Description of the project for the general public

In many professions threats caused by a sudden gas ignition or explosion, hot liquid or vapour explosions, contact with hot objects, contact with electrical arc, etc. are encountered. Thermal hazards in these emergency situations may have large intensities exceeding 100 kW/m^2 and 1000°C and are characterized by short time of duration. In some cases, e.g., during putting out forest fires, the firefighters are exposed to longer thermal expositions with lower intensities due to large distance of operation from the fire source. Protection against the thermal and steam hazards is mostly based on wearing special multilayer protective clothing which can stand very high temperatures as well as thermal and steam loads. The structure of the typical protective garment and skin is presented in fig. 1.

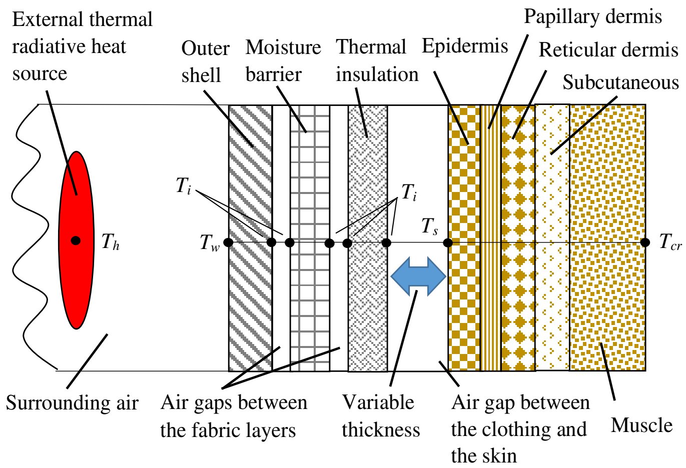

Fig. 1. Schematic of the multilayer protective clothing and the human skin

The thermal hazards may have radiative, convective and conductive character while the steam hazards have usually form of hot jets impingements. All transport phenomena in protective clothing strongly depend on the microstructure of fabrics. Thermal radiation which is incident on the external surface of the protective garment penetrates through the non-grey semi-transparent multilayer clothing and reaches the skin. The convective and conductive heat transfer from hot objects to the surface of the protective clothing lead to a rise in the outer fabric temperature and heat transfer to the skin. Steam jets incident the clothing, penetrate it and condensate increasing moisture amount and temperature in the fabric. Moreover, the people during routine and emergency activities intensively sweat. The moisture may also come from the surroundings. Therefore, even if no steam interactions, the water in the form of the vapour and liquid is usually present in the clothing, i.e., in the pores and gaps and in the bounded state in the textile fibres. Its presence leads to changes in the fabrics thermo-physical and optical properties and to additional energy transport due to moisture movement. Heat and mass transfer phenomena in the protective garments may be furthermore accompanied by a movement of the person who is wearing the clothing which leads to changes in the air gap size and air flow in the clothing. Moreover, profound investigations of energy transfer in protective garments and studies on their thermal protective performance also require modelling of heat transfer in the skin. Therefore, thermal analyses of the protective clothing are complicated and challenging.

Most of models presented till now in the literature assumed one-dimensional heat and moisture flow and contained a lot of simplifications. These models had inherent limitations and, e.g., the convective heat transfer in the air gap and through porous fabrics related to person movement could not be reliably modelled. The influence of fabric microstructure on the hygro-thermal and optical properties of clothing has never been considered. Therefore, in this project a new micro-macroscale model of heat and moisture transport in the single and multilayer protective clothing is proposed. The model will account for most important heat and moisture transfer modes in garments and in the human skin or in skin imitating material and will be formulated for three-dimensional geometry which will represent section of the clothing and body, e.g., part of an arm, a leg, a chest, etc. Moreover, the model will account for fabric microstructure, e.g., obtained from CT scans. To prove correctness and accuracy of the proposed model an experimental stand, which will allow for simulation of interactions of radiative heat fluxes and steam jets with single and multilayer protective clothing and with stationary and moving air gap between the clothing and stabilizing plate, will be built. In the final step, to have the overall view into transport phenomena in protective garments the developed model and experimental stand will be applied for parametric studies and optimization of heat and moisture transport in the single and multilayer protective clothing subjected to thermal and steam loads. The obtained results will allow for estimation of the real skin temperature, evaluation of skin burns as well as optimization of the clothing structure and fabrics morphology in terms of their thermal protective performance.