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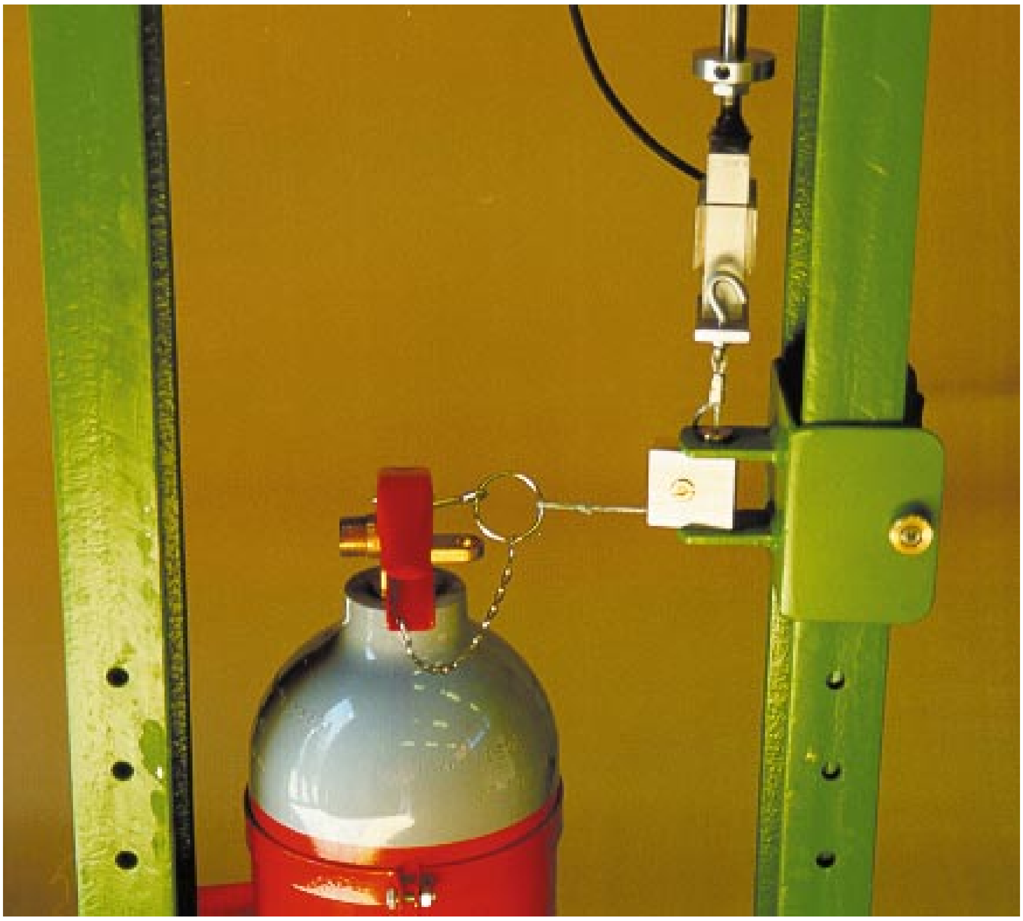
Tauno Andstén, Hemmo Juutilainen, Jukka Vaari & Henry Weckman

Test method for actuating and safety devices of portable fire extinguishers

Nordtest Project No. 1435–99



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Abstract

The procedures included in the standard EN 3–5 for measuring the force required to activate the operating devices and to release the safety devices of portable fire extinguishers are described only briefly and at a quite general level. As a consequence, the measurements may be carried out in different ways in different testing laboratories which may lead to entirely different results.

In this study, a test procedure which has been in use for more than ten years at VTT BUILDING TECHNOLOGY has been further refined. The report includes sections on theoretical considerations of the measurements as well as a description of the test equipment and results of several test series which were carried out. Based on the findings, a proposal for a new Nordtest method is prepared. The method, which is intended to be used in conjunction with EN 3–5, focuses on controlling the factors which have the greatest influence on the measurements and which may distort the results. As the designs of extinguishers and their actuating and safety devices in practice are very variable and require individual mounting and fixing in the test device, the mechanical design of the test device itself is not specified in any greater detail.

Preface

This study has been financially supported by Nordtest, the Rescue Department of the Ministry of the Interior and the Safety Technology Authority.

Of the authors, Tauno Andstén and Hemmo Juutilainen designed the test equipment and carried out the experimental work. Jukka Vaari wrote the chapter on theoretical considerations while Henry Weckman compiled the report. Tauno Andstén was the project leader and responsible for the total management of the project work.

The authors are thankful to the financiers, to Dr. h.c. Toivo Pohja, who rebuilt the test equipment and to all our colleagues at VTT BUILDING TECHNOLOGY who supported us in various ways during the work.

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Espoo, 15 August 1999

Tauno Andstén *Hemmo Juutilainen* *Jukka Vaari* *Henry Weckman*

Contents

1. Introduction

The European standard EN 3–5 [1] defines the maximum force required to release the safety device and to activate the operating device of portable fire extinguishers. The defined forces are important as they relate directly to the usability and safety of the extinguisher. The standard does not, however, contain detailed instructions on how the measurements of the forces should be carried out. For this reason a well documented method is needed by testing laboratories in order to obtain repeatable and reproducible results.

The aim of this study is to develop and document a method which could complement the current brief description included in EN 3–5 [1]. The study also comprises an assessment of the accuracy of the new method and a proposal for a formal Nordtest test method. The new method could be used for an initial trial period by the Nordic fire testing laboratories and at a later stage it could be incorporated in a future revised version of the standard EN 3.

Chapter 2 of this report presents the requirements and methods of measurement for the maximum force required to release the safety device and to activate the operating device of portable fire extinguishers as described in the European standard EN 3–5 [1] and also in the recently withdrawn Nordic test method NT FIRE 024 [2]. This chapter also describes the test procedures which were used prior to this study at VTT BUILDING TECHNOLOGY.

Chapter 3 contains a discussion of various theoretical aspects related to measurements of the forces required to operate a portable fire extinguisher. Chapter 4 describes the experimental work carried out in this study including a description of the test equipment with calibration methods and experimental results. Chapter 5 contains a short discussion of the new test method.

Appendix A presents some common types of actuating and safety devices used in portable fire extinguisher. Appendix B contains photographs of the new test device while Appendix C contains the formal proposal for a new Nordtest test method.

2. Commonly used test methods

2.1 Test methods and requirements specified in EN 3–5

Appendix A shows some typical examples of operation mechanisms and security devices used in current portable fire extinguishers.

2.1.1 Operation and emission control mechanisms and devices

Section 4.1 of the standard EN 3–5 [1] defines the requirements imposed on operation and emission control mechanisms and devices of portable fire extinguishers. The force or the energy required to activate the operating devices shall not exceed the values given below in Table 1 for various types of devices.

Table 1. Maximum force or energy required to activate the operating devices of portable fire extinguishers according to EN 3–5 [1]. The figures are in general valid for temperatures up to 60 °C.

Type of operating device	***Maximum allowance***	
	Force [N]	***Energy [J]***
Finger trigger	100	—
Squeeze grip lever	200	—
Strike knob	—	2

For CO_2 type extinguishers with squeeze grip lever operating devices the force shall be no greater than 200 N at temperatures up to 40 °C and at 60 °C it shall be no greater than 300 N.

By *activation* the standard implies all actions required for pressurisation of the extinguisher (if it is not permanently under pressure) and the initial release of the extinguishing agent.

Concerning the description of how these forces shall be measured, the standard is extremely brief. Annex B of the standard gives this procedure:

> **"The forces, which shall be measured with the use of a dynamometer, shall be applied statically and perpendicularly at the normal point where force is used to render the extinguisher operable." [1]**

The method to be used for measuring the energy required to activate extinguishers with operating devices of the strike knob type is sufficiently well defined in Annex F of the standard, and these devices will therefore not be further considered in this report.

For full compliance testing of portable fire extinguishers, the tests on the operating devices shall be carried out using six extinguishers, four of which have been subjected to the temperature cycle defined in section 3.1 and Annex A of EN 3–5 [1] and two of which have been subjected to external corrosion conditions defined in section 5.1 and Annex H.1 of EN 3–5 [1]. This requirement is specified in the standard EN 3–6 [3].

2.1.2 Safety devices

According to section 4.2 of the standard EN 3–5 [1], the release of the safety device shall require a force between the limits of 20 N and 100 N. The standard does not, however, describe how the measurements shall be carried out.

The standard also requires that the safety devices shall be so constructed that any unaided manual attempt, using a force or impact equal to twice the relevant value given in Table 1, to initiate discharge without first operating the safety device shall not deform or break any part of the mechanism in such a way as to prevent the subsequent discharge of the extinguisher.

In addition to these requirements, the standard also contains a number of qualitative requirements imposed on the construction and operation of safety devices of portable fire extinguishers.

According to the standard EN 3–6 [3], for full compliance testing, the tests on the safety devices shall be carried out using six extinguishers, four of which have been subjected to the temperature cycle defined in section 3.1 and Annex A of EN 3–5 [1] and two of which have been subjected to external corrosion conditions defined in section 5.1 and Annex H.1 of EN 3–5 [1]. Additionally one test shall also be carried out on the operating device of an extinguisher without first releasing the safety device. The force to be applied in this case shall be equal to twice the respective value given in Table 1.

2.2 Test methods and requirements in NT FIRE 024

The Nordic test method NT FIRE 024 [2] has been withdrawn in May 1997. This was a consequence of the acceptance of the European standard series EN 3 which in practice made national and regional standards obsolete in the CEN member countries.

2.2.1 Actuating devices

Section 5.2.7 b) of NT FIRE 024 [2] specifies a number of requirements which must be met by actuating devices of portable fire extinguishers. The force required to actuate discharge may not exceed the values given in Table 2.

Table 2. Maximum force required to activate the operating devices of portable fire extinguishers according to NT FIRE 024 [2].

Type of operating device	***Maximum force [N]***
Squeeze grip with one finger	100
Squeeze grip with whole hand	200[1)]
Impact button	400

[1)] For CO_2 type extinguishers 300 N.

NT FIRE 024 gives a slightly more detailed description of the test procedure than the standard EN 3–5 does. Sections 7.9 b) and 7.9 c) of the test method state:

> **"The measuring device shall permit the actuating force to be read off to an accuracy of ± 5 N within the measuring range 50 – 450 N.**
>
> **The extinguisher is positioned vertically, force is applied to the outermost part of the control device respectively the centre of the impact button with a force increase of max 100 N/s. The force required to press the control device all the way down is recorded by means of a pressure gauge, weighing equipment etc." [2]**

Even though the descriptions in both EN 3–5 and NT FIRE 024 are somewhat brief, they contain, however, an important difference. Regarding the point where the force shall be applied in tests on extinguishers with a squeeze grip lever, EN 3–5 specifies "*at the normal point where force is used to render the extinguisher operable*", while NT FIRE 024 specifies "*to the outermost part of the control device*".

Concerning the requirements on extinguishers with a strike knob, EN 3–5 specifies a maximum value expressed in energy units [2 J], while NT FIRE 024 gives the value in force units [400 N].

2.2.2 Safety devices

Section 7.2 a) of NT FIRE 024 [2] prescribes that the seal used for sealing the safety device shall break when it is subjected to a tensile force of 50 ± 30 N. Contrary to EN 3–5, NT FIRE 024 contains a description of the method to be used for measuring the force required to release the safety device. Section 7.10.1 includes the following:

"Equipment: Dynamometer that permits measurement of tensile force with an accuracy of 5 N.

Testing: 6 safety devices are fitted and sealed for testing in a manner equivalent to mounting on the extinguisher. A dynamometer is connected to the safety devices. The tensile force required to release the safety devices is measured" [2]

Similarly to EN 3–5 also NT FIRE 024 contains various other, mostly qualitative, requirements on the safety devices.

There is also a minor difference between EN 3–5 and NT FIRE 024 regarding safety devices. NT FIRE 024 presumes that only tensile force will be used to release the safety devices, while EN 3–5 does not include such a restriction.

2.3 Earlier studies at VTT

In 1987, shortly after the Nordic test method NT FIRE 024 [2] was accepted, an investigation was conducted at VTT BUILDING TECHNOLOGY where the consequences of the new method were studied [4]. In connection with this study also a number of new test devices were designed. One of these was an equipment which was used for measuring the force required to activate a portable fire extinguisher and the force required to release the safety device of the extinguisher.

Figure 1 shows a photograph of the new test equipment which was developed in this study. The new version is a slightly revised version of the original design from 1987. Both the new and the old test equipment consists of these main components: a heavy metal rig, mounting brackets, electric spindle motor, load cell and data acquisition and recording devices.

Figure 1. General view of the test equipment used for measuring the forces required to activate a portable fire extinguisher and to release the safety device of the extinguisher. The photograph shows the new version of the equipment which was developed in this study. It is a redesigned version of the original equipment from 1987 [4].

The testing device shown in Figure 1 has been in use at VTT BUILDING TECHNOLOGY since 1987 for the testing of portable fire extinguishers according to both former national regulations [5], NT FIRE 024 [2] as well as the currently used standard EN 3–5 [1]. Table 3 presents the performance criteria according to various standards and regulations which illustrates the different approaches they apply especially regarding the force required to release the safety devices of portable fire extinguishers.

Table 3. Requirements imposed in various standards and regulations on the maximum force required to release the safety device of a portable fire extinguisher and the maximum force required to activate the operating devices of the extinguisher. The three figures in the last column relate to extinguishers with a finger trigger release mechanism, a squeeze grip lever mechanism and CO_2 extinguishers with a squeeze grip lever mechanism, respectively.

Standard or regulation	***Maximum force required to release the safety device [N]***	***Maximum force required to activate the operating devices [N]***
EN 3–5 [1]	20 – 100	100; 200; 300
ISO/DIS 7165 [6]	20 – 100	100; 200; 300
NT FIRE 024 [2]	50 ± 30	100; 200; 300
Former Finnish regulations [5]	30 ± 10[1)]	—

1) Prior to the tests the extinguishers shall be subjected for 28 days to comditions where the temperature is alternating between +20 ± 2 °C and +55 ± 2 °C every 12 hours and where the air is saturated with water vapour.

3. Theoretical considerations

3.1 Compressive force acting on a squeeze grip

3.1.1 Experimental set-up

Figure 2 shows schematically the squeeze grip of a portable fire extinguisher. The moving grip K is attached to the hinge P, and when a compressive downward force acts on the grip, it forces the piston M downwards resulting in an opening of a valve and consequent release of the extinguishing agent.

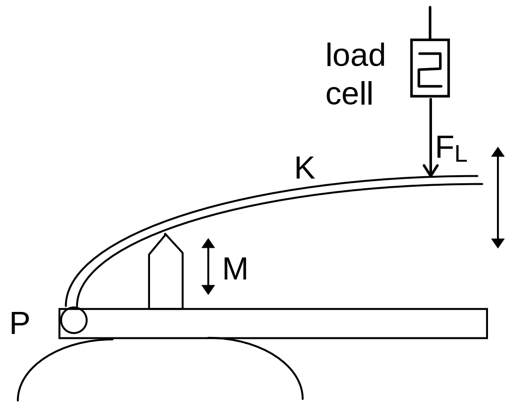

Figure 2. The schematic side view of the squeeze grip of a portable fire extinguisher under an external compressive force.

The compressive force is measured using a load cell, and the value at the release of the extinguishing agent is recorded. The load cell is a device used to convert small changes in the physical dimensions of a solid object into an electrical signal. This is accomplished by attaching strain gauges to the deforming object. As the dimension of the object changes, so does also the dimension of the strain gauge. This causes a small but measurable change in the electrical resistivity of the strain gauge. To increase the sensitivity and thermal stability of the measurement, a bridge connection is usually employed. This may have up to four strain gauges attached to the deforming object. Using more than one strain gauge increases the sensitivity of the measurement but, at the same time, the effects of a changing temperature are cancelled out.

3.1.2 Calculation of the torque acting on the grip

Figure 3 displays the forces acting on the moving part of the grip during the measurement of the compressive force.

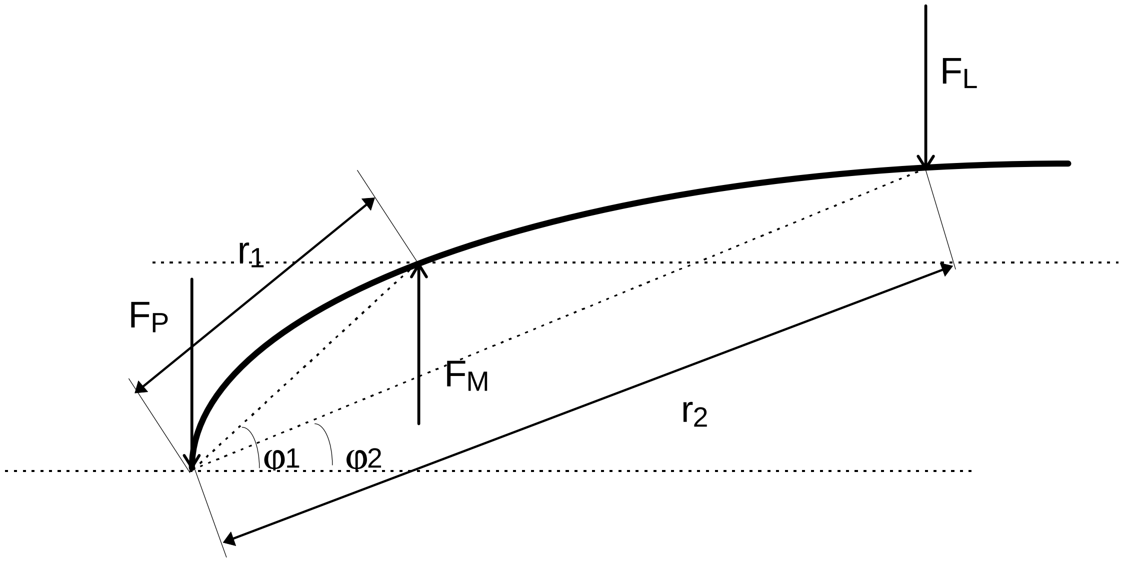

Figure 3. The free-body picture of the squeeze grip.

In Figure 3, F_P denotes the supporting force acting on the hinge, F_M is the force exerted by the piston on the grip, and F_L is the external force acting on the grip. If the resultant of these forces is zero, the grip either does not move or moves with a constant speed. However, due to the small mass of the grip, smooth temporal variations in the magnitude of the external force do not in any significant way affect the force balance.

The force acting on the piston must be rather large before the valve of the extinguisher is opened. One of the functions of the grip is to act as a lever, enabling fast operation of the extinguisher with a relatively small manual force. Consider the torque acting on the grip with respect to the hinge P. If the resultant torque is zero, the grip does not move, or rotates around P with a constant angular speed. In vector form, with the notation of Figure 3,

$$\bar{\tau}_P = \bar{F}_P \times \bar{0} + \bar{r}_1 \times \bar{F}_M + \bar{r}_2 \times \bar{F}_L . \qquad (1)$$

The force on the hinge does not affect the torque balance due to the length of the arm being zero. According to the sign convention of the vector product, the torque is positive when it causes the grip to rotate counterclockwise. In scalar form, the torque balance reads

$$F_M r_1 \sin\left(\frac{\pi}{2} - \varphi_1\right) - F_L r_2 \sin\left(\frac{\pi}{2} - \varphi_2\right) = F_M r_1 \cos\varphi_1 - F_L r_2 \cos\varphi_2 = 0. \tag{2}$$

The magnitude of the external compressive force is then

$$F_L = F_M \frac{r_1 \cos\varphi_1}{r_2 \cos\varphi_2}. \tag{3}$$

The effect of the proportionality term of Eq. (3) is graphically presented in Figure 4 for typical values of r_1, r_2, φ_1 and φ_2 encountered in real extinguishers. It is seen that the ratio of the arms has a stronger influence on the external force than the ratio of the cosine terms.

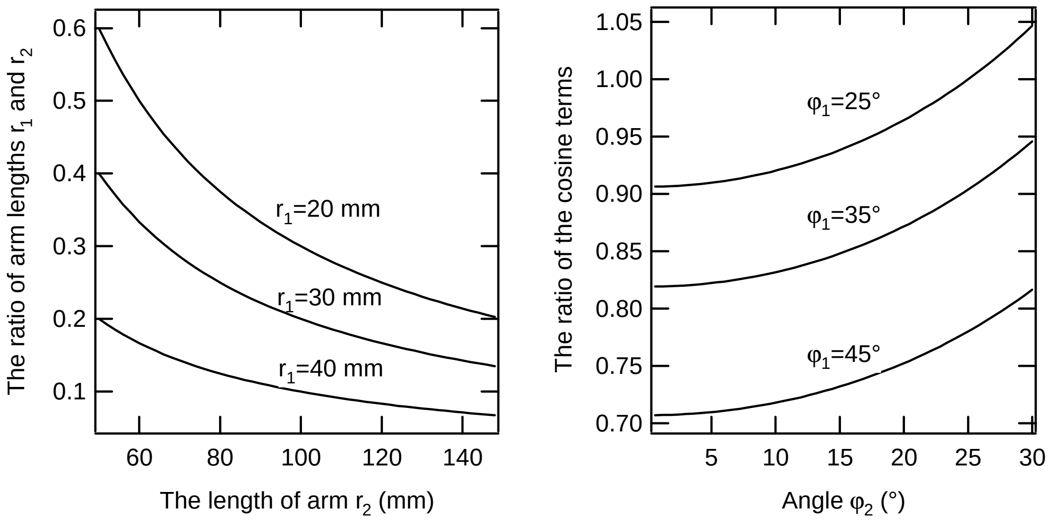

Figure 4. A graphical presentation of the proportionality term of Eq. (3). Left: the ratio of the arms r_1 and r_2 as a function of r_2 drawn for three different lengths of r_1. Right: the ratio of the cosines as a function of the angle φ_2 drawn for three different values of φ_1.

The force exerted by the piston on the grip is proportional to the external compressive force; however, the proportionality term is not constant but depends on the alignment of the grip. Also, strictly speaking, the arm lengths r_1 and r_2 are not constant, for r_1 is shortened as the piston moves down, and r_2 changes due to the construction of the mechanical frame of the measuring apparatus, which is built to ensure that the horizontal position of the compressive force is not changed as the grip moves. If the grip construction is linear, we have φ_1=φ_2, and the compressive force depends only on the ratio of the arm lengths.

3.1.3 Error analysis

The primary factor causing uncertainty in the measurement of the compressive force is the uncertainty in the arm length r_2. This is simply because the grip construction changes from one extinguisher to another, and it becomes difficult to unambiguously determine the point on which the compressive force should be exerted. Such a point is not given in the standard EN 3–5 [1]. If the angle φ_2 is large, there is more uncertainty due to the fact that as the exertion point of the compressive force moves along the surface of the grip, φ_2 depends on r_2. As these factors depend on the geometry of the grip, quantitative error analysis should be done on a case-by-case basis.

Consider next the effect of a non-horizontal grip surface on the measurement of the compressive force. In Figure 5, the compressive force is exerted on a sloping flat surface which forms an angle φ_2 with the horizontal. In the test device used in this study the compressive force is caused by a vertically moving steel rod equipped with a small wheel at the tip. We assume that the wheel is frictionless. In this case, the only force exerted by the grip on the rod is the normal force N. Since the normal force is not parallel to the compressive force, there must exist a horizontal side load F_S acting on the rod, which cancels out the horizontal component of the normal force.

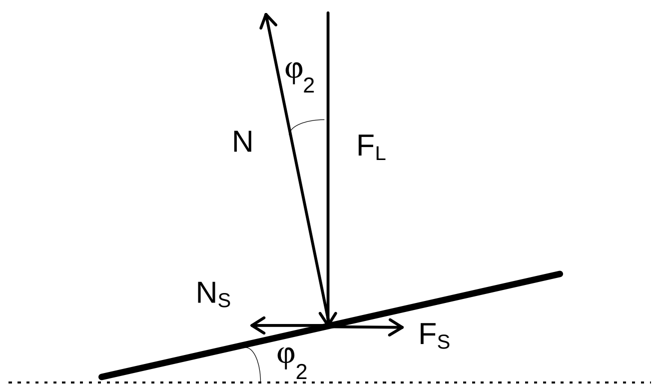

Figure 5. The compressive force acting on a non-horizontal grip surface.

With the notation of Figure 5, the force balance reads

$$
\begin{aligned}
F_L &= N\cos\varphi_2 \\
F_S &= N\sin\varphi_2 = F_L\tan\varphi_2
\end{aligned}
\tag{4}
$$

Regarding the load cell used in the measurements, the side load F_S is a source of error, since the design and installation of the mechanical framework has been intended for an ideal vertical compressive force acting on a horizontal surface. With a side load F_S present, the total load seen by the load cell is the normal force N. According to the technical specification of the load cell, the side load effect is 0.05 % of the applied load at 1º cone from the axis, and 0.2 % of the applied load at 3° cone from the axis. Theoretically, the side load effect becomes

$$\frac{N - N\cos\varphi_2}{N} = 1 - \cos\varphi_2. \tag{5}$$

This gives a 0.015 % effect for 1º cone and a 0.14 % effect for the 3º cone, somewhat underestimating the real side load effect, which may have other contributions as well.

Next we consider the time resolution requirement of the measurement. Assume that the time-dependent compressive force $F_L(t)$ has to press the grip downward a vertical distance of z_L before the valve is opened. The measurement apparatus works such that the force-exerting steel rod moves down with a constant speed v_L. Thus, the measurement will be completed in a time given by $t_L=z_L/v_L$. When the valve opens, the force exerted by the piston on the grip drops suddenly. The error in the determination for the triggering force becomes then the difference between the real triggering force and the most recent measurement of the compressive force. It is evident that to improve the accuracy, the speed v_L must be made small or alternatively the time resolution Δt has to be chosen such that a sufficient number of force measurements can be made in time t_L. For example, if $t_L/\Delta t=100$, and the force F_L is a linear function of time until the triggering of the valve, the error caused by the finite time resolution to the determination of the triggering force becomes 1 % at maximum.

Finally, it should be noted that the above discussion relates to the mechanics of the grip and the load cell. The actual release mechanism inside the extinguishers is not considered here in detail. However, in most extinguishers, the extinguishing agent is pressurised, and the release of the agent is simply achieved by a valve held closed by a steel spring. The moving piston must then overcome the force exerted by the spring, and this force is proportional to the compression of the spring. This causes no additional considerations to the torque calculation presented above.

A small class of extinguishers is constructed such that when the grip is squeezed, the extinguishing agent is first pressurised and then released. The pressurisation of the extinguishing agent involves a punctuation of a membrane beyond which the pressurising gas is stored in a small cylinder. The mechanics of the punctuation depends on the speed with which the piston moves towards the membrane. If the grip is pressed down very fast, the punctuation may require a different force compared to the case of a slow pressing. The mechanism of the punctuation may also be different; for example, very slow pressing of the grip may result in incomplete punctuation, which causes the de-pressurisation of the extinguisher with no extinguishing agent delivered. Strictly, the relevant quantity that should be measured in this case is the impulse by the piston on the membrane. These aspects are, however, outside this study.

3.2 Tensile force acting on a seal

3.2.1 Experimental set-up

The experimental set-up for the measurement of the seal release force of a portable fire extinguisher is schematically shown in Figure 6.

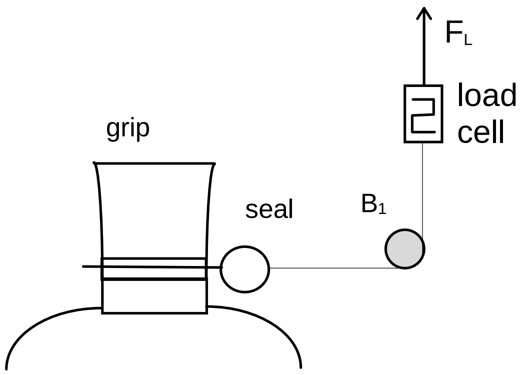

Figure 6. The schematic illustration of the set-up for the measurement of the release force of the seal.

The load cell is again used to measure the external applied load. The load is exerted on thin rod and mechanically transmitted to the seal using the pulley block B_1.

3.2.2 Side load effects

Consider the free-body picture of the load cell and the associated steel rods, shown in Figure 7. The geometry of the measurement is simple, and the possible source of error is either a significant friction in the pulley block or the alignment of the pulley block. The mechanical construction of the pulley block has negligible friction, which allows us to concentrate of the alignment problem.

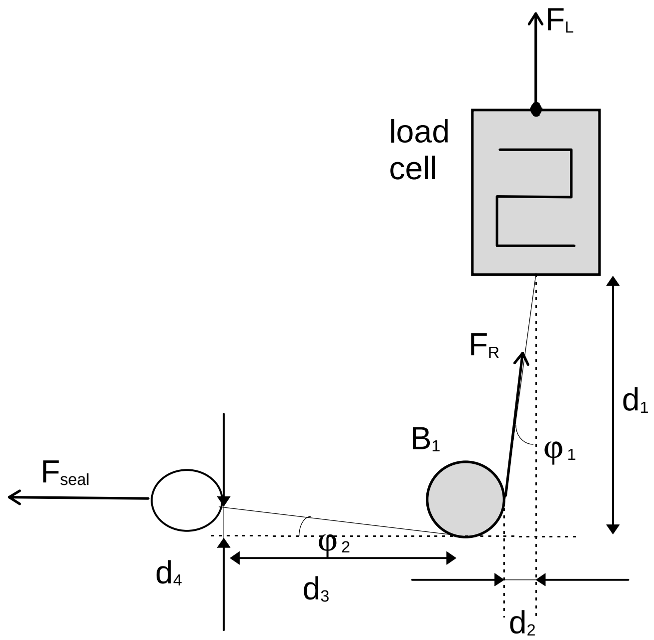

Figure 7. The origin of the side load in the seal release measurements. The angles are exaggerated for clarity.

Consider a situation in which the pulley block has been placed a distance of d_2 from the ideal position in the horizontal direction. The wire that transmits the load then forms an angle of

$$\varphi_1 = \tan\left(\frac{d_2}{d_1}\right) \tag{6}$$

with the vertical. The force on the wire can be divided into vertical and horizontal components as

$$\begin{aligned} F_R \cos\varphi_1 &= F_L \\ F_R \sin\varphi_1 &= F_S \end{aligned} \tag{7}$$

with F_S being the side load acting on the load cell. If the pulley block has been placed a distance of d_4 from the ideal position in the vertical direction, the wire forms an angle of

$$\varphi_2 = \tan\left(\frac{d_4}{d_3}\right) \tag{8}$$

with the horizontal. In this case, the ideal tensile force on the seal is related to the force on the wire by

$$F_{seal} = F_R \cos\varphi_2. \tag{9}$$

Combining the results, the applied load and the ideal tensile force on the seal are related by

$$F_{seal} = F_L \frac{\cos\varphi_2}{\cos\varphi_1} = F_L \frac{d_3\sqrt{d_1^2 + d_2^2}}{d_1\sqrt{d_3^2 + d_4^2}}. \tag{10}$$

In the ideal case we have $\varphi_1 = \varphi_2 = 0$ and therefore $F_{seal} = F_L$. The force (including the side load) seen by the load cell is F_R, and the measured quantity thus relates to the tensile force on the seal by

$$F_{seal} = F_R \cos\varphi_2 = F_R \frac{d_3}{\sqrt{d_3^2 + d_4^2}}. \tag{11}$$

Note that if the angle φ_2 is not zero, the measurement will overestimate the true tensile force required to release the seal. In practice, the errors caused by the displacements d_3 and d_4 can be neglected as long as the angles φ_1 and φ_2 are of the order of a few degrees.

4. Experimental

The test equipment which was originally designed in 1987 was slightly redesigned for this study. Appendix B contains photographs showing details of the current equipment. The main parts of the apparatus are still the same as before, i.e. a heavy metal rig, mounting brackets, electric spindle motor, load cell and data acquisition and recording devices. The components that underwent the greatest changes were the mechanical parts needed for fixing and aligning the fire extinguisher firmly and correctly in the test rig for the measurements.

4.1 Principle

For measuring the force required to activate the operating device of a portable fire extinguisher, the extinguisher is fixed firmly in the test rig and aligned in such a way that the force exerted by the spindle motor will be directed perpendicularly at the normal point where force in practice will be used in order to render the extinguisher operable. The force exerted on the operating mechanism is measured continuously with the load cell until the extinguishing agent is being discharged.

The measurements of the force required to release the safety device of the extinguisher are carried out in a similar way. However, the mounting position of the extinguisher will in most cases be different due to the location of the safety devices. For measuring tensile forces, various pulleys and wires may have to be used in order to correctly align the direction of the force in relation to the location of the safety device. Also in this case the tensile force exerted on the safety device is measured continuously with the load cell until the seal breaks.

Both measurements are carried out on six extinguishers as specified in EN 3–6 [3]. Prior to the tests the extinguishers are subjected to various environmental conditions required by the standard. The conditions were also presented above in section 2.1.2.

4.2 Test equipment

Appendix B contains photographs showing details of the test equipment used in this study.

In addition to the equipment presented and shown here, a cyclone will be used for collecting extinguishing powder being discharged during tests on powder extinguishers.

4.2.1 Test rig

The test rig of the equipment consists of a framework with the external dimensions 1350 mm × 400 mm made of steel U channel (U: 100 mm × 50 mm) and a base made of two square hollow steel profiles (50 mm × 50 mm, 500 mm long). Figure 8 below and Figures 1, 2 and 4 in Appendix B show a general view of the test rig.

The test rig also comprises various mounting brackets, filler plates and straps required for fixing and aligning the extinguisher firmly and in correct position in the frame of the test rig. For measuring tensile forces a pulley device and wire may have to be used in some cases. Figures 8 – 12 in Appendix B show details of some of these auxiliary devices.

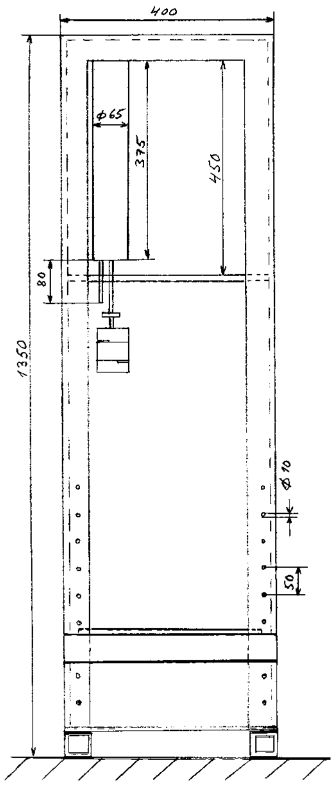

Figure 8. Schematic drawing of the test rig used in this study.

4.2.2 Spindle motor

The forces required to activate the fire extinguishers and to release their safety devices is created with the aid of an electric spindle motor which is permanently fixed to one of the vertical members of the test rig. The spindle motor used in this investigation was a *Dynox Type CS 50/8–300* electric actuator. The shaft (ø 12 mm) of the motor can be extended and retracted at a constant velocity of 9 mm/s. The maximum force exerted by this device is 500 N.

The stroke length of the shaft is 300 mm, but it is here restricted to 50 mm with a cross member of the framework (See Figures 1 and 8). The alignment of the shaft is further secured with the aid of a guiding pin, which can be seen in Figure 5 in Appendix B.

The shaft of the spindle motor is fixed to the upper part of the load cell mentioned in the next section.

4.2.3 Load cell

The load cell used for the actual measurements of the force exerted in the tests on the fire extinguishers is the *Model 606–S–100* manufactured by *Tedea Ltd (Israel)*. The maximum capacity of this load cell is 100 kg while its specified accuracy is 0.04 % of the rated output and temperature effect 0.0037 % of the load per °C. A force exerted on the opposite ends of the load cell will cause a small deformation of the cell. The deformation is measured with the aid of four strain gauges mounted inside the cell. The deformation of the strain gauges causes a small change in the electrical resistivity of the strain gauges. These changes in resistivity, which are proportional to the deformation and thus to the exerted force, can be measured with the aid of a Wheatstone bridge type circuit. In this case a 6-wire full bridge circuit was being used.

The shaft of the spindle motor is fixed to bottom part of the load cell. As the same load cell is used both for measuring both compressive and tensile force, an exchangeable plunger (see Fig. 5 in Appendix B) or hook assembly (see Figs. 6 and 7 in Appendix B) is mounted to the load cell depending on which force is to be measured. The free end of the plunger (ø 12 mm) is equipped with a roller (ø 16 mm, width 5 mm) in order to reduce the mechanical friction between the plunger and the grip of the operating mechanism of the extinguisher. To further align the movement of the plunger and roller, a 6.5 mm thick aluminium plate (14 mm × 64 mm) with a groove matching the width of the roller was fixed to the grip with double-coated plastics tape. This aluminium plate can be seen on top of the upper lever of the extinguisher shown in Figure 5 in Appendix B.

4.2.4 Data acquisition and recording equipment

The output from the load cell, which in this case is of the order of one millivolt, is amplified with a linear DC amplifier (*RS 846–171*) in order to obtain voltages in a usable range for ordinary data recording and acquisition equipment. The gain of the amplifier is approximately 1000.

The voltage from the amplifier is measured with the data acquisition device *Model DT2805* manufactured by *Data Translation, Inc.* This device is installed as a 16-bit expansion board in the ISA bus of an ordinary PC type computer. The data acquisition card is controlled by the program *Labtech Notebook for Windows, V. 9.02*. The system is capable of reading the voltage to be measured at a frequency of at least up to 900 Hz. In this study readings were taken at 10 and 100 measurements per second. The data acquisition device converts the analogue voltages into digital values which are stored on the hard disk on the computer by the controlling program. The data which is stored as ordinary ASCII data on the hard disk can be retrieved and analysed by any suitable spreadsheet program. In this study the data processing was carried out with the program *Microsoft Excel 95®*.

4.3 Calibration

The load cell was calibrated both without external load and with weights of 1, 2 and 5 kg which were suspended from the hook assembly of the cell. Each weight was in turn suspended from the hook for about 1 min while the voltage output from the load cell was read at a frequency of 10 and 100 readings per second. Depending on whether the cell was calibrated for tensile or compressive force, the weights were either suspended directly from the bottom hook of the hook assembly or from the upper hook via a pulley attachment (see Figures 6 and 7 in Appendix B). The shaft of the spindle motor was moving upwards for calibration of the tensile force and downwards for the compressive force. The calibrations were carried out before the start of the actual test programme and after it was finished more than one month later.

The force corresponding to each weight used for the calibration is obtained by multiplying the mass of the weight by the acceleration of free fall (9.81 m/s^2).

The results obtained in the two calibration series for both tensile and compressive force are given in Table 4. Figure 9 shows the raw data measured during one of the tensile calibration series.

Table 4. Results of calibration for tensile and compressive force. The first calibration series was carried out before the start of the actual test programme and the second after it was finished over one month later.

Mass of the weight [kg]	***Measured voltage [V]***			
	Tensile force		***Compressive force***	
	1st calibr.	***2nd calibr.***	***1st calibr.***	***2nd calibr.***
0	–0.012	0.0075	–0.0098	–0.0075
1	0.186	0.188	–0.2075	–0.205
2	0.386	0.388	–0.405	–0.4
5	0.983	0.985	–1.001	–1.0

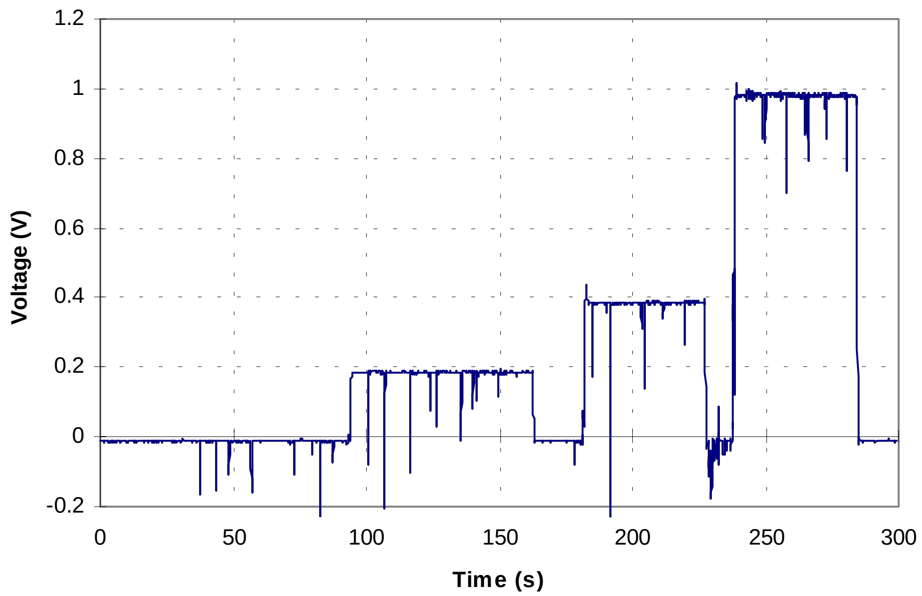

Figure 9. Results of the first calibration for tensile force. The peaks are caused by the swaying weight suspended from the load cell.(Compressive force produces similar results, but with negative voltage readings.)

Plotting the measured voltage vs. mass values of the first calibration series given in Table 4 gives the calibration lines shown in Figures 10 and 11. The measurements values fit in both cases a straight line quite well as can be seen from the figures.

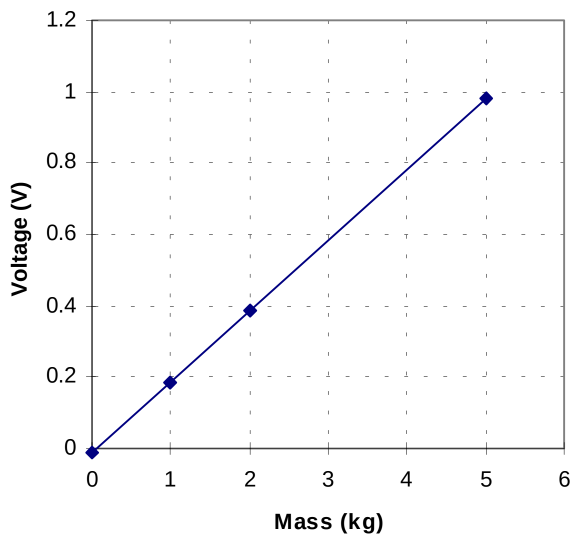

Figure 10.The calibration line for tensile force used in this study.

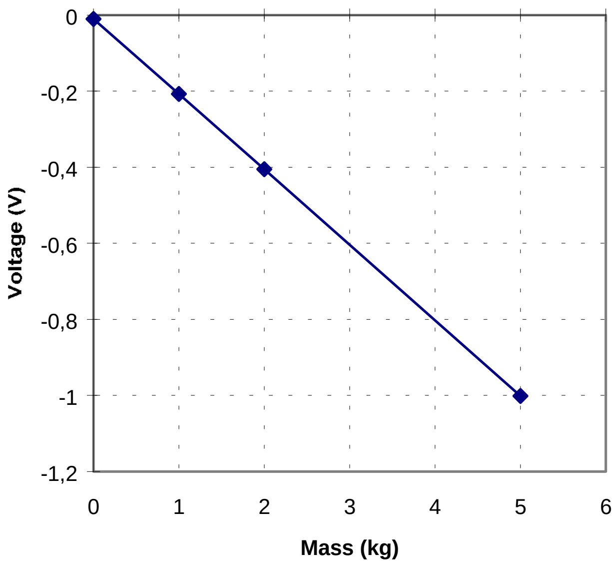

Figure 11.The calibration line for compressive force used in this study.

The tensile and compressive force F (in newtons) as a function of the measured output voltage U (in volts) from the load cell can also be written in analytical form:

1) For tensile force

$$F[N] = 9.81 \cdot (5.02 \cdot U[V] - 0.01) \tag{12}$$

For compressive force

$$F[N] = 9.81 \cdot (-5.04 \cdot U[V] - 0.01) \tag{13}$$

The statistical standard errors of the slopes of Equations (12) and (13) are ±0.004 and ±0.005, respectively while the corresponding values for the Y-intercepts are ±0.002 and ±0.003. The errors relate only to the constants inside the parenthesises.

Ideally, the expressions given in Equations (12) and (13) should be identical except for the direction of the force. The small discrepancy between the two may be the result of the friction of the pulley that was used for suspending the weights for calibration of the compressive force.

4.4 Test results

In order to evaluate the redesigned test equipment, three test series were carried out: (1) tests on safety devices; (2) tests on actuating devices and (3) analysis of error sources. In the analysis of error sources the effects of various misalignments of the test equipment and other factors were studied.

The tests were carried out using different types of commercially available portable fire extinguishers.

4.4.1 Tests on safety devices

Two different extinguishers were used in this test series:

- A 5 kg CO_2 extinguisher with a squeeze grip lever actuating device.
- A 2 kg powder extinguisher with a finger trigger actuating device.

Manufacturers and importers of extinguishers provided seals of three different types (two made of plastics and one of lead) and also sealing wires of three types (two made of metal and one of plastics). Various combinations of seals and wires were used in the tests.

Prior to the tests, the safety devices of the extinguishers were sealed with the provided seals and wires. This operation was carried out manually in the laboratory using of a pair of pliers. Next, one extinguisher at a time was fixed in the test rig and the safety device was aligned in an appropriate position in relation to the load cell:

- The CO_2 extinguisher was fixed in the test rig with its longitudinal axis in the vertical direction. The safety device of the squeeze grip lever mechanism was of the pull ring/locking pin type which is pulled out perpendicularly to the longitudinal axis of the extinguisher. The ring was therefore fixed with a string via a pulley attachment to the hook assembly of the load cell. In this case the force required to release the safety device was measured as tensile force. (Figures 2 and 3 in Appendix B show the CO_2 extinguisher being tested.)

- The powder extinguisher was mounted with its longitudinal axis in the horizontal direction. The safety device of the finger trigger release mechanism consisted of a sealed push button which is pushed down perpendicularly to the longitudinal axis of the extinguisher. The extinguisher was aligned so that the plunger assembly of the load cell acted directly on the push button. In this case the force required to release the safety device was measured as compressive force.

Next, the data acquisition system was activated and 60 s later the spindle motor was switched on in order to either raise or lower the shaft and load cell depending on whether it was tensile or compressive force that was being measured. The test was continued until the safety device was unambiguously released. After this the data acquisition system was switched off. Figure 12 shows an example of a typical force versus time plot. During the measurement the force acting on the safety device slowly increases until the sealing wire breaks (at test time ~ 1.4 seconds) and the safety device is fully released. After this, the force rapidly decreases.

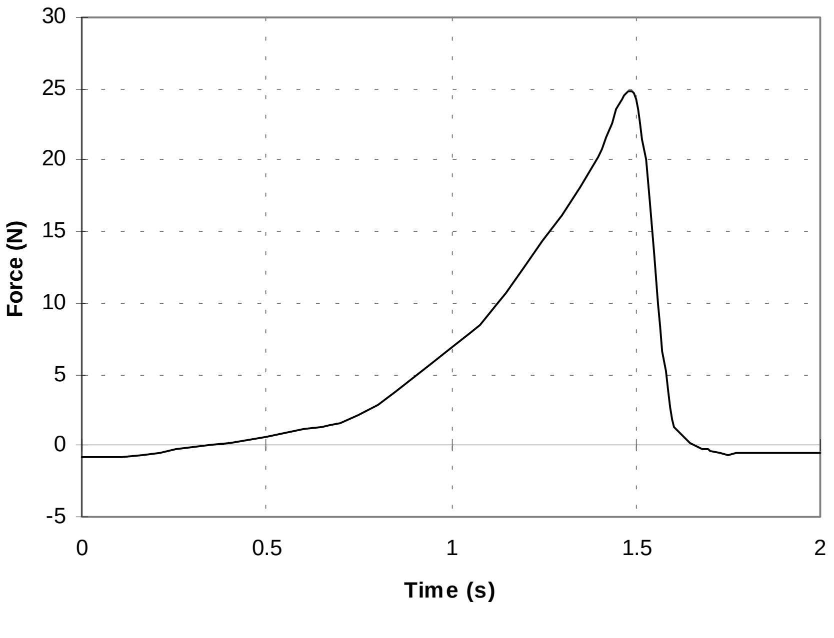

Figure 12. Example of a measurement of the force required to release the safety device of a portable fire extinguisher.

The maximum value of the time–force curve is the value that is being sought through these measurement and which is compared against the specified requirements.

Table 5 lists the results of all tests on safety devices which were carried out in this study.

Table 5. Results of measurements of the force required to release the safety device of portable fire extinguishers.

Test #	***Type of seal***	***Type of sealing wire***	***Release force [N]***
CO_2 extinguisher: Pull ring/locking pin safety device (tensile force)			
1	Plastics–1	Metal–1	27
2	– " –	– " –	20
3	– " –	– " –	26
4	– " –	– " –	20
5	– " –	– " –	30
6	– " –	– " –	24
7	Plastics–1	Plastics	81
8	– " –	– " –	65
9	– " –	– " –	68
10	– " –	– " –	73
11	– " –	– " –	68
12	– " –	– " –	77
13	– " –	– " –	85
14	– " –	– " –	77
15	Lead	Plastics	76
16	– " –	– " –	56
17	– " –	– " –	73
18	– " –	– " –	78
19	Lead	Metal–1	29
20	– " –	– " –	26
21	– " –	– " –	22
22	– " –	– " –	24
Powder extinguisher: Finger trigger safety device (compressive force)			
23	Plastics–2	Metal–2	27
24	– " –	– " –	28

The material of the wire used for sealing the safety device seems to have the greatest influence on the measured force. The average force for the two metal wires is 25.3 N with a standard deviation of 3.3 N while the average is 73.1 N and the standard deviation 7.8 N for the plastics wire. The seal type does not seem to have any significant influence on the measured force in these limited test series.

The standard EN 3–5 [1] prescribes that the force required to release safety devices shall be "between the limits of 20 N and 100 N". All 24 tests shown in Table 5 meet this requirement.

4.4.2 Tests on actuating devices

Three different portable fire extinguishers were used for these tests:

- A 6 litre foam extinguisher with a squeeze grip lever actuating device.
- A 5 kg CO_2 extinguisher with a squeeze grip lever actuating device.
- A 2 kg powder extinguisher with a finger trigger actuating device.

The foam extinguisher was charged either with nitrogen only at various pressures, with 6 litres of plain water and nitrogen at 14 bar or with 6 litres of foam solution and nitrogen at 14 bar. The CO_2 extinguisher was normally charged with carbon dioxide and the tests were carried out at the temperatures +20 °C and +40 °C. The powder extinguisher was charged only with nitrogen at 14 bar.

For the tests each extinguisher in turn was fixed to the test rig and the actuating device was aligned in an appropriate position in relation to the load cell:

- The foam and CO_2 extinguishers were fixed in the test rig with their longitudinal axis in the vertical direction. The extinguishers were aligned so that the plunger assembly of the load cell acted directly on the upper lever of the squeeze grip actuating device. In this case the force required to activate the operating device was measured as compressive force. (Figures 4 and 5 in Appendix B show the foam extinguisher being tested.)

- The powder extinguisher was mounted with its longitudinal axis in the horizontal direction. The extinguisher was aligned so that the plunger assembly of the load cell acted directly on the finger trigger of the actuating device. Also in this case the force required to activate the operating device was measured as compressive force.

After this, the data acquisition system was activated and 60 s later the spindle motor was switched on in order to lower the shaft and load cell with the plunger and press down the actuating device of the extinguisher until the discharge was commenced. The data acquisition device was then switched off. Figure 13 shows an example of a typical force versus time plot. During this measurement the plunger with the roller is first being lowered towards the grooved aluminium plate which is fixed to the upper lever of the squeeze grip operating mechanism. After the roller has touched the groove (at test time ~0.7 s), the force increases as the handle is being pressed down. The sudden decrease in the force (between 0.9–1.0 s) is caused by a transition point in the movement of the actuating mechanism of the extinguisher. Then the force again increases as the lever is pressed further down until the valve of the operating mechanism opens (at 1.5 s) and the extinguishing agent starts to discharge. After this, the force on the lever rapidly decreases.

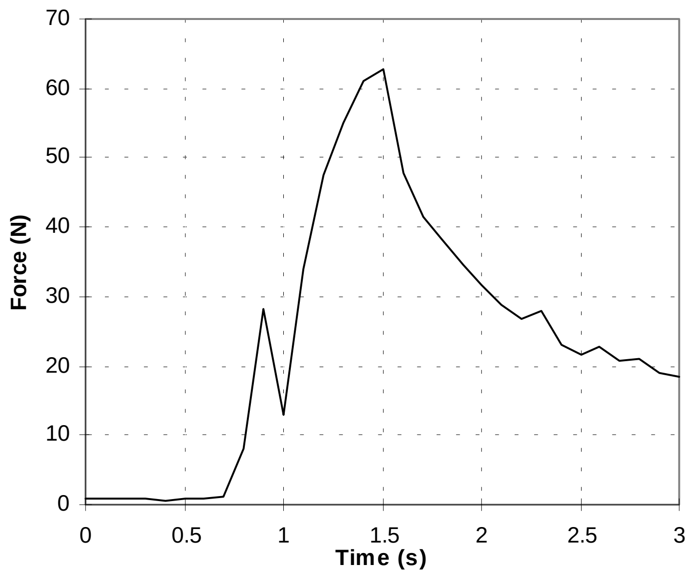

Figure 13. Example of a measurement of the force required to activate the operating device of a portable fire extinguisher.

As before, the maximum value of the time–force curve is the value that is being sought through these measurement and which is compared against the specified requirements. For a full compliance test series, the tests shall be carried out on six extinguishers as required by the standard EN 3–6 [3].

Table 6 lists the results of all tests on actuating devices which were carried out in this study.

Table 6. Results of measurements of the force required to activate the operating device of portable fire extinguishers.

Test #	***Charge***	***Activation force [N]***
Foam extinguisher: Squeeze grip lever actuating device (compressive force)		
1	Nitrogen, 18 bar	57
2	Nitrogen, 19 bar	59
3	Nitrogen, 21 bar	61
4	Nitrogen, 22 bar	57
5	Nitrogen, 23 bar	90
6	– " –	98
7	6 litres water, N_2 14 bar	53
8	– " –	49
9	– " –	46
10	– " –	48
11	– " –	45
12	6 l foam solution, N_2 14 bar	51
13	– " –	46
14	– " –	46
15	– " –	49
CO_2 extinguisher: Squeeze grip lever actuating device (compressive force)		
16	CO_2, at +20 °C	155
17	– " –	155
18	CO_2, at +40 °C	263
Powder extinguisher: Finger trigger actuating device (compressive force)		
19	Nitrogen, 14 bar	55
20	– " –	73

The pressure of the charge of the extinguisher seems to have some influence on the required activation force: For the foam extinguisher, the required force is around 50 N when the pressure is 14 bar and increases to 90–100 N at 23 bar. This is also quite obvious for the CO_2 extinguisher: The force is 155 N when the temperature is +20 °C and 263 N at +40 °C.

The standard EN 3–5 [1] specifies that the for extinguishers with a squeeze grip lever "the force required to activate the operating device(s) shall not be greater than 200 N".

For CO_2 this value is valid for temperatures up to +40 °C. At +60 °C the maximum force is 300 N. For extinguishers with a finger trigger the maximum force is 100 N. All 20 tests shown in Table 6, except Test # 18, meet these requirements.

The standard EN 3–5 [1] further requires that it shall not be possible to initiate discharge without first operating the safety device with activating forces that equal twice the relevant values mentioned in the paragraph above. One test on a foam extinguisher where the safety device was still in place was also carried out. The result is shown in Figure 14. The maximum force to be exerted by the spindle motor was set to be 500 N for this test.

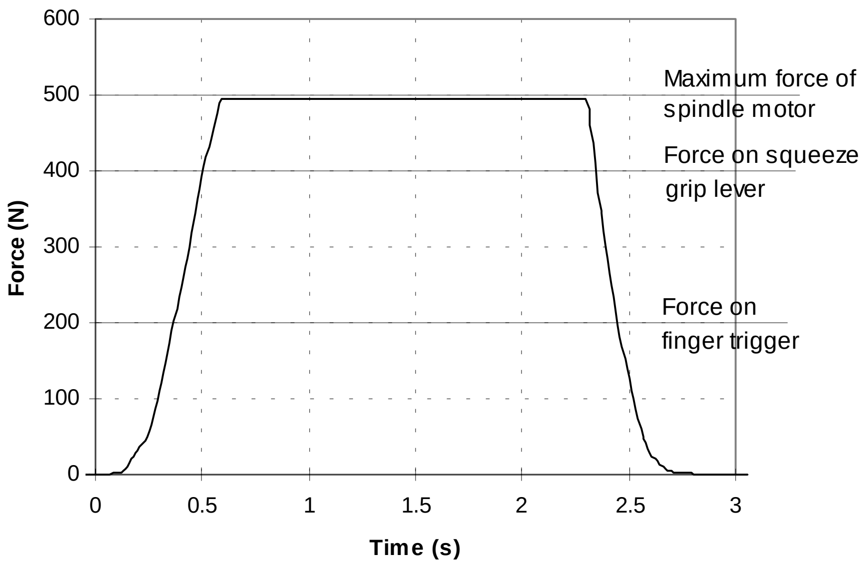

Figure 14. Example of a measurement of the force exerted on the operating device of a portable fire extinguisher with the safety device still in place. The horizontal lines show the maximum force exerted by the spindle motor and the minimum requirements for operating devices of the squeeze grip lever and finger grip types.

4.4.3 Analysis of error sources

In order to study how sensitive the method is to various misalignments of the test device and other factors, a number of additional tests were carried out.

Inclination of the test rig. For these measurements the test rig was inclined arbitrarily 6.6° by placing an object under one side of the base plate of the rig. Calibration measurements were carried out for both tensile and compressive force using the 5 kg calibration weight. The results are shown in Table 7.

Table 7. Results of calibration measurements for studying the effects of a small inclination of the test rig.

Mass of calibration weight [kg]	**Measured force [N]**	
	Inclination 0°	**Inclination 6.6°**
0 kg	0.27	0.27
5 kg (tensile force)	48.40	48.02
5 kg (compressive force)	49.34	50.33

An inclination of 6.6° of the test rig appears to cause errors of only 1–2 % compared to an non-inclined rig.

Displacement of the hook assembly. Particularly for the measurements of tensile force, a hook assembly is fixed to the bottom part of the load cell instead of the plunger which is used otherwise. When the hook assembly is in the correct position, the centre of the hook is located concentrically with the axis of the shaft of the spindle motor. For these measurements the hook was displaced by 40 mm. Also in this case calibration measurements were carried out for both tensile and compressive force using the 5 kg calibration weight. The results are shown in Table 8.

Table 8. Results of calibration measurements for studying the effects of a small displacement of the hook assembly.

Mass of calibration weight [kg]	**Measured force [N]**	
	Displacement 0 mm	**Displacement 40 mm**
0 kg	0.49	0.49
5 kg (tensile force)	48.40	49.32
5 kg (compressive force)	49.34	50.09

The error caused by the displacement seems also here to be of the order of 1–2 %.

Point where the compressive force is applied. As was shown in the theoretical error analysis, the greatest uncertainty will affect measurements of the compressive force required to activate the operating device of fire extinguishers with a squeeze grip lever actuating mechanism. In these measurement the exact point on the upper lever cannot be unambiguously defined in a test standard due to the very varied designs of practical extinguishers. The standard EN 3–5 [1] calls for "*at the normal point where force is used to render the extinguisher operable*", while NT FIRE 024 [2] requires "*to the outermost part of the control device*".

To study how the exact location of the point where the compressive force is exerted on the upper lever of a squeeze grip actuating device, a series of tests was carried out using a 6 litre foam extinguisher which was charged for the tests only with nitrogen at 14 bar. The total length of the movable upper lever of this extinguisher was 80 mm measured from the point where it was hinged to the permanent lever. Measurements of the force required to activate the operating mechanisms were carried out by applying the compressive force at various points along the upper lever. The results are given in Table 9.

Table 9. The effect of the location of the point on the squeeze grip lever of a portable fire extinguisher where the force required to activate the operating mechanism is initially applied.

Distance from the hinge of the lever to the point where the compressive force is initially applied [mm]	***Compressive force required to activate the operating mechanism of the extinguisher [N]***
15	84
30	67
40	55
50	52
60	42
70	39

The exact location of the point where the force is applied has obviously a considerable effect on the results and care must be taken to define it properly in the test method. The error may in extreme cases affect the final result by a factor of more than two.

Frequency of measurements. The frequency at which the measurements are taken will also have a certain influence on the test results. The measured force will change quite rapidly short before (and after) the exact moment when the safety device is released or the operating mechanism is activated. If the time between consecutive measurements is unduly long, the peak value of the force may fall between two measurements and will thus be missed.

In this study the frequencies 10 and 100 measurements per second were used. However, it was found that the time between two measurements may be slightly too long for the lower frequency. Figure 13 above shows an example of this. Between the test times 1.0 s and 1.4 s, the force increases steadily and quite smoothly. Going to the next reading at 1.5 s there is an obvious kink of the curve, and this reading is already a part of the descending curve. The peak value would thus be somewhere between the readings 1.4 s and 1.5 s. From the increasing and decreasing sections of the curves, the peak value of around 66 N can be extrapolated. The reported maximum force was in this case 63 N, so the difference would be 3 N or nearly 5 % which is somewhat greater than the errors caused by misalignment of the test equipment.

Care must be taken to use a sufficiently high measurement frequency in order not to unduly distort the time–force curve and risk missing the peak values.

Errors occurring during the application of force. When the sealing wire of the safety device of an extinguisher breaks, parts of the wire may still remain in the hole drilled through the locking pin of the device. When the pin with the remains of the wire is pulled further out, irregularities in the measured force may occur. This situation is illustrated in Figure 15.

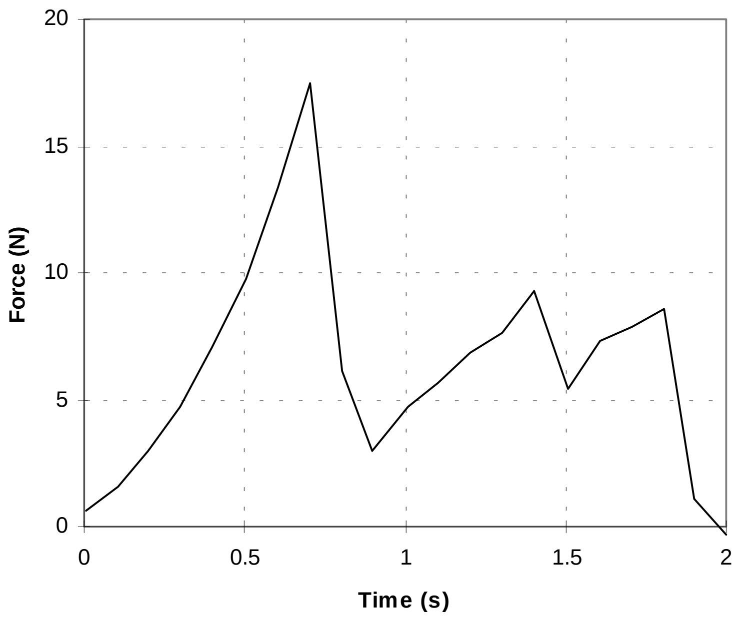

Figure 15. Irregularities in the measured force during the release of the safety device of a fire extinguisher. The irregularities beginning at test time 0.9 s are caused by parts of the sealing wire remaining in the locking pin after the wire has been broken.

If the measurement of the force required to activate operating devices of the squeeze grip lever type is continued sufficiently long after the discharge of the extinguishing agent has started, the movable upper lever may be pressed against the fixed lower lever. When this happens, the force will increase rapidly. Such a situation is shown in figure 16 where the discharge first starts at test time ~1.6 s, after which the upper lever is still being pressed down until it touches the lower lever (at ~3.5 s) when the force again increases rapidly.

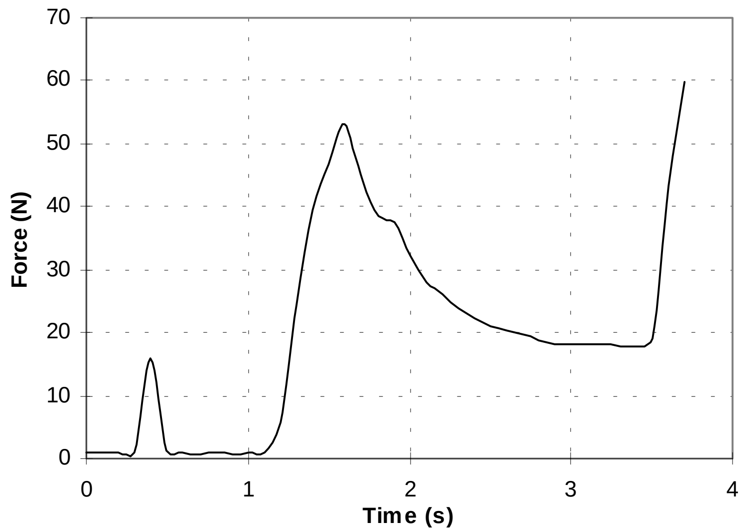

Figure 16. The measured force during activation of the operating device of the squeeze grip lever type. The application of force is continued until the movable lever of the grip is pressed against the fixed lever. At this point the force increases rapidly.

5. Summary

The results of the experimental part of this study show that the method outlined here can be used for measuring the force required to activate the operating devices and to release the safety devices of portable fire extinguishers. However, care must be taken to eliminate the factors which may distort the results.

Appendix C contains a proposal for a Nordtest method which specifies the principles to be applied for measuring the forces discussed in this study. As the extinguishers in practice are provided with actuating and safety devices of a very varied design which require the extinguishers to be fixed in the test rig in various ways and positions to correctly align the extinguisher, the test rig itself is not described in any great detail in the proposal. The draft test method focuses instead on the factors which are known to influence the test results, such as for instance the alignment of the components, the point where the force is to be applied, the minimum frequency at which measurements are to be made, etc. It is up to the user to find a suitable way of fixing the extinguisher in the correct position in relation to the force. This fixing may require the use of various spacers, supports, fixtures and straps. The design of the extinguishers may furthermore require that the test force has to be applied as tensile force with the aid of pulleys and wires. Figures 8 – 12 in Appendix B contain examples of different auxiliary devices which were used for the measurements carried out in this study. Particularly when testing powder extinguishers, a cyclone or similar device may be useful for collecting the discharged powder.

The proposal is presently written as a standalone test method, although it relies heavily on the standard EN 3–5 [1]. The proposal can also easily be written as *supplementary specifications* containing only the description of the detailed test procedure. The latter procedure has been used for instance in the Nordtest method NT FIRE 020 [7] which contains some supplementary specifications to the standard ISO 4736 [8].

References

1. EN 3–5, Portable fire extinguishers – Part 5: Specification and supplementary tests. Brussels, BE: European Committee for Standardization. 1995. 15 p.

2. NT FIRE 024, Fire fighting equipment: Portable fire extinguishers. Helsinki, FIN: Nordtest. 1986. 1 + 32 p. (This method has been withdrawn in May 1997)

3. EN 3–6, Portable fire extinguishers – Part 6: Provisions for the attestation of conformity of portable fire extinguishers in accordance with EN 3 Part 1 to Part 5. Brussels, BE: European Committee for Standardization. 1995. 29 p.

4. Uuden yhteispohjoismaisen käsisammuttimien testausstandardin vaikutukset, osa III. (The consequences of the new Nordic test method for portable fire extinguishers, Part III). Espoo, FIN: Technical Research Centre of Finland, Fire Technology Laboratory. 1987. (Research Report PAL6298) 8 p. + app. 21 p. (Unpublished report in Finnish)

5. Käsisammuttimet, määräykset, ohjeet tarkastuksesta ja huollosta. (Portable fire extinguishers, regulations, instructions for inspection and maintenance). Helsinki, FIN: Ministry of the Interior, Rescue Department. 1983. (Regulations 1983:6) 23 p. (In Finnish)

6. ISO/DIS 7165, Fire-fighting – Portable fire extinguishers – Performance and construction. Genève, CH: International Organization for Standardization. 1997. 63 p.

7. NT FIRE 020, Small chimneys: Heat insulation, tightness and mechanical strength at elevated temperatures. Helsinki, FIN: Nordtest. 1985. 5 p.

8. ISO 4736, Fire test – Small chimneys – Testing at elevated temperatures. Genève, CH: International Organization for Standardization. 1979. 6 p.

Appendix A: Examples of typical operating mechanisms and security devices

Commonly used types of operating mechanisms

The most common types of operation and emission control mechanism or devices used in portable fire extinguishers are finger trigger devices and squeeze grip lever devices.

Figure 1 shows a stored pressure portable fire extinguisher which is activated by pressing down a ***finger trigger device***. This type of device is most often used in small powder extinguishers with a nominal charge of 1 – 3 kg and which in many cases also lack a discharge hose. The actuation of the finger trigger opens a control valve which enables the propellant to force the extinguishing powder to flow out through the diptube and into the nozzle or hose assembly.

Figure 1. A stored pressure portable fire extinguisher with a finger trigger operating device. No. 1 is the safety device, No. 2 the finger trigger device, No. 3 the control valve, No. 4 the diptube and No. 5 the nozzle [1].

Figure 2 displays another stored pressure portable fire extinguisher which in this case is activated with a ***squeeze grip lever device***. These devices are most commonly used in fire extinguishers with a charge of more than 3 kg, but they are also used frequently for smaller water based and carbon dioxide extinguishers. The actuation device consists of a two-part squeeze grip where the lower part is fixed and the upper part movable. Pressing down the upper part of the squeeze grip opens a control valve which enables the propellant to force the extinguishing powder to flow out through the diptube and into the hose assembly.

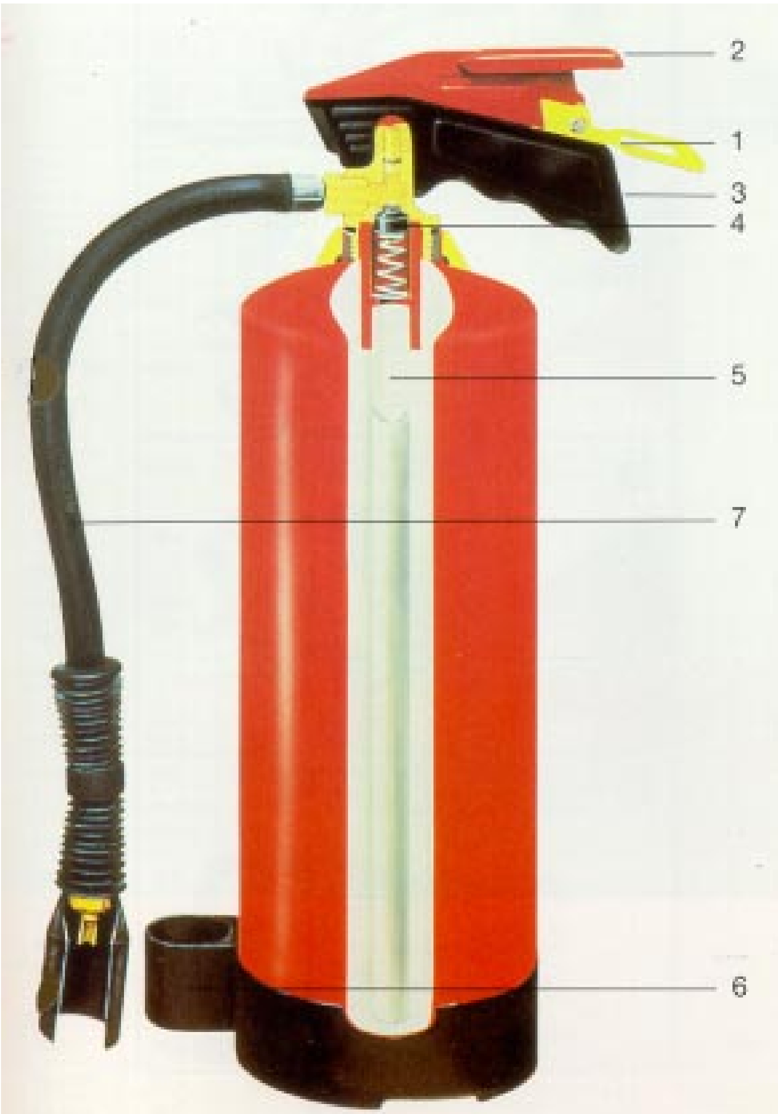

Figure 2. A stored pressure portable fire extinguisher with a squeeze grip lever operating device. No. 1 is the safety device, No. 2 the squeeze grip lever device, No. 4 the control valve, No. 5 the diptube and No. 7 the hose assembly [2].

Figure 3 shows a portable fire extinguisher which is pressurised only at the moment of operation. This extinguisher is also activated with a ***squeeze grip lever device***. When the movable part of the grip lever is pressed down, it will first puncture a burst disc of a propellant gas cartridge located inside the extinguisher body. This will cause the propellant gas to flow out and pressurise the fire extinguisher. Continuing pressing of the movable part of the grip lever will the act on the control valve of the extinguisher as in the two previous cases with stored pressure portable fire extinguishers.

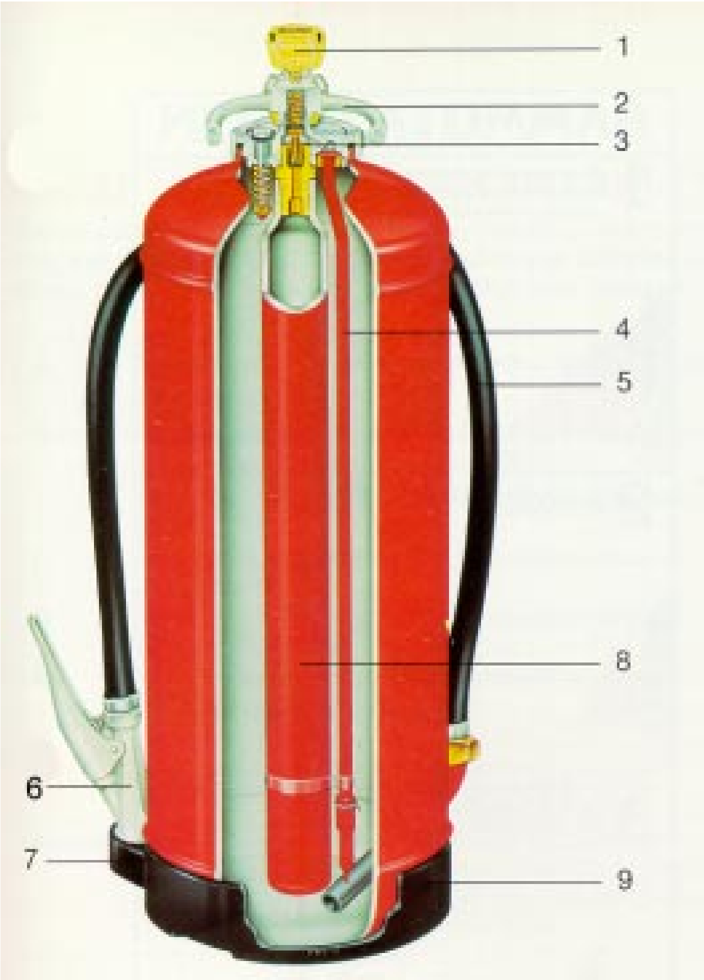

Figure 3. A portable fire extinguisher which is pressurised only at the moment of operation. The actuating device a squeeze grip lever operating device. No. 1 is the safety device, No. 2 the squeeze grip lever device, No. 3 the puncture device, No. 4 the blowpipe, No. 5 the hose, No. 6 the control valve and No.8 the propellant gas cartridge [2].

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Commonly used types of safety devices

The most common safety device consists of a thin (ø 2 – 3 mm) locking pin with a pull ring in one end. The upper and lower parts of a squeeze grip lever are joined together with the locking pin which is pushed through two or four holes drilled in the levers. A small hole is drilled in the other end of the pin through which a metal wire is drawn so that it locks the operating mechanism of the extinguisher in place. The ends of the metal wire are joined with a lead seal so that it is not possible to release the safety device or to operate the extinguisher without breaking the seal.

In order to use the fire extinguisher, the safety device must first be released by pulling out the locking pin by the pull ring. Through this action the sealing wire will break and the upper grip lever can be pressed down and thus open the control valve and discharge the extinguishing media. The force required to break the sealing wire is the force which is to be measured.

Instead of metal locking pins various ingeniously designed plastic parts may be used for the same purpose particularly in smaller extinguishers with finger trigger actuating devices. In some cases the combination of locking pin, pull ring, sealing wire and seal may be replaced by a single plastic part which will be broken and removed before the extinguisher is used.

References

1. Jauhesammutin *Gloria P 2 G, P 2 GM* (Powder Extinguisher *Gloria P 2 G, P 2 GM*). Brochure, Oy Mercantile Ab, 1997. 2 p. (In Finnish)

2. Ennakointi on turvallisuutta (Anticipation is safety). Brochure, Oy Mercantile Ab, 1991. 16 p. (In Finnish)

Appendix B: Photographs of the test equipment

Figure 1. General view of the test rig.

Figure 2. Testing the safety device of a CO_2 extinguisher – general view.

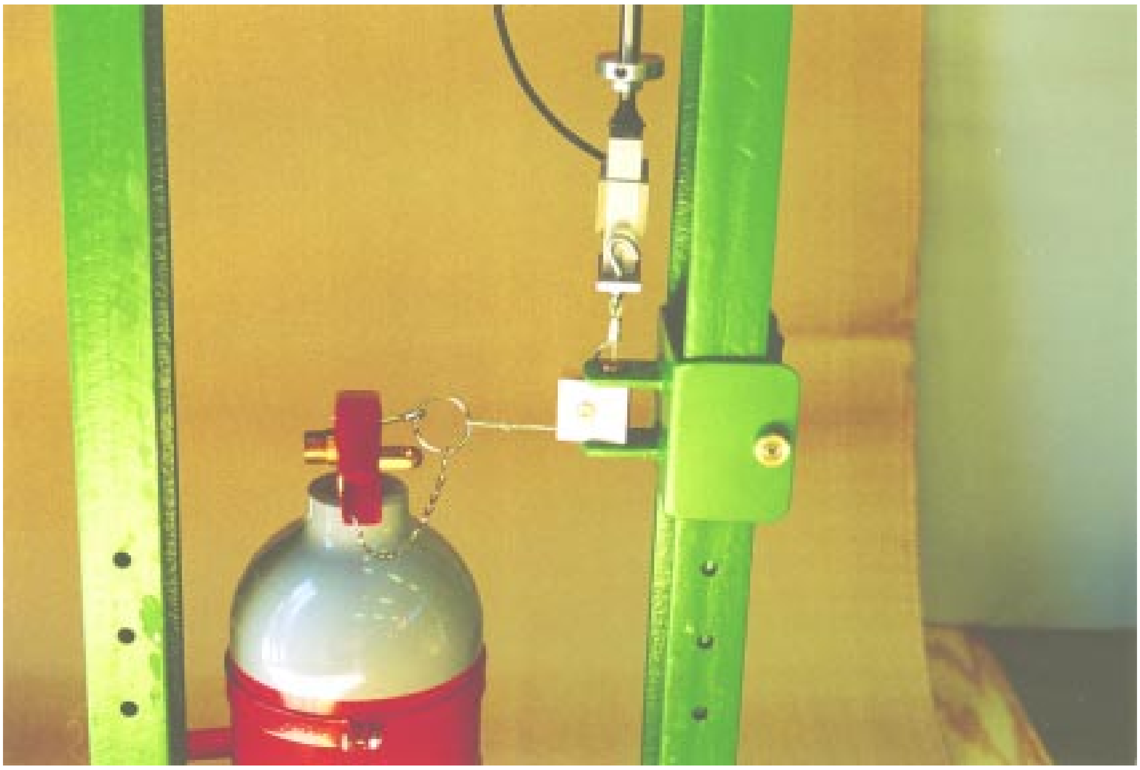


Figure 3. Testing the safety device of a CO_2 extinguisher – detailed view.

Figure 4. Testing the actuating device of a foam extinguisher – general view.

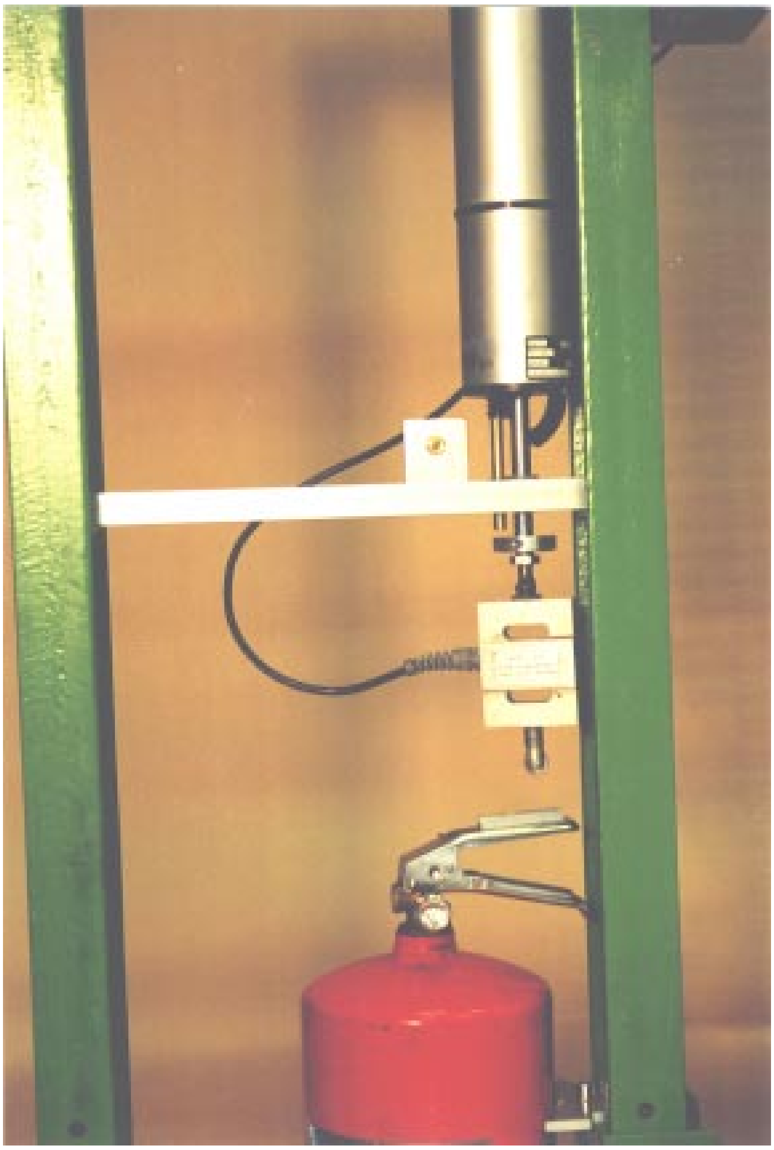


Figure 5. Testing the actuating device of a foam extinguisher – detailed view.

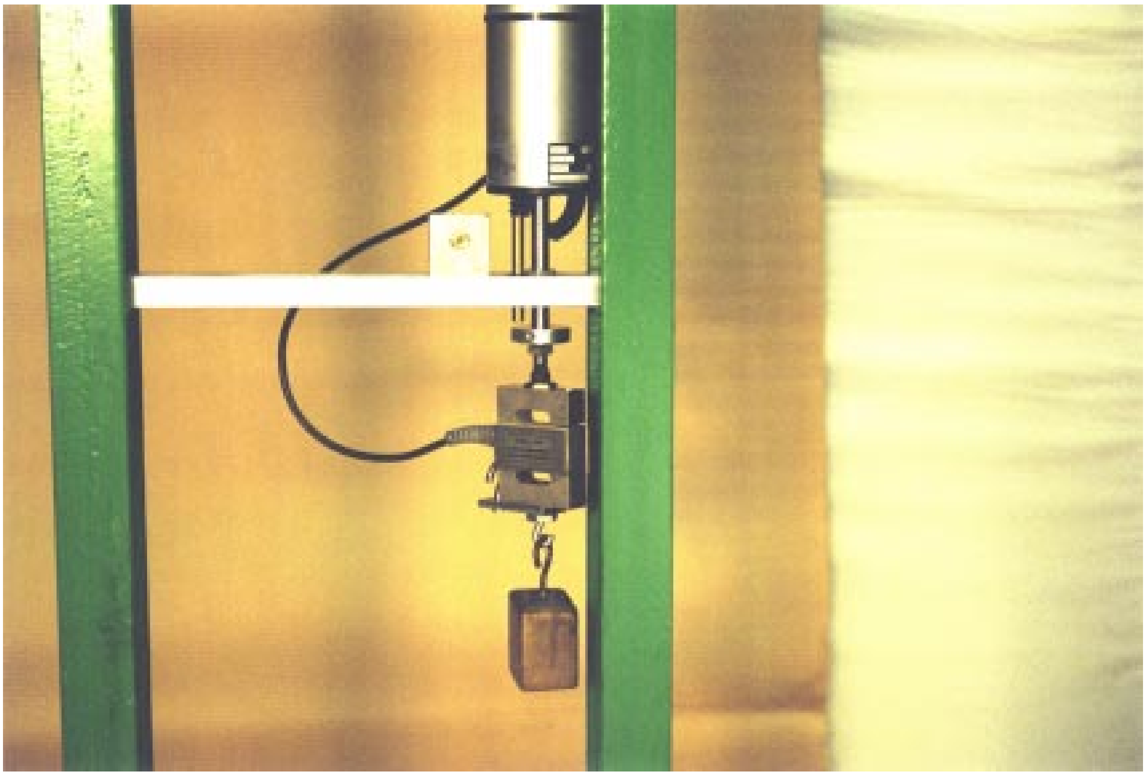


Figure 6. Calibration of tensile force.

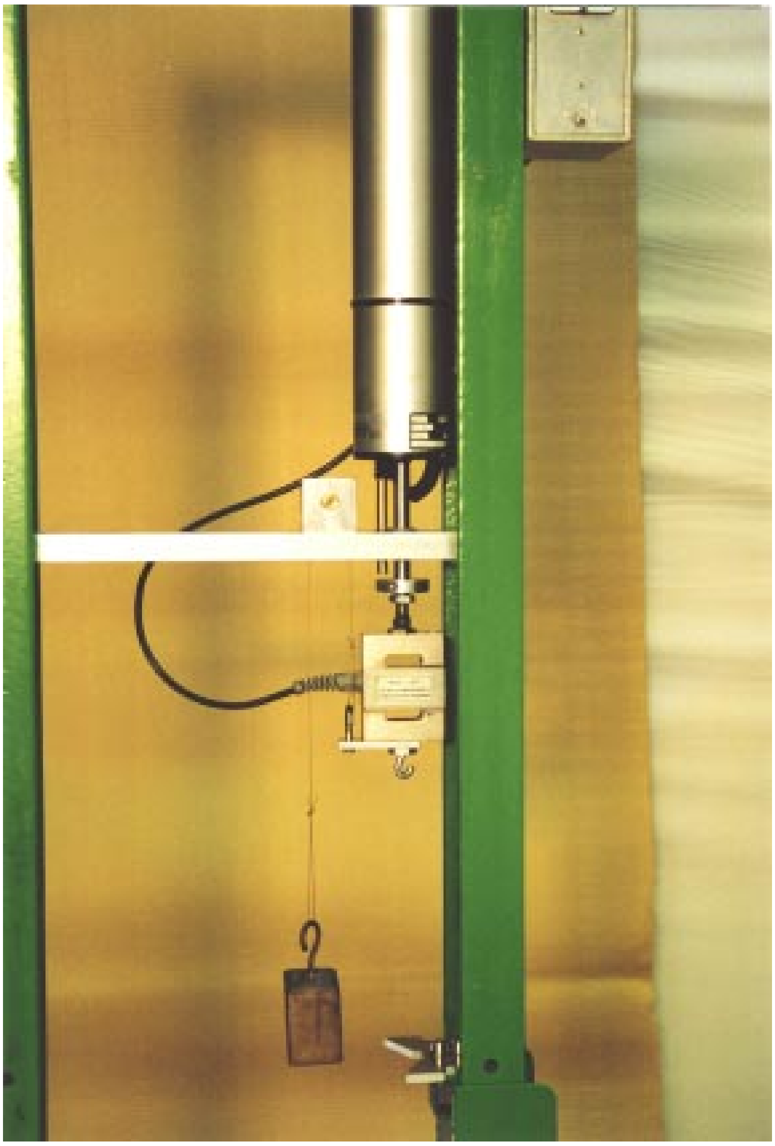
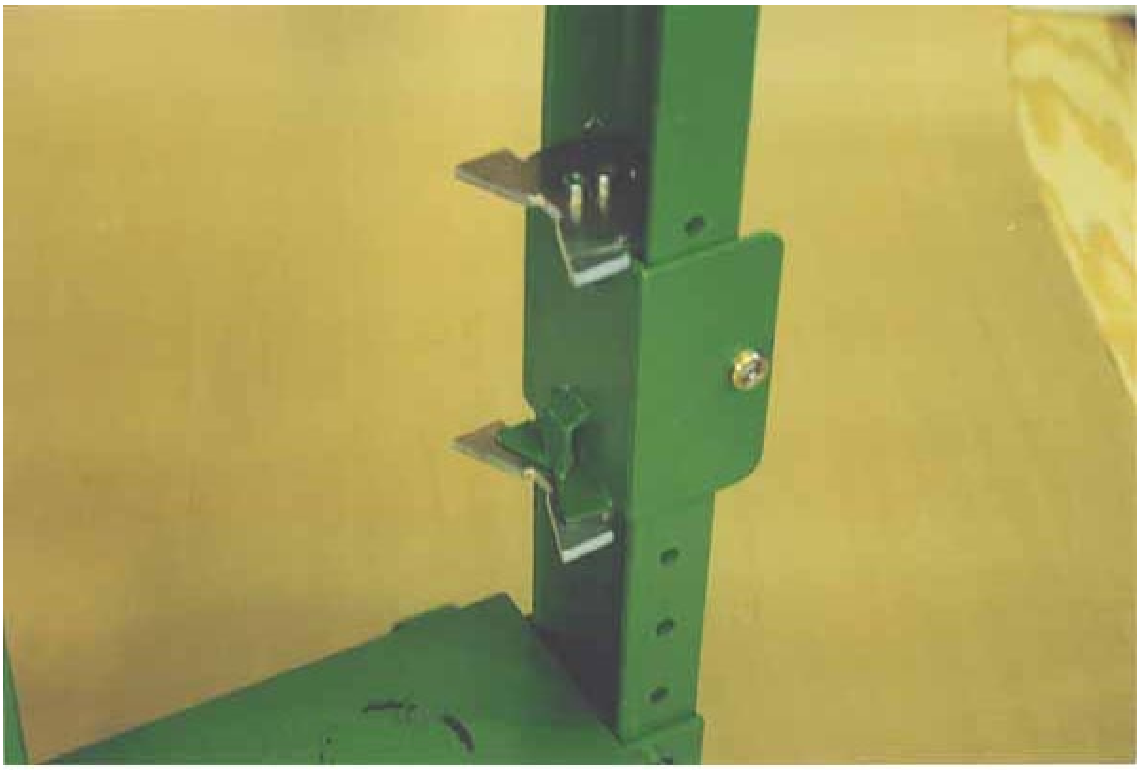
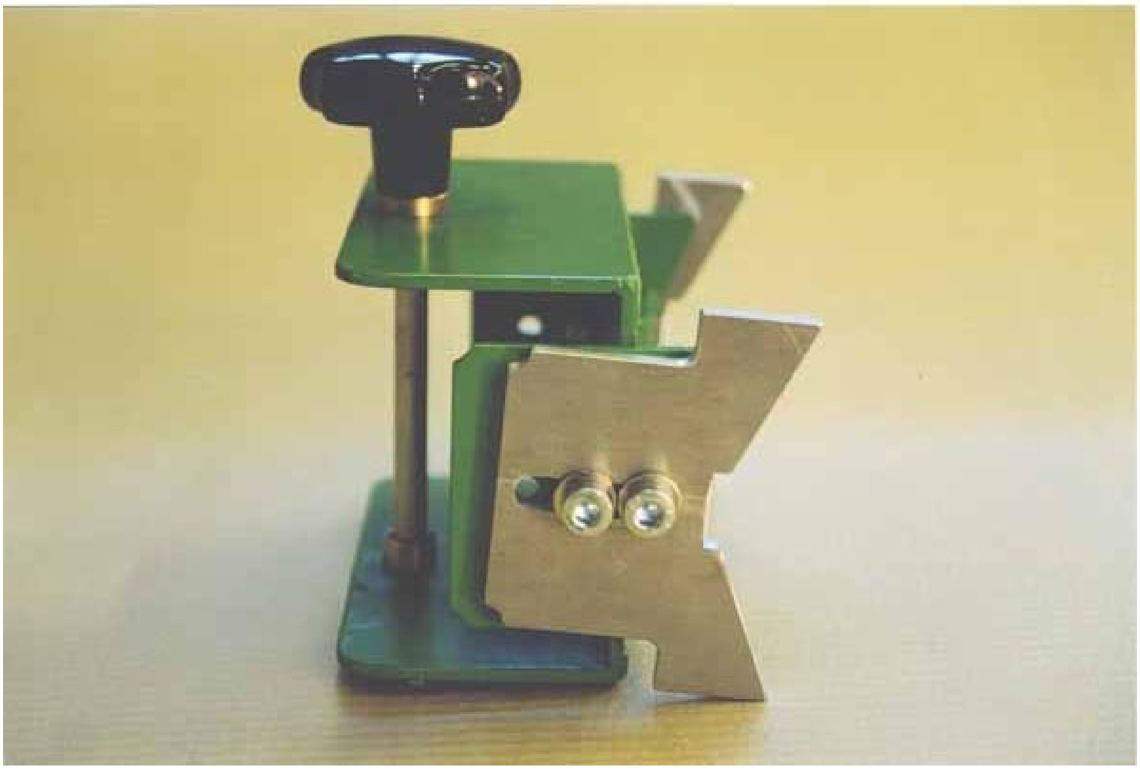


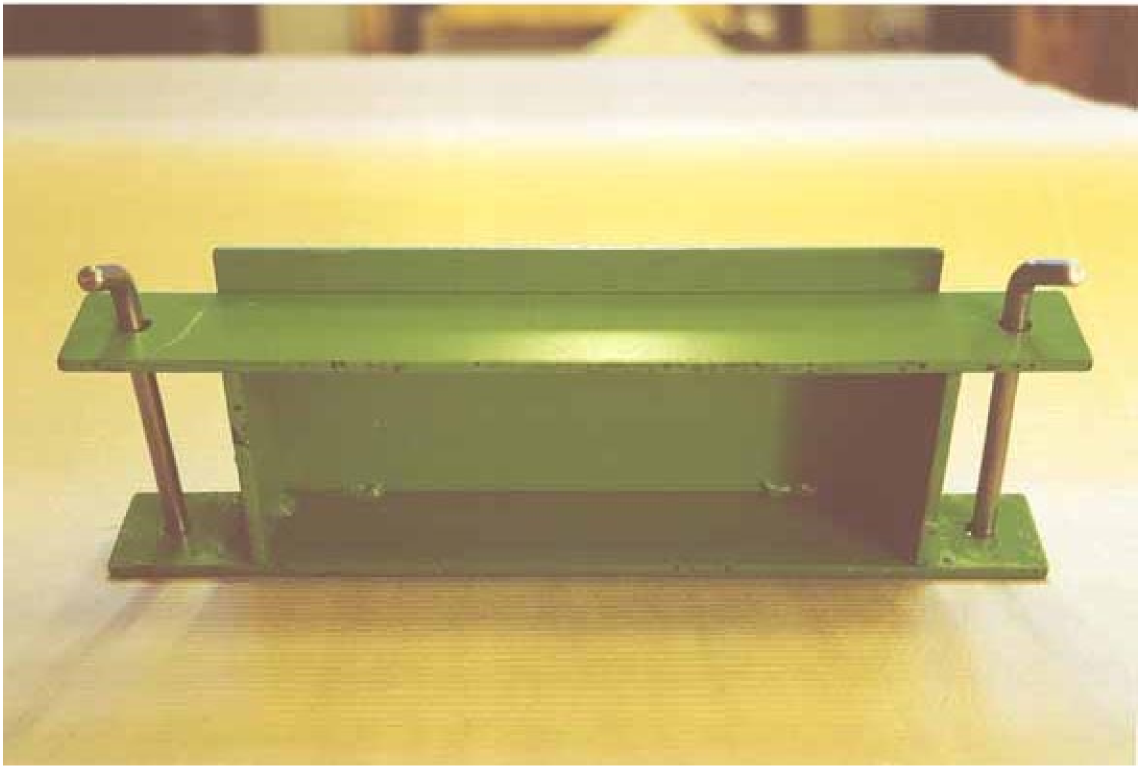
Figure 7. Calibration of compressive force.





Figures 8 and 9. Auxiliary device used for fixing extinguishers vertically in the test rig.

Figures 10 and 11. Auxiliary devices used for fixing extinguishers in the test rig.



Figures 10 and 11. Auxiliary devices used for fixing extinguishers in the test rig.

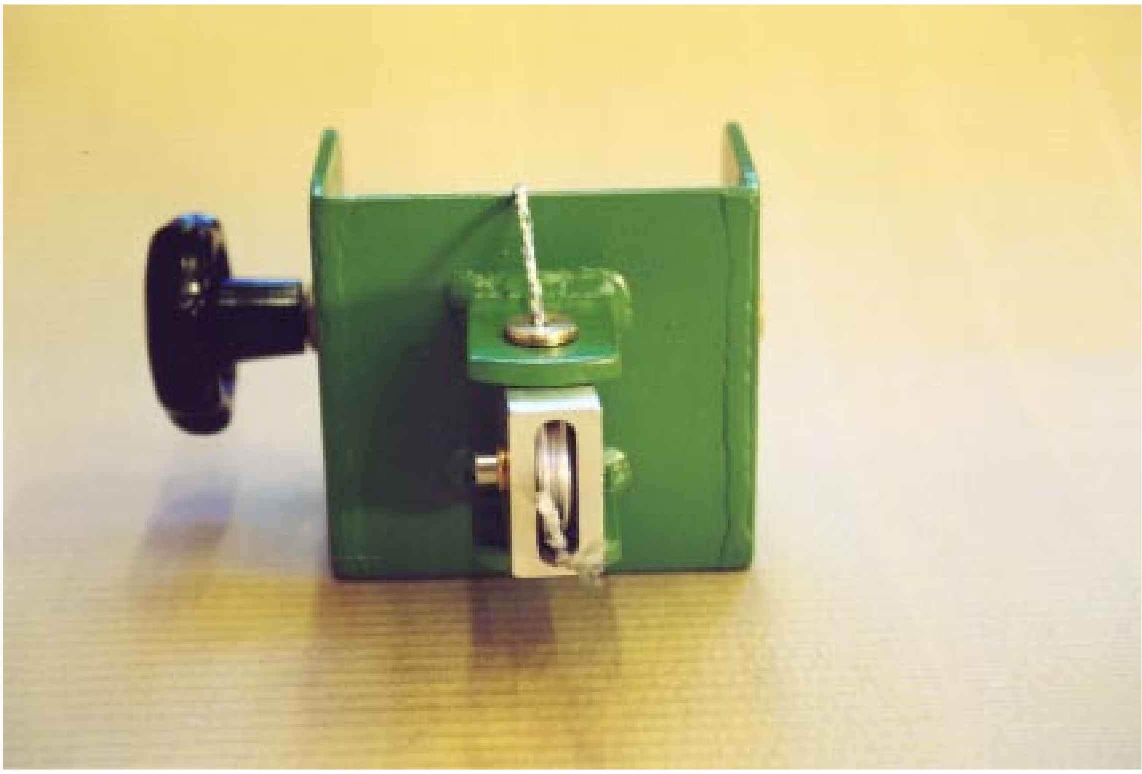


Figure 12. Pulley device used for calibration and for testing of tensile force.

Appendix C: Proposal for a new Nordtest method

Portable fire extinguishers: Force required to activate operating devices and to release safety devices

0. FOREWORD

The European standard series EN 3 specifies the description, characteristics and performance requirements and test methods of portable fire extinguishers.

The methods for measuring the force required to activate the operating devices and to release the safety devices of portable fire extinguishers are described at a general level in the standard EN 3–5. The description may, however, lead to different interpretations of how the measurements are to be carried out in practice. This Nordtest method, which is to be used in conjunction with EN 3–5, describes test methods which are more specified than those in EN 3–5. The procedures included in this Nordtest method also meet the demands of EN 3–5.

1. SCOPE

This Nordtest method contains test procedures for measuring the force required to activate the operating devices and to release the safety devices of portable fire extinguishers. The procedures described here are intended to supplement the corresponding procedures included in EN 3–5 and to eliminate any potential ambiguities in them.

2. FIELD OF APPLICATION

This Nordtest method is suitable for portable fire extinguishers within the scope of EN 3 in which the operating device is of the finger trigger or squeeze grip lever type.

Extinguishers with an operating device of the strike knob type are tested according to Annex F of EN 3–5.

3. REFERENCES

EN 3–1:1996. Portable fire extinguishers – Part 1: Description, duration of operation, class A and B fire tests.

EN 3–2:1996. Portable fire extinguishers – Part 2: Tightness, dielectric test, tamping test, special provisions.

EN 3–3:1994. Portable fire extinguishers – Part 3: Construction, resistance to pressure, mechanical test.

EN 3–4:1996. Portable fire extinguishers – Part 4: Charges, minimum required fire.

EN 3–5:1996. Portable fire extinguishers – Part 5: Specification and supplementary tests.

EN 3–6:1995. Portable fire extinguishers – Part 6: Provisions for the attestation of conformity of portable fire extinguishers in accordance with EN 3 part 1 to part 5.

4. DEFINITIONS

For the purpose of this Nordtest method, the definitions given in EN 3 apply.

5. SAMPLING

The sampling is to be carried out as specified in EN 3–6.

According to EN 3–6, six extinguishers are required for these tests. Four of the extinguishers shall prior to the tests be subjected to the temperature cycle defined in section 3.1 and Annex A of EN 3–5 and two of which have been subjected to external corrosion conditions defined in section 5.1 and Annex H.1 of EN 3–5. Additionally one test shall also be carried out on the operating device of an extinguisher without first releasing the safety device.

6. TEST METHOD

6.1. Principle

Each extinguisher is in turn fixed firmly in a test rig so that its safety device or actuating device is aligned and located correctly in relation to a force cylinder and load cell combination. Depending on the actual construction of the extinguisher, either a compressive or tensile force is then exerted with the force cylinder on the safety device or actuating device. The force is slowly increased until the safety device is released or the extinguisher is activated and the extinguishing media starts to discharge. The magnitude of the exerted force is recorded continuously during this process and the maximum measured value is the one to be reported. The forces required to released the safety device and to activate the operating device are in general measured separately. The same procedures apply to the measurements of both of these forces.

One test shall also be carried out on the operating device of an extinguisher without first releasing the safety device. The force to be applied in this test shall be equal to twice the respective value specified in Table 1 of EN 3–5 (this information is also included in Annex B2 below).

6.2. Equipment

The main parts of the test equipment are: a test rig, force cylinder, load cell and data recording equipment.

6.2.1. Test rig

Due to the widely varying design of practical extinguishers, no detailed description of a test rig suitable for every conceivable extinguisher can be given. The test rig shall, however, allow the extinguisher to be fixed firmly to the test rig with its safety or actuating device located and aligned correctly in relation to the force cylinder with the load cell. To achieve this, a metal framework with various auxiliary equipment, such as mounting brackets, straps, pulleys, wires, etc., may be used.

> Annex A shows an example of a test rig which has been used for testing of several types of commonly used extinguishers.

6.2.2. Force cylinder

A force cylinder shall be used for exerting the force on the safety device or actuating device of the extinguisher being tested. The force cylinder shall be capable of creating a compressive and/or tensile force of at least 500 N. The control mechanism of the force cylinder shall be able to extend or retract the shaft of the cylinder at a rate of 10 ± 2 mm/s. The force cylinder may be either of electric, pneumatic or hydraulic type.

> A suitable force cylinder is for instance *Dynox Type CS 50/8–300*, which is used in the test equipment shown in Annex A.

6.2.3. Load cell

A load cell capable of measuring compressive and/or tensile force up to at least 1000 N with an accuracy better than 0.1 % shall be fixed to the shaft of the force cylinder. The opposite side of the force cylinder is provided with exchangeable suitable devices needed for transmitting the force to the extinguisher. Such auxiliary devices may be e.g. a plunger with a roller for exerting direct compressive force or a hook to which a wire can be fixed for exerting tensile force.

The load cell shall be calibrated for both compressive and tensile prior to each test series. A suitable method is to use a series of weights of known mass which are suspended from the load cell. The mass of the weights should be in the range 0–5 kg. The force cell shall be operating during the calibration.

> A suitable load cell is for instance *Tedea Ltd, Model 606–S–100*, which is used in the test equipment shown in Annex A. This load cell contains a bridge of strain gauges.

6.2.4. Data recording equipment

The output from the load cell shall be recorded by an analogue or preferably by a digital device. If a digital device is used, it shall be capable of taking readings at a frequency of at least 100 s^{-1}.

> A suitable data recording equipment consists for instance of a data acquisition device *Data Translation Inc, Model DT2805*, which is controlled by a computer. The computer is also used for processing the data. This is the set-up used in the test equipment shown in Annex A.

6.3. Testing environment

The tests shall be carried out indoors at ordinary ambient conditions.

6.4. Pre-conditioning of test samples

Four of the six extinguishers shall prior to the tests be subjected to the temperature cycle defined in section 3.1 and Annex A of EN 3–5 and two of which have been subjected to external corrosion conditions defined in section 5.1 and Annex H.1 of EN 3–5.

6.5. Test procedure and data processing

6.5.1. Fixing and aligning the extinguisher

The extinguisher shall be fixed firmly with the aid of suitable auxiliary devices in the test rig and aligned so the force exerted by the force cylinder is directed perpendicularly at the normal point where the force in practice will be used in order to release the safety device or to activate the operating device of the extinguisher.

In most cases the exact point where the force is to be directed is self-evident. However, for actuating devices of the squeeze grip lever type, this point shall be located at a distance measured from the hinge of the lever, which is between 0.7 and 0.8 times the free length of the movable lever. The free length of the lever is measured along the upper side of the lever from the point where the valve actuator of the extinguisher initially contacts the lever to the free end of the lever.

If the test is to be carried out using tensile force, suitable auxiliary devices, such as pulleys and wires, shall be mounted between the extinguisher and the load cell for correctly aligning and transmitting the force.

6.5.2. Measurement of the force

The data recording device shall be started at least 60 s before the force cylinder is activated. The activation of the force cylinder causes the shaft of the cylinder to either extend or retract at a constant rate and exert a force on the safety device or actuating device of the extinguisher. The application of force is continued until the safety device is unambiguously released or the discharge of the extinguishing media starts. The data recording device shall be stopped after the application of force has ended.

When testing actuating devices of fire extinguishers which are pressurised only at the moment of operation, the application of force shall be interrupted for 5 s after the burst disc of the propellant gas cartridge has been punctured.

6.5.3. Data processing

The data recording device records continuously the exerted tensile or compressive force as a function of time. The maximum measured force is the force required to release the safety device or to activate the operating device of the particular sample of the extinguisher being tested. Figure 1 shows a typical example of a time vs. force curve for the safety device of a CO_2 extinguisher. Figure 2 shows a similar curve for the operating device of a foam extinguisher.

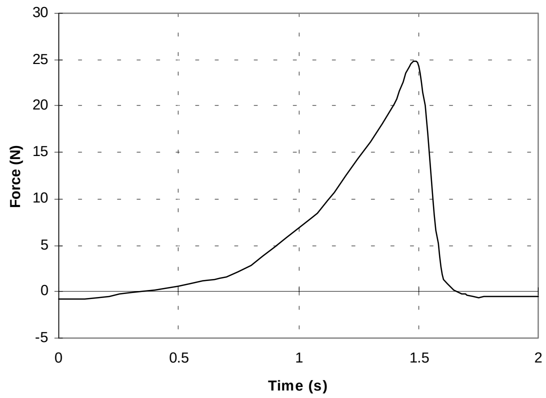


Figure 1. Example of the measured force during a test on the safety device of a CO_2 extinguisher.

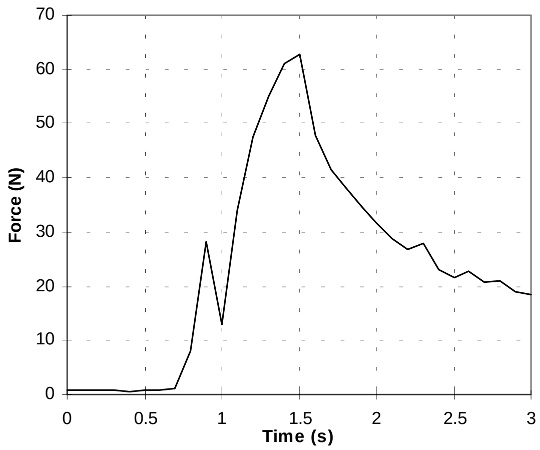


Figure 2. Example of the measured force during a test on the operating device of a foam extinguisher.

6.6. Applicability

The method is applicable to any portable fire extinguisher with an operating device of either finger trigger or squeeze grip lever type and which can be fixed and aligned correctly in the test rig.

The force measurements described in this method are simple and are as such both repeatable and reproducible. The great variations in the individual extinguishers which are introduced when the extinguishers are assembled may, however, have an unfavourable effect on the repeatability and reproducibility. This great variability affects particularly the safety devices of which the seals and wires in most cases are applied manually.

6.7. Uncertainty

The accuracy of a single force measurement on a correctly fixed and aligned extinguisher is better than ± 10 %.

6.8. Test report

The maximum force measured on each of the six extinguishers in a test series shall be reported individually on a report form according to EN 3–6. See Annex B.1.

6.9. Acceptance or rejection of the results

The acceptance criteria for the force required to release the safety device as well as the force required to activate the operating device of an extinguisher are given in EN 3–5. See Annex B.2.

Annex A. Example of a test equipment according to this method

The test rig consists of a

- base made of two 500 mm long 50 mm × 50 mm square hollow steel profile,
- framework of steel channel U profile U: 100 mm × 50 mm, and
- various mounting accessories.

The force cylinder is a *Dynox Type CS 50/8–300* electric actuator, with a stroke length of 300 mm, exerted force of 500 N and shaft velocity of 9 mm/s.

The load cell is a *Tedea Ltd, Model 606–S–100* based on a bridge of strain gauges and with a maximum capacity of 100 kg.

The data recording equipment (not shown above) consists of a *Data Translation, Inc, Model DT2805* data acquisition board mounted in a PC type computer and using a *Labtech Notebook for Windows V. 9.02* controller program.

A dust collecting cyclone for tests on powder extinguishers (not shown above).

Annex B. Requirements imposed by EN 3

B.1. Reporting the results

The relevant sections of EN 3–6 require the following information to be entered in the test report:

11. Operating temperature according to clause 3 of EN 3-5:1996				
Sample no.	**1**	**2**	**3**	**4**
Temperature at start of cycle in °C Temperature at end of cycle in °C	+ 60 1)	+ 60 1)	1) + 60	1) + 60
1) For water based agents, +5, 0, –5, –10, –15, –20 or –30 °C as claimed by the manufacturer. For other agents, –20, or –30 °C as appropriate.				

11.1 Force to remove safety device according to clause 4.2 of EN 3-5:1996				
Actual in N Permitted in N Satisfactory (yes/no)				

11. 2 Force to activate according to clause 4.1 of EN 3-5:1996				
Actual in N 1) Permitted in N Satisfactory (yes/no)				
1) If greater than 200 N at 60 °C for CO_2, then carry out test 11.7.				

11.7 Force to activate at 40 °C (CO_2 only)				
Actual [N] Permitted [N] Satisfactory (yes/no)	≤ 200	≤ 200		
Compliance according to clause 4 of EN 3-5:1996 (yes/no):				

12. Operating and control mechanisms according to clause 4 of EN 3-5:1996	
12.1 Safety device removal according to clause 4.2 of EN 3-5:1996	
Actual removal force in N Permitted removal force in N Satisfactory (yes/no)	

12.2 Safety device resistance to damage according to clause 4.2 of EN 3-5:1996	
Force/energy applied to operating mechanism Extinguisher operable (yes/no) Satisfactory (yes/no)	

17. Resistance to external corrosion according to clause 5.1 of EN 3-5:1996		
Preparation Actual	**Required**	**Satisfactory**
ISO 3768 Duration h	> 480	
Sample no.	**1**	**2**
Safety device removal according to clause 4.2 of EN 3-5:1996 Actual force in N Permitted force in N Satisfactory (yes/no)	20 to 100	20 to 100
Force to activate according to clause 4.1 of EN 3-5:1996 Actual in N Permitted in N Satisfactory (yes/no)		

B.2. Acceptance criteria

According to EN 3–5,

- the release of the safety device of a portable fire extinguisher shall require a force between 20 N and 100 N;

- the force required to activate the operating devices of a portable fire extinguisher shall not exceed 100 N for a finger trigger device or 200 N for a squeeze grip lever device. (For CO_2 extinguishers with a squeeze grip lever operating devices the force shall be no greater than 200 N at temperatures up to 40 °C and at 60 °C it shall be no greater than 300 N.); and

- a force acting on the operating device of a magnitude equal to twice the relevant value given above without first releasing the safety device, shall not deform or break any part of the mechanism in such a way as to prevent the subsequent discharge of the extinguisher.