AUTHOR'S DESCRIPTION OF A THESIS (PhD)

NATIONAL
UNIVERSITY OF PUBLIC SERVICE
Doctorate Committee

PIMPER, LÁSZLÓ

Improvement of the tactics and the applied technical equipment of mobile tank fire fighting

author's description of a doctorate thesis (PhD) and
its official evaluations

Budapest
April 15, 2016.

NATIONAL UNIVERSITY OF PUBLIC SERVICE

PIMPER, LÁSZLÓ

Improvement of the tactics and the applied technical equipment of mobile tank fire fighting

author's description of a doctorate thesis (PhD) and

its official evaluations

Director of studies:

Dr. Vass, Gyula Fire-Chief Colonel PhD

Budapest

DEFINITION OF THE SCIENTIFIC PROBLEM

It is almost general situation in big industrial establishments that in addition to production plants, an array of various size and design surface tanks is installed, that give the area a peculiar look from a big distance. Bigger and bigger volume tanks and storing facilities are installed as the demand for oil products is growing, the storing requirements are increasing, and as efforts are exerted for safe supply. With the grown storage quantities the hazards also increased, including the extent of risk of fire and explosion. Elaboration of new safety methods was required, that involved the field of fire protection in general, including also tank fire fighting.

In the recent years several such tank fire incidents occurred in the world that attracted public attention, in many cases due to the prolonged elimination of the accidents.

In case of larger tanks, the efforts to extinguish the flames can be successful only by the deployment of an adequately designed resource system; the success of tank fire fighting is determined even before the incident has developed; the possible incompletion of the preparation cannot be eliminated, or it can be done only by big expenses.

The success of fighting tank fires significantly influences the environmental consequences of the accident in addition to its direct damages. This approach clearly shows the importance of successful and efficient tank fire fighting in order to reduce the effects that pose risks to the safety of the environment: harmful load on the environment caused by the fire can be reduced by the reduction of pre-burn time and response; while the environment pollution caused by the fire fighting can be reduced by the minimization of the quantity of used extinguishing materials and by the improvement of their quality. Fire fighting foam agents used for "traditional" foam generation have significant harmful load on the environment due to the chemicals in them.

In my works I researched the possibility of the reduction of environment pollution by returning to the principles determining mobile tank fire fighting.

Efficiency of fighting tank fires by mobile equipment are determined by three partial areas that act and change in continuous interactions: tactics and procedure of the intervention; the used materials, and the available system of technical assets. In these fields the expectations continually change; laws specify more and more strict requirements, while newer and newer possibilities are created in parallel as the result of permanent research and development processes. This continuous improvement also stresses the actuality of researching tank fires and their mobile fire fighting. In addition to the higher level expectations to conform to the environmental requirements, modernization efforts of disaster management and fire safety make it necessary to improve the field of tank fire protection and the related intervention field; they further emphasize their actuality.

In parallel with the higher demand for safety of the society, the expectation of a higher level conformity to the regulations of industrial safety is also present.

All three of these partial fields cover many issues, so the number of the elements to be analyzed and developed is extremely wide. My research work aims to develop some elements after general revision of tanks, tank fires, fire fighting methods and mobile tank fire fighting; I do not examine in details the composition and developments of the materials that are used during tank fire fighting (foam agents, dry powders, fire water), the training of the responding personnel and commanders, the design and models of the installed system (elements), the questions of technical realization of the technical system elements.

I consider the specific technical solutions of the technical equipment used during mobile tank fire fighting as my direct research field. One of the most important purposes and tasks of the technical activities is to ensure the modernized response tactics, the developed (applicable) extinguishing media, the technical designs and the technical conditions of the expectations in an optimum way and at the available highest technical standards. With respect to this, I research the technical development possibilities as a user (doing mobile tank fire fighting), and I don't examine the questions of technical design work and structure. I handle the extremely actual questions of industrial safety, fire protection and disaster management only from the aspect of mobile tank fire fighting; several authoritative literature publications were and are made in this research area.

RESEARCH TARGETS

- To study the design and most important features of atmospheric storage tanks and their bunds;
- To systematize, examine and evaluate tank fire scenarios, and fire incidents involving storage tanks and their bunds, their occurrence frequency, and the special tank fire phenomena;
- Identification of the reduction opportunities of the harmful load on the environment due to tank operation and tank fire fighting, creation of the principles of environment-friendly fire fighting;
- Systematization and evaluation of the tank fire fighting systems and their designs;
- Examination and evaluation of the resource and condition system of mobile tank fire fighting; study and evaluation of the methods for determining the calculation procedures of foam application rate and operating time; systematization and analysis of the technical equipment and materials; and definition of the opportunities and directions of technical development.

- Study of the physical properties of large, full surface tank fires and their mobile fire fighting opportunities, definition of the possibilities of development;

  Performance of researches based on foam and tank fire fighting tests that approximate real circumstances the best;
- Examination of the possibilities for fighting rimseal fires by mobile equipment; identification of the development directions and the marginal conditions.
- Examination and evaluation of the spreading of fire fighting foam on large surface pool fires.
- Examination and evaluation of the applicability of oil- and water-repellent, floating, fire resistant, foam-like material that consists of small beads with cavity (dry foam) for firefighting purposes.

RESEARCH HYPOTHESES

1. Preparations for mobile tank fire fighting can be more successful by the systematization and organization of atmospheric storage tanks and bunds, and their burning characteristics; and elimination of possible fires can be guaranteed at a high level.
2. A planning method can be developed for fighting the fires of atmospheric storage tanks by mobile equipment that fits the fire scenario and the response characteristics better, in order to determine the foam application rate and the duration of the fire fighting operation.
3. Based on systematization and evaluative analysis of the technical equipment and materials of mobile fire fighting and also on natural and artificial model tests, the possibilities and directions of technical development can be determined.
4. In case of a full surface tank fire, the temperature of the flame space and the burning liquid is lower on the middle of the surface, than around the tank shell.

   In the course of deploying mobile foam monitors the best foam efficiency and the most efficient surface firefighting can be ensured by applying the foam on to the middle of the burning liquid surface.
5. A tactics procedure can be developed for fighting rimseal fires on open top floating roof tanks that can be followed to response successfully, safely and efficiently by approaching the fire by firemen through the catwalk of the tank, and by deployment of transportable and mobile equipment.
6. In case of large surface pool fires the foam can flow on the open surface of a pool to bigger distances, even more than 50 meters, without being shot; and it can extinguish the fire, if other circumstances preventing foam flow, especially the wall-effect occurring due to hot tank shell and other metal structures, are eliminated.

7. The oil- and water-repellent, floating, fire resistant, foam-like material that consists of small beads with cavity (dry foam) can also be used for firefighting purposes. According to my suppositions this material group, beyond vapour suppression and other applications for enhanced safety, as it is specified by the manufacturer and justified by earlier researches, can be used also to fight fires. I respect it as an obvious result if during model tests in frames of my research I can extinguish fires successfully by using this material.

RESEARCH METHODS

When I started my work, I localized and processed the earlier publications, case studies, professional recommendations in relation to the selected research area, and I extended this analyzing work continuously by learning and evaluating new materials that I could obtain during the research period. I studied and evaluated scientific dissertations published in the subject of fire safety. During the research and elaboration of the subject and processing the applicable chapters of domestic and international literature on it, I used general research methods such as analysis, synthesis, induction and deduction. The special feature of my research was many executed experiments as an empirical research method – by natural means, and by artificial modeling.

During my work, I cooperated with the specialists of several "professional centers" who examine and develop issues related to my work, especially with the professionals of the LastFire, the Joint Oil Industry Fire Forum, the Loughborough University, the National Research Institute of Fire and Disaster, and the MOL Group. I consulted with fire safety, industrial safety and security specialists of huge oil industry companies, the workers of FER Fire Brigade, and the professors of the National University of Public Service. I based my work on the available scientific knowledge concerning tank fires and mobile tank fire fighting; I developed my scientific activity intentionally, in a planned manner, executed by examinations, experimental and analysis techniques based on general and special methods. I realized the research conditions expediently; I applied exact and reproducible research methods, under controlled conditions. I had an opportunity to execute natural, real size fire fighting experiments in the course of my researches.

My work was based on actual observations and experiments, and was directed on examination of various elements of modern mobile firefighting systems, and on performing foam fire fighting and tank fire fighting researches. Most of the data used in this thesis were generated under my control, in the period between 2005-2016, at the FER Fire department Brigade under my control.

I got a lot of help for performing such experiments from Duna Refinery in Százhalombatta, the MOL HSE organization, the previous and present managers of FER Fire Brigade, and from the professional staff of the industrial fire brigade in Százhalombatta.

A part of my professional recommendations are already integrated in the dispositional sections of the relevant domestic regulations on fighting fires of storage tanks and bunds.

In order to disseminate my achievements abroad, I participated in, and I organized international professional conferences and forums, and I am continually in contact with the representatives of leading professional organizations in the field of tank fire fighting.

BRIEF DESCRIPTION OF THE PERFORMED INVESTIGATION, IN CHAPTERS

I explained the reasons of my chosen subject in the introduction of the thesis, and explained the actuality of the fire fighting tactics of mobile tank fire fighting and the applied technical equipment systems. I defined my research goals, I set up hypotheses and I selected the most important research methods, by which I intend to achieve my objectives.

In harmony with my research goals, I presented and analyzed in Chapter 1 of my thesis the design and most important features of atmospheric storage tanks and their bunds, the related technologies, the types of their fires, the frequency of their occurrence and their special phenomena. Based on the evaluating analysis of the fire scenarios, I determined the aspects that can be used to identify and systematize the types of tank fires and their most important fire fighting features. I evaluated the various tank designs, and the consequentially various frequencies of tank fire incidents; based on these data I planned my researches described in the following chapters of the thesis.

In the following Chapter 2 of the thesis, I researched the system of the execution of tank fire fighting by mobile equipment, its conditions and development possibilities. I reviewed the stationary and mobile fire fighting systems, and I systematized the conditions of damage control by equipment and materials transported to the site.

Based on these analyses, I selected the partial fields of development to study in the course of my researches: development of modern application of dry chemicals; the researches in relation to the fire resistant dry foam consisting of oil- and water repellent, floating beads with cavity in them, developed as a new fire fighting material; development of technical equipment of mobile tank fire fighting; and research of planning methods of tank fire fighting by mobile equipment.

I summarized the circumstances and most important results of my empiric tests in Chapter 3 and 4 of my thesis: Chapter 3 describes two series of experiments about natural fire fighting for improvement of the applied fire fighting tactics, while Chapter 4 describes the development of the application of the fire fighting material by real size and model experiments.

I described the fire fighting experiments performed for research of the properties of full surface tank fires in the first part of Chapter 3. I examined the temperature conditions of tank fires by observations and measurements, and based on these data, I elaborated the method of foam application by high pressure mobile jets that allows the lowest foam destruction and the most efficient surface fire fighting.

I examined the fighting of the most frequent tank fire scenarios on a real tank, in operational size in the frame of a series of experiments: mobile fighting of rimseal fires on open top floating roof tanks, what researches are also included in Chapter 3.

In the first part of Chapter 4, I researched the flow characteristics of the foam generally used for tank fire fighting, during real size, empiric experiments. As a conclusion of my thesis, at the end of Chapter 4, I researched fire fighting applications of a new group of materials: based on model experiments I examined the possibility of application of oil- and water-repellent, floating, fire resistant, dry foam that consists of small beads with cavity for firefighting purposes.

The results of the researches described in four chapters of the thesis confirm my research hypothesis directed towards the improvement and increased efficiency of mobile fighting of large, atmospheric, standing cylinder, storage tanks. I revealed several further research directions and possibilities during my research works, in addition to achieving my goals.

SUMMARIZED CONCLUSIONS

1. **Concerning systematization of the large size, atmospheric, standing, storage tanks and the characteristics of their fire scenarios**

- Based on the categorization and analysis of the various tank fire scenarios, with respect to the complexity of the intervention, the firefighting resource requirement and the occurrence frequency data, I determined the most important tank fire fighting scenarios that require improvements: fighting full surface fires and rimseal fires of open top floating roof tanks.
- I have proven by analysis of the fire scenarios occurring at large size atmospheric storage tanks, that various fire scenarios occur depending on the design of the storage tanks, especially on their roof structure.
- I established and proved by examples that in case of fires of large atmospheric storage tanks, the dimensions of the fires, the shape and location of the flaming zone determine the possibilities and methods of fire fighting. I classified the point, linear and surface fire types, I defined the most important burning and fire fighting characteristics of the individual subcategories in harmony with my scientific goal, using international and domestic research results.

- I established that in case of fighting jet fires the flames of the flowing liquid and the surface fire have to be extinguished at the same time, permanently during the intervention. The possibility of fighting the jet fire of a flowing liquid in a combined way is determined by the effective shooting range of the deployed dry-powder extinguishers.
- I have proven by measurements during experiments that when a boilover occurs, the size of the fire surface and the magnitude of heat radiation increase, what poses direct risks to the vicinity of the burning storage tank and also to the personnel acting there.
- Fire fighting has to be performed before a boilover occurs. If it fails, resources taking part in the response have to be prepared to be quickly withdrawn and to protect the area from a bigger distance; the personnel and equipment have to be withdrawn immediately when the hissing sound appears before such phenomenon.

2. Research of the resource system of tank fire fighting, with special respect to mobile tank fire fighting

- The environmental impacts of foam fire fighting can be really understood only by making a full eco-balance because quick fire fighting (even in case of applying extinguishing materials with more disadvantageous environmental properties) can reduce the total harmful load on the environment, air pollution, soil- and water contamination caused by the burning products and the used extinguishing agents.
- Before the application of fluorine-free foam agents for tank fire fighting, it is recommended to perform analysis and tests with respect to the protected area, the inflammable liquid types, the available fire fighting technology, and the applied response tactics; also ask the opinion of the manufacturer of the foam agent that you plan to use.
- Concerning fighting a jet-like "spatial" fire of an inflammable liquid spilling out due to the damaged shell of a large storage tank, protected by a bund, I have proven the necessity of coaxial jet equipment capable of creating a combined powder-foam extinguishing agent stream.

  I have proven that efficiency of this intervention type can be improved by the application of a coaxial jet for combined powder-foam extinguishing agent stream.
- I identified the methodological and technical development possibilities offered by the availability of equipment operating a coaxial jet for combined powder-foam extinguishing agent stream.
- I evaluated the researches about development of practical applicability of oil- and water-repellent, floating, fire resistant, dry-foam that consists of small beads with cavity; I identified its adequacy for fighting fires of atmospheric storage tanks.

- I elaborated the method of introducing calculation methods in Hungary for planning of mobile tank firefighting as specified in the European directives, in which I harmonized the domestic specialties with the international instructions, by evaluating analysis of the planning procedures about fighting tank fires by mobile equipment, and by the experiments described in the chapters below. I gave a specific professional proposal to determine the rules of determination of the foam application rate and the planned operating time; and to modify and supplement the procedure of planning and execution of the tank fire fighting operations.
- The safety of fighting large surface fires, including tank fires, can be improved efficiently by keeping mobile water supply systems available. The modern systems tailored to the local conditions can be mobilized quickly by roll-off containers; and they are suitable to deliver big volume flows of fire water.
- In case of large surface pool fires including also tank fires, the applicability of foam and water monitors can be increased by the reduction of the limitations about their working position, by the extension of their effective operation range, and by the improvement of the controlled selection of their solution capacity.
- I determined the direction for further development of the "mobile tank fire fighting center": the general applicability of the unit can be improved and optimized by achieving the foam monitor of the equipment can be positioned free, what is extremely important especially in case of unfavorable location of roads and other traffic surfaces, and in case of adverse weather conditions (wind direction and speed).
- The domestic emergency management system can be improved for mobile tank fire fighting by utilizing the local emergency response capabilities of the plants operating large storage tanks. The resources available in these plants can efficiently complete the capabilities of the national disaster management system.

3. Research of the tactics of mobile tank fire fighting, natural fire fighting tests

OBSERVATIONS OF FULL SURFACE TANK FIRE FIGHTING TESTS

- The surprising magnitude of flame deterioration observed during the tests, and the increased temperature measured at the tank in windward direction also shows the importance of protection of the adjacent, endangered tank. In case of strong wind with adverse direction, make sure the rim-seal of endangered adjacent tanks are protected.
- Based on heat radiation measurements I established that in case of a full surface tank fire,
  - the value of heat radiation was much higher towards wind direction than from the wind side, and it was much higher at the top of the adjacent tanks than at ground level.

- a strong, permanent heat radiating zone was formed at the bottom of the flame space; the thickness of this "flame base" is about 5 meters (0,12 D), and about 20-30 % of the complete heat radiation was emitted from this zone.
- in addition to the lower flame zone, a strong heat radiating fireball shape zone was formed about in every 2,5 seconds in the middle of the flame.
- the second strongest radiation after the "flame base" was formed just above the tank, about 20-30 meters (0.5-0.75 D) above the lower zone.

I realized that the present water source inspection practice has to be extended in order to enhance operational reliability of the fire water systems by regular flushing of the fire water main by a big volume flow (design value at the area) at certain points determined by hydrodynamic design, and by quantity and quality control of the fire water that can be taken from the system.

- I proved the extinguishing time - solution capacity / application rate relationship by real size firefighting test; with the increased firefighting capacity the extinguishing reduced.
- The spreading foam is extremely destructed when it touches the hot metal surfaces. Therefore extinguishing may last longer at distant locations from the application point where the metal surfaces are not cooled by the foam jet.
- Concerning firefighting of full surface fires of large, atmospheric hydrocarbon storage tanks, I proved by experiments, supported by measurements and observations
  - that the temperature is lower at the middle section of the pool surface than around the tank shell; the temperature is the highest around the tank shell; lower and lower temperature are measured in the direction of the middle of the surface.
  - I determined the most favorable way of applying the foam in case of fighting a full surface tank fire by foam monitors: the firefighting foam shall be applied to the middle of the burning liquid surface, therefore the smallest possible degree of foam destruction can be reached as it spreads on the liquid surface.
  - The most advantageous point of applying the foam is the lower temperature flame space between the hot, flat "flame base" above the surface of the tank and the top, hotter flame zone of the flame space. The firefighting foam can be applied to the pool surface with the smallest losses through this layer, aimed low above the tank shell.
- I proved the efficiency of the modern, new firefighting tactics developed for tank fire fighting based on the deployment of high capacity foam monitors, and the firefighting efficiency of the modern foam agents applied in 1 % mixtures.

I proved the benefits and adequacy of the "mobile tank firefighting center" concept, and the necessity of the mobile pressure booster pump designed to full capacity, and installed into the mobile unit.

– The measurements proved that in case of full tanks the top section of the shell is exposed to the biggest heat load, and that the position of the shell cooling water curtain installed 50-80 centimeters below the top reinforcing rib is inadequate: it leaves the top section of the shell unprotected above the cooling-showering ring; what is also not protected by the positive cooling effect of the stored material inside. It is recommended to design the shell cooling system to the highest possible section of the shell. Make sure of gentle foam application in order to avoid a bath of the extinguishing material, what results in an increased proportion of destroyed foam. Additionally, the bathed foam may carry a thin layer of the burning material onto the surface, thus also causing a fire on the foam surface. For this purpose:
  - Avoid applying the foam too fast as a solid jet.
  - Apply the firefighting foam with the highest possible expansion rate in order to reduce bathing and in order to improve the heat protecting properties of the external foam layer of the flowing jet.
  - As far as possible, the foam blanket shall be made by continuous application of the foam aiming its jet to the bund walls, the tank or to other structures so it splashes and flows.

RESEARCH OF MOBILE FIREFIGHTING OF RIMSEAL (RING) FIRES BY EXECUTING REAL SIZE FIREFIGHTING TESTS

- I proved by a series of tests the possibility of extinguishing rimseal fires by mobile equipment: the rimseal fire of open top floating roof tanks can be extinguished safely and efficiently by the deployment of mobile equipment and experienced commanders and firemen.
- In case of laying of a vertical fire hose line, application of a hose line lain on the stairs was a quicker solution than pulling the fire hose up vertically.
- Design of the dry vertical lines installed to the tanks shall be modified: the top end point of the vertical line besides the stairs should be 2,5-3 meters lower, to a point that can be reached from the top section of the stairs, without stepping on the catwalk.
- Tests have proven that a vertical line fed from close to the road, usually from the fire wall of the tank (with an endpoint design as specified in the above point) is very useful in case of fighting of a rimseal fire by handheld foam jets.

- Firefighting shall be done from below near to the point reaching the top, covered by the shell, by shooting up - falling down medium expansion rate foam.
- After extinguishing the area of the top access point, the rimseal fire shall be fought section by section in two directions after going up to the catwalk; application of low expansion rate foam jets is useful here. The foam jets shall be aimed to the internal wall of the tank shell.
- With respect to the above mentioned two foam expansion rates, the so called combined foam nozzles can be used very well that can be used as medium- and as low expansion rate foam nozzles as well.
- The necessary manpower has to be present on the catwalk in order to handle the hoses but in case of many people, load-carrying capacity of the catwalk is also important.
- In addition to the full regular fire fighters' gear of the acting firemen, usually other special heat protective clothing is not required; the firefighting can be performed safely by "forward application" of the low expansion rate foam jets with the consequential "remote protection".
- Depending on the position of the floating roof vertical hoses and the hoses laid on the catwalk have to be kept away from the hot tank shell; it requires special care and the necessary number of firemen in case of advancing section by section with the foam jets.
- The capacity of the applied foam nozzles have to be designed with multiplied reserves because the fire may spread over the rimseal; to the areas of the tank shell and roof contaminated by the stored material, but application of foam nozzles with a higher solution capacity than 400 liters per minute is not recommended in order to be able to handle the hose adequately and due to safety reasons.
- Avoid operation of the jets by a too high pressure and a sudden change of the pressure. Perform openings and closings for hose extensions very carefully, gradually both at the distributor and at the nozzles. Undisturbed communication between the distributor operator and the jet operators shall be operating under every circumstance in order to minimize the extension time of the hoses and to maintain safety of the intervention.
- It is not recommended to apply bigger hoses than „C" (52 mm diameter) due to the awkward handling and the limited walking space.
- Application of film forming foam agent is necessary; in case of non-film forming foam agents the risk of re-inflammation is very high.
- Depending on the condition and position of the catwalk and the connected handrails, it may be necessary to protect the acting firemen against falling, or fixing these people, especially the ones handling the nozzles and the hoses, but it increases the time of the firefighting.

4. Artificial model research for the improvement of foam firefighting of pool fires

FOAM FLOW TESTS ON OPEN POOL (LIQUID) SURFACES

- I have proven by experimental means that the firefighting foam can flow to bigger distances - more than 50 meters - on the open surface of a combustible liquid pool and it can extinguish the fire, even without shooting the foam, if suitable foam agent and equipment is applied.
- I have proven by a series of tests that the penetration speed reduces as the distance from the foam application point increases.
- The fact was verified during the performed foam flow tests that a higher expansion rate foam results in a better firefighting performance in case of using the same foam agent; therefore it is preferable to use such elements in the foam firefighting systems that provide higher expansion rate foam.
- The tests did not prove the general consideration that application of low expansion rate foams is more beneficial in terms of flow speed and distance of the foam than application of higher expansion rate foams, such as medium expansion rate foam.

RESEARCH OF APPLICABILITY OF OIL- AND WATER-REPELLENT, FLOATING, FIRE RESISTANT DRY FOAM THAT CONSISTS OF SMALL BEADS WITH CAVITY FOR FIREFIGHTING PURPOSES OF INFLAMMABLE LIQUID STORAGE TANKS

- Dry foam is applicable for firefighting purposes in case of adequate circumstances and application method.
- Based on firefighting model tests, at least 10 cm layer thickness is necessary to firefighting.
- The required quantity of dry foam beads shall be applied onto the surface in a short time. The material cannot exert its firefighting effect if it is applied under a prolonged time.
- In case of using a dry foam quantity what is almost capable of extinguishing the fire, but is less than that, it will temporarily decrease the flaming considerably: the size of the fire surface and/or the flame height decreases. Firefighting of the surface with limited flames due to dry foam application is easy by using a little extinguishing media (e.g. sprayed water).
- For sake of successful firefighting, the nearby hot surfaces require cooling because the dry foam does not have any cooling effect.
- I made recommendations concerning further researches about the oil- and water-repellent, floating, fire resistant foam-like materials for the following goals: development of the conditions of practical usage; possibilities of using simultaneously with other extinguishing materials; research and/or development of materials with similar qualities (e.g. natural materials).

NEW SCIENTIFIC ACHIEVEMENTS

1. During real size fire fighting experiments, using measurements, **I proved** that in case of **full surface fires of large atmospheric liquid hydrocarbon storage tanks, the temperature is lower in the middle of the liquid surface than near to the tank shell, where the highest temperatures were measured**, and I proved that on an open surface of an inflammable liquid, **the fire fighting foam can flow to big distances from the foam application point, even to more than 50 meters, and it extinguishes the fire.**
2. Following the systematization and characterization of tank fire scenarios, based on real-size fire fighting tests aiming at the development of tactical operation processes of tank fire fighting, and directing at the evaluation of the applicability of technical equipment, and based also on observations and evaluating analysis of various calculation methods**, I made specific professional recommendations about the calculation of the foam application rate and the associated operating time for tank fire fighting by mobile equipment, and about modification of its procedure.**
3. Based on experiences of empiric researches and natural experiments and drills, I determined **the principles of the firefighting tactical procedure about rimseal firefighting of open, floating roof tanks by mobile means.**
4. By experiments of model tests, aiming at the development of the technical equipment system of tank fire fighting I proved **that the oil- and water-repellent, floating, fire resistant, foam-like material that consists of small beads with cavity** ("dry foam") **can be used for firefighting purposes.**

RECOMMENDATIONS OF THE THESIS

I suggest application of the contents of this thesis and the results of my research work for the specialists involved in installation or operation of large atmospheric storage tanks containing inflammable liquids, and for the fire protection and industrial safety specialist.

Furthermore, I recommend my thesis for the specialists working with the tactical emergency control procedure of firefighting and rescue, its technical equipment systems, fire water supply, extinguishing materials, foam and dry powder extinguishing, particularly the branch of tank fire safety and firefighting, and further subfields in relation to them. I recommend using them in the development and research of these activities, and in the training system of fire brigades.

I recommend my thesis as textbook, as study-aid, technical description, and as suggested topic of initiatives for further researches of the NUPS Institute of Disaster Management, HHK Military Technical Doctor School, the Disaster Management Training Center, Szent István University, Ybl Miklós Architectonic Faculty, and other higher level educational institutes.

PRACTICAL APPLICATION OF THE RESEARCH RESULTS

I suggest using the contents of my thesis, the findings and conclusions of my research work and my research results as follows:

1. The results of my thesis can be used to modernize the national and international regulations and professional recommendations, and for improvement of calculation methods and the professional requirement system used for planning tank fire fighting, especially tank fire fighting by mobile equipment.
2. It can be used for improvement and optimization of preparation and implementation of the establishment and operation processes in relation to tank fire fighting.
3. Improvement of the tactical procedure of tank fire fighting in order to improve efficiency of the firefighting activities.
4. The findings, conclusions and results of my researches can be used to reduce the environment pollution caused by mobile tank fire fighting, to reduce the usage of extinguishing materials, and to introduce the application of new extinguishing materials with more favorable characteristics with regard to their harmful load on the environment.
5. It can be used to systematize the available resources exclusively for fighting tank fires and the ones that can be used to fight tank fires also, therefore to improve the operation safety of high capacity mobile firefighting potentials.
6. It can be used to improve the efficiency and operational safety of the technical equipment of mobile tank firefighting, especially fire engines and roll-off containers, equipment operating by coaxial powder-foam combined firefighting jet, the high capacity foam and water monitors, the mobile tank firefighting centers, fire water supply, the foam agent supply and foam making equipment.
7. It can be used to develop the national emergency system what is capable of fighting tank fires, by cooperation of resources of the national disaster management system and the plants that have high capacity equipment to extinguish tank fires.
8. It can be used to elaborate and execute programs for improvement of efficiency and safety of high capacity firefighting, foam firefighting and tank fire fighting, especially the inevitable training programs for optimum and safe execution of response tasks performed in the area of tanks and their bunds, and the related technologies.

9. It can be used to determine the direction of further researches and developments, especially:
    a. development of calculation methods establishing planning of mobile tank fire fighting concerning examination of the duration of pre-burn and the effects of the effectively operating cooling equipment on the firefighting time and on the required foam application rate;
    b. research and development of practical application procedure of oil- and water-repellent, floating, fire resistant, dry-foam that consists of small beads with cavity; and materials with similar application characteristics.

LIST OF PUBLICATIONS OF THE AUTHOR IN RELATION TO THE SUBJECT

EDITED ARTICLES IN PROFESSIONAL MAGAZINES (ALSO AVAILABLE ON-LINE)

In foreign language magazines published in Hungary

1. Pimper, László; Mészáros, Zoltán: Koseki Hiroshi: Large scale diesel oil burns; AARMS Academic and Applied Research in Military and Public Management Science Volume 13, Issue 2, 2014. pp. 329-336

In Hungarian language authoritative magazine

2. Pimper, László: Tests of propagation of fire foam on liquid surface; Védelem (Defense) review on disaster management and fire safety 2010. Year XVII. No. 3. pp. 17-20.
3. Pimper, László: Inflammable liquid storing tanks and their usual fire scenarios; Védelem (Defense) review on disaster management and fire safety ISSN 1218-2958 2012. Year XIX. No. 2. pp. 21-25.
4. Pimper, László: Hydro-Chem – if the powder stream is too short…; Védelem (Defense) review on disaster management ISSN 1218-2958 2012. Year XIX. No. 5. pp. 19-22.
5. Pimper, László: Fighting bund fires of tanks storing inflammable liquid; Védelem (Defense) review on disaster management 2012. Year XIX. No. 3. pp. 15-19.
6. Pimper, László: DryFoam – fire foam without water; Védelem (Defense) review on disaster management ISSN 1218-2958 2014. Year XXI. No. 1. pp. 61-63
7. Mórocza; Árpád; Pimper; László: Railway transport of liquefied hydrocarbon gases; Védelem (Defense) review on disaster management 22. (5): pp. 9-12. (2015)
8. Mórocza; Árpád; Pimper; László: Railway accidents – Mobile emergency decanter for liquefied hydrocarbon gases; Védelem (Defense) review on disaster management 22.(6): pp. 15-17. (2015)

NON-EDITED ARTICLES IN PROFESSIONAL MAGAZINES

Hungarian language article

9. Pimper, László: Fighting fires of atmospheric storing tanks – Mobile tank firefighting and experiments at the FER Fire Department; MOL Hungarian Oil and Gas Plc. Professional Scientific Magazine ISSN 1217-2820 2005/2. pp. 201-220
10. Pimper, László: Fireman training ground in Duna Refinery of MOL Plc. I.; Védelem (Defense) review on disaster management and fire safety 2007. No. 4. pp. 43-44.
11. Pimper, László: Fireman training ground in Duna Refinery of MOL Plc. II.; Védelem (Defense) review on disaster management and fire safety ISSN 1218-2958 2007. No. 5. pp. 25-28.
12. Pimper, László: Don't make a person do the work of a machine! Flórián Press Hungarian Fire Safety Magazine ISSN 1215-492x pp. 372-373 Year 20. No. 9, 2011. September
13. Pimper, László: New perspectives in powder fire firefighting: Hydro-Chem technology; Flórián Press Hungarian Fire Safety Magazine Year 22. No. 5, 2013. May, pp.188-193

LECTURE PUBLISHED IN THE PUBLICATION OF AN INTERNATIONAL PROFESSIONAL CONFERENCE

Edited lecture in a foreign language magazine

14. László, Pimper: Tasks and objectives of the organization Lastfire - Researches and tests of FER Fire department; In: РИЗИК И БЕЗБЕДНОСНИ ИНЖЕЊЕРИНГ ЗБОРНИК РАДОВА 6. МЕЂУНАРОДНОГ НАУЧНОГ САВЕТОВАЊА КОПАОНИК 31.јануар - 05. фебруар, 2011. ISBN 978-86-84853-83-9 pp.324-337.

Non-edited lecture in a foreign language

15. László, Pimper: The system of mobile tank fire-fighting equipment; In: Conference publication: 5th International Conference for Fire Brigades in the Oil & Chemical Industry; Budapest, November 17-18, 2009 Published by: FER Fire Brigade and Service Ltd. Százhalombatta; Compact Disk ISBN 978-963-06-8639-6
16. László, Pimper: The role of the mobile fire-water supply system in the fire-water supply of Duna Refinery; In: Conference publication 6th International Conference for Fire Brigades in the High Hazard Industry; Budapest, October 25-26, 2011 Published by: FER Fire Brigade and Service Ltd. Százhalombatta; Compact Disk ISBN 978-963-08-2468-2
17. László, Pimper: Tank-fire tests of FER Fire Department; In: 1st International Professional Day of the National Association of Industrial Fire Departments, Tiszaújváros, May 16. 2012. ISBN 978 -963-08-4023

18. László, Pimper: Dry powder-foam dual agent firefighting: If the throw range of dry powder is too short… In: 8th International Conference for Fire Brigades in the High Hazard Industry; Date and place of the conference: Budapest, Hungary, 10 - 11. 11. 2015. FER Fire Brigade and Service Ltd. Százhalombatta; 2015. pp. 1-11. (ISBN:978-963-12-4086-3)
19. László, Pimper: Research of the application of anhydrous fire fighting foam; Védelem (Defense) review on disaster management and fire safety: pp. 15-29. (2016).
20. Pimper László: Research of tankfire-fighting application of the oil and water resistant, bead shaped, fireproof, buoyant dry foam; Védelem (Defense) review on disaster management and fire safety: pp. 44-64. (2016).

PUBLISHED IN THE PUBLICATION OF A NATIONAL PROFESSIONAL CONFERENCE

21. Pimper, László: Basic questions of mobile tank firefighting – Application rate; Conference publication: 5th International Conference for Fire Brigades in the Oil & Chemical Industry; Budapest, November 17-18, 2009 Published by: FER Fire Brigade and Service Ltd. Százhalombatta; Compact Disk ISBN 978-963-06-8639-6
22. Pimper, László: Protection of the intervening crew against thermal impact during fighting tank fires; Conference publication: 6th International Conference for Fire Brigades in the High Hazard Industry; Budapest, October 25-26, 2011 Published by: FER Fire Brigade and Service Ltd. Százhalombatta; Compact Disk ISBN 978-963-08-2468-2
23. Pimper, László: Firefighting of large atmospheric storage tanks; Conference publication: 7th International Conference for Fire Brigades in the High Hazard Industry; Budapest, November 27-28, 2013 Published by: FER Fire Brigade and Service Ltd. Százhalombatta; Compact Disk ISBN 978-963-08-7588-2

PROFESSIONAL-SCIENTIFIC CURRICULUM VITAE OF THE DOCTORAND

Name: Pimper, László **Place and date of birth:** Tapolca, July 12, 1971

I obtained wide practice mainly in the field of firefighting and technical rescue during my two and half decade fire fighter carrier both in the field of civil protection and industrial areas. I have been in various manager positions for 22 years. I have been working in the full-time industrial fire brigade of the Százhalombatta Duna Refinery in the past two decades, and I participated in elimination of several fires and accidents.

I have been managing FER Fire Brigade and Service Ltd, what operates industrial fire brigades in seven large oil and chemical industry centers of the country by now.

In addition to my managing tasks, I participate in training of disaster management and fire safety specialists, I hold lectures, and I perform consulting tasks as well. In the recent years, I helped the work of students as a consultant eleven times, who were writing their thesis in the National University of Public Service, Szent István University and in Óbuda University; I am the consultant of two theses under preparations at the moment. I also participate in the activity of various professional organizations; I have been the vice president of the National Association of Industrial Fire Brigades. I am a member of the Directorate of the Hungarian Firefighter Association, and I am the head of its International Committee.

I hold lectures regularly in various international forums, national and international conferences, and I manage the organizing committee of the International Conference of Industrial Fire Brigades, organized biannually in our country. I am cooperating with famous foreign scientists, specialists and organizations during my researches.

Studies: I obtained a fire safety engineer graduate in the Ybl Miklós Technical College, I graduated at the Accounting College as an Economy Specialist Engineer, and then I completed the Zrínyi Miklós University of National Defence, Bolyai János Military Technical Faculty and I became a graduate disaster management engineer.

Language skills: I have advanced level combined („C" type) English and elementary level combined („C" type) German language exams.

Professional career:

1992-1996	I was employed in Veszprém county, in the professional fire brigade of Ajka city.
1996-2006	I was employed in Százhalombatta in the professional industrial fire brigade of MOL Duna Refinery (FER Fire Brigade and Service Ltd.) in various manager positions: team leader; head of firefighting and rescue department, at the same time deputy manager and deputy fire chief.
2007-	I am managing the FER Fire Brigade and Service Ltd. as its Managing Director, and as its Fire-chief.

Recognitions: Recognition plaque of the Minister of the Interior (2015)

Budapest, April 15, 2016

Pimper, László