FFI RAPPORT

TESTING OF THE CHEMICAL, ATOMIC AND TOXIC COMPOUND SURVEILLANCE SYSTEM - CATSS

TØRNES John Aasulf, PRYDZ Petter, NILSSEN Jan Rune, SAGSVEEN Bendik

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8) ABSTRACT
A first prototype of the Chemical, Atomic and Toxic compound Surveillance System (CATSS) has been developed at FFI. The prototype has been tested during winter conditions at FFI and has been field tested at Ørland Main Air Station from February to April 2006. The results have been good, and the tests have shown that only small modifications to the design of the Templum stations are necessary. The Templum has also been displayed at several conferences during 2005-2006.

Some of the materials used in the Templum prototype have been tested against methyl salicylate, a simulant for sulphur mustard. These tests show that the carbon material used in the Templum does not absorb/adsorb much of the simulant, even after 202 days exposure, and is therefore very suited for its purpose. The POM-C plastic material used in the instrument bottom plate, however, takes up quite much of the simulant and has therefore been substituted by a metal plate.

The software used both in the Templum and in the CATSS central is now being modified and made more user-friendly. This work is not finished yet, but will continue in 2007.

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CONTENTS

		Page
1	INTRODUCTION	7
2	SYSTEM DESCRIPTION	8
2.1	Mechanical design	8
2.2	Software	11
2.3	Power consumption	11
3	SHRIVENHAM SYMPOSIUM	12
4	WINTER TESTS 2005-2006	12
4.1	Compatibility tests	12
4.2	Winter test at FFI	14
4.3	Field test at Ørland Main Air station	17
5	FUTURE DEVELOPMENT	20
6	CONCLUSION	22
References		23

TESTING OF THE CHEMICAL, ATOMIC AND TOXIC COMPOUND SURVEILLANCE SYSTEM - CATSS

1 INTRODUCTION

Detection and reporting of possible chemical, biological, radiological and nuclear (CBRN) events in the armed forces of most countries is normally done manually. In case of C-events, detection is either carried out using C-sensitive detection paper, systems based on wet chemistry or C-sensitive electronic detectors. The subsequent warning is conveyed by voice, cable or radio communication to neighboring or higher units. The arrival of increasingly advanced command, control and information systems (C2IS) has actualized the question for an automatic, unattended system which is able to detect, identify, warn and report a release of N- and C-agents and other toxic materials. Norway and many other countries are to an increasing extent involved in military operations in many regions around the world. The risk of being exposed to poisonous agents cannot be excluded (1) and an interest for a surveillance system being able to detect releases of chemical agents, toxic industrial materials/chemicals (TIMs/TICs) or releases of radiological materials has materialised. For this reason, the Norwegian Defence Research Establishment (NDRE) has since 2001 been conducting a program to develop and assemble a prototype of an automatic and network based CBRN surveillance system. The system is based on off-the-shelf sensor equipment. Main activities have consisted of designing and building of the sensor unit cabinets and the software connecting and conveying the information from various sensors to a central computer. The computer is carrying out logging, computing and data interpretation and presentation. The surveillance system has been named Chemical, Atomic and Toxic compound Surveillance System (CATSS).

The work with the CATSS system was started in 2001, and a demonstrator was ready in 2004 (2). The demonstrator has been shown at the Eight International Symposium on Protection against Chemical and Biological Warfare Agents in 2004 (3). The functionality of the demonstrator was tested during two field exercises in 2004; Exercise Kristiania 21-22 September (4) and Force Protection Concept Experiment in Kirkenes on 22-24 November (5). After the testing of the demonstrator was finished, a prototype was designed by the students Christian Karlsson and Halvor Skrede as a project at the Akershus University College, faculty of product design (6). This prototype was displayed for the first time at the VIIIth International CBRN Defence Symposium at Shrivenham in November 2005 (7). After this symposium, the CATSS prototype has gone through extensive field testing, both at FFI and at Ørland Main Air station. These tests will be described in this report.

2 SYSTEM DESCRIPTION

2.1 Mechanical design

A new CATSS sensor unit with a unique new design, called Templum (shown in the pictures below), was made by two students (Christian Karlsson and Halvor Skrede) at Akershus University College, faculty of product design (6) during 2005. The CATSS mechanical design is shown in Figure 2.1.

Figure 2.1 The newly designed CATSS unit called Templum during operation (left) and transport (right). The Templum is made from carbon (black) and aluminium (gray)

The CATSS mechanical structure is composed of two instrument compartments, separated and connected by four aluminium tubes, also acting as cable gates. The lower compartment is supported by four telescopic legs. The legs can be folded back, along the sides of the compartments, working as handles suitable for carrying the CATSS. The instrument (top) and computer (lower) compartments are made from laminated carbon fibre composite, with flanges, top-caps and bottom plates in aluminium. Flanges and top caps are glued onto the composite compartments. Access into the instrument compartments is made by sliding them upwards on sliding rails, splitting the compartments at the bottom plate interface. The main materials used in this design are shown in Table 2.1.

Component	Material	Manufacturer/Supplier
Instrument compartments	Carbon fibre / Epoxy pre-preg HexPly ES/EH84	Hexcel Composites
Top-caps and bottom plates	Aluminium 6082-T6	Astrup AS
Other structural metal components	Aluminium 6082-T6 and Stainless steel AISI 304	Astrup AS CCB Stål AS
Other structural plastic components	POM-C (polyacetal copolymer)	Astrup AS
Telescopic legs	Carbon fibre / vinyl ester composite	Exel OY
Glue	Araldite AY105 / HY991	Huntsman / Lindberg og Lund AS

Table 2.1 CATSS construction materials

The instrument compartments are laminated on an aluminium plug, and cured at 120 °C for 90 minutes at a vacuum of 0.9 bar. The lay-up is given in Table 2.2. Duplicolor clear acryl paint (up to nine layers) was used on the outside of the carbon compartments.

Ply number from inside	Angle (deg)	Thickness (mm)
1	0/90	0.2
2	±45	0.2
3	0/90	0.2
4	±45	0.2
5	0/90	0.2
6	±45	0.2
7	0/90	0.2
Total thickness		*1.4*

Table 2.2 Lay-up for instrument compartment

The diameter of the Templum is 29 cm and the height without legs is 79 cm. The length of the legs could be adjusted from 79 cm to 170 cm. The detectors currently in the prototype are shown in Table 2.3 below. The GPS-receiver and antenna is placed on top of the upper compartment. The total weight of the Templum, including detectors, is 17.3 kg.

Sensor function	Model	Manufacturer
Chemical warfare agents	LCD 3.1	Smiths Detection, UK
Toxcic industrial chemicals	Multiwarn II	Dräger, Germany
Gamma radiation	Automess	Automation und Messtechnik, Germany
Temp/Humidity	MTO	G.Lufft- und Regeltechnik, Germany
GPS	MR-350	USGlobalSat, USA

Table 2.3 Overview of the sensors installed in the Templum

The integration of the hardware components into the Templum was carried out at FFI. An ultrasonic wind sensor from Gill Instruments, UK, was used earlier in the CATSS demonstrator. The wind sensor was not included in the Templum, but will probably be used again in the next version. This will be done because information of the wind magnitude and direction is important for the prediction of the movement of a toxic vapour cloud.

The upper and lower compartments could easily be opened by sliding the outer carbon casing upwards as shown in Figure 2.2. The internal computer, a VIPER-400-M64-F32-I (Intel XScale TM PXA255 with 400MHz microprocessor, 64MByte SDRAM, 32MByte FLASH) could be unfolded to ease the access as shown in Figure 2.2.

Figure 2.2 The Templum opened to have access to the upper (detector) and lower (computer) compartments. The computer in the lower compartment is unfolded

Communication between the Templums and the central is carried out by radio or cable. One radio solution was tested during the winter field test at Ørland Main Air station (see Chapter 4.3) but was not found to be ideal for the system because of its large size. A better radio-system has therefore to be selected.

2.2 Software

The previous version of the CATSS software described in a FFI-report (8) used Microsoft Windows XP as the operating system both in the Templums and in the central. The new version is using Arcom Embedded Linux in the Templums and Microsoft Windows XP in the central as the operative systems. The software in the Templums is written in the C language with the GCC compiler as the development platform. The CATSS Central software is developed as a module in the Normans Engine system (9) written in the C++ language using Microsoft Visual Studio.net as the development tool.

2.3 Power consumption

It is important to know the power consumption for the whole Templum. This was found by measuring the current drawn by the Templum (excluding radio communication) for a period of 22 hours (80 000 sec). The measurements were done indoors at a temperature of approximately 22 ºC.

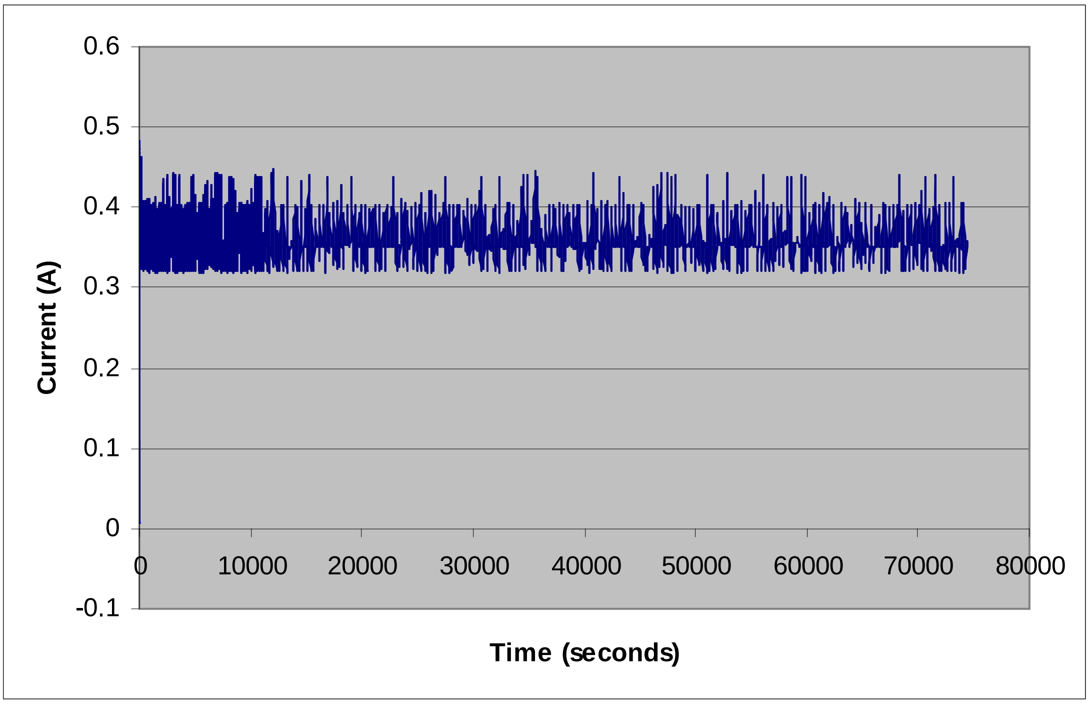

Figure 2.3 Templum power consumption

It was found that the CATSS power consumption was between 0.3 A and 0.4 A during the whole test period. It is, however, important to remember that if a battery is used as a power supply, low temperatures will reduce the effect. Currently, a lead battery from Biltema (88 Ah) has been tested at three different temperatures (20 ºC, 0 ºC and -20 ºC). The effect was reduced from 79.20 Ah at 20 ºC, via 63.84 Ah at 0 ºC to 39.12 Ah at -20 ºC). This means that the effect is reduced to 50% when the temperature is lowered from 20 ºC to -20 ºC. The battery has dimensions 35 cm x 18 cm x 20 cm and a weight of 23.15 kg.

3 SHRIVENHAM SYMPOSIUM

The new design of the Templum and the new software was displayed for the first time at the VIIIth International CBRN Defence Symposium at Shrivenham in November 2005 (7). A display booth was rented at the symposium (see Figure 3.1) and an oral presentation was held. Some interested people visited the stand, but no specific deals were made.

Figure 3.1 CATSS on display at the Shrivenham symposium, UK, in November 2005

4 WINTER TESTS 2005-2006

4.1 Compatibility tests

It is important to find out whether or not the materials used in construction of the Templum could withstand an attack with chemical warfare agents. It was decided to carry out laboratory tests to find the amount of the simulant methyl salicylate (MS) that would be absorbed/adsorbed by the two materials polyacetal (POM-C) used in the detector base plate and the carbon/epoxy material used in the production of the Templum (se Chapter 2.1). MS is a blister agent simulant with a boiling point of 223 ºC.

Polyacetals, like POM-C, are semi-crystalline plastic materials based on formaldehyde with the acetal structure -O-C-O-. It is amorphous in structure over certain temperature ranges (at higher temperatures), whereas the molecules assumes a definite order at lower temperatures. Semi-crystalline plastics are tough, stable and hard at room temperature. POM-C has the ability to absorb 0.25 % moisture at 23 ºC and 50 % relative humidity (RH). The maximum operating temperature is 100 ºC (continuous) and 140 ºC (short term) (www.germanlipa.de). Glass transition temperatures are reported from -85 ºC to -74 ºC (10).

The material used in the side panels of the Templum is a carbon : epoxy (60 : 40) (% weight) material with product name HexPly EH84 produced by Hexcel Composites, California, USA (www.hexcel.com). The material is of Prepreg type, i.e. the epoxy is added by the producer.

The experiments were carried out by exposing the two types of material (POM-C and carbon/epoxy) to a saturated atmosphere of MS in an exicator. The POM-C material was first sliced into 100 µm thick pieces with an area of about 25 mm^2. This gives pieces with volume 2.5 mm^3. Enough POM-C pieces to get a total mass of 300 mg were used. The carbon/epoxy material was not possible to slice into small pieces. For this material, one larger piece with area (approximately 9.6 cm^2) and a thickness of 0.6 mm was used. Similar control samples, which were not exposed to MS, were prepared for both materials.

The weight gains of the materials were measured at certain intervals during a time period of 202 days. The weight gains were measured 1-2 times per week in the beginning and later every 1-2 weeks during the whole period.

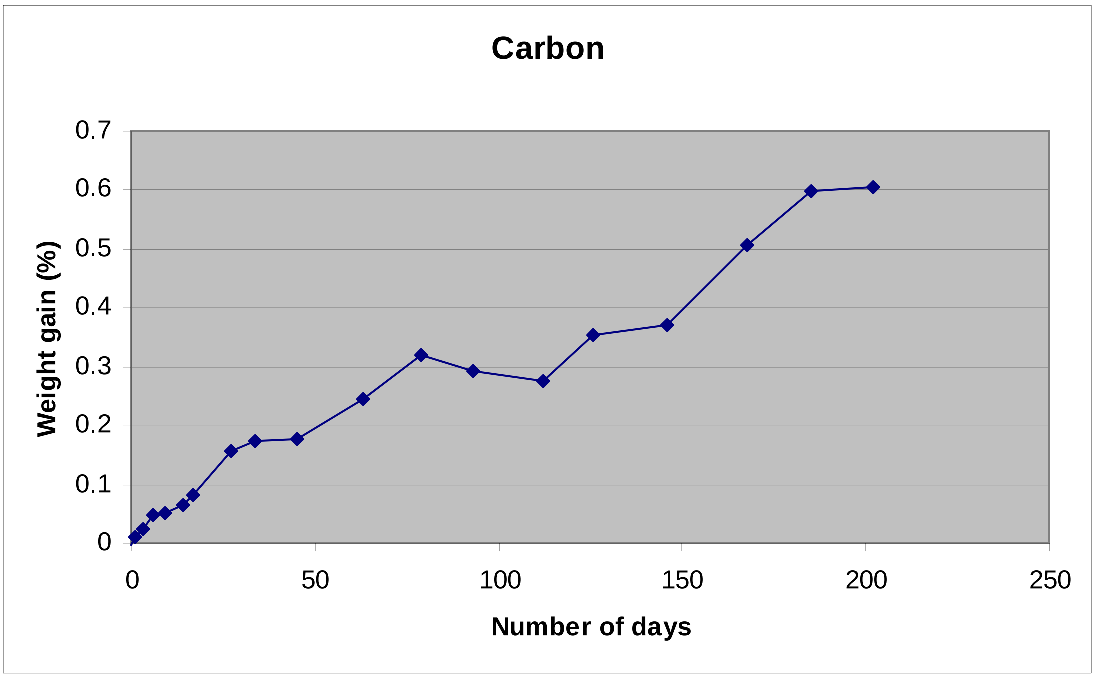

Figure 4.1 Sorption of methyl salicylate by the carbon/epoxy material used in the Templum

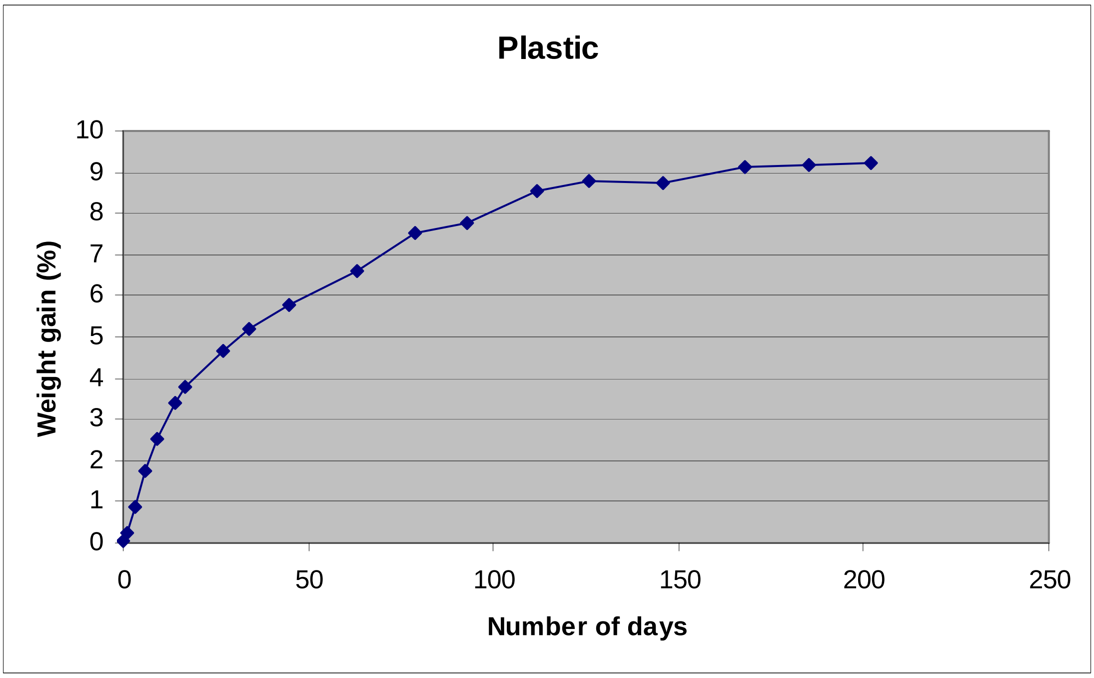

Figure 4.2   Sorption of methyl salicylate by the plastic material POM-C

The results given in Figure 4.1 show that not much (less than 0.6 % weight) of the test agent MS is absorbed by the carbon/epoxy material. This material is therefore very suited for this purpose. The POM-C material, however, takes up a large portion of MS (up to 10 % after 202 days) as shown in Figure 4.2. This material is therefore not suited in the construction of the Templum and is now replaced by a steel plate.

4.2 Winter test at FFI

In order to find out whether the Templum could withstand snow and cold weather, it was placed outside one of the buildings at FFI for one month from December 5th 2005 until January 6th 2006. The temperature and humidity inside the upper compartment of the Templum were logged by a temperature/humidity logger from HOBO. The compartments were opened two times during the period to check for water inside. The inside of the Templum was found to be dry all the time.

The weather conditions at Gardermoen airport, 25 km from Kjeller, during the winter test are shown in Table 4.1. This table show that the temperature fluctuated between -14.3 ºC to +9.1 ºC with most of the days below zero degrees. The maximum snow depth during the test was 22 cm at December 8th.

Day	Min temp.	Max temp.	Max wind	Mean wind	Relativ humidity	Precipitation	Snow-depth
Dec 05							
5	-1.4	0.2	6.2	3.4	98	2.7	12
6	0	0.9	7.7	4.8	98	3.5	17
7	-0.8	0.7	10.3	4.8	99	5.3	15
8	-2.1	-0.7		3	98	15.7	22
9	-9.2	-1.6	3.1	0.7	98	2	20
10	-8.6	1.4	6.7	1.7	99	0	16
11	-0.8	9.1	6.2	2.2	93	1.2	15
12	-2.3	7	6.7	3.1	54	0	
13	-5.2	2.6	5.1	1.7	83	0	10
14	-5.5	1.1	4.1	1.9	91	0	13
15	-2.9	2.8	8.2	4.1	74	0	
16	-6	-0.5	5.7	2.9	67	0	10
17	-9.9	-0.4	8.2	4.3	72	0	10
18	-7.6	0.3	9.3	1.4	80	0.3	12
19	-14.3	-4.5	1.5	0.5	96	0	12
20	-11.9	-4.5	2.6	0.8	95	2.5	16
21	-13	-6.8	1.5	0.7	96	0	16
22	-6.8	-1.1	3.1	1.2	100	2.2	14
23	-6.8	1.3	6.7	2.7	99	0.2	13
24	-5.3	1.2	8.7	2.7	80	0.9	
25	-5.7	2.3	10.3	6.4	60	0	
26	-5.1	2.5	11.8	7.5	71	0.1	15
27	-10.7	-5		4.5	88	0	15
28	-12	-7.1	8.7	5.8	89	0	15
29	-7.9	-5.6	13.4	8.9	88	0	15
30	-6.6	-3.8	10.3	1.5	95	6.6	
31	-5.3	-2.7	3.6	1.7	95	8	19
Jan 06							
1	-5.1	-2.7	7.2	2.7	94	2.7	21
2	-13.2	-3.8	2.1	0.5	93	0.4	19
3	-15	-8.9	1.5	0.5	94	0	19
4	-9.7	-7.5	2.1	0.7	96	0	19
5	-8.5	-4.4	1.5	0.8	98	0.2	19
6	-6	-4.3	3.1	1.9	97	0.4	19

Table 4.1 Weather at Gardermoen airport in December 2005 and January 2006 (Source: met.no)

At the end of the month, the detectors were turned on and connected to the CATSS central to find out if they worked after being exposed to the ambient weather for one month. The system worked without problems until it was turned off 4 hours later.

Figure 4.3 The Templum at FFI during the winter test in December 2005

The temperature and humidity was also logged inside the Templum. The results are shown in Figure 4.4 and are in good agreement with the data from Gardermoen shown in Table 4.1.

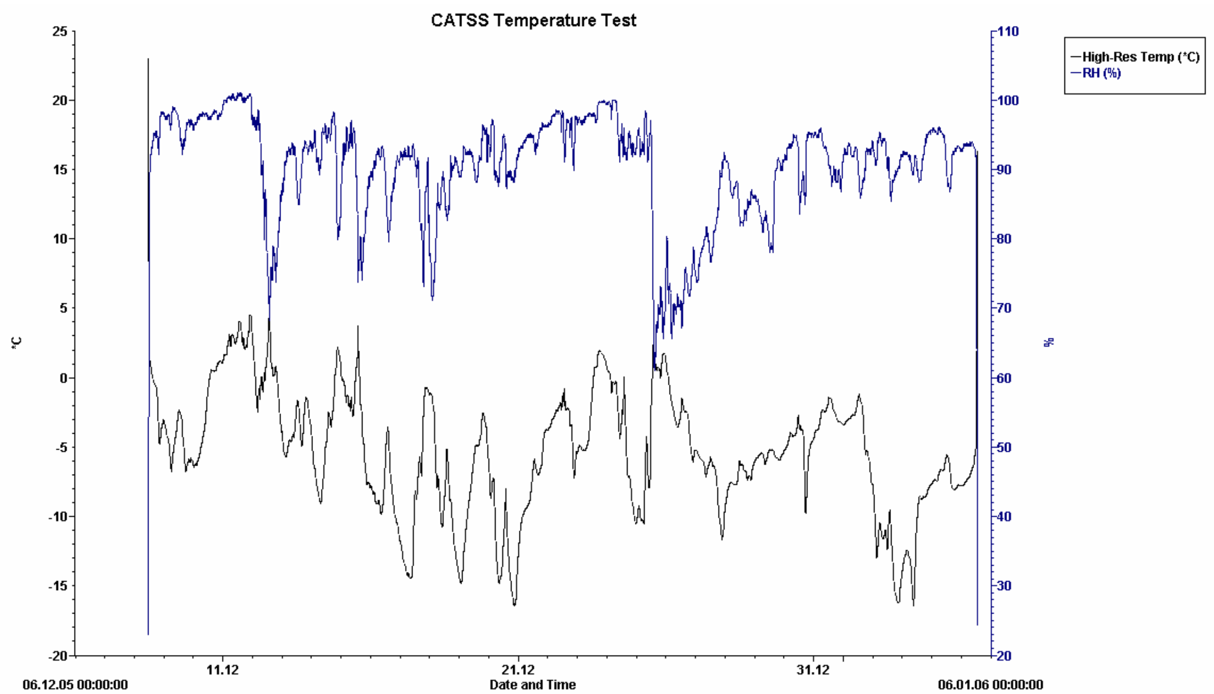

Figure 4.4 Temperature (°C)(lower graph) and relative humidity, RH (%) (upper graph), during the winter test, measured inside the upper compartment of the Templum using a HOBO data logger

4.3 Field test at Ørland Main Air station

In order to test the performance of the complete CATSS system during winter conditions, the system was deployed at Ørland Main Air station from 23 February until 5 April 2006. Two Templum sensor stations (called unit no 1 and unit no 2) were mounted up and connected to a central via radio. The distances between the Templum sensor stations and the central were below 100 m. The positions of the Templum units were:

Position CATSS no 1: 32V NR3125063210 (63.69539N 9.63207E)
Position CATSS no 2: 32V NR3131763236 (63.69548N 9.63340E)

The CATSS stations had to be fastened to the fence in order to prevent it from being turned over by the wind (we were told) (see Figure 4.5).

The CATSS central was placed in a simulated control room inside a medical container complex. The radio antenna for the central was mounted on the rooftop of one of the containers.

Figure 4.5 CATSS mounted up at Ørland Main Air station

The radio system used between the Templum CATSS stations and the terminal in this test was WM 600 TacLAN system from Kongsberg Defence Communications AS. The radio uses WLAN over UHF (225-400 MHz) with maximum effect 1W. Two relatively small portable units (WM600P) were used in each Templum (Figure 4.6) and one larger unit (WM600) was used in the control room close to the CATSS central. The portable units (WM600P) have dimensions 56 mm x 106 mm x 205 mm and weigh 0.7 kg each. These units were too large to fit inside the Templum casing. The radios were therefore mounted outside the Templum under a plastic cover during the field test (see Figure 4.5).

Figure 4.6 Portable radio WM600P from Kongsberg Defence Communications AS

The CATSS central was connected to Internet in order to be able to monitor and control the CATSS system with TightVNC remotely from FFI or other computers connected to Internet. A password was used to prevent unauthorised connections. One day was used to set up the system, including set-up of TightVNC connection to Internet.

During the test period some bugs in the CATSS software was identified:

Map – centre to new position at Ørland was not implemented
We did not obtain GPS-fix from unit no 1 (this GPS was later found to be out of order)
The system needs a more automatic and user-friendly start-up procedure
The legs were unstable in high positions

We also needed to bring the lap-top out to the CATSS unit to get it up running. This would require a more weather-proof computer in order to prevent water from entering the computer. This will not be necessary in the next software version, which will have a more user-friendly user interface and an automatic start-up procedure.

Only one false alarm appeared during the whole test period. It was observed on unit no 1 on February 28 (at 08:56) where 8 bars of Lewisite in negative mode were reported (shown in Figure 4.7). The alarm was reset remotely from FFI one hour later and did not reappear. The reason for this false alarm is not known.

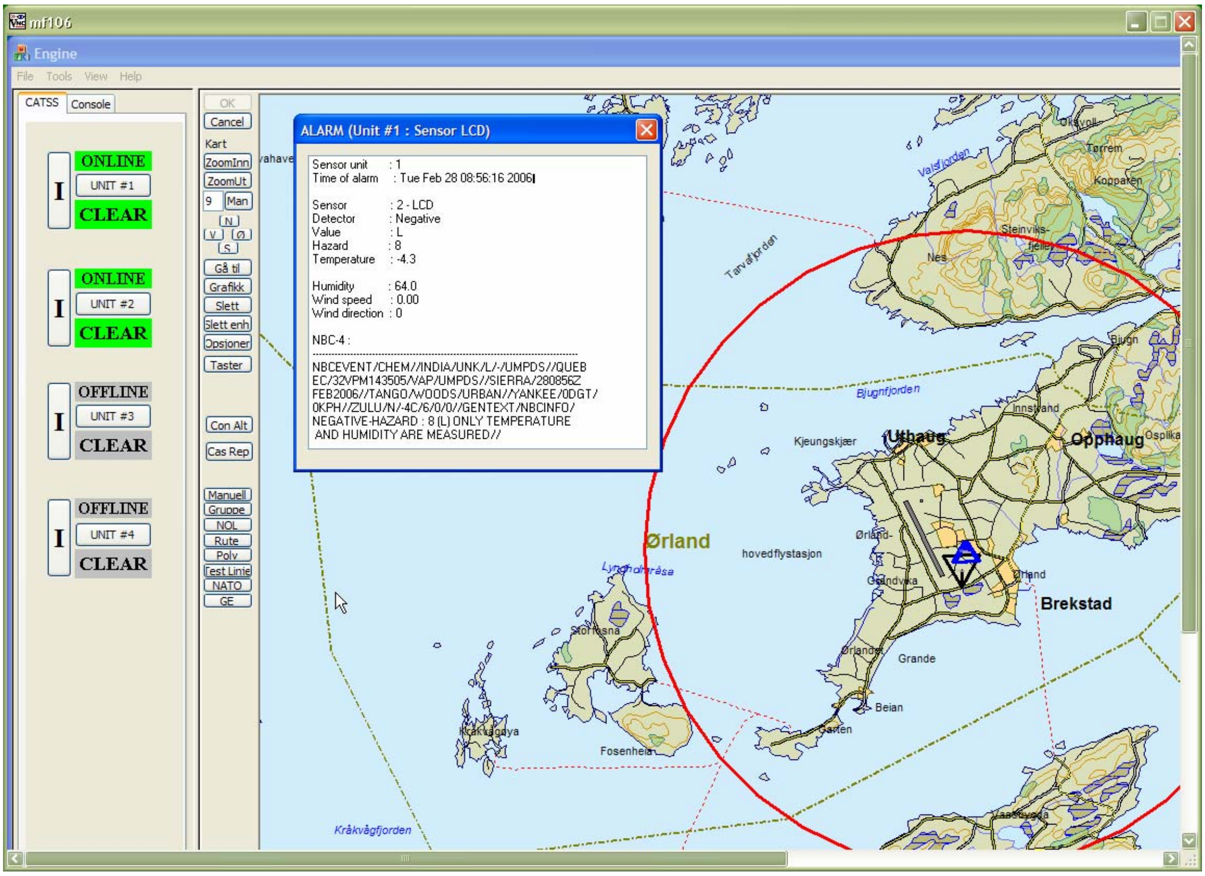

Figure 4.7 CATSS screen view taken February 28 2006 at 08:56 from Ørland Main Air Station. A false Lewisite alarm (hazard level 8) appeared on unit 1

The weather logg at Ørland Main Air station during the test period was obtained from Meteorologisk institutt (met.no) and is given in Figure 4.8 for February and in Figure 4.9 for March 2006. The temperatures during the test (23 February – 5 April) was quite low; down to a minimum temperature of -15.4 ºC on 6 March (not shown in the figures), and minimum 24-hour average temperature of -8.9 ºC on 1 March. The maximum snow coverage was 25 cm on 7 March (not shown in the figures).

The CATSS system was dismantled from Ørland Main Air station on April 5th and brought back to FFI at Kjeller.

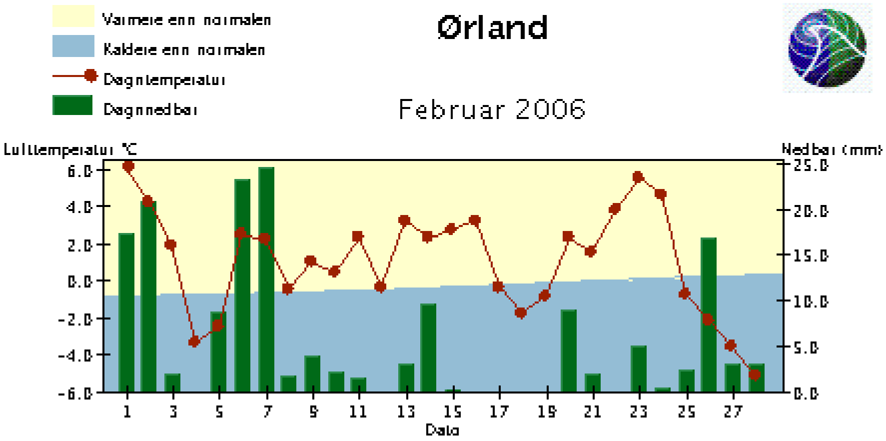

Figure 4.8 *Weather at Ørland Main Air Station in February 2006. The maximum snow coverage was 19 cm at February 28. Temperature is shown as red line and precipitation as green bars (source: met.no)*

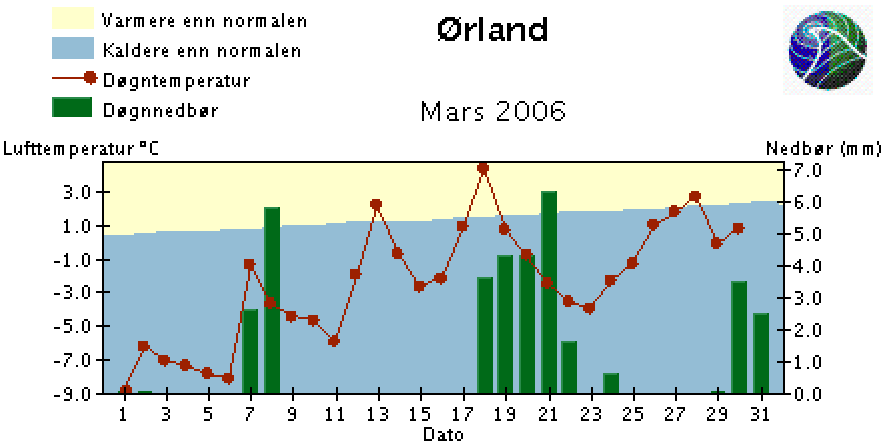

Figure 4.9 *Weather at Ørland Main Air Station in March 2006. The maximum snow coverage was 25 cm at March 7. Temperature is shown as red line and precipitation as green bars (source: met.no)*

5 FUTURE DEVELOPMENT

Some improvements have been made to the Templum after the field test at Ørland. The changes are mainly on the legs to make them more stable and to make the Templum simpler to mount up. Tent-plugs could now be used to fasten the legs to the ground through holes in the feet. In addition, a hook should be added at the bottom of the Templum main casing to connect weights, to improve the stability in heavy wind.

Another change is that the interchangeable instrument plate made of plastic has been substituted with a steel metal plate. This was done because the plastic absorbed the chemical warfare agents simulant (mehyl salicylate) to a great extend (see Chapter 4.1). In order to easy see if the Templum and its sensors are turned on, some light emitting diodes (LED's) should be mounted on the outside of each unit. A push-button could be used to light up the LED's when needed in order to keep the Templums as invincible as possible in the dark.

The Multiwarn II version currently used in the Templum is no longer available from Dräger. The new Multiwarn on the marked is larger, and would therefore require a Templum with larger diameter than the current one. Another disadvantage with the Multiwarn II is that it can only detect up to four industrial gases at one time without replacing the internal sensors. Replacing the Multiwarn II with a second LCD's is therefore an option to be considered. One LCD should then be doped with ammonia and the other with acetone in order to be able to respond to the most relevant industrial chemicals. In this way each LCD would have a smaller range of chemicals it is programmed to respond to, and therefore lower the probability of false alarms.

The radio used in the field test at Ørland Main Air Station is too large to fit into the Templum casing. A smaller radio should be selected in the future. It is also important to select an unclassified radio if the Templums are located some distance from the military camp. It was also a problem that the radio contact was lost several times during the test period at Ørland Main Air Station.

The wind sensor used in the previous version of CATSS (2),(8) has not been used in the current version of Templum. Wind data is, however, important when the data from CATSS are interpreted in order to give warnings to the users. A wind sensor is therefore needed in the CATSS system. The wind should be measured at about 10 m above the ground in order to obtain good wind readings. A telescopic mast could be used to mount the wind sensor. The number and positions of the wind sensors need to be evaluated.

Collaboration with LencoSoftware in Oslo has been established. LencoSoftware will develop new software for the CATSS central and make it more user-friendly. FFI, in cooperation with LencoSoftware will also produce a new version of the software for the Templum sensor stations. The plan is also to couple the messages from CATSS to a prediction model which could give the users a warning of where the vapour cloud is moving if something is detected. This will make the information from CATSS more unique.

It is also necessary to define the optimal distance from the Templums to the centre of the military camp. Too small distance will not give long enough warning time in case of a release of chemical or radiological agents. On the other hand, too long distance will make it necessary to have very many Templums in order not to have gaps between them. A balance between the economic realistic number and the necessary response time needs to be found.

An industrial partner will furthermore have to go through the design of the CATSS system to check if the system is ruggedized enough for military and civilian use.

6 CONCLUSION

A first prototype of the Chemical, Atomic and Toxic compound Surveillance System (CATSS) has been developed at FFI. The prototype has been tested during winter conditions at FFI and has been field tested at Ørland Main Air Station from February to April 2006. The results have been good, and the tests have shown that only small modifications to the design of the Templum stations are necessary. The Templum has also been displayed at several conferences during 2005-2006.

Some of the materials used in the Templum prototype have been tested against methyl salicylate, a simulant for sulphur mustard. These tests show that the carbon material used in the Templum does not absorb/adsorb much of the simulant, even after 202 days exposure, and is therefore very suited for its purpose. The POM-C plastic material used in the instrument bottom plate, however, takes up quite much of the simulant and has therefore been substituted by a metal plate.

The software used both in the Templum and in the CATSS central is now being modified and made more user-friendly. This work is not finished yet, but will continue in 2007.

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