float glass
item	**advantage**	**shortcomings**	**improvement**
General: this document describes a research program and requires 12 tests per ladder.	Gives insight.	Too much testing within capacity.	Limit program with smart choice.
General.		Unclear on which ladder to test.	Be specific, apply on a medium performing ladder if any
General.		Initial unloaded time of 17h.	Add instruction to wait 17 h prior to first test.
2 measuring air temperature.	One measurement.	Essential for behaviour of elastomer	Measure temperature of feet and bottom material (usually some difference) and monitor

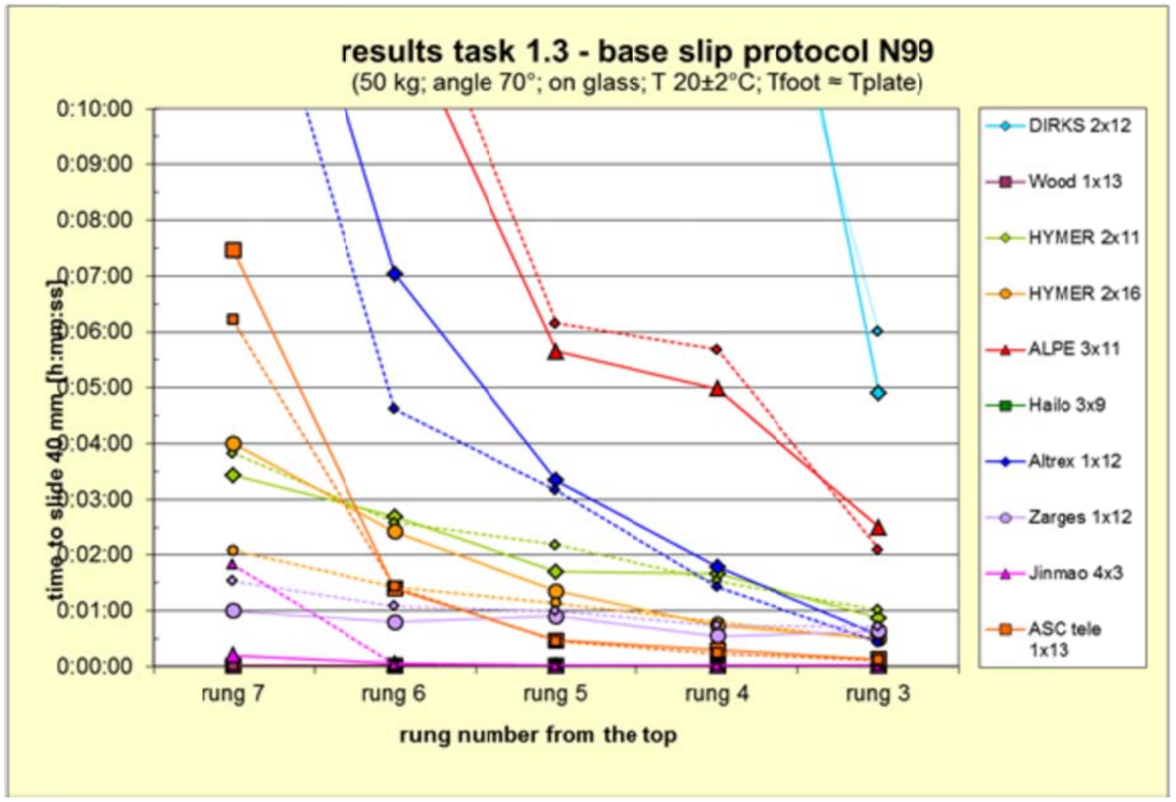
Task 1.1 – critical analytical review			../N99 float glass
item	**advantage**	**shortcomings**	**improvement**
		molecules are foot temperature and bottom temperature.	them during testing.
3 fit wheels on top.	Reduces friction/influence from wall contact strongly.	Less representative for use: changes geometry and weight, extra effort, complicates testing.	Use just smooth wall or other way to reduce wall friction (unless ladder is equipped with wheels).
4 choice of wall material.	Much choice.	Not univocal, different choices will influence test results.	Glass is theoretically the best but unpractical. Choose Stainless Steel with Rz of N64.
4 preparing wall surface.	Reduces influence further, except that several materials are possible.	Unnecessary effort, in combination with material choice and wheels no sense.	Don't prepare.
5 use of float glass.	Easy available.	Are their enough spec's to have reproducible wall/base material? Also EN 572 part 1 (physical mech. Properties) is applicable, not mentioned.	Order EN 572 part 1 too! Check if there are enough spec's for reproducible material.
6 clean-room certified dry hygiene wipe.		Infinite choice available.	state the requirements and leave purchase free. Cloth needs to be dry, not leave fluff behind, absorbing debris (grease/oil).
8 wait 20 minutes.	Clear instruction.	Time consuming, not relevant.	Ethanol needs to be evaporated. Temperature is indication. Measure temperature and wait until it is in range.
9 measuring temperature.		Method not representative.	See under 2.
13 attach to	Easy to realise.	Rung distance varies, so results may give wrong	Record rung distances

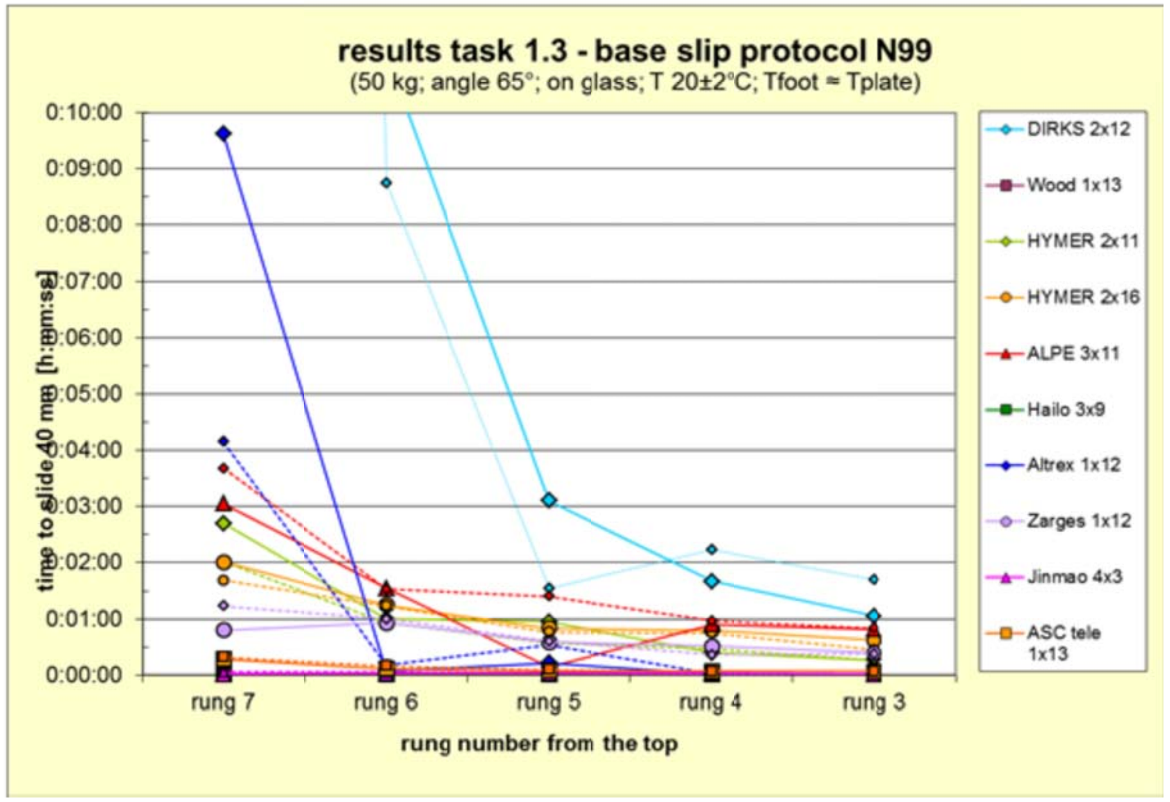
Task 1.1 – critical analytical review			../N99 float glass
item	**advantage**	**shortcomings**	**improvement**
different rungs.		impression.	additional to result.
13 add weight.		No tolerance mentioned.	Give tolerance as in N64.
14 wait 2 minutes.	Clear instruction.	Maybe too long.	Time to be optimized to prevent unnecessary time consumption, maybe 1 minute enough.
16 recording of test result.	Good for less than 40mm.	Not clear about failure.	Record failure: distance after 1 minute or time needed to slide completely, pass/fail criteria can change later!
17 waiting time of 10 minutes.	Clear instruction.	Perhaps unnecessary time consumption (but time too short for recovery of feet material, in that case around 17 hours needed).	Duration in combination with pressure essential for elastomers. Therefore specify duration per step. Ideal duration to determine in project.
24 test on 4th rung.	Clear.	Foreseeable use is 3rd rung.	Continue to 3rd rung.
27 to 45 Tests at 70 degrees and 65 degrees.	As previous comments for 75 degrees.	As previous.	As previous.

Appendix 5. Second series of tests - results









Appendix 6. Final Base Slip Protocol task 1.7

base slip test for leaning ladders

Part 1 - stainless steel

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page 1 of 10

General

This protocol describes a procedure to test the resistance against base slip of single and multi-section ladders that are intended to be used as leaning ladder. This protocol has to be executed before the base slip test on float glass, and apart from being a test in itself, it serves as a preconditioning for the base slip test on glass.

MOTIVATION: The reason to do both tests on stainless steel and float glass is that it creates the possibility to check many variables that can posses risks to the user. The main variables are:

- different angles (prevents manufacturers optimizing for one angle and being dangerous at another angle),
- different vertical test loads (small loads can be dangerous because the feet profiles are not compressed enough to have sufficient contact surface; large loads can be dangerous because friction properties of polymers deteriorate under pressure),
- with and without horizontal force
- on different materials with different character (good performance on one material can be accompanied by poor performance on another material).

MOTIVATION: The reasons to start with testing on steel are as follows. According to the test results of task 1.2, 1.3 and 1.4 of the project it seems that the worst case is on steel with worn feet and on glass with new feet. However, there are a number of reasons to start on steel. First, the results with new feet show less reproducibility. On top of that, new feet may differ due to packaging or transport. Once the feet are worn off, the results are more consistent. With testing on glass the feet will not wear very much because of the extreme smooth surface with little interaction with polymers. Also because of the much lower test load used. So to wear them a little bit testing on steel first with 150 kg is preferred. Additionally, it will help to prevent eventual vacuum effects of the new feet on glass. Last but not least: the ladder will be used in practice with worn feet much more then with new feet. To be sure there is wear in the right contact area before starting on steel under 65 degrees and under 70 degrees. These preparing tests set an defined starting condition for all ladder feet.

MOTIVATION for testing with angle of 65° on steel: according to the results of task 1.3 testing at an angle of 65° on glass seems to be too severe but is reasonably foreseeable use that has to be covered somewhere.

Section 1: equipment/requisites

1. A flat rigid floor that is horizontal.
2. A flat vertical wall of at least 6 meters height that is perpendicular to the floor, solid enough to prevent vibrations or other movements under the pressure of the ladder and its test loads (vertical test load and bucket with water).

> Remark: A 4 meter wall will suffice for labs that only want to test ladders up to a maximum length of e.g. 4 meters .

3. Two pulley wheels to guide a stainless steel cable; the pulley wheels shall have a sheave diameter of 35 mm – 45 mm, and comply with EN 12278 *Mountaineering Equipment – Pulleys – Safety Requirements and Test Methods*.

> MOTIVATION: Searching for pulleys according to EN 12278 will result in finding small, ridged and smooth running pulleys. Searching for pulleys in general will result in finding industrial pulleys with large diameters and for large cable diameters. Measurements show that the force loss due to cable bending is very small (negligible) with the prescribed diameters.

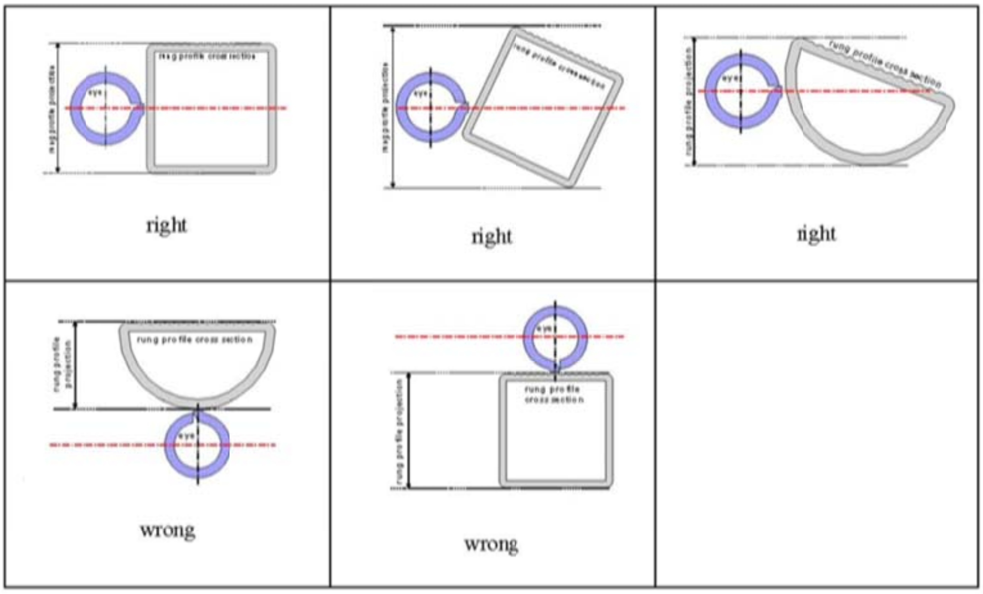
4. An extra flexible stainless steel cable; the stainless steel cable shall have a diameter of 2 mm, is unsheathed, has low stretch, is made of stainless steel A4-AISI 316 1.4401 and is manufactured in accordance with DIN 3053.

> MOTIVATION: A 2 mm cable consumes less bending force than a 4 mm cable (as required in the initial steel protocol) and results in a more accurate determination of the horizontal force applied on the ladder.

5. A bucket that can contain at least 30l and means to attach the bucket to the vertical end of the cable with a total mass of 2 ± 0,1 kg .
6. A system that can deliver a water flow of 3 ± 0,15 l/min without interruption. The system enables the start and stop of the water flow without residual flow. The water flow should be side ways in the bucket to prevent a vertical dynamic force at the bottom of the bucket.

> MOTIVATION ± 0,15 l/min is = 5 %. This is a reasonable achievable bases on the experience of the tests in the project.
> During one of the pre-conditioning tests in task 1.2 a horizontal force of 20,2 kg was measured. Using a bucket of 20 l is therefore critical. For further tests a bucket of 30 l is used.

7. An eye bolt that is fixed rigidly to the lowest rung to be able to attach the steel cable. The position of the eye bolt shall be such that the centre line of the attached horizontal cable (see the red line in the illustrations below) imaginary runs through the rung. The inner diameter of the eye bolt shall be 12 ± 3 mm and the surface of the eye bolt shall be smooth. The mass of the eye bolt and the fixture shall be 0,5 ± 0,1 kg.



MOTIVATION: The previous protocol (N64): a horizontal force F_2 shall be applied to the ladder using a horizontal bar between the stiles at the base of the ladder 50 mm above the floor. In this protocol the horizontal force should be applied on the lowest rung of the ladder. The influence of the height of the point of engagement of the horizontal force on the results is expected to be negligible.

If the centre line through the horizontal cable would be extended through the ladder, it can go cross the ladder plain under, through or above the area between the highest and lowest point of the rung. If it would pass under or above, there is an increasing chance for a resulting moment with vertical components that would influence the test. Therefore the centre line shall cross with the rung itself. Any movement in the construction or any applying of the force that can cause vertical components will influence the results negatively and shall be avoided. Therefore the construction with the eye is chosen, where the cable will be pulled towards the outer end of the eye which is perpendicular on the cable and thus cannot experience vertical forces. If the eye would be mounted flexible on the rung, it would cause moments and vertical forces in many cases. Therefore this is not acceptable. The effect of the mass of the construction shall be limited. 0,5 kg is small in comparison with the mass of the ladder and the vertical test load of 150 kg, but it should not be forgotten that the 0,5 kg are applied on a favorable point for the ladder.

8. A construction that

- has the pulleys mounted according to the dimensions in illustration A
- has the steel cable led along the pulleys as shown in illustration A
- has the bucket attached to the steel cable at the vertical end of the cable
- has the cable fixed to the eye bolt that is fixed to the bottom rung of the ladder
- enables the water bucket to descend freely
- the horizontal cable between the eye bolt on the bottom rung and the lowest pulley is not sloping more than 1% of the length . Influence is also circa 1% of the force.

page 4 of 10

MOTIVATION: Fulfilling these requirements the eventual resulting vertical force will be within 1 % of the horizontal force which is comparatively a small influence. The deviation of the horizontal force will be even much smaller.

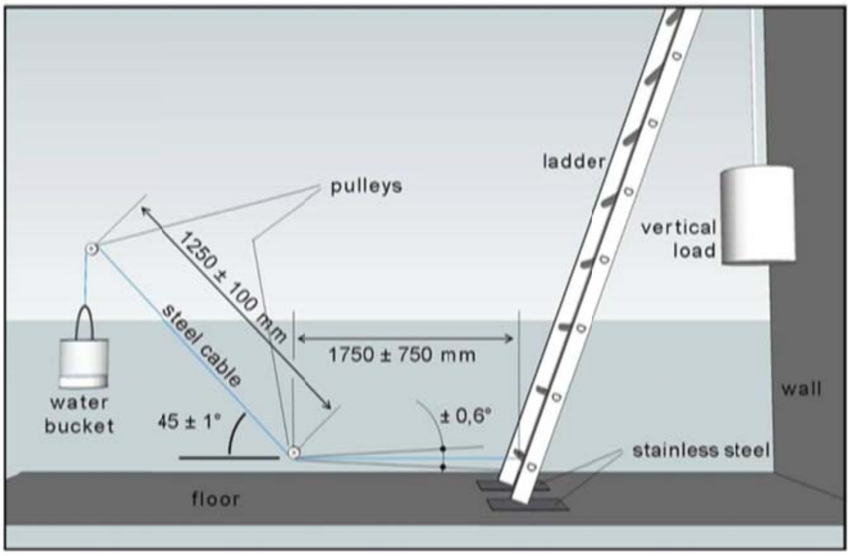


Illustration A: sketch with the main parts of the base slip test set up.

9. 17 hours prior to and during the tests, the samples, room and equipment shall be 21 ± 2.0 °C.

MOTIVATION: Polymers need time to get de-stressed (stress in the feet polymers can occur by carrying the own mass of the ladder) and the de-stressed condition is the only accurate starting point for the test that can be achieved. During the test program the polymers will get stressed all the same way, but as the temperature has big influence on this process it has to be defined. To de-stress the polymers at room temperature, according to a specialist in this field, 17 hours are sufficient.

10. Stainless steel as contact surface on floor and wall. The stainless steel shall be type AISI 304 (1.4301).

    The stainless steel on the floor shall be of a suitable thickness to support the mass of the ladder plus the vertical test load without relevant deformation (without dents or waves). The stainless steel on the floor shall be fixed to the floor to prevent sliding during the test. It shall be long enough to allow the ladder to slide at least 40 mm freely on the plate.
    The steel on the wall shall be of a suitable thickness to support the leaning of the ladder under the vertical test load without relevant deformation (without dents or waves). The steel on the wall shall be fixed to the wall to prevent movement or vibration during tests. It shall be long enough to allow the top of the ladder to decent freely during sliding against the plate.

MOTIVATION: Glass on the wall would reduce the influence of the wall contact, but is much less practical and causes more risk for the test engineers during the tests. On top of that, sticking to stainless steel on the wall makes it possible to use the results for cross reference. By far most situations in practice have more wall friction than on glass and the test should not stop innovation to make safer ladders through the contact with the wall.

The surface of the stainless steel on the floor and the wall need to be treated by mechanical polishing to achieve a R_z of 3,3 µm uniformly along the surface.

Measurement conditions for the roughness measurements of R_z between 0,5 µm and 3 µm shall be done according to DIN EN ISO 4288:1998 and DIN EN ISO 3274:1997.

- stylus tip radius rtip = 2 µm
- single measure length lr (λc) = 0,8 mm
- total measure length ln = 4 mm
- traverse length (measured length plus start-up and trailing length) lt = 4,8 mm

Measurements to be made at twenty random locations, and in the direction parallel to the sliding movement. The average of the twenty measurements shall be between 2,8 µm and 3,8 µm. No single measurement shall be less than 2,4 µm or greater than 4,4 µm .

MOTIVATION: As we have observed some variations in roughness measuring equipment an accurate specification of the roughness measurement is important.

11. Cotton cloth: Unbleached cotton 100 - 120 g/m².
12. Cleaning aid: ethanol 96 volume %.
13. Inclinometer with sufficient accuracy to adjust the ladder angle within ± 0,2°.
14. A vertical test load with a mass of 150 ± 1 kg, including the aids to apply the test load on a rung, (e.g. a hoisting strap).
15. A lightweight bar to block both feet of the ladder on the floor at the same time. The bar is to be held in place on the floor and removed before starting the test by the test engineer.
    Any lightweight material that do not damages the plates while in contact with the it.
16. A support stand to keep the ladder feet off the ground while the ladder is in between two sequential test positions.
17. Facilities to keep the test area at a temperature of 21 ± 2,0 °C
18. A thermometer to measure the temperature with an accuracy of at least ± 0,2 °C.
19. Ruler to measure the feet displacement with a resolution of 1 mm, class II accuracy.
20. A stopwatch with an accuracy of 1 % or less.

Section 2: preparation

21. Prior to testing the ladder feet shall have been unloaded (off the ground) for at least 17 hours (e.g. lying in a horizontal position or resting with the bottom rung on a support) at a temperature of 21 ± 2,0 °C .

22. The test length is to be adjusted by extending the ladder to a length as close as possible to 6300 mm, but not more than 6300 mm. In case of an extending ladder (e.g. a leaning rung ladder consisting of two or more parts) extend the top part first.
    Ladders that are above 6300 mm at their minimum length shall be tested at their minimum length. Alternatively, a shorter ladder of the same type can be used if available. However, the vertical test load mentioned in section 3 shall be applied on the rung as if it concerns the longer model.

MOTIVATION: Testing a 6300mm ladder requires a wall of about 6 m height. A higher wall in combination with controlled temperature may cause practical problems in many laboratories. With this length and method the vast majority of consumer ladders as well as professional ladders (estimated more than 99% of all ladders on the market) can be tested without changing the ladder construction by shortening it.

23. The stainless steel on the wall shall be on such a position that the ladder top feet/rollers are in contact with the steel during the whole test. This means that the contact point of the ladder with the stainless steel on the wall can descent at least 40 mm before it slides off the steel. The starting contact point will be on a height roughly between 90 % and 91 % of the ladder length if the ladder is positioned under 65 ± 0,2 °.

24. The stainless steel on the floor shall be on such a position that the ladder feet are in contact with the steel during the whole test. This means that the contact point of the ladder with the stainless steel on the floor can slide at least 80 mm before it slides off the steel. The starting contact point will be on a distance from the wall roughly between 42 % and 43 % of the ladder length if the ladder is positioned under 65 ± 0,2 °.

25. Temperature of the stainless steel on the floor shall be 21 ± 2,0 °C during the test.

26. The contact surfaces, both on the floor and at the wall, shall be cleaned with cotton cloth and ethanol before the testing: one cleaning per tested ladder, no cleaning in between repeated tests. After cleaning remove possible residues of the ethanol with a dry cotton cloth.

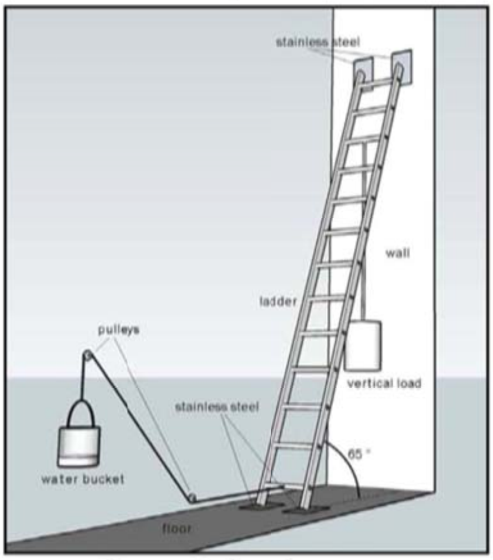


Illustration B: base slip test setup.

Section 3: test procedure

The ladder feet shall be new, in good condition and not 'scuffed' or damaged.

27. Pre-treatment: Before executing the first test, the ladder feet shall be prepared. The preparation exists of executing the following test procedure three times at an angle of 65° and three times at an angle of 70°.

MOTIVATION: Advantage of new feet: need no preparation and has no influence of preparation, should be the same for all. Advantage of prepared feet is that tests are more reproducible, influence of eventual packaging or previous surface contacts are absent, more representative for most use. These preparing tests set an defined starting condition for all ladder feet. The results of the preparation tests will not count for the verdict.

28. Prior to carrying out the test, the feet of the ladder shall be cleaned with a dry cotton cloth without ethanol or any cleaning fluid. Cleaning will only be done before testing the ladder, no cleaning in between repeated tests.

29. Extend the ladder to its maximum length or the first position of use under 6300 mm. The top part in case of a multiple part extending ladder has to be extended first before extending other parts.
    - In case that a ladder touches the wall with an other part than the top part, extend the ladder above 6300 mm until the ladder only leans against the wall with the top end.
    - Ladders that have single parts longer than 6300 mm, have to be tested on the length of the single part.

30. See illustration B. Position the ladder at an angle of 65 ° ± 0,2 ° with the floor. When the ladder feet touch the ground **start counting time**. Measure the angle with an inclinometer at 1,5 meter from the floor. Measure both stiles. The steepest stile is leading for the angle.

    If the ladder has no preferred top/bottom or back/front side, it shall be realised that the ladder will be positioned in the same orientation at each test..

    Seen from the front view, the vertical alignment of the ladder should be in a way that the centreline through the middle of the bottom rung and the middle of the top rung is perpendicular to the floor. See illustration C.

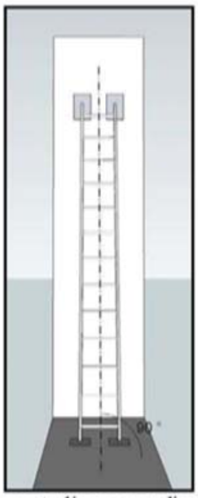


Illustration C: centerline perpendicular to the floor

page 8 of 10

31. Block the base of the ladder manually with the lightweight bar mentioned under point 15 to prevent outwards movement.

MOTIVATION: A lot of thinking has been done to devise a system that blocks and releases the feet automatically. An automatic lock and release system needs to be reproducible and may not introduce any extra pushing or pulling. It turns out that such a system needs to be very sophisticated. Requiring such system in this protocol would compel laboratories to spend a large amount of money. Including requirements for a blocking and releasing system would results in all sorts of solutions that causes the tests to be executed differently in separate laboratories with deviational judgements as a result. From experiences of the tests in the project blocking and releasing the base can be done manually. It needs to be done at the lowest point on the ladder, i. e. the feet, both feet at the same time and with a beam that is operated in the middle in between the feet. It needs to be a lightweight beam of which the weight does not hinder the ladder base to slide once its released. Attention that the beam does not touch the floor plates while sliding to avoid damage.

32. Check whether the temperatures at the stainless steel on the floor and the feet of the ladder close to the contact surface are within the required limits during the tests. Record the measured temperature.

33. Determine a reference point at the base of the ladder as the origin of measurement for outwards movement of the feet of the ladder.

34. After 120 ± 10 s from the start of counting under point 30, apply the vertical test load
    - At the centre of the 3rd rung from the top on ladders with a maximum length up to 9 m;
    - At the centre of the 2nd rung from the top on ladders with a maximum length between 9 m and 12 m;
    - At the centre of the top rung on ladders with a maximum length beyond 12 m.
    If rungs are double or triple on the same level (in case of a extending ladder) use the rung closest to the wall.
    Avoid that the application of the vertical test load gives a dynamic effect.

MOTIVATION: Users are allowed to climb a ladder until the 4th rung from the top. In practice it's well known that users climb higher than the 4th rung (reasonable foreseeable use). When climbing on a ladder, the shear force between the ladder and the floor increases. The greater the shear force becomes, the less horizontal force is necessary in order to slide the ladder. For extending ladders with a length above 9 m this effect can be simulated by positioning the vertical test load on a higher rung.

35. Attach the steel cable to the eye bolt in such a way that it can move free within the eye.

36. After 240 ± 10 s from the start of counting under point 30 remove the bar from the base of the ladder in a way that the ladder can slide freely without vibrations or dynamic effects.

37. 5 seconds after removing the bar start the water flow and monitor the outwards movement of the feet.

38. When the ladder has slipped 40 mm, stop the test by stopping the water flow within 5 seconds and detach the vertical test load within 10 seconds. If the feet don't move parallel, stop when the first foot has reached 40 mm. If 40 mm have not been reached after 30l the test shall be stopped as well.

MOTIVATION: A time range of 5 seconds to stop the water flow is introduced to minimize the deviation of the water mass to 0,25 kg.

39. Lift the ladder feet off the ground and start counting 5 minutes ± 30 s before starting the repeating test.

40. Record the total mass of the bucket with water including means for connection to the steel cable in kg.
    Record the displacement in mm of the feet if the test has been terminated at 30l.
    If the base has slipped 40 mm without water record the mass of the empty bucket including means for connection tot the steel cable.

page 9 of 10

41. Carry out a further four tests as described above. The feet shall be positioned at the same position on the stainless steel each test. In between the repeated tests no cleaning is done. If the ladder slips away before the water flow has started during 2 tests, no more testing is required
42. Report all 5 values of total mass of the bucket including means for connection to the steel cable in kg, unless fail is observed after 2 tests.
43. Calculate the average and the standard deviation of the five results. For ladders not reaching 40 mm within 7 minutes a value of 30 kg shall be used in this calculation. If the ladder slid across the 40 mm before the water flow was started, a value of the actual mass of the bucket and hook shall be used in this calculation.

Section 4: PASS/FAIL criterion (preliminairy)

Note: The pass/fail criteria mentioned in 44 and 45 are preliminary criteria which are based on the test results necessary to develop this protocol. After the proficiency test definite criteria will be defined.

44. If the ladder slid across the 40 mm before the water flow was started during 2 tests, it has failed.
45. If the calculated average value minus the standard deviation is equal or above @@ kg the ladder has passed the test. If the value is lower, it has failed.

base slip test for leaning ladders

Part 2 – float glass

final version 2015-12-01

page 1 of 7

General

This protocol describes a procedure to test the resistance against base slip of single and multi-section ladders that are intended to be used as leaning ladder . This protocol has to be executed only after the base slip test on stainless steel.

MOTIVATION: The reason to do both tests on stainless steel and float glass is that it creates the possibility to check many variables that can posses risks to the user. The main variables are:

- different angles (prevents manufacturers optimizing for one angle and being dangerous at another angle),
- different vertical test loads (small loads can be dangerous because the feet profiles are not compressed enough to have sufficient contact surface; large loads can be dangerous because friction properties of polymers deteriorate under pressure),
- with and without horizontal force
- on different materials with different character (good performance on one material can be accompanied by poor performance on another material).

MOTIVATION The reasons to test on glass are several. Glass, float glass in particular, has a homogeanic surface, reproducible manufactured and is widely available. A glass surface is comparable with the surface of smooth ceramic tiles. Ceramic tiles are commonly used to pave floors and so a reasonable foreseeable use. A ladder placed on ceramic tiles is a worst case of reasonably foreseeable use. (a relatively often reported underground with base slip accidents) Compared with steel, glass and ceramic have principally different interaction with polymers because the polymers cannot penetrate into the surface structure.
The reasons to test under an angle of 70 degrees are:
65 degrees on glass seem to be a too severe test for the big majority of ladders/state of technique.
Looking at the results of task 1.3, 70 degrees gains more distinctive results which enables easier and more reliable distinction of the good ladders and bad ladders.
Including both 70 degrees and 65 degrees in the base slip test will prevent optimizing ladder feet for just one angle.

MOTIVATION: The reasons to start with testing on steel are as follows. According to the test results of task 1.2, 1.3 and 1.4 of the project it seems that the worst case is on steel with worn feet and on glass with new feet. However, there are a number of reasons to start on steel. First, the results with new feet show less reproducibility. On top of that, new feet may differ due to packaging or transport. Once the feet are worn off, the results are more consistent. With testing on glass the feet will not wear very much because of the extreme smooth surface with little interaction with polymers. Also because of the much lower test load used. So to wear them a little bit testing on steel first with 150 kg is preferred. Additionally, it will help to prevent eventual vacuum effects of the new feet on glass. Last but not least: the ladder will be used in practice with worn feet much more then with new feet. To be sure there is wear in the right contact area before starting on steel under 65 degrees and under 70 degrees. These preparing tests set an defined starting condition for all ladder feet.

Section 1: equipment/requisites

1. A flat ridged floor that is horizontal.
2. A flat vertical wall of at least 6 meter height that is perpendicular to the floor, solid enough to prevent vibrations or other movements under the pressure of the ladder and its test loads.

Remark: A 4 meter wall will suffice for labs that only want to test ladders up to a maximum length of e.g. 4 meters .

3. 17 hours prior to and during the tests the samples, room and equipment shall be 21 ± 2.0 °C.

MOTIVATION: Polymers need time to get de-stressed (stress in the feet polymers can occur by carrying the own mass of the ladder) and the de-stressed condition is the only accurate starting point for the test that can be achieved. During the test program the polymers will get stressed all the same way, but as the temperature has big influence on this process it has to be defined. To de-stress the polymers at room temperature, according to a specialist in this field, 17 hours are sufficient.

4. Float glass as contact surface on the floor. The float glass shall meet the relevant requirements of EN572 Part 2:2012. The float glass on the floor shall be of a suitable thickness to support the mass of the ladder plus the vertical test load without relevant deformation (without cracks or waves). The float glass on the floor shall be fixed to the floor to prevent sliding during test. It shall be long enough to allow the ladder to slide at least 40 mm freely on the plate
5. The steel on the wall shall be of a suitable thickness to support the leaning of the ladder under the vertical test load without relevant deformation (without dents or waves). The steel on the wall shall be fixed to the wall to prevent movement or vibration during tests. It shall be long enough to allow the top of the ladder to decent freely during sliding against the plate..

MOTIVATION: Glass on the wall would reduce the influence of the wall contact , but is much less practical and causes more risk for the test engineers during the tests. On top of that, sticking to stainless steel on the wall makes it possible to use the results for cross reference. By far most situations in practice have more wall friction than on glass and the test should not stop innovation to make safer ladders through the contact with the wall.

The surface of the stainless steel on the wall need to be treated a by mechanical polishing to achieve a R_z of 3,3 µm uniformly along the surface.

Measurement conditions for the roughness measurements of R_z between 0,5 µm and 3 µm shall be done according to DIN EN ISO 4288:1998 and DIN EN ISO 3274:1997

- stylus tip radius r_{tip} = 2 µm
- single measure length lr (λ_c) = 0,8mm
- total measure length ln = 4 mm
- traverse length (measured length plus start-up and trailing length) lt = 4,8 mm

Measurements to be made at twenty random locations, and in the direction parallel to the sliding movement. The average of the twenty measurements shall be between 2,8 µm and 3,8 µm. No single measurement shall be less than 2,4 µm or greater than 4,4 µm.

page 3 of 7

> MOTIVATION: As we have observed some variations in roughness measuring equipment an accurate specification of the roughness measurement is important.

6. Cotton cloth: Unbleached cotton 100 - 120 g/m².
7. Cleaning aid: ethanol 96 volume %.
8. Inclinometer with sufficient accuracy to adjust the ladder angle within ± 0,2 °.
9. A vertical test load with a mass of 50 ± 0,5 kg, including the aids to apply the test load on a rung, (e.g. a hoisting strap).
10. A lightweight bar to block both feet of the ladder on the floor at the same time. The bar is to be held in place on the floor and removed before starting the test by the test engineer.
    Any lightweight material that do not damages the plates while in contact with the it.
11. A support stand to keep the ladder feet off the ground while the ladder is in between two sequential test positions .
12. Facilities to keep the test area at temperature of 21 ± 2,0 °C
13. A thermometer to measure the temperature with an accuracy of at least ± 0,2 °.
14. Ruler to measure the feet displacement with resolution of 1 mm, class II accuracy.
15. A stopwatch with an accuracy of 1% or less.

section 2: preparation

16. Prior to testing the ladder feet shall have been unloaded (off the ground) for at least 17 hours (e.g. lying in a horizontal position or resting with the bottom rung on a support) at a temperature of 21 ± 2.0 °C
17. The test length is to be adjusted by extending the ladder to a length as close as possible to 6300 mm, but not more than 6300 mm. In case of an extending ladder (e.g. a leaning ladder consisting of two or more parts) extend the top part first.
    Ladders that are above 6300 mm at their minimum length shall be tested at their minimum length. Alternatively, a shorter ladder of the same type can be used if available. However, the vertical test load mentioned in section 3 shall be applied on the rung as if it concerns the longer model.

> MOTIVATION: Testing a 6300mm ladder requires a wall of about 6 m height. A higher wall in combination with controlled temperature may cause practical problems in many laboratories. With this length and method the vast majority of consumer ladders as well as professional ladders (estimated more than 99% of all ladders on the market) can be tested without changing the ladder construction by shortening it.

18. The stainless steel on the wall shall be on such a position that the ladder top feet/rollers are in contact with the steel during the whole test. This means that the contact point of the ladder with the stainless steel on the wall can descent at least 40 mm before it slides off the steel. The starting contact point will be on a height roughly between 93 % and 94 % of the ladder length if the ladder is positioned under 70 ± 0,2 °.
19. The float glass on the floor shall be on such a position that the ladder feet are in contact with the glass during the whole test. This means that the contact point of the ladder with the float glass on the floor can slide at least 80 mm before it slides off the glass. The starting contact point will be on a distance from the wall roughly between 34 % and 36 % of the ladder length if the ladder is positioned under 70 ± 0,2 °.

20. Temperature of floor support surface shall be 21 °C ± 2.0 °C during the test.
21. The contact surfaces, both on the floor and at the wall, shall be cleaned with cotton cloth and ethanol before the testing: one cleaning per tested ladder, no cleaning in between repeated tests. After cleaning remove possible residues of the ethanol with a dry cotton cloth.

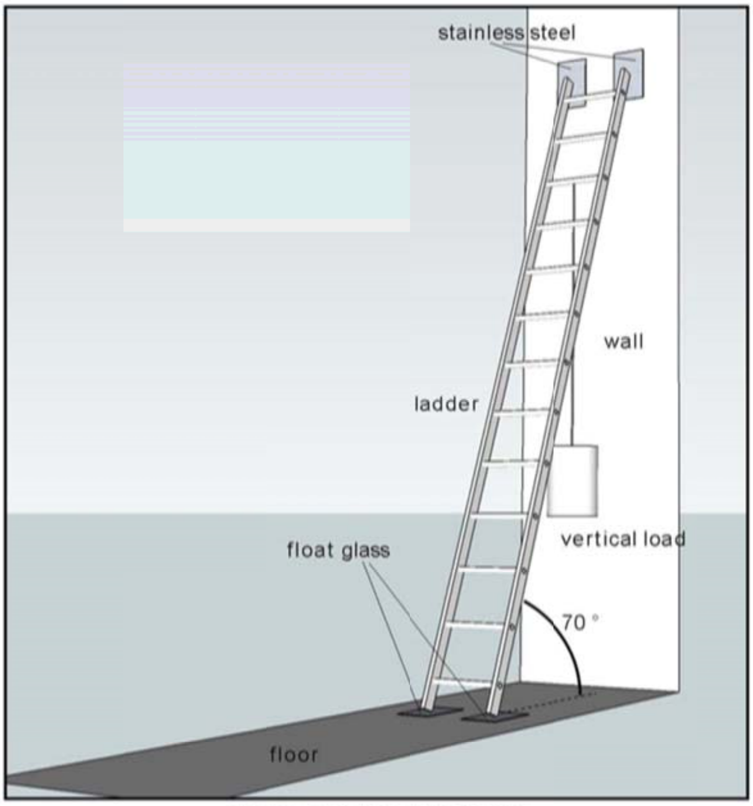


Illustration A: base slip test setup

Section 3: test procedure

note: ladder feet need to be pretreated according to Base slip test for leaning ladders; Part 1 – stainless steel.

22. Prior to carrying out the test, the feet of the ladder shall be cleaned with a dry cotton cloth without ethanol or any cleaning fluid. Cleaning will only be done before testing the ladder, no cleaning in between repeated tests.
23. Extend the ladder to its maximum length or the first position of use under 6300 mm. The top part is case of a multiple part extending ladder has to be extended first before extending other parts.
    - In case that a ladder touches the wall with an other part than the top part, extend the ladder above 6300 mm until the ladder only leans against the wall with the top end.
    - Ladders that have single parts longer than 6300 mm, have to be tested on the length of the single part.

24. See illustration A. Position the ladder at an angle of 70 ° ± 0,2 ° with the floor. When the ladder feet touch the ground **start counting time**. Measure the angle with an inclinometer at 1,5 meter from the floor. Measure both stiles. The steepest stile is leading for the angle.

    If the ladder has no preferred top/bottom or back/front side, it shall be realised that the ladder will be positioned in the same orientation at each test.

    Seen from the front view, the vertical alignment of the ladder should be in a way that the centreline through the middle of the bottom rung and the middle of the top rung is perpendicular to the floor. See illustration B

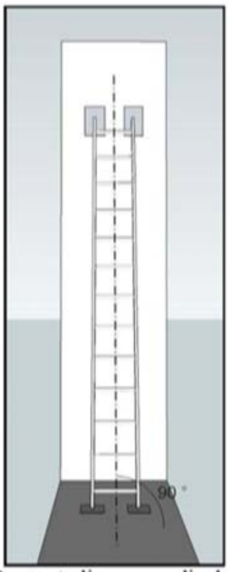


Illustration B: centerline perpendicular to the floor

25. Block the base of the ladder manually with the lightweight bar mentioned under point 10 to prevent outwards movement.

MOTIVATION: A lot of thinking has been done to devise a system that blocks and releases the feet automatically. An automatic lock and release system needs to be reproducible and may not introduce any extra pushing or pulling. It turns out that such a system needs to be very sophisticated. Requiring such system in this protocol would compel laboratories to spend a large amount of money. Including requirements for a blocking and releasing system would results in all sorts of solutions that causes the tests to be executed differently in separate laboratories with deviational judgements as a result. From experiences of the tests in the project blocking and releasing the base can be done manually. It needs to be done at the lowest point on the ladder, i. e. the feet, both feet at the same time and with a beam that is operated in the middle in between the feet. It needs to be a lightweight beam of which the weight does not hinder the ladder base to slide once its released. Attention that the beam does not touch the floor plates while sliding to avoid damage.

26. Check whether the temperatures at the stainless steel on the floor and the feet of the ladder close to the contact surface are within the required limits during the tests. Record the measured temperature.

27. Determine a reference point at the base of the ladder as the origin of measurement for outwards movement of the feet of the ladder.
28. After 120 ± 10 s minutes from the start of counting under point 24 apply the vertical test load.
    - At the centre of the 4[rd] rung from the top on ladders with a maximum length up to 9 m;
    - At the centre of the 3[nd] rung from the top on ladders with a maximum length between 9 m and 12 m;
    - At the centre of the 2[nd] rung on ladders with a maximum length beyond 12 m.

    If rungs are double or triple on the same level (in case of a extending ladder) use the rung closest to the wall.

    Avoid that the application of the vertical test load gives a dynamic effect.

MOTIVATION: users are allowed to climb a ladder until the 4th rung from the top, so a lower rung would be unrealistic as simulation for use. A higher rung would introduce a small safety factor and include reasonable foreseeable use. However, at longer ladders the user stands relatively closer to the top, resulting in higher force to slide away. Above 9 m this effect can be simulated by positioning the vertical load on a higher rung.

Remark: when testing on float glass the application of the test load at the rungs differs from testing on stainless steel. When testing on float glass, the top rung isn't used because it is expected that the majority of the ladders fails due to the smooth surface of glass.

29. After 240± 10 s after start of counting under point 24 remove the bar from the base of the ladder in a way that the ladder can slide freely without vibrations or dynamic effects .
30. Record the displacement of the feet at 60 ± 2 s after unblocking the ladder base. If the feet have moved more than 100 mm stop the test and record >100 mm.

Motivation: based on the results of task 1.3 the one minute sliding time results in 4 out of 10 samples to fail. Two minutes would mean 7 out of 10 samples will fail. That seems a too severe judgement. Task 1.6 shows different results. It is decided to keep the time of one minute till after the proficiency tests.

31. Remove the vertical load within 10 seconds after testing?? and position the ladder in a way the feet are unloaded. Lift the ladder feet off the ground and start counting 5 minutes ± 30 s before starting the repeating test.
32. Carry out a further four tests as described above. The feet shall be positioned at the same position on the float glass each test. In between the repeated tests no cleaning is done.
33. If 2 tests result in > 100mm the ladder has failed the requirements and testing of the sample can be stopped.
34. Report all 5 displacement values in mm, unless 100 mm is reached within 1 minute record ">100 mm".
35. Calculate the average displacement and the standard deviation. For a displacement >100 mm calculate with 100 mm.

Section 4 = PASS/FAIL criterion

Note: The pass/fail criteria mentioned in 36 and 37 are preliminary criteria which are based on the test results necessary to develop this protocol. After the proficiency test definite criteria will be defined

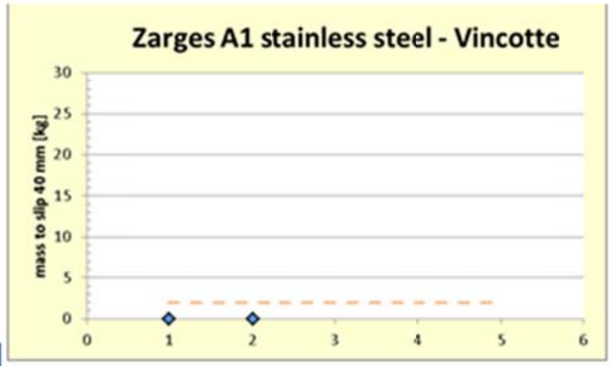
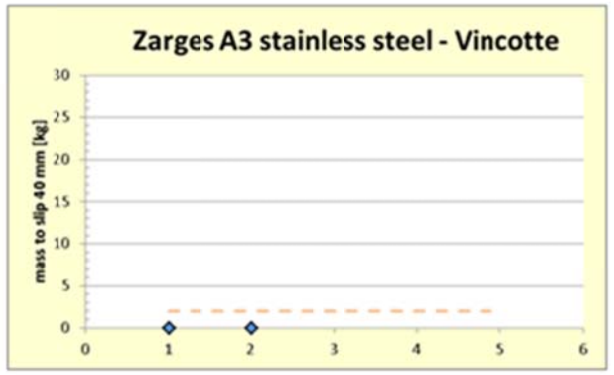
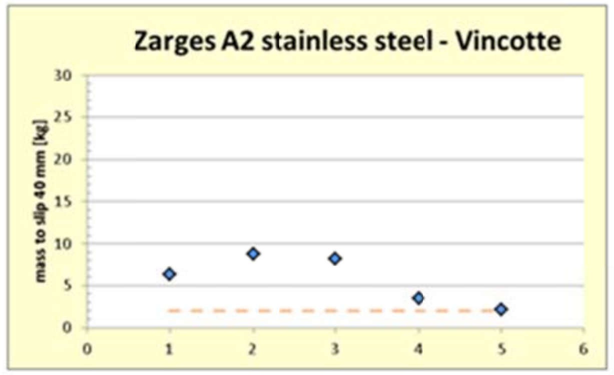
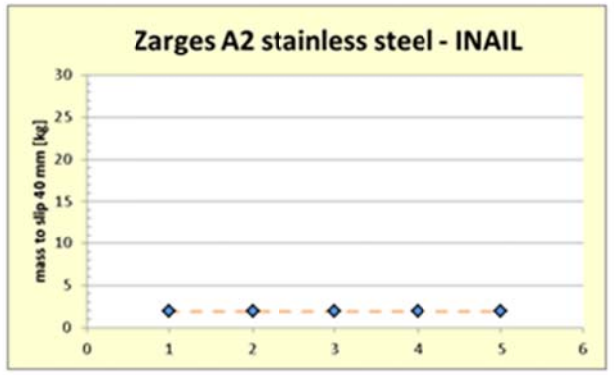
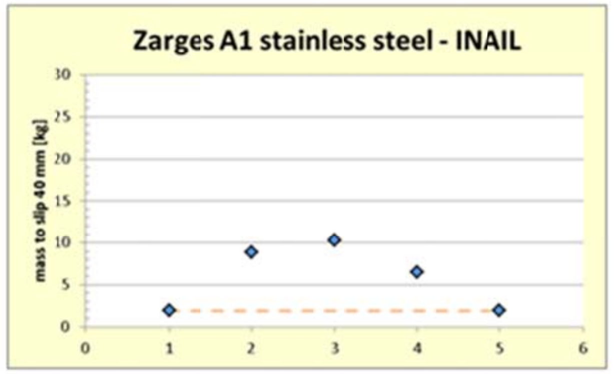
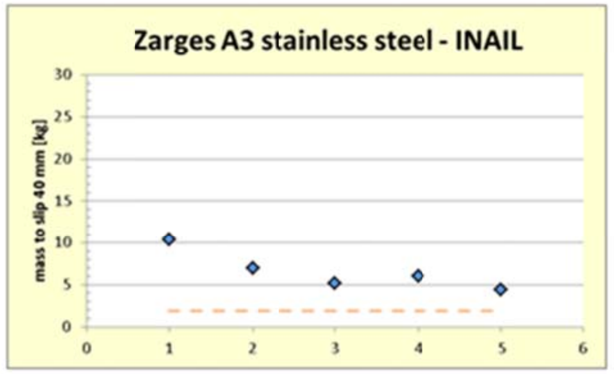
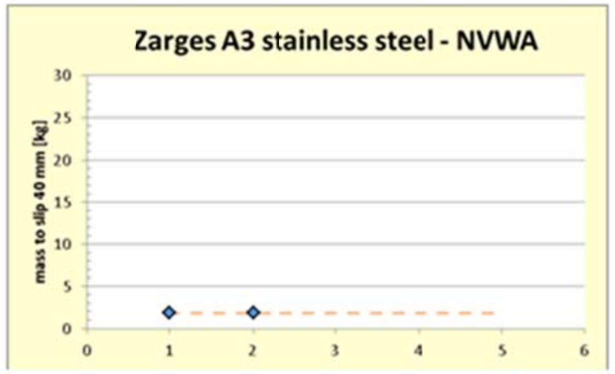
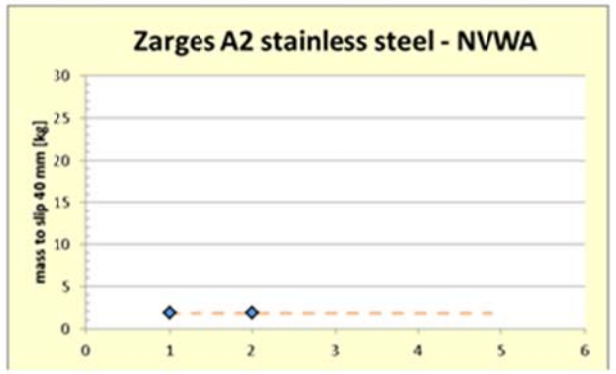
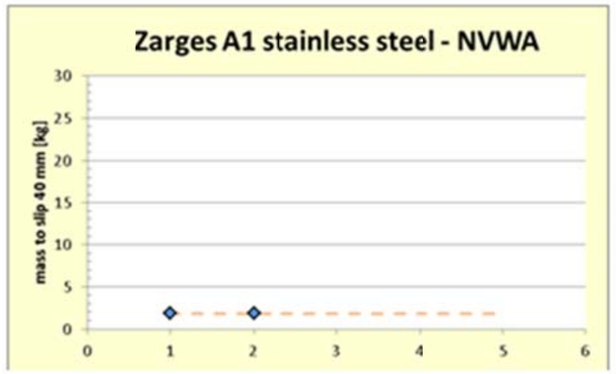
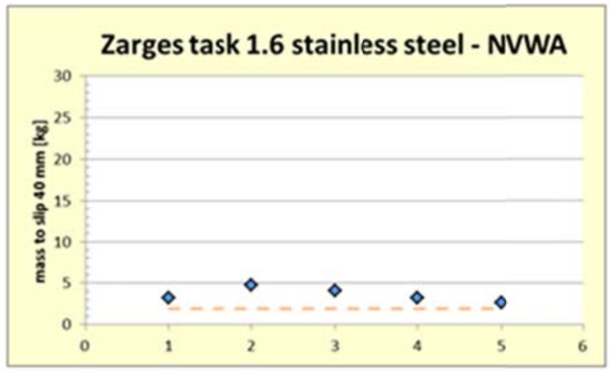
36. If the average value minus the standard deviation is equal or below 40mm, then record the test as a pass.
37. If the average value minus the standard deviation is above 40mm record the test as a fail.

Appendix 7. Template for recording results

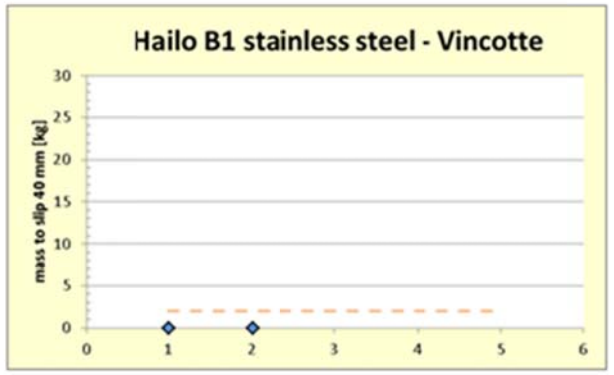
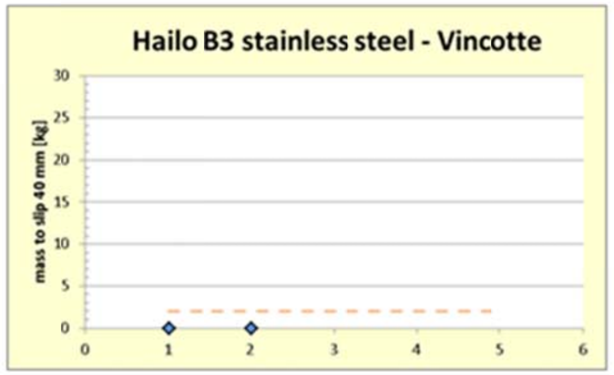
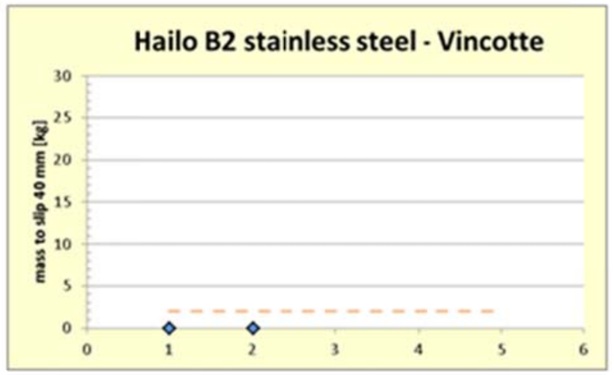
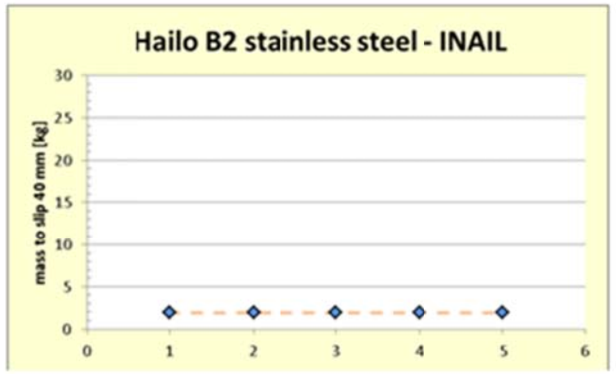
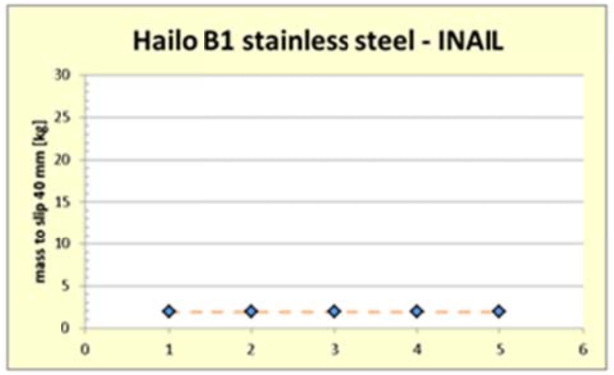
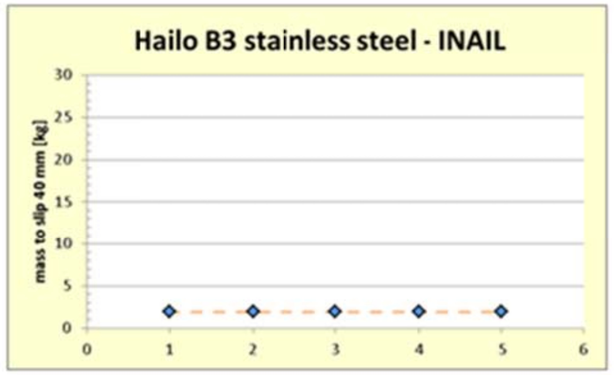
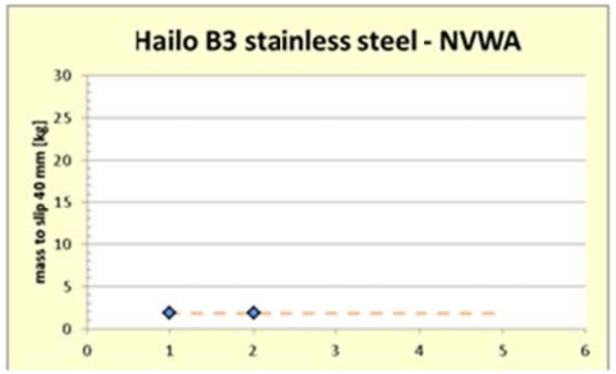
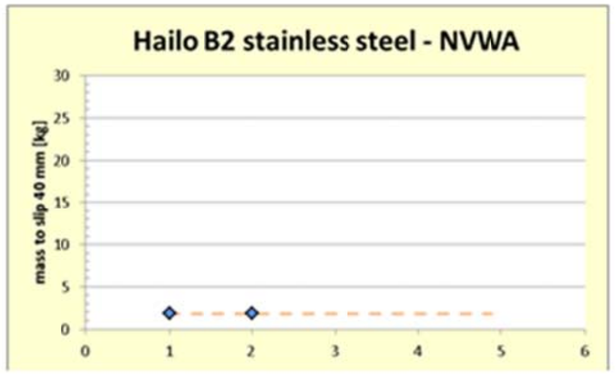
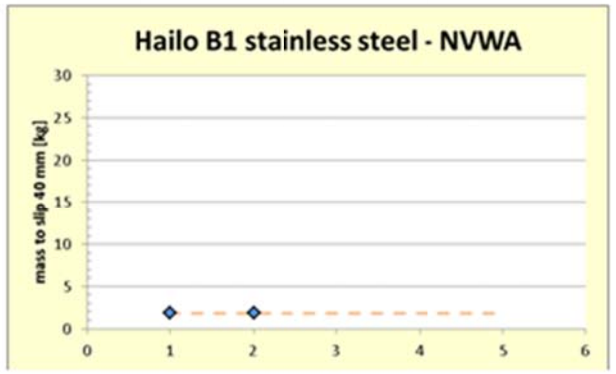
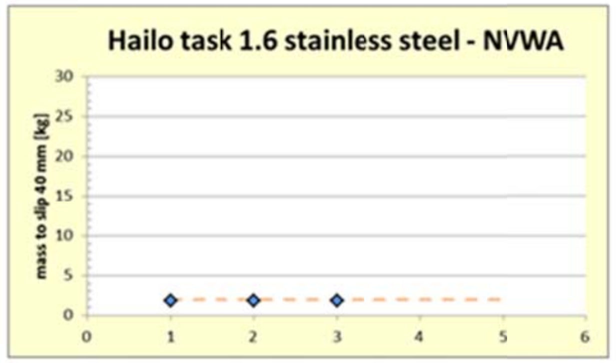
CHAFEA/2014/CP/02 proficiency tests base slip ladders
Result Registration Form

B	C	D	E
Laboratory:	INAIL/DIT - Italy	Date of test:	25 february 2016
preparations on steel		protocol on steel	protocol glass
A2 Zarges Z600-12			
65°	70°	65°	70°
mass [kg]	mass [kg]	massa [kg]	displacement [mm]
1.94 (slipped - empty bucket)	slipped at 40 mm with 12.85	1.94 (slipped - empty bucket)	2,0
1.94 (slipped - empty bucket)	slipped at 38 mm with 13.35	1.94 (slipped - empty bucket)	6,0
1.94 (slipped - empty bucket)	slipped at 30 mm with 16.15	1.94 (slipped - empty bucket)	6,0
		1.94 (slipped - empty bucket)	6,0
		1.94 (slipped - empty bucket)	6,0
	average	**#DEEL/0!**	**5,2**
	stdev	**#DEEL/0!**	**1,8**

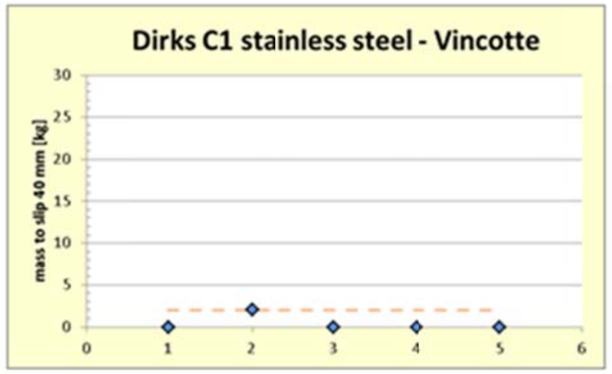
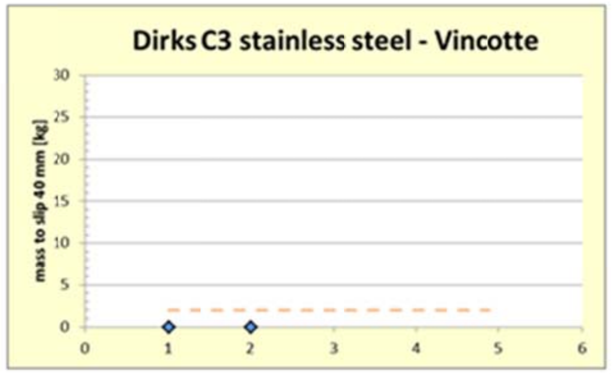
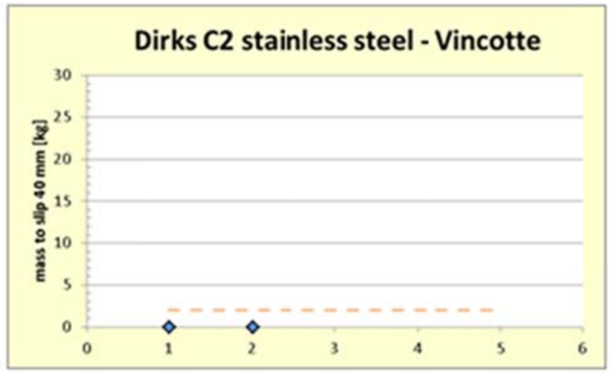
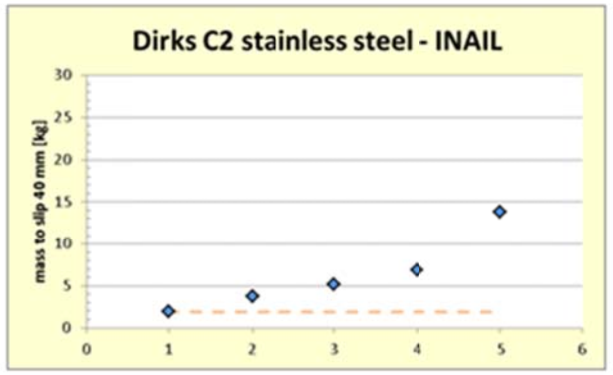
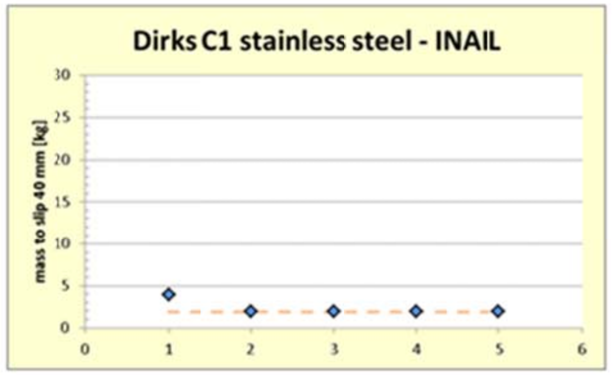
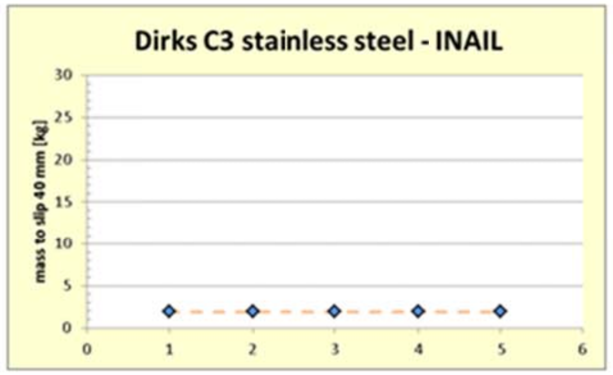
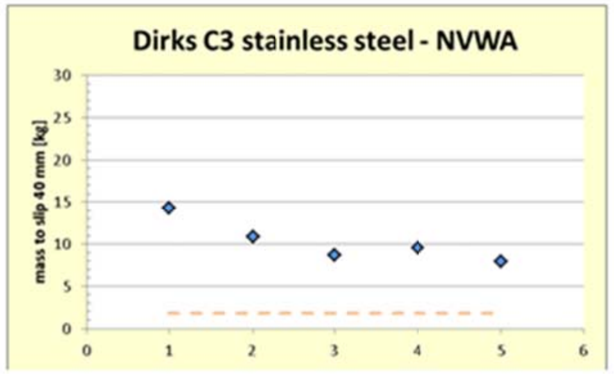
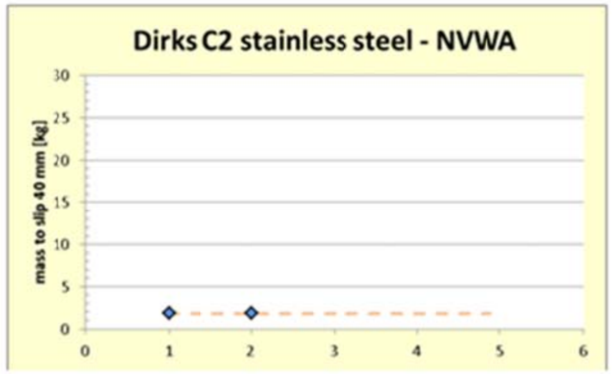
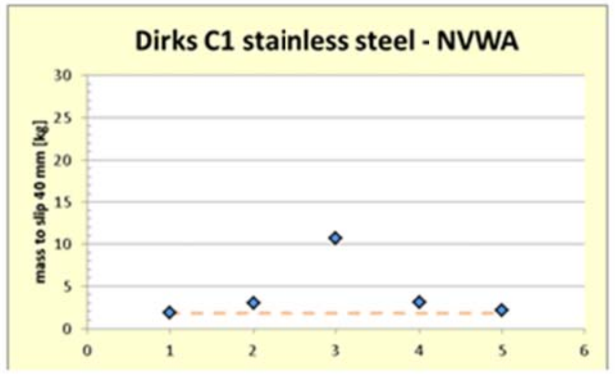
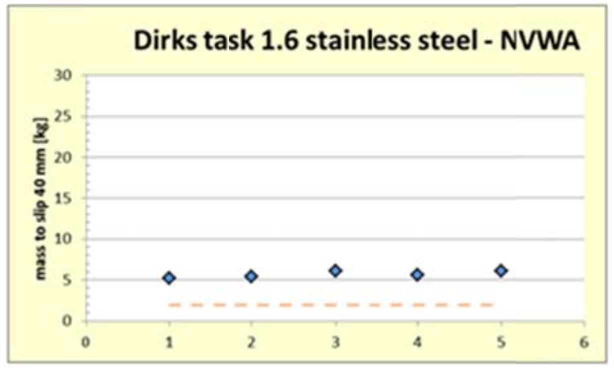
Appendix 8. Results

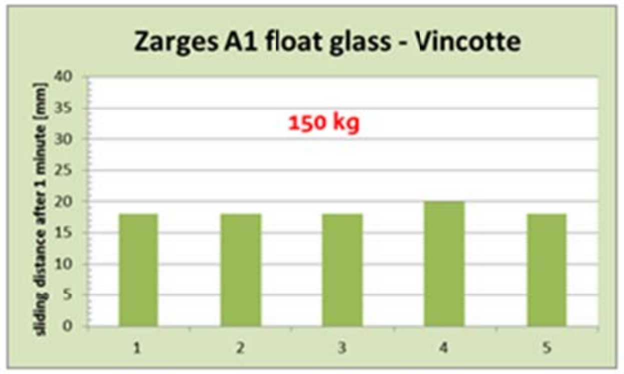
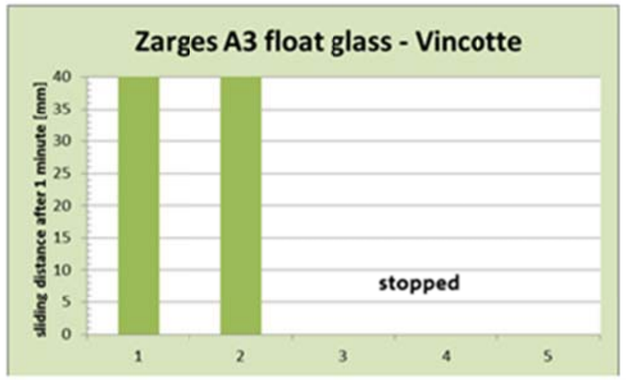
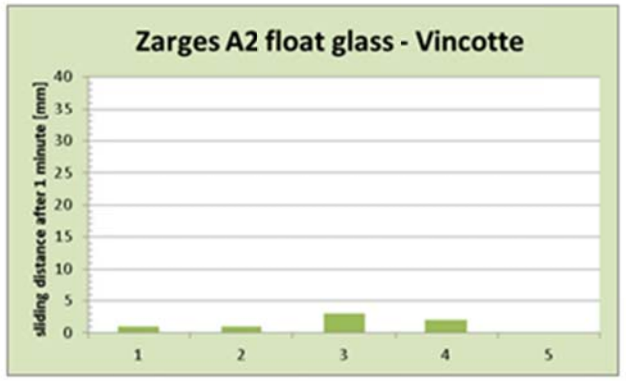
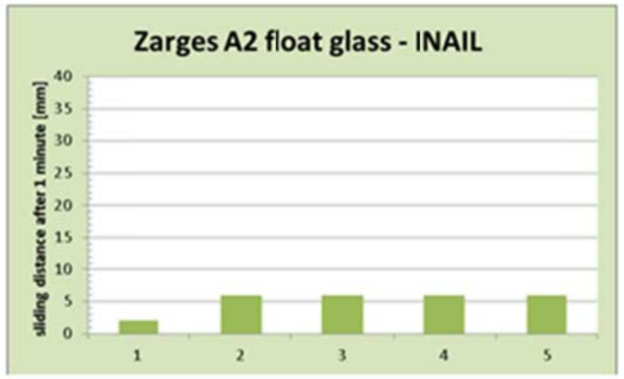
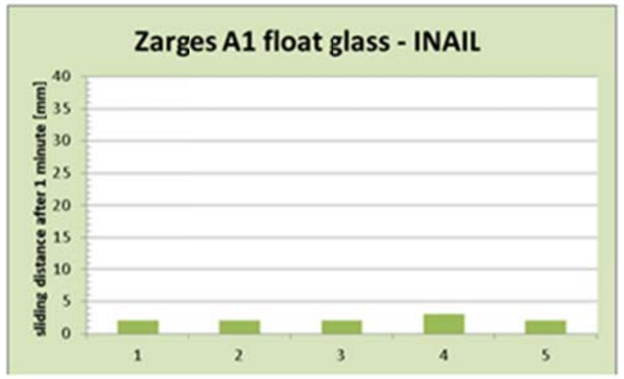
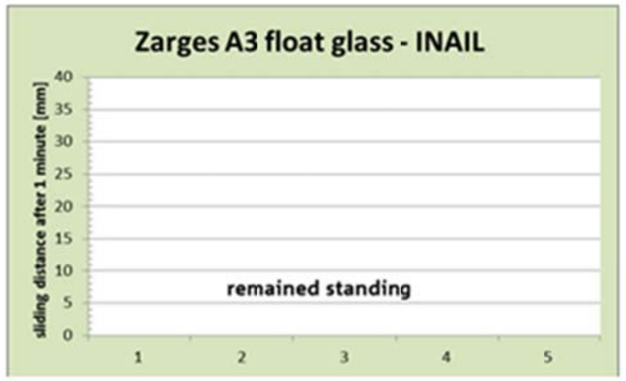
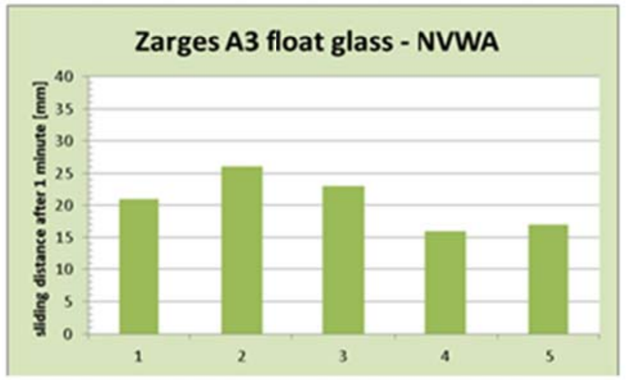
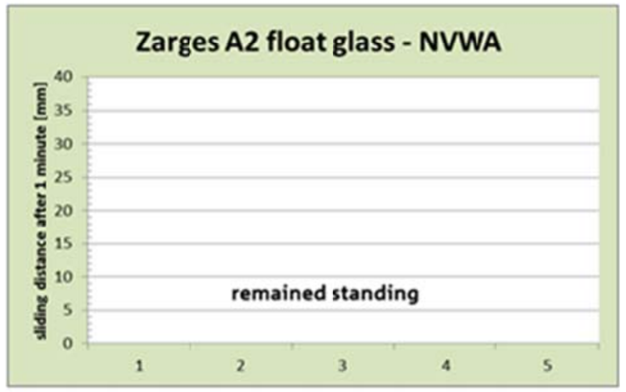
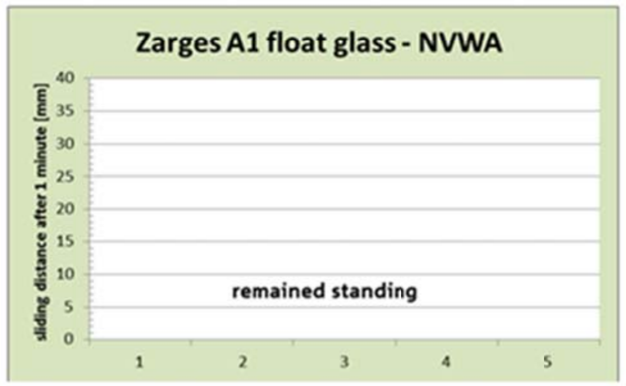
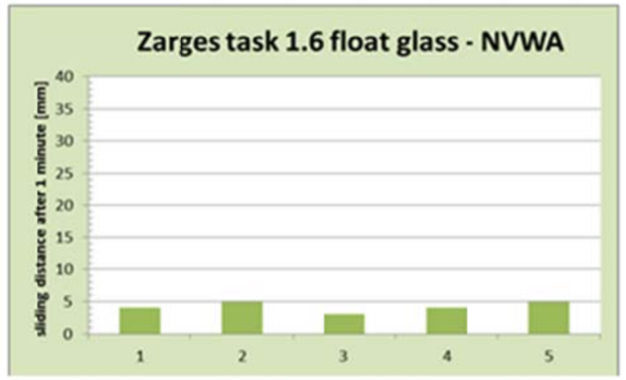
Base Slip Test - Results Proficiency task 2.1				
Zarges stainless steel Rz 3,3 µm 65° / 150 kg	**Round 1 (new feet)**	**Round 2**	**Round 3**	**task 1.6**
Vincotte - ladder released without bucket - ------- empty bucket 2 kg - load @ 3rd rung from top				
INAIL - ------- empty bucket 1,94 kg - load @ 3rd rung from top				
NVWA - ------- empty bucket 1,85 kg - load @ 3rd rung from top				

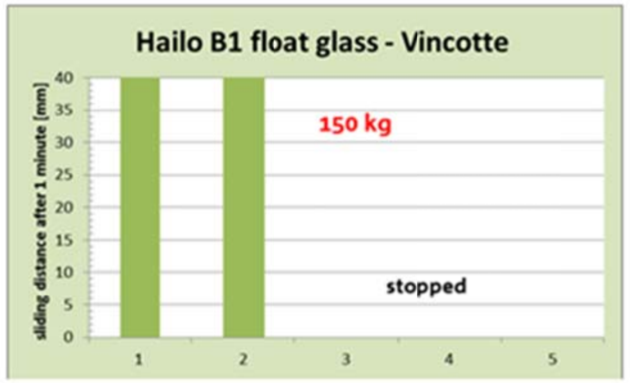
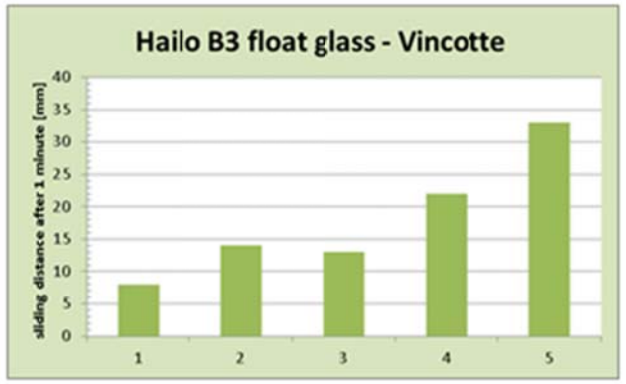
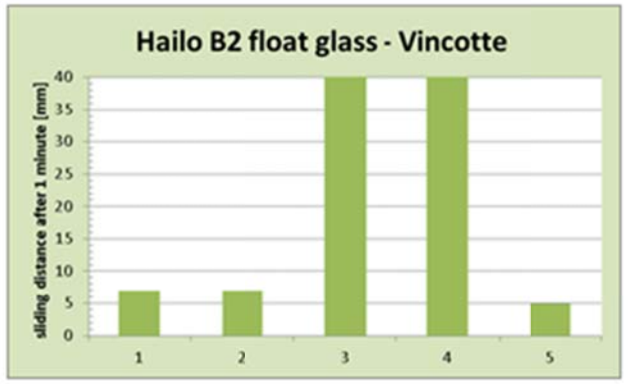
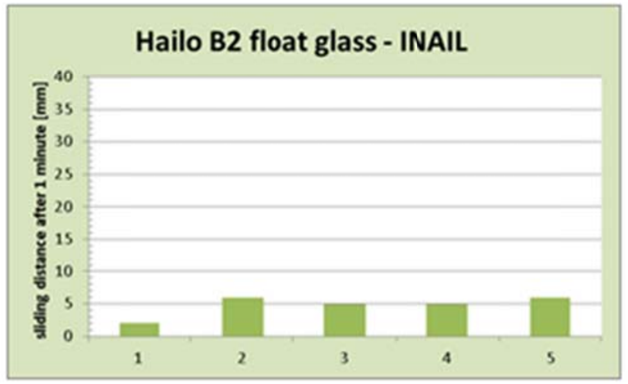
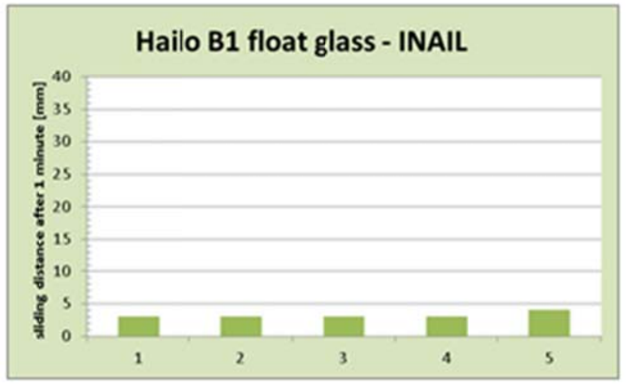
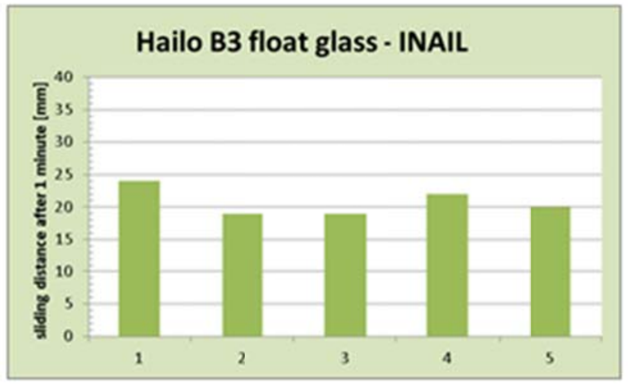
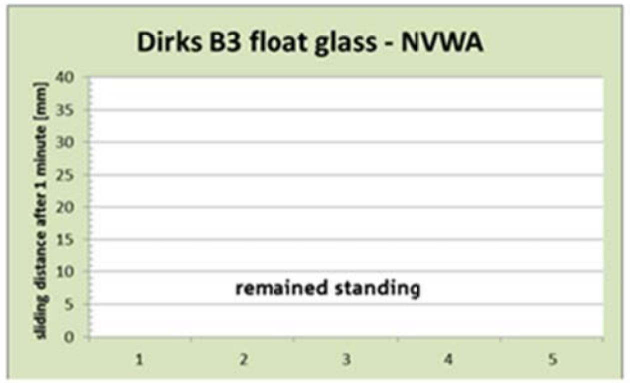
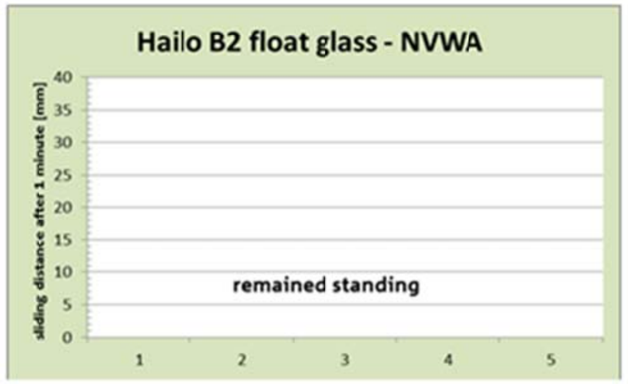
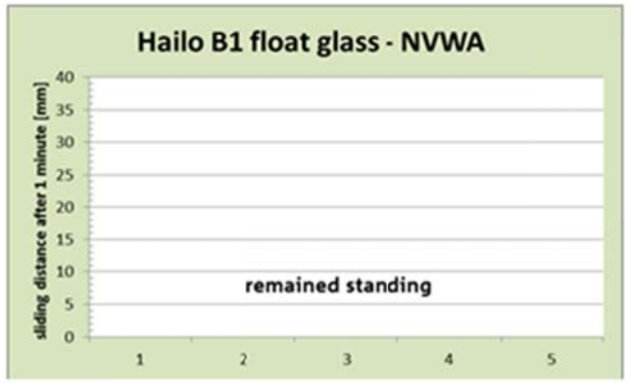
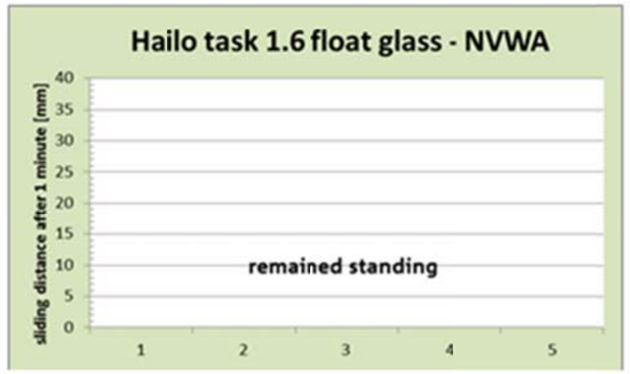
Base Slip Test - Results Proficiency task 2.1

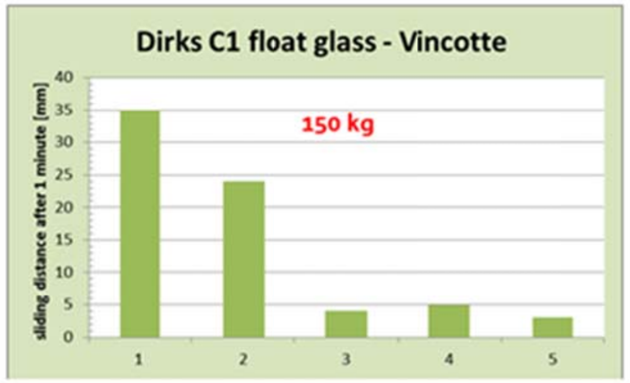
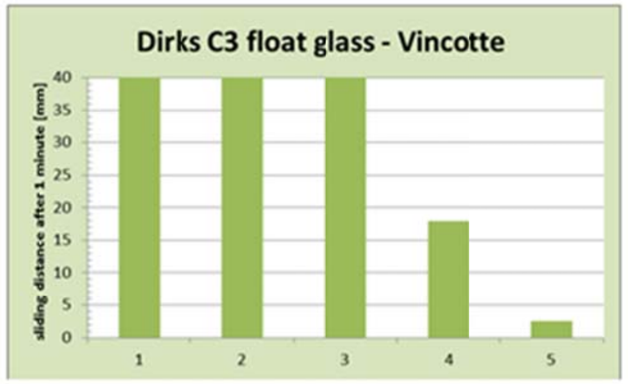
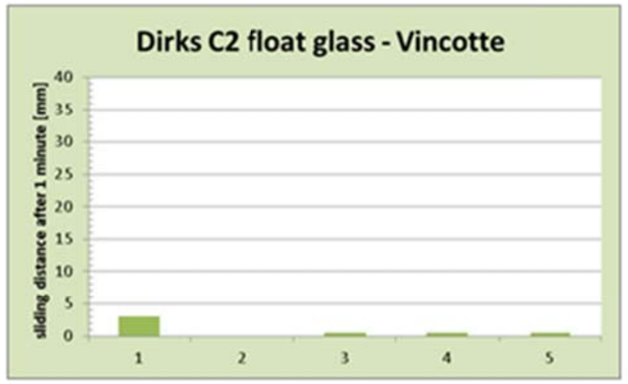
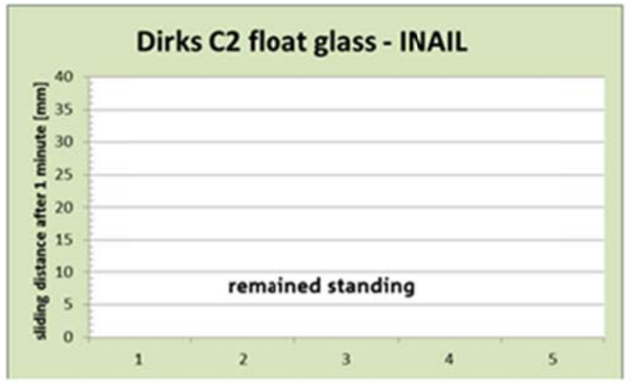
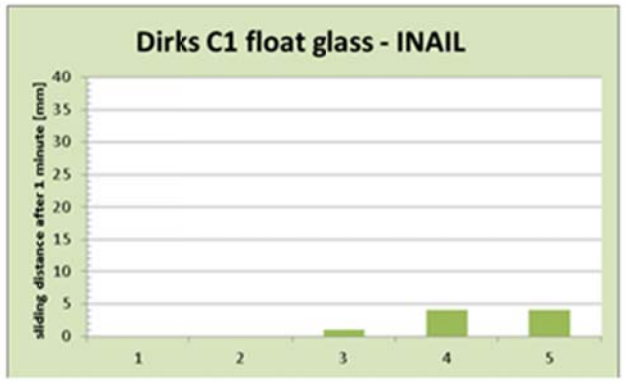
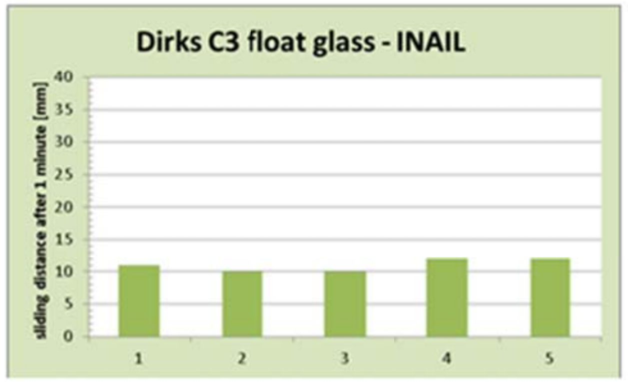
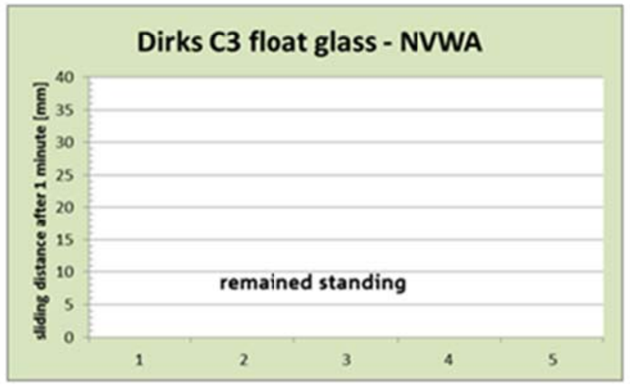
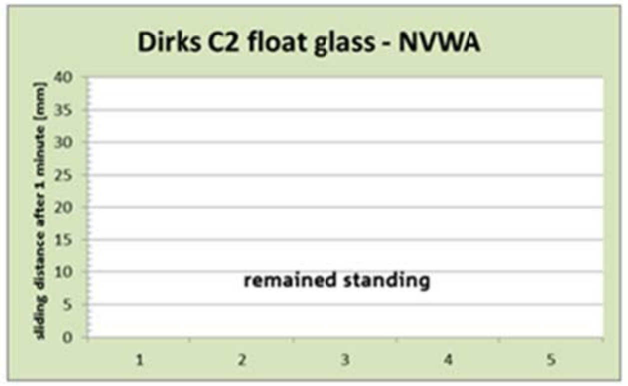
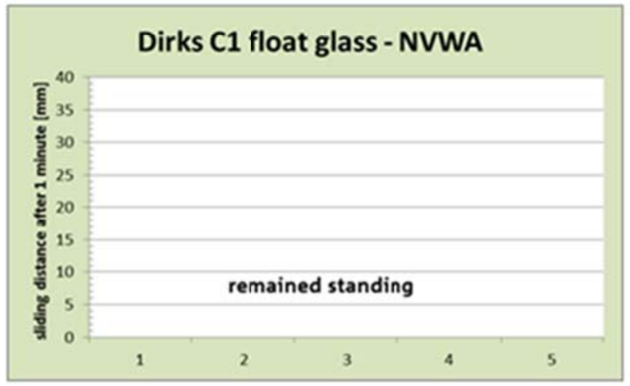
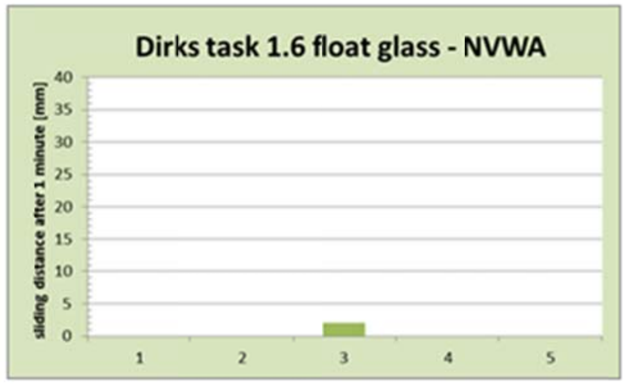
Hailo stainless steel Rz 3,3 µm 65° / 150 kg	**Round 1 (new feet)**	**Round 2**	**Round 3**	**task 1.6**
Vincotte - ladder released without bucket - -------- empty bucket 2 kg - L = 5830 mm - load @ 3rd rung from top				
INAIL - -------- empty bucket 1,94 kg - L = 5830 mm - load @ 3rd rung from top				
NVWA - -------- empty bucket 1,85 kg - L = 5830 mm - load @ 3rd rung from top				

Base Slip Test - Results Proficiency task 2.1

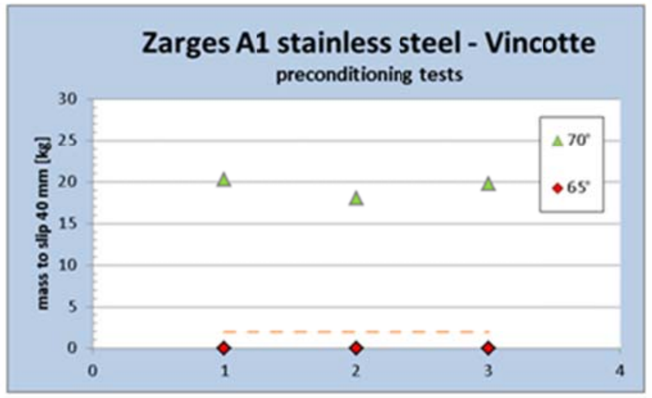
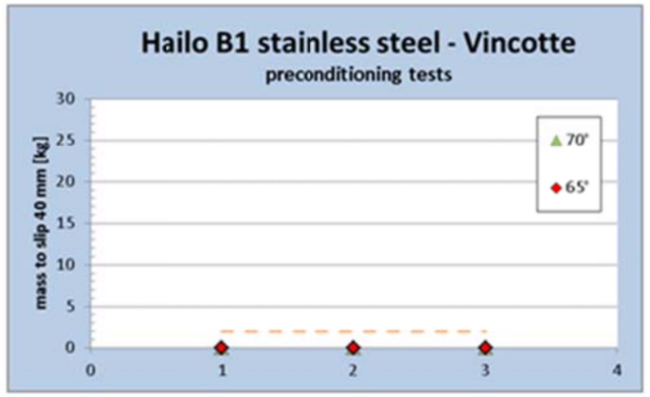
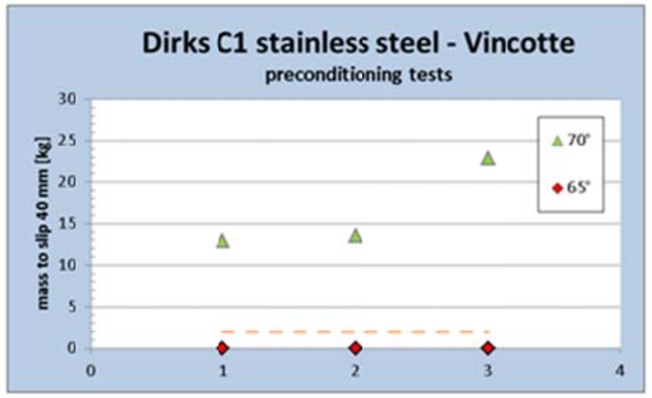
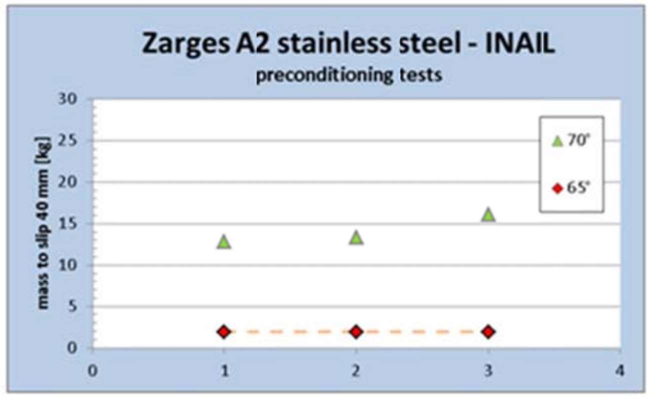
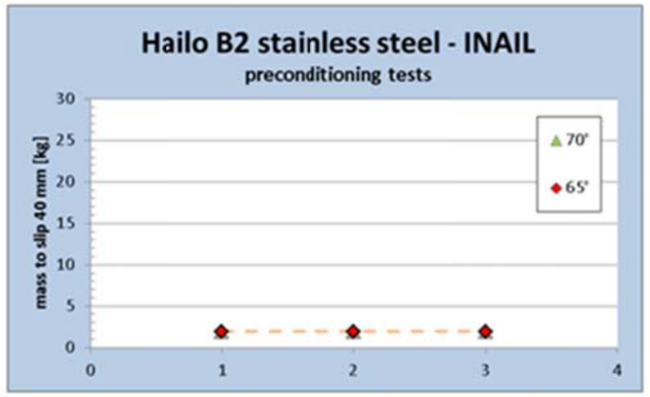
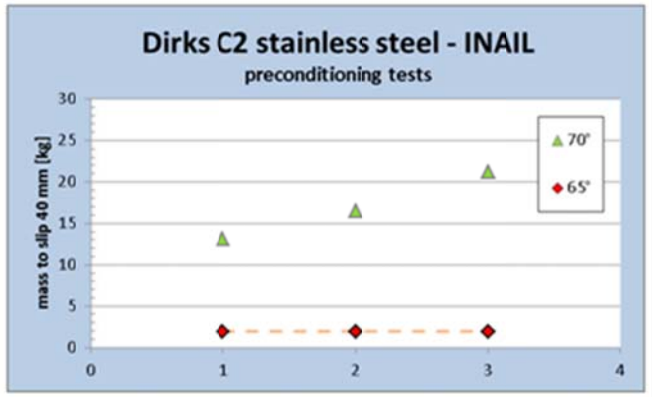
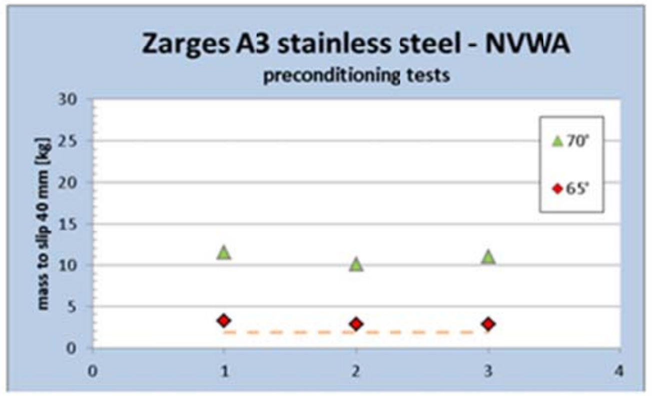
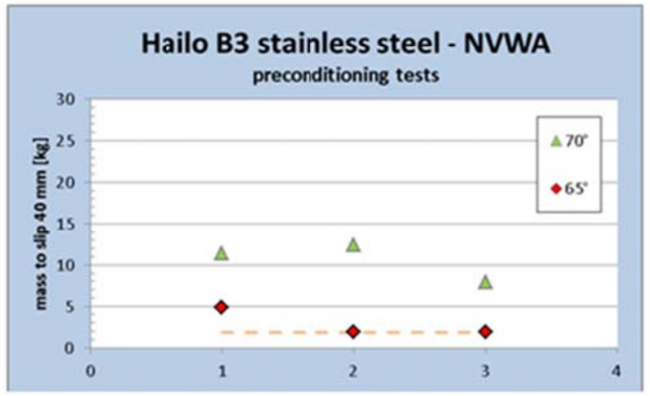
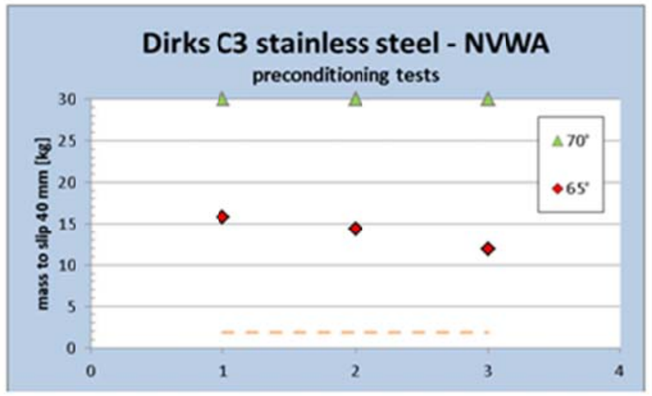
Dirks stainless steel Rz 3,3 µm 65° / 150 kg	**Round 1 (new feet)**	**Round 2**	**Round 3**	**task 1.6**
Vincotte - ladder released without bucket - -------- empty bucket 2 kg - L = 6100 mm - load @ 2rd rung from top				
INAIL - -------- empty bucket 1,94 kg - L = 6120 mm - load @ 3rd rung from top				
NVWA - -------- empty bucket 1,85 kg - L = 6150 mm - load @ 2rd rung from top				

Base Slip Test - Results Proficiency task 2.1				
Zarges float glass 70° / 50 kg	**Round 1 (new feet)**	**Round 2**	**Round 3**	**task 1.6**
Vincotte - load @ 4th rung from top - 5 minutes after stainless steel				
INAIL - load @ 4th rung from top - 5 minutes after stainless steel				
NVWA - load @ 4th rung from top - 17 hours after stainless steel				

Base Slip Test - Results Proficiency task 2.1				
Hailo float glass 70° / 50 kg	**Round 1 (new feet)**	**Round 2**	**Round 3**	**task 1.6**
Vincotte - L = 5830 mm - load @ 4th rung from top - 5 minutes after stainless steel				
INAIL - L = 5830 mm - load @ 4th rung from top - 5 minutes after stainless steel				
NVWA - L = 5830 mm - load @ 4th rung from top - 17 hours after stainless steel				

Base Slip Test - Results Proficiency task 2.1				
Dirks float glass 70° / 50 kg	**Round 1 (new feet)**	**Round 2**	**Round 3**	**task 1.6**
Vincotte - L = 6100 mm - load @ 3rd rung from top - 5 minutes after stainless steel				
INAIL - L = 6120 mm - load @ 4th rung from top - 5 minutes after stainless steel				
NVWA - L = 6150 mm - load @ 3rd rung from top - 17 hours after stainless steel				

Appendix 9. Preconditioning test

Base Slip Test - Results Proficiency task 2.1			
Preconditioning tests stainless steel 150 kg / Rz 3,3 µm	**Zarges**	**Hailo**	**Dirks**
Vincotte			
INAIL			
NVWA			

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EB-02-16-591-EN-N

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doi: 10.2818/915338