coldcut systems

Version: 2021:02

PROJECT REPORT

SAFETY DISTANCE WHEN USING COBRA

Cold Cut Systems Svenska AB | P.O. Box 10181 | SE-434 22 Kungsbacka, Sweden
Visiting address: Borgås Gårdsväg 15, Kungsbacka | Phone +46 300 40 41 00
info@coldcutsystems.com | www.coldcutsystems.com

coldcut systems

Version: 2021:02

Project Report
Safety Distance when using Cobra

Abstract

Cold Cut Systems manufactures the Cobra Ultra High Pressure Lance (UHPL) firefighting equipment. The significant pressures involved when using this equipment make the likelihood of injury due to unsafe use quite high. The resultant injuries have the potential to be significant and possibly life threatening.

Cold Cut Systems has re-evaluated the safety distances that should be applied when using the cutting extinguisher. The safety distances should be considered as a guideline and should be adapted to suit each organisation's own practical application.

The safety distances communicated so far are generous and derived from a guideline from the Water Jet Technology Association, which is mainly aimed at water cutting and cleaning, a process that generally requires a much higher pressure than those generated by the cutting extinguisher.

The re-evaluation has been carried out using practical tests together with established theory. The tests were carried out at TST Sweden AB's office in Borås – TST develops personal protective equipment (PPE) for working with high-pressure water and tests it to existing standards at its test facility.

The results of the tests performed with Cobra showed that at two meters, a sweeping motion at a speed of 0.5 meters per second, water and abrasive does not penetrate a firefighters PPE.

Theoretically, these results mean that if someone is at a minimum of two meters away from the nozzle, when it is spraying water and abrasive in a sweeping motion, it will not penetrate a PPE. Thus, the current safety distance of 10 meters in front can be renegotiated and evaluated, within each organisation. In practice, this may facilitate the development of new methods and areas of use of Cobra.

This report aims to share the results from the tests and, together with established theory, provide a safe and reliable basis for all Cobra users to evaluate their organisation's methods and uses of Cobra.

It is up to each organisation to absorb this report and the information that emerges, the responsibility to assess the risks and apply mitigation lies within each organisation.

Table of contents

Introduction

The cutting extinguisher is often described as a tool that can quickly cut through different types of materials to reach a fire in concealed spaces and cool the hot fire gases with the help of a water mist.

The ability to quickly pierce through any known construction material to cool hot fire gases with water mist is the key attribute of the Cobra – but in terms of safety, the cutting ability can be a risk when it comes to safety distances and handling.

This report aims to offer a scientific basis for revised safety distances that may help the Cobra user to develop new methods, and to be confident in their knowledge to use Cobra at times when people are at a safe distance.

At present, when handling Coldcut Cobra, the user is advised to maintain a safety distance of 5 meters behind the front of the lance and 10 meters in front of the lance. These safety distances have no “scientific basis” but are based on old practice, probably originated from Water Jet Technology Associations (WJTA) guidelines when using water jet machines (source unknown).

In order to develop methods and guidelines with the cutting extinguisher, the safety distances need to be re-evaluated through theoretical sampling and practical tests.

A major focus in training and method development of Cobra is on safety, not least for the firefighter who can avoid entering a life-threatening environment, but also in handling the cutting extinguisher.

Training and knowledge in use of the cutting extinguisher is required – as is training and knowledge in the use of the hydraulic tools used in a rescue operation, for example in a car accident.

This project has been planned, developed and carried out by Coldcut Systems AB. The practical tests were performed in collaboration with TST Sweden AB in Borås.

Theory

A cutting extinguisher operates under high pressure, usually between 200–300 bar, and atomizes the water via a nozzle into fine droplets in the form of a water mist, like the function of a high-pressure sprinkler.

The output velocity of the water when it leaves the nozzle is roughly 200 m/s which can be compared to a high-pressure sprinkler droplet velocity of 2-20 m/s.

One of the first reports about the cutting extinguisher, mentions the importance of ensuring a safety distance during use. It states that an unprotected hand feels severe pain up until about 5-6 meters from the nozzle, at approximately 7 meters the water jet is harmless (painless) to unprotected skin.

The reasoning is that a water jet breaks up[1], considering different instabilities, at a certain distance from the nozzle. How big a distance between the nozzle and the water jet break up depends among other things on Reynold's number, nozzle design and diameter. Data exists (Litteraturdata. Kuhn, see B. Andersson, 2000) that gives information regarding the distance at which a water jet breaks, depending on the diameter of the nozzle.

A water jet with a diameter of 2 mm will, according to the data, break after 0,074 s - with a speed of 200 m/s, this means that the water jet from the cutting extinguisher will break completely at approximately 15 meters. However, when performing practical tests, the result differed from the theoretical, showing a break after 5-6 meters - though the total throw length was approximately 15 meters.

A conclusion considering the difference between theoretical data and practical tests, is that the core of the water jet breaks at 5-6 meters and that the data only reflects the throw length of 15 meters. The breakage depends on the mixture of air, after 5-6 meters the air and water droplets have the same velocity, hence the core of the water jet will break and distribute in the air. (B. Andersson, 2000).

J. Bjerregaard; D. Olsson (2007) comes to the same conclusion – all experiments showed that the water jet initially consists of an inner core for all series of experiments, and at about 5 meters from the nozzle it breaks into a water spray. There is no longer a core of water in the centre of the jet, but the water droplets are relatively evenly distributed over the cross-section of the jet.

In these tests (2007), the water jet had penetrated various building elements before, with the use of abrasive and without, it appears that penetration has no influence when the water jet breaks. All tests show a break at 5-6 meters - independent of abrasive or not as well as type of building element.

An average value of the velocity was taken at the center of the water mist at 5 meters. The mean value measured 17 (+/- 1,6) m/s - this means that the velocity has decreased significantly from the initial velocity of 200 m/s.

---

[1] Definition of water jet break: a point at which the water changes from being concentrated at the inner core of the jet to a more uniform distribution over the cross-sectional area of the jet, and at which the angle of spread of the jet increases significantly.

The knowledge that the water jet breaks and mixes completely with air at 5 meters, shows good evidence to reconsider the current safety distance of 10 meters.

Regulations and standards

The cutting extinguisher is a firefighting tool, so the user should be dressed accordingly. There are national and international regulations and standards that specify how firefighting Personal Protective Equipment (PPE) should be designed and worn.

Swedish regulations

- Swedish Work Environment Authority's regulations on smoke and chemical diving (AFS 2007:7)

Sweden's regulation AFS 2007:7 is directing work with smoke and chemical operations, with the aim of preserving health and preventing accidents while performing breathing apparatus (BA) attacks in connection with smoke and/or chemicals.

The regulation defines firefighting PPE: Full protective clothing for the protection of the body, neck, arms, and legs with non-flammable outer material which, in combination with insulating or lining material, provides adequate thermal insulation.

The fire suit is part of the personal protective equipment (PPE) and is therefore subject to specific rules.

European standards

- Protective clothing for firefighters - Performance requirements for protective clothing for firefighting activities (SS-EN 469:2020)

The standard specifies the minimum performance requirements for protective clothing designed to be worn during firefighting activities. The requirements detailed in the standard cover design, heat and flame, mechanical, chemical, comfort, and visibility.

- Respiratory protective devices – Full face masks – Requirements, testing, marking (SS-EN 136:1998)

The standard specifies the minimum requirements for full face masks for respiratory protective devices.

Method

To develop new methods and guidelines for Cobra, practical tests together with established theory form the basis for re-evaluating safety distances when handling Cobra.

The aims of the practical tests were:

- To find a distance where Cobra does not cut through, nor leave marks, on PPE covered skin exposed to Cobra
- To find a distance where Cobra does not cut through, nor leave marks, on a BA mask exposed to Cobra

Experimental setup

The Cobra unit used for the tests was a C360P, with a 300 bar pressure at the pump and water flow rate of 58 l/min, nozzle diameter 2.3 mm. This creates a water jet speed of approximately 225 m/s at the nozzle. For easier handling of the lance, a test lance was used, which is a shortened version of Cobra hand lance. Technically, the test lance has no controls for calling water or abrasive, and no controls for securing or calling additives. In practice, it operates in the same way as Cobra hand lance but with manual override.

TST Borås contributed to the tests with its custom-made test bench consisting of a conveyor cart which moves at a speed of 0.5 m/s along a horizontal path of about 1.5 meter. The conveyor cart was started manually via a remote control.

In all tests, Cobra was used with manual override at approximately 10 m from the setup.

To mimic reality as closely as possible, the applicable regulations and standards have been complied with. The current Swedish regulation for BA-attacks is AFS 2007:7, which refers to specific rules for fire protection suits - thus the current SS-EN standards have been complied with regarding fire protection suits and masks.

First setup

The moving conveyor cart was covered with materials to correspond to skin covered with clothing representative of what was to be tested. In this case, a firefighter dressed in cotton t-shirt and a fire suit which complies with the European standard *Protective clothing for firefighters - Performance requirements for protective clothing for firefighting activities* (SS-EN 469-2020).

Above the horizontal track, on which the conveyor cart was travelling, was a rack where the Cobra lance was fixed at different heights.

The test setup corresponds to a sweeping motion with Cobra.

Figure 1 Conveyor cart with test clothing

Figure 2 Cobra lance fixed to the rack

Figure 3 Cobra test lance fixed to the rack

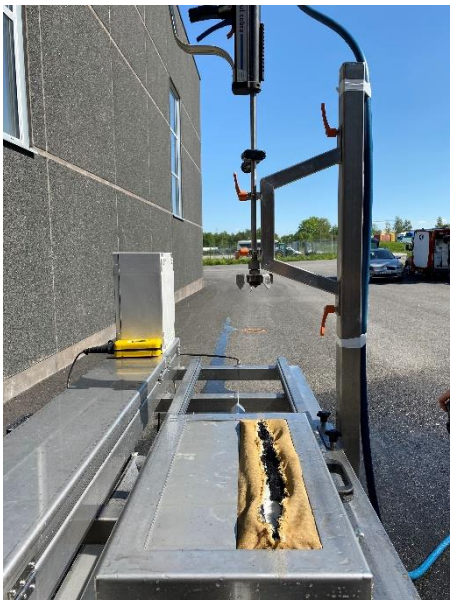


Figure 4 Test setup, picture after first test

Second setup

A manikin doll was used as a dummy for the tests. Dressed in a cotton t-shirt and a fire suit, which complies with the European standard *Protective clothing for firefighters - Performance requirements for protective clothing for firefighting activities* (SS-EN 469-2020). The test object was placed on a forklift at a measured distance from the Cobra. The test object measured 0.75 meters high and was suspended on a forklift 0.7 meters above ground.

Cobra was placed on the moving conveyor cart, further explained above, to correspond to a sweeping motion.

Figure 5 Test setup, 5 m from nozzle to test object

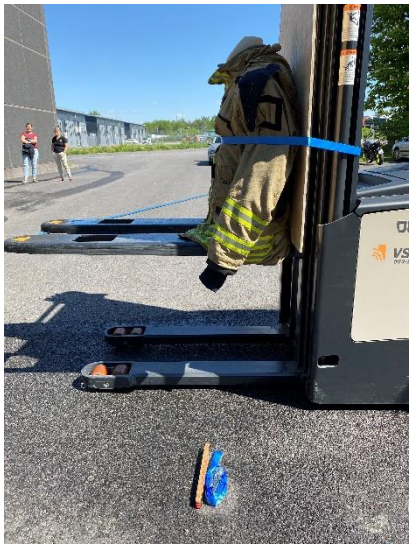


Figure 6 Test object fixed

Figure 7 Cobra test lance fixed

Figure 8 Test setup

Third setup

A BA mask, which complies to European standard *Respiratory protective devices – Full face masks – Requirements, testing, marking* (SS-EN 136), was fixed to the forklift at 2 meters from Cobra and at a height of 0.8 meters.

The cobra was again placed on the moving conveyor cart, further explained above, to correspond to a sweeping motion.

Figure 9 BA Mask test at 2 m, before

Figure 10 BA Mask test at 2 m, after

Procedure

The tests were performed in TST Borås laboratory on site, where they (TST) normally perform tests from ultra-high pressure (UHP) water jets on their own manufactured protective clothes.

At first, three trials were performed at the relatively short distance of 0.32 meters and 0.93 meters – two trials were made at 0.93 meters, one with abrasive and one without. The conveyor cart was prepared with three layers of material corresponding to skin and on top a t-shirt and a fire suit. The abrasive was already induced when the test started.

After the first test the Cobra lance was changed to a Cobra test lance which is equivalent to a Cobra lance, only easier to handle. See detailed description under Experimental setup.

For all tests, Cobra was started and allowed to spray for 3 seconds to reach the correct working pressure, then the conveyor cart moved horizontally at a speed of 0.5 m/s. Starting point of the conveyor cart was before the water jet, then straight through the water jet and stopped at the other side of the water jet.

Following tests were performed at longer distances. To reflect a sweeping movement, Cobra was fixed on the moving conveyor cart and a test object (manikin doll) was dressed in clothes corresponding to a fire fighters PPE.

The test object was suspended on a forklift and fixed with a strap as the pressure from Cobra would blow the doll away. The first tests were performed without abrasive to find the distance at which only the water jet itself penetrates the clothes or makes impact on the textile.

The following tests were performed with abrasive, which was already induced at the beginning of the test. The tests were considered complete when the textile of the outer garment had been affected.

All “longer distance-tests” started at a predetermined distance of 5 meters, which is the current guideline for people behind the Cobra lance nozzle. Once the test was performed, the test object (manikin) was moved forward one meter, to reduce the distance to Cobra. This test procedure (change of 1 meter) was performed down to 2 meters from the Cobra, which was the distance deemed reasonable to have as the shortest distance for guidelines when working with the Cobra. The tests with abrasive and water were also performed at 2.5 meters.

The test object was suspended at a height of 0.7 meter until the test at 3.0 m with abrasive – the textile was worn due to repeated attempts at the same spot. With a new height of 0.8 meter above ground, the tests could continue, and the effect of the abrasive could be detected faster.

At 2 meters distance from Cobra, one test with abrasive was performed at a BA mask. The test was performed in the same way as the last test on the manikin explained above.

Results

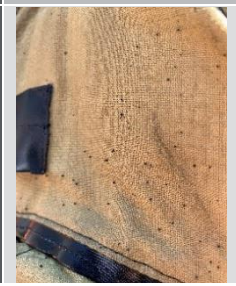
Short Distance Test – Cobra with water & abrasive

Test nr.	1	2	3
Distance from Cobra [m]	0.32	0.93	0.93 – Without abrasive
Comments	Cut right through fire suit, t-shirt and three layers of build-up equivalent to skin.	Cut right through fire suit, t-shirt and three layers of build-up equivalent to skin.	Did not cut through fire suit but moved textile fibers, hence it cut right through t-shirt and one of three layers of build-up equivalent to skin.
Pictures			

Long Distance Test – Cobra with water

Test nr.	4	5	6	7
Distance from Cobra [m]	5.0	4.0	3.0	2.0
Height above ground [m]	0.7	0.7	0.7	0.7
Comments	No impact, except wet.	No impact, except wet	No impact, except wet.	No impact, except wet.
Pictures				

Long Distance Test – Cobra with abrasive

Test nr.	8	9	10	11	12
Distance from Cobra [m]	5.0	4.0	3.0	2.5	2.0
Height above ground [m]	0.7	0.7	0.8	0.8	0.8
Comments	Abrasive visible on test object. No visible damage on garment.	Abrasive visible on test object. No visible damage on garment.	New height due to worn textile. Abrasive visible on test object. No visible damage on garment.	Visible damage on garment, no damage on t-shirt inside outer garment.	Visible damage on garment, no damage on t-shirt inside outer garment.
Pictures					

BA Mask Test – Cobra with abrasive

Test nr.	13
Distance from Cobra [m]	2.0
Height above ground [m]	0.8
Comments	Visible marks on the outside of the visor, as if it were blazed. No noticeable marks on the inside of the visor.
Pictures	 

Discussion

The tests were carried out on the assumption that in case of an accident during an incident, the water jet hits the fire suit in a sweeping motion. The fire suit is part of the firefighters PPE which is established by national and international regulations and standards. Given the sweeping motion, it is assumed that no accident happens in a static position – either tripping or falling, which creates a sweeping motion with the cutting extinguisher.

Previous tests, described in B. Andersson 2000, are performed on an unprotected hand and states that severe pain is felt at 5-6 meter from the nozzle, but already at 7 meter no pain is felt. The tests presented in this report have taken more height and include the clothing worn by the firefighter and the crew around the user of the cutting extinguisher. A reasonable scenario as this is applicable to a real incident.

The results of this report show that at a distance of 2 meters, marks are visible on the outer garments, but the textile fibres remain in place, leaving the inner garments undamaged. At about 1 meter (0.93 m), Cobra cuts through the outer garments and penetrates the skin.

These results indicates that Cobra will not cut through, nor move the fibres in the textile, at more than 2 meters. This applies on a fire suit which complies to the European standard.

Two independent sources, B. Andersson (2000) and J. Bjerregaard; D. Olsson (2007), have come to the same practical conclusions regarding breakage of the water jets. Both have measured a complete break at 5-6 m. This is because, according to Andersson (2000), the water droplets are completely mixed with the air and both elements have the same speed, hence there is no longer an inner core in the water jet. It is most likely the coherent, inner core of the water jet that causes pain and damages the garment.

In J. Bjerregaard; D. Olsson (2007), the average velocity at 5 meters was measured to be about 17 m/s. With an initial velocity of about 225 m/s, this means that the water is slowed down quickly, which in turn causes less damage.

Possible sources of error

In the first tests, performed at 0.32 and 0.93 meter, Cobra was fixed in a vertical position while in the long distance tests, Cobra was fixed in a horizontal position. In the vertical position, the water jet was “helped by gravity”, which causes all the water to land on the sample, while in the horizontal position there could be some "wastage" as the water droplets travel in a projectile motion. This should not have any influence on the outcome of the tests, considering the high speed of the water.

Lessons learned

Do not use a black t-shirt on the test object. Dress the test object in a white/light t-shirt under the PPE so that it is visible if abrasive has penetrated the outer garment. Change the height of the test object to avoid worn-out textiles due to repeated attempts on the same surface.

Conclusion

The tests presented in this report shows that at 2 meters from the nozzle, water and abrasive does not penetrate the PPE.

Supported with the tests from B. Andersson (2000), it can be concluded that at 5-6 meter from the nozzle, the PPE is undamaged, and no pain is felt. This with water and abrasive, and the jet hits the PPE in a sweeping motion.

The aim of this report was to ensure scientifically based distances that help the Cobra user to develop new methods, and to be confident in their knowledge to use Cobra at times when people are at a safe distance. It is up to every organisation to do their own risk assessment and apply the results presented in this report.

Reference List

AFS 2007:7. *Arbetsmiljöverkets föreskrifter om rök- och kemdykning samt allmänna råd om tillämpningen av föreskrifterna*. https://www.av.se/globalassets/filer/publikationer/foreskrifter/rok-och-kemdykning-foreskrifter-afs2007-7.pdf

B. Andersson, *Skärsläckaren - tillkomst och utveckling*. Karlstad: Räddningsverket, 2000.

J. Bjerregaard; D. Olsson. *Skärsläckaren - experimentella försök och beräkningar*. Lund, 2007.

Swedish Institute for Standards. 2004. *Respiratory protective devices – Full face masks – Requirements, testing, marking* (SS-EN 136:1998).

Swedish Institute for Standards. 2020. *Protective clothing for firefighters - Performance requirements for protective clothing for firefighting activities* (SS-EN 469:2020).

Appendices

Declaration of conformity (from TST)

TST Sweden AB
Segloravägen 22

50464 Borås

Sweden

Phone: +46 320 20 58 80
E-mail: Info@tst-sweden.se

Date: 6 Juni 2021

Subject: Test on protective clothing from CCS

Requested by: Cold Cut Systems, CCS

Contact name:	Catrin Tammjärv
Street:	Segloravägen 22
City:	50464 Borås
Country:	Sweden

Phone:	+46 320 20 58 77
Mobile:	
E-mail:	Catrin@tst-sweden.se

Test location:	TST Sweden AB

Persons present:
Per-Arne Andersson, TST
Catrin Tammjärv, TST
Lena Håkansson, CCS
Daniel Scott, CCS

Test:

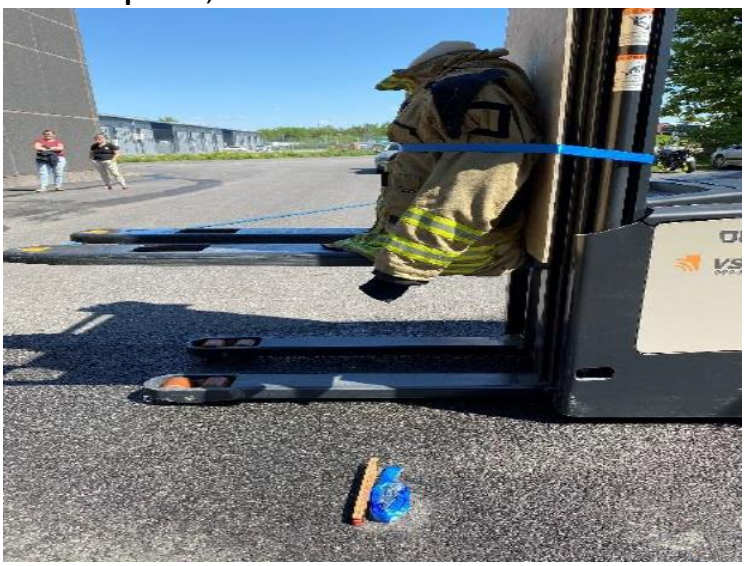
Test of protective clothing from CCS.
CCS had their own car with high-pressure pump (water and abrasive)
The stand-off distance from the nozzles the surface of the material has to be a constant 75 mm and the
traverse speed should be **0,5 m/s** but now we will test which distances affect the clothes.

Subject:	**Test on protective clothing (CCS)**
Material:	Protective clothing for firefighting
Pump:	Cobra unit C360P 300 Bar pressure [58 l/min] Water flow
Accessories:	Singel Nozzle Ø=2,3 mm, Waterjet speed ~225 m/s, Test lance from Cobra Traverse speed 0,5 m/s

Test setup no 1, Distance 0,35m

TST Sweden AB
Segloravägen 22, SE-504 64 Borås, Tel +46 320 20 58 80
www.tst-sweden.com info@tst-sweden.se
ISO 9001:2015 and ISO 14001:2015

Test setup no 2, Distance 5m Horizontal



Test setuo no2,Test object fixed

Test setup no2, Test lance fixed

Test setup no2, 3m

Test setup no 3, BA Mask test

SAVING LIVES

Setup. no.	Pressure [bar]	V [l/min]	Nozzle			Feed rate [mm/s]	Time [sec]	RPM [1/min]	a [°]	Distance [mm]	Result	Comments
			n	Ø [mm]	Type							
1	300	58	1	2,3	Cobra	500	--	-	90	75	Penetration	Vertical Test with Abrasive Single jet nozzle
1	300	58	1	2,3	Cobra	500	-	-	90	320	Penetration	Vertical Test, with Abrasive
1	300	58	1	2,3	Cobra	500	-	-	90	930	Penetration	Vertical Test, with Abrasive
1	300	58	1	2,3	Cobra	500	-	-	90	930	Penetration	Vertical Test, only water
2	300	58	1	2,3	Cobra	500	-	-	90	5000	No Penetration	Horizontal Test, only water
2	300	58	1	2,3	Cobra	500	-	-	90	4000	No Penetration	Horizontal Test, only water
2	300	58	1	2,3	Cobra	500	-	-	90	3000	No Penetration	Horizontal Test, only water
2	300	58	1	2,3	Cobra	500	-	-	90	2000	No Penetration	Horizontal Test, only water
2	300	58	1	2,3	Cobra	500	-	-	90	5000	No Penetration	Horizontal Test, with Abrasive
2	300	58	1	2,3	Cobra	500	-	-	90	4000	No Penetration	Horizontal Test, with Abrasive
2	300	58	1	2,3	Cobra	500	-	-	90	3000	No Penetration	Horizontal Test, with Abrasive
2	300	58	1	2,3	Cobra	500	-	-	90	2500	No Penetration	Horizontal Test, with Abrasive
2	300	58	1	2,3	Cobra	500	-	-	90	2000	No Penetration	Horizontal Test, with Abrasive
3	300	58	1	2,3	Cobra	500	-	-	90	2000	No Penetration	Horizontal Test, with Abrasive

TST Sweden AB
Segloravägen 22, SE-504 64 Borås, Tel +46 320 20 58 80
www.tst-sweden.com info@tst-sweden.se
ISO 9001:2015 and ISO 14001:2015