RESEARCH AND DEVELOPMENT PROGRAM OF THE GERMAN ARMED FORCES SCIENTIFIC INSTITUTE FOR PROTECTION TECHNOLOGIES IN THE FIELD OF FIRE PROTECTION AND HALON REPLACEMENT

Hagen Schilling, Rainer Pauli, Felix R. Kümmerlen
Fachgebiet Brandschutztechnik
Wehrwissenschaftliches Institut für Schutztechnologien – ABC-Schutz (WIS)
Humboldtstrasse 100, 29633 Munster, Germany;
Phone +49-5192-136-300, Fax +49-5192-136-355, E-mail: HagenSchilling@bwb.org

Prof. Dr. Reinhard Grabski
Institut der Feuerwehr Sachsen-Anhalt
Biederitzer Strasse 5, 39175 Heyrothsberge, Germany
Phone +49-39292-61-600

Historical Background And Core Tasks of WIS Munster

Since 1958 the Federal Armed Forces Scientific Institute for Protection Technologies – NBC Protection (WIS = Wehrwissenschaftliches Institut für Schutztechnologien – ABC-Schutz) is responsible for NBC Defence and Research Tasks and Fire Protection Technologies for the Federal Armed Forces in Germany. In the origin on Feb. 1th 1958 a Federal Test Centre 53 for NBC Defence (Erprobungsstelle 53 der Bundeswehr für ABC-Schutz) was set-up in a part of the premises of the former Army Test Centre Munster-Nord (Heeresversuchsstelle Munster-Nord) in North Germany. In the beginning, this agency was tasked with testing the procedures and equipment designed to provide adequate protection to both personnel and materiel of the Federal Armed Forces against nuclear, biological and chemical weapons. Further tasks assigned to this agency included the testing of fire protection technologies. In the course of time, its activities took on new dimensions, as increased emphasis was laid on the scientific aspect of its terms of reference. As a result, the name of this agency was changed to WIS Munster.

WIS Munster is one of the eleven Technical Agencies and Scientific Institutes of the Federal Office of Defence Technology and Procurement (BWB) in Koblenz which has to report the the MoD in Bonn. The Ministry of Defence consists of a military branch (Army, Air Force, Navy, Medical Service) and of the civilian administration where the BWB Koblenz and the different eleven scientific and technical agencies belong to (Figure 1).

Especially in view of the extended mission of the German Federal Armed Forces NBC defence, Fire Protection and Environmental Services remain highly important, because increased mission requirements lead to higher NBC equipment requirements. Short-term goals are for instance improvement of combat efficiency and survivability, in particular for Crisis Reaction Forces in hot climate, improvement of present measuring, reconnaissance, detecting, analyzing, and decontamination procedures as well as qualitative and quantitative improvement of water purification equipment. Because of the ban of Halon the development of new fire protection technologies were also highly priorisized.

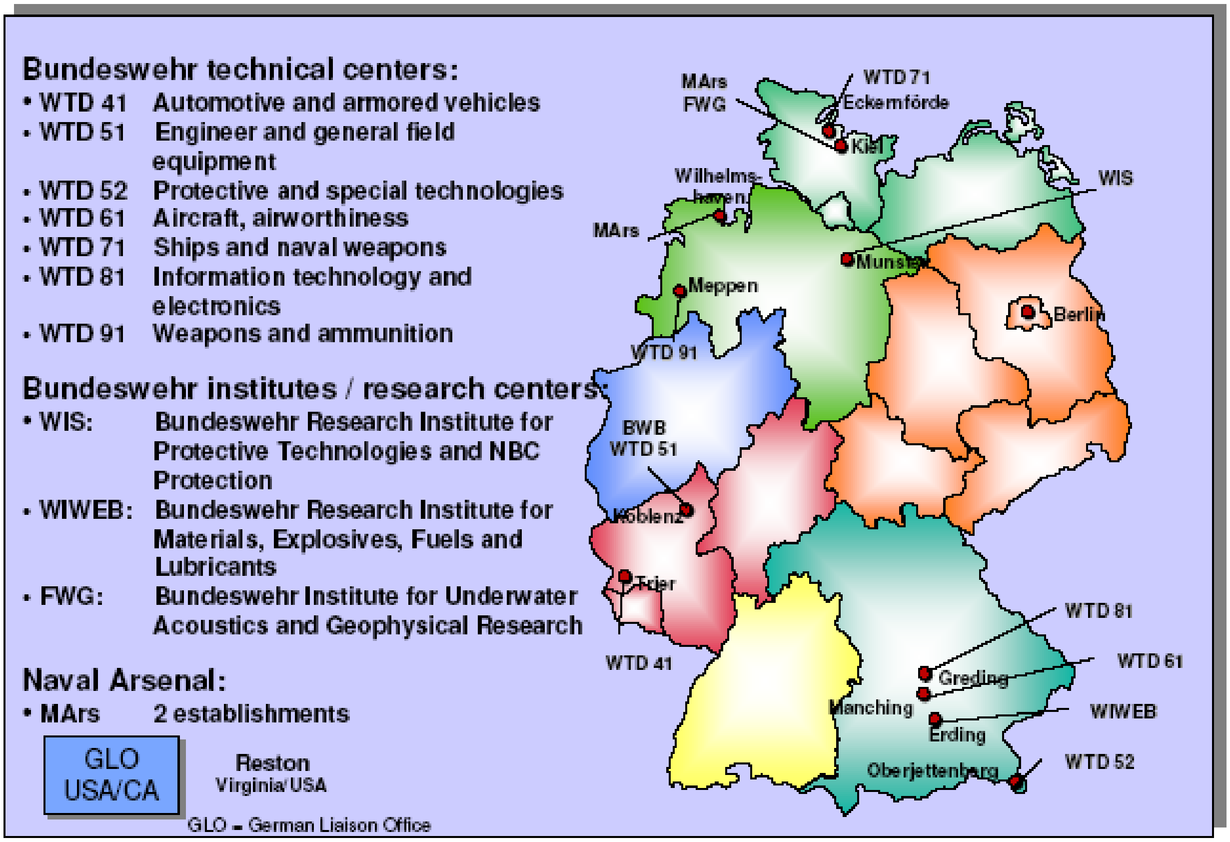

Figure 1: Technical and Research Centers of BWB

WIS work is characterized by a close interconnection between basic research on a theoretical and experimental level and its practical application to the development and testing of procedures and equipment. The current projects involve almost equal shares of the categories of research and technology, development and testing as well as environmental protection. The detailed tasks and responsibilities of WIS are

- Scientific tasks in the field of NBC-Protection
- Conduct theoretical and experimental basic research in the field of NBC-Defence and fire protection
- Develop, test and harden military materiel and equipment against the impact of NBC agents and fire
- Simulation technology and theoretical work for system tests
- Environmental programs including Radioactive Waste Collection and destruction of chemical warfare agents and water purification
- Fire Protection Technology Center for the Federal Armed Forces

At present WIS has a staff of 260 employees who work in the different laboratories, technical facilities and large-scale simulators over the institute's entire area of 200 acres. Nearly 40 scientists with a masters degree or Ph-D. in physics, biology, chemistry or engineering and 60 engineers with a bachelor degree are cooperating with 100 technicians and laboratory assistants in the different laboratories.

Since the reorganization of WIS Munster in 2004 we have four different departments which are responsible for General Service (Central Chemical and Biological Laboratories, Environmental Protection, Data Processing and Operation Services), Decontamination and Water Purification, NBC Detection and Hardening and the Physics Department (Nuclear Protection, Fire Protection Technology Center).

Fire Protection Technology Center (FPTC)

Why is the Fire Protection Technology connected to the Physics department and why is WIS Munster beside its responsibilities in the field of NBC-effects also responsible for the fire protection for the Federal Armed Forces in Germany? The reason for this decision of MoD to chose WIS Munster as the responsible Technical Center is the fact that at WIS there are not only special laboratories and installations for investigating fire protection programs on side but there are also very specialized chemical and biological and even specialized toxicity laboratories.

Quite often fire protection for the Federal Armed Forces has to meet different and sometimes more complex demands than fire protection in the civil sector – e.g. the shorter response times and special features of fire fighting on military airfields, the automatic fire alarm and extinguishing systems in tanks, ships and aircraft or the heat-protection clothing and flame-retardant combat clothing. The necessary investigations and tests can be carried out in physical and chemical laboratories, technical installations and on a fire test field. At present emphasis is placed, inter alia, on the examination of different compositions of extinguishing agents which have to meet today's requirements for environmental compatibility. In general, biological degradability is aimed at, which allows ecological disposal. Also necessary toxicological analyses of extinguishing agents and gases are carried out by the biologists of WIS.

The ban on halone requires an intensive search for alternative extinguishing agents and extinguishing procedures tailored to the special demands of the military sector. Furthermore, WIS acts as an inspection and certification office for fire extinguishing agents and extinguishing equipment of the German Armed Forces. In the Fire Protection Technology Center 20 scientists, engineers, technicians and laboratory assistants are working. Because of the possibility to include scientists and personnel of the other chemical, biological, environmental and even medical sections during fire protection programs this number of 20 people can be increased with these specialists. WIS has also many connections to other Proving Grounds (for example WIWEB (Basic materiel research), WTD 91 (Ammunition and Weapon effects), WTD 41 (Vehicle and tank system tests). Basic research investigations were also performed with other institutes and universities (IDF Magdeburg) in the field of fire protection. Even the large free field thermal simulator and thermal laboratory simulators which exists at WIS in the Balanced Nuclear

Hardening section can be used for experimental investigations of large systems, materiel samples or tests of fire protection garment.

The FPTC at WIS in Munster is responsible for all fire fighting equipment in all services of the German Armed Forces. This includes research and development, fielding, and logistic support as well as surveillance of extinguishing agents in storage. The fire fighting equipment includes:

- extinguishing agents
- handheld extinguishers
- extinguishing systems for land vehicles, ships and aircraft,
- stationary extinguishing equipment
- responsibility for logistic support (materiel) detection and alarm sensors
- fire protection garment

Additional tasks are:

- Research programs (extinguishing foams, liquids, powder, gases, sensors, scenarios methology, etc.)
- Studies and classification (rescue of crew members, air field classification, special fire scenarios, medical impact, etc.)
- International cooperation
- Halon replacement
- Approvement for all new materiel or equipment for fire fighting technology
- Focal point for cooperation with civilian agencies

To carry out these tasks the FPTC is equipped with facilities like

- laboratories to test all necessary equipment and extinguishing procedures
- fire houses 9000 and 170 m^3
- fire pools 50, 100 and 200 m^2
- nozzle test rig for water mist
- all associated measuring systems
- high speed camera system
- support from the central biological and chemical laboratories

As in about 1980 environmental awareness became prevailing, we were aware that our synthetic foam and halon needed to be replaced. The foam was easily substituted by biodegradable Aqueous Film Forming Foam (AFFF), but halon turned out to be a real problem.

After the Montreal Protocol became effective, and after the even more stringent national Halon Prohibition Law in 1991, an intense search for replacement extinguishing agents began. That is the reason why Halon replacement was the major part of our work in the last years. According to the Kyoto Protocol, Germany is obliged to reduce the release of gases with a Global Warming Potential. Alternatives such as FM 200 or FE 36 cause also environmental problems. Although a real drop-in replacement for halon was not and probably will not be found, reasonable alternative solutions were developed and tested for the following applications:

Examples of Solutions for the Replacement of Halon

Handheld Halon Extinguishers

In handheld extinguishers halon was replaced by extinguishing powder, CO_2 or foam extinguishers. Their reduced extinguishing performance was compensated in part by using larger and more extinguishers. For most applications this proved to be sufficient, but as these replacements can not maintain an inert atmosphere and for weight reasons, halon is still being used in handheld extinguishers on aircraft.

Extinguishing Systems in Tank Engine Compartments

The WIS in Munster compared gaseous and powder extinguishants in the engine compartments of armored vehicles. The results were satisfying with gases as well as with extinguishing powder. The German Army decided to equip their vehicles with a nitrogen extinguishing systems. Extinguishing powder was not chosen because with their Leopard 2 a huge cloud of smoke and powder would be blown vertically into the air in the process of extinguishing, thus revealing the tank's position. Another reason was that nitrogen is a clean agent and also environmentally neutral.

Extinguishing Systems in Machinery Spaces of Ships

In the existing Frigates 123 the halon system was replaced by a carbon dioxide system. As carbon dioxide is toxic, this was not a fortunate solution for a manned room, but at that time no better alternative was available. For her successor, Frigate 124, numerous tests were performed at WIS in Munster in a mock-up small-scale machinery space with liquid and gaseous extinguishing agents. Best results were achieved with water mist with 3% AFFF added. Water mist not only extinguishes the fire, it also reduces ambient air temperatures and suppresses smoke. These test results were confirmed in the full-scale model of a machinery space at the Meppen Proving Ground (WTD 91). It is intended to equip the machinery spaces of all future ships and boats of the German Navy with water mist extinguishing systems.

Explosion Suppression Systems

An armoured vehicle, e.g. a battle tank or a reconnaissance vehicle, encounters multiple threats during its mission. Of interest here are the impact of projectiles, shaped charges or mines.

The impact of a warhead generates a number of hazards for crew and equipment of the vehicle. These are the warhead itself, fragments and splinters of destroyed equipment and possibly the fire generated, if combustible materials get in contact with glowing fragments. If a fuel tank or a hydraulic system is destroyed by the warhead, the fuel is dispersed in small droplets and the combustion is very fast, in an explosion-like manner. The heat, the sudden pressure increase and the toxic by-products of this explosion are threatening health and life of the crew.

In modern tanks the amount of combustible material is reduced, e.g. through the replacement of hydraulic devices by electric ones. But the amount of fuel needed for an explosion is small – e.g. about 0.2L diesel in the experiments we have conducted. To prevent such an explosion-like fire, explosion suppression systems have been developed and installed. They extinguish the fire fast enough to prevent severe damage to the crew, typically within 250ms. In the past, for the suppression of the flame usually Halon 1301 was used.

The search for a substitution in this particular application turned out to be difficult. Currently there is no "drop-in" replacement for Halon 1301. The chemicals currently used for explosion suppression systems are hydrofluorocarbons like HFC-236fa ($C_3F_6H_2$) and HFC-227ea (C_3HF_7). These agent are not as efficient as Halon 1301, the minimum extinguishing concentration is > 5 Vol%. As a rule of thumb, the amount of volume and weight needed for the storage of the agent is doubled. Toxic by-products are also an issue for a successful suppression. Hydrofluorocarbons are pyrolyzed in the flame and toxins like hydrofluoric acid (HF), fluorophosgene (COF_2) or CO are produced.

HF is corrosive and lethal in concentrations above 2500ppm (15 min exposure). HF production was always an issue in Halon using systems, and it is even more with the new chemicals, as higher agent concentrations have to be reached for a successful suppression. Therefore the placement of the nozzles and the distribution system has to be designed even more carefully than before. But despite these difficulties the design of explosion suppression systems with gaseous chemical agents is a well developed technology. But the chemical agents discussed above have also an environmental drawback. They have a very high global warming potential, about 3000 to 6000 times that of CO_2. This has led to the search for alternative solutions.

Suppression Systems with Water Mist

Two different design approaches are used today. The first consists of a central reservoir, where the water is stored. Upon activation of the system, a gas generator (like the one used in airbags) drives the water through a pipe system to the nozzles. This system allows optimal placement of the nozzles. But the pipes have to be kept filled with water and the so called 'wet main' system will not work if the pipes are damaged somewhere (e.g. by a warhead fragment). The second approach is to use several bottle-nozzle combinations placed within the crew compartment. Within a bottle, the agent (e.g. water) and the expellant (e.g. nitrogen or a gas generator) are stored. No elaborate pipe system is needed. After activation the gases produced by the gas generator mix up with the agent and are used to pressurize, vaporize and expel the agent from the bottle. The mixing of gas and agent improves the dispersion of the agent and therefore the nozzle design is more simple. The drawback is the more difficult placement of the system components.

Since 2001 the hybrid gas generator technology was investigated at the test site in Munster. As an example of these investigations the following experiments with a mock-up of an armoured vehicle are shown. The basic test condition should represent a mine or explosive projectile which penetrates the hull. Fuel is sprayed into the crew compartment and incinerated by glowing fragments. The aim was to achieve a deflagration fire scenario which could be repeated easily in a consistent manner.

Test Results with a Multiple Role Armoured Vehicle

As a test scenario the crew compartment of the MRAV (Multiple Role Armoured Vehicle), a light reconnaissance vehicle, was chosen. A full scale stainless steel mock-up was build (Figure 2) according to the current geometric specifications of the MRAV design. The crew compartment has a volume of about 12 m³. No clutter or mannequins were installed in the interior. The mock-up is not pressure resistant, therefore additionally pressure release lids were installed at the top of the mock-up. For each test, Diesel fuel (F54) was heated up to 85°C ±5 °C. For about 2.5 s the fuel was injected under a pressure of 80 bar into the crew compartment. This resulted in about 200 ml fuel distributing in small droplets within the crew compartment.

The fuel was ignited by a constantly glowing heater plug. A shield of about 50 cm diameter (reflector) was installed between the heater plug and the IR-Sensors to prevent early activation of the suppression system. The reflector also helped to distribute the fuel within the crew compartment before the ignition occurred.

Figure 2: The MRAV-Mockup

Data acquisition included two standard CCD video cameras with 25 fps and in some cases a CMOS high-speed camera with a shutter speed of 7,8 µs to monitor the flame spread (Figure 3). In three thermocouple trees (TCT) the temperature is recorded at six different heights. Pressure and oxygen sensors were installed in the compartment. The tests have been conducted in co-operation with Aerojet. Up to four hybrid gas generators (HFE) have been installed in the crew compartment. The position and number of the hybrids was varied to find the configuration of optimum performance.

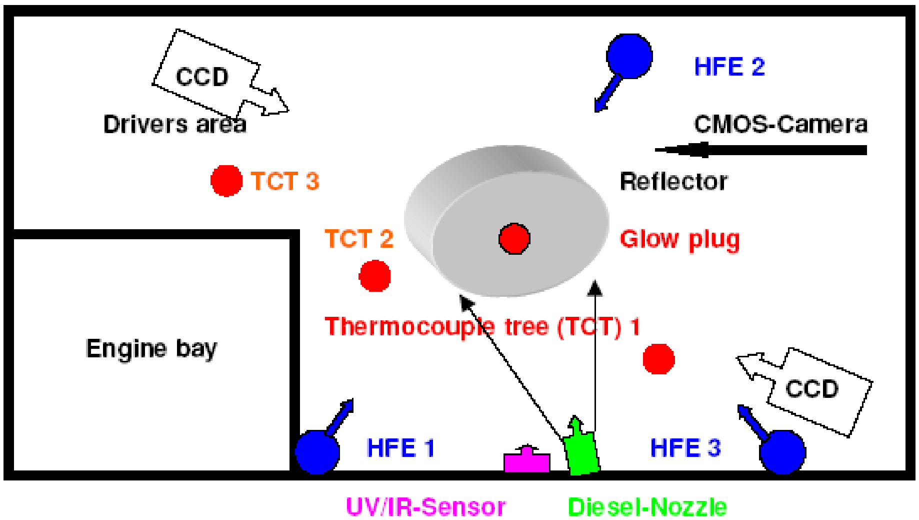

Figure 3: Test Setup

The most important result of the investigations was, that fire suppression with a water mist system can be achieved. Extinguishing times short enough to preserve life and health of the crew are feasible. As it could be expected, there was a dependence between the amount of water used and the extinguishing times. In general, with an increased amount of water the extinguishing times decreased (Figure 4). In some cases there was a re-ignition about a second after a suppression. This was due to the fuel injection time of about 2.5 sec. For a comparatively long time a combustible mixture remained in the crew compartment and could be ignited by the glowing heater plug. But in the majority of the experiments there was no re-ignition.

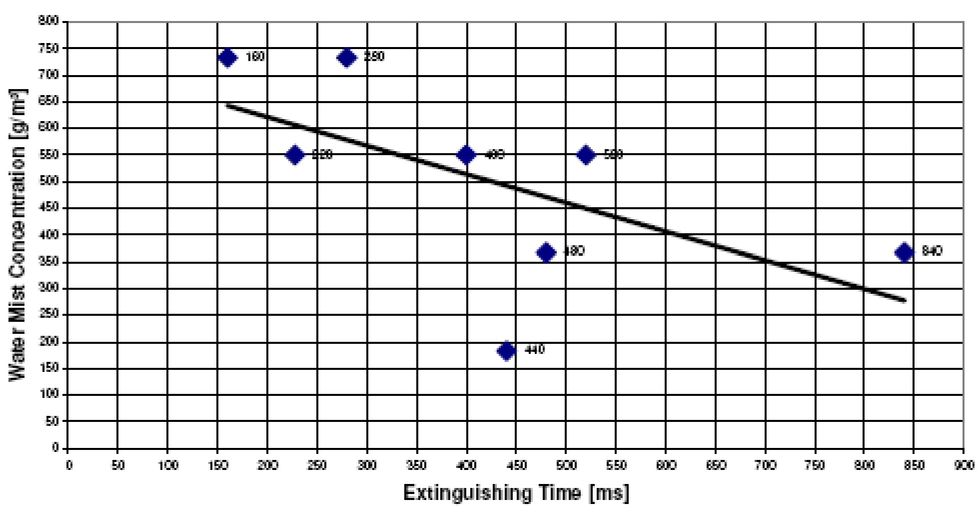

Figure 4: Extinguishing Times and water mist concentration

Due to the somewhat unpredictable nature of a fire suppression experiment numerical simulations have been carried out to investigate the possibilities of fire suppression with water mist. The first aim was to investigate the ability of water mist to replace gaseous agents in this particular application. Using an Euler-Lagrange model of water mist of two different droplet sizes and for comparison of typical gaseous agents it could be shown that water mist of a small enough droplet size worked in several aspects like a gas. Of special importance was the finding of the numerical simulation that small droplet water mist could move around obstacles, following the flow pattern of the surrounding air.

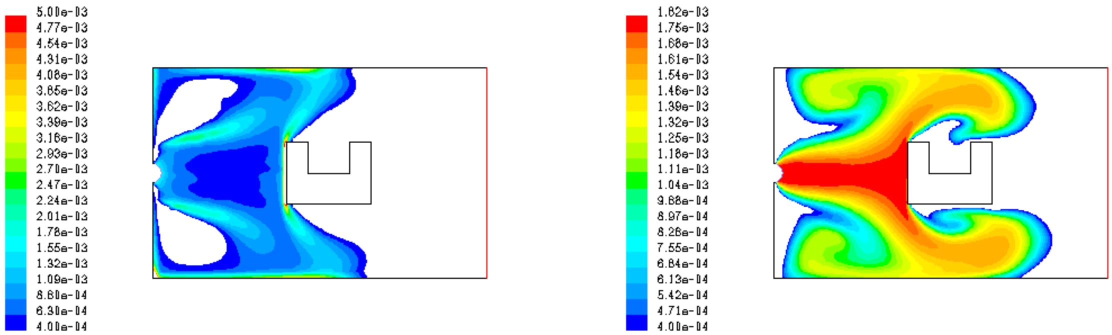

Figure 5: Examples of simulated distribution pattern of water mist with large (left) and small drop sizes

We started first with two dimensional models and succeeded with real three dimensional experimental setups. The droplet sizes were also changed and different extinguishing gases (HFC-236) were compared with water mist. In the detailed presentation results of these theoretical program will be presented.

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