Introduction of Fire Research in China

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ABSTRACT

Fire research is urgently needed so as to mitigate fire damage with moderate costs. A system of fire research consisting of basic research, applied research and development of new technology for fire prevention and protection is being formed in China. A general structure of organizations related to fire research is outlined. Typical research work in the State Key Lab of Fire Science is given as an example of fire research in China including: Field-Zone-Network modeling of building fire, mechanism of boilover, forest fire behavior, computer modeling of fire spread in micsogravity, and duality of fire rules and its application.

WHY FIRE RESEARCH IS NEEDED

Fire loses have been increasing in China. A fire statistics with exclusive of forest fire is given in Table 1. It should be pointed out that the fire loss refers only the Direct Property Loss (DPL) . Neither indirect losses such as fees for suppression by fire brigades and the losses as a result of breaking production and supply of electricity, gas, water and so on, nor the fees paid in relation to death and injury of people in fires are included in the calculation of fire losses.

Statistics about forest fire shows that in China the forest coverage rate is 13 percent of the total land with around 0.13 hectares per person, which is much lower than the averages in the world. However, China is one of the counties with frequent forest fires. On average over 100 people died, 600 injured and 900,000 hectares of forest are damaged annually by fire, which is about 0.8 percent of the total forest coverage .

Table 1 . Fire Statistics in China (1988-1994)

Year	Number of fires	Death	Injury	DPI (Million Yuan)	DPL/GNP (%)
1988	29852	2234	3206	354.24	0.025
1989	24154	1838	3195	491.26	0.031
1990	58176	2011	4897	523.59	0.030
1991	45159	2049	3752	519.48	0.027
1992	39391	1937	3388	690.25	0.029
1993	38094	2467	5977	1120	0.035
1994	39120	2831	4236	1240	0.035

Fire has draw more attention from government officers, fire community and the whole society as well. It is started to be recognized that in order to mitigate fire damage with a moderate cost, better knowledge of fire and application of new concept and technology to fire prevention and protection are urgently needed among many aspects related to fire .

WHO ARE RESPONSIBLE FOR OR DOING FIRE RESEARCH

General Structure of Fire Administration[1,2,3]

Fire prevent and protection are administrated by several ministries separately according to the type of fire and the type of work done in the prevention and protection of fire. The Ministry of Public Security is in charge of the fire suppression and supervision of fire protection excluding forest fire. The professional fire brigades are under the Fire Protection Bureau, Ministry of Public Security. Ministry of Forestry is responsible for the prevention and suppression of fire in forest and forestland. The forest police troop (professional forest fire brigade) was established in 1988. The troop of ten thousands becomes the main force to attack the forest fires in northeast and the inner Mongolia of China. Ministry of Construction is in a position to draw up and officially issue the national codes of fire protection design. Ministry of Labour is the representative of the Chinese government in labour safety including issue of the regulations related and supervision of their performance in practice. Fire safety of labour is one the aspects covered by the labour safety .

Framework of Fire Research

A system of fire research is being established in China, in which three categories of research are included. They are basic research, applied research and development of new technology for fire prevention and protection. In each category there are some typical organizations. The State Science and Technology Commission (SSTC) is a government administration of planning, coordinating and funding national projects of science and technology including fire science and technology. In the 9th five years plan there is a key research project "Study of technology for prevention and control of building fire and industrial hazard" funded jointly by the SSTC and related ministries. The National Science Foundation of China (NSFC) is a government agency of funding basic research. Fire science is an area with priority to support. The institutions under the Chinese Academy of Science and the universities are main bodies doing basic research. The State Key Lab of Fire Science is a representative institution of basic fire research with a national level in China. Those institutions under the Ministries mentioned in last section are the important organizations for applied research and development of new technology. Some work of developing technology and new products of fire prevention and protection is also carried out in the companies related or branches of big manufactures.

The objective of dividing up the fire research into three categories is to make a good use of the limited funding provided by the government and raise the research level in each category. However, the problems still exist of low-level overlapping between research organizations and of transfer of

research into practice.

State Key Lab of Fire Science (SKLFS)

A Key Study Development Project (KSDP) was initiated in china in 1988, which was supported by the State Planning Commission through the World Bank loan. The main objective of the KSDP is to promote research and train qualified personnel in the selected research areas by the establishment of the so-called State Key Laboratories in each of the areas. The State Key Laboratories should be, according to the goal, the national representative and step into the international community in their own area of research. The State Key Lab of Fire Science is one of the laboratories. Research orientation of the SKLFS is study of the mechanism and rules of most aspects of fire, such as ignition, spread of fire and smoke, and suppressions. It provides technical support to engineering research and development of new technology for fire safety. The structure of the SKLFS, its function and coordinate in fire safety are given respectively in fig 1, 2 and 3.

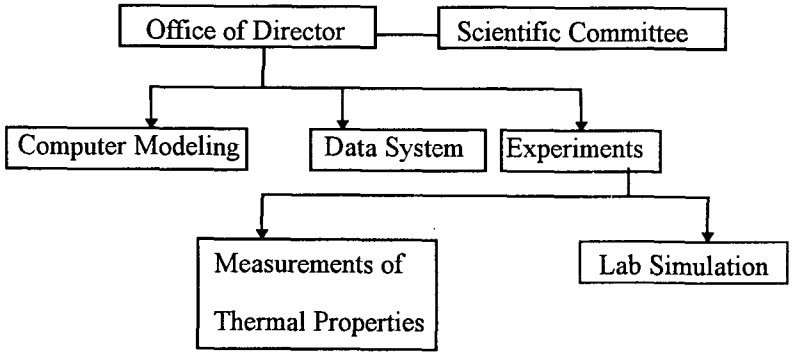

FIGURE 1 Structure of the SKLFS

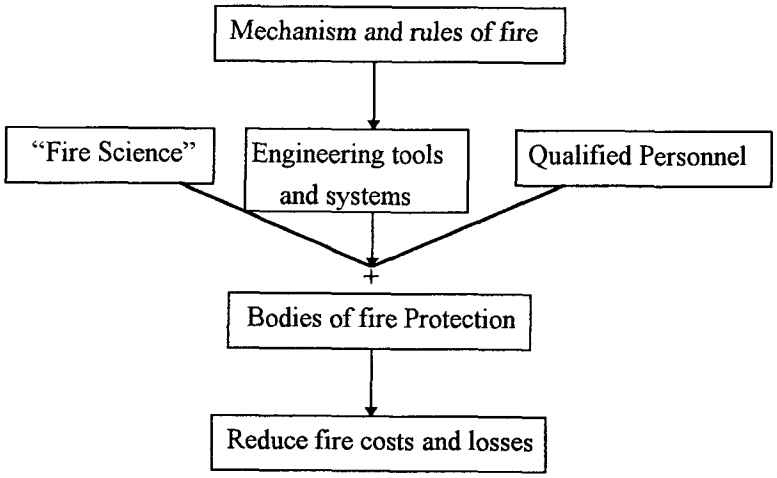

FIGURE 2 Function of the SKLFS in fire safety

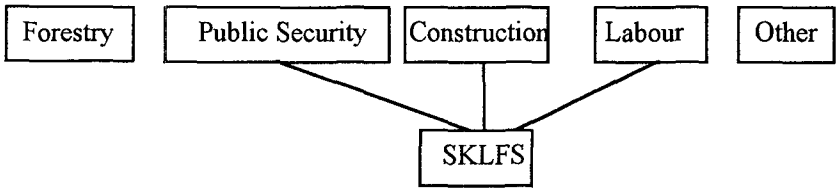

FIGURE 3 Coordinate of the SKLFS in fire safety

Several facilities have been built to conduct experiments at SKLFS, such as:

- Wind tunnel with a test section of 1.8 × 1.8m^2 and 7 meters long, in which a fuel bed can turn
- Full scale burning hall of 24m(L) × 18m(W) × 30m(H)
- Half scale 5-story building
- Full scale guest room
- Thermal radiation apparatus with water curtain
- Boilover apparatus
- Furniture calorimeter
- Salty water simulation apparatus
- Water mist apparatus
- Several small-scale experimental setups

Apart from research, which will be introduced in the next section, many activities have been carried out in the SKLFS. Among them there are:

* First National Symposium on Fire Science was held in march 1988. 40 participants came from ministries of forestry, public security and construction as well as Chinese Academy of Science and universities.
* China--Japan Joint Seminar on Fire Science was held in October 1990. 60 people attended the seminar.
* China--Japan--USSR Joint Seminar on Fire Science was held in November 1991. There are 80 participants.
* First Asian Conference of Fire Science and Technology was held in October 1992. Over 100 participants came from 10 countries and regions. An Asian association for fire science and technology was established during the conference. Professor T. Hirano was elected as the president of the association with its secretariat in the SKLFS.
* An International Seminar on Fire Safety Frontier was held in October 1995 at USTC;
* A journal " Fire Safety Science " has been initiated and the first issue was published in September 1992, which is written in both Chinese and English.
* A book " Introduction to Fire Science " and many papers have been published, and several reports have been produced. Most of them are written in Chinese.
* The courses of " Fire Science " leading to Master (from 1984) and Doctor (from 1990) degrees and "Thermal Safety Science and Engineering" leading to Bachelor (from 1996) degree have been initiated in the University of Science and Technology of China.

WHAT HAS BEEN OR IS BEING DONE

Many projects have been done or are being done of fire research in various institutes and universities. It is impractical to describe all those work in a single paper. Accordingly, several work in the SKLFS
will be presented below as an example of fire research in China

Field-Zone-Network (FZN) Models For Building Fire

Modeling of a fire has drawn much attention in the fire research commentates. Freedman listed 62 models of building fire in 1991[4]. Generally, there are three kinds of models[5] with regards to the methods of modeling: network modeling, zone modeling and field modeling. It has been found by experiment and observation of fires that the gas layering phenomenon, which is a basic assumption of the zone modeling, is unclear in some spaces during a building fire, for example in a space of strong fire origin or with strong ventilation or with complicated geometry or in a large scale. Field modeling can do better in these cases. However, large capacity of computer is needed for doing so. Therefore, people are thinking new models which can be used for predictions of fire processes in a multistory or even a high-rise building with a acceptable combustion of accuracy and economy. The development of the Field-Zone (FZ) modeling and the Field-Zone-Network (FZN) modeling is just a kind of such attempts.[6,7,8]

The main idea of FZ modeling is to use field modeling in the spaces with fire origin, strong ventilation, complicated geometry or those fire processes which need to be understood in details, and to use zone modeling in other spaces of the building. The FZN modeling is a further development of the FZ modeling, in which the network modeling is applied in the spaces faraway from fire origin. The research being done on FZ and FZN modeling is, firstly to deal with the interfaces between the contiguous space spaces with different models correctly, secondly to improve the numerical method, and thirdly to develop a single computer code incorporating FZ or FZN models.

Preliminary predictions have been made of smoke movement with the FZN modeling in a five-story building. A fire source with heat release rate of 7500w and mass production rate of 0.001kg/s is located at the f room of the third floor. The power of the fire source is supposed to become two times bigger in 28 second after ignition.

Predications obtained by the FZN modeling show that the recalculating flow appears in the f room , that the hot gas enters the z room through the opening from the f room shortly after the fire starts and forms hot layer in the room , that then the hot layer drops below the top of the opening , and hot gas spreads into the corridor and other spaces including rooms and stairways which is studied by network modeling.

Study on Boilover Phenomena and Its Prediction Method

Boilover phenomena have usually been observed when a relatively large fuel surface area was burning with a water sublayer, e.g., in a crude oil storage tank , and it is always considered as one of the most hazardous fire behaviors for its special combustion behavior. Once boilover happens in an oil tank fire, the fire loss can be upgraded. Studies on boilover phenomena , both on its fire behavior and mechanism, have been conducted widely[9,10,11]. Unfortunately, because of the complexity of the boilover phenomena, the mechanism of boilover is still not clearly understood.

As the results of the careful observation on the experimental simulation of boilover phenomenon, a typical boilover process could be empirically divided into three basic stages, i.e., a quasi-steady period, a premonitory period and a boilover period. Generally thinking, the premonitory phenomena are the additional ones to liquid pool fires without water sublayer, i.e., they represent the effect of water layer on the oil burning. Hence, to understand the mechanism of the premonitory phenomena is the first step to understand the occurrence of boilover. Therefore, our objectives were firstly aimed at careful observation on the premonitory phenomena, and then making measurements in the premonitory period[12]. Especially, the emission of micro-explosion noise, one of the most prominent premonitory phenomena, was investigated carefully on both its acoustic characteristic and its emission mechanism. Simultaneous measurements reveal that the water boiling on the oil/water interface results in the emission of micro-explosion noise, which may provides us with a possible knowledge to predict the occurrence of boilover .

Based on study of the emission mechanism of micro-explosion noise in the premonitory period, a novel approach for boilover predication was presented[13,14], i.e. prediction of occurrence of boilover by its micro-explosion noise. Nevertheless, in a real fire situation, the micro-explosion noise was always contaminated by background noise. So, the key technical point of this approach is to identify the micro-explosion noise from environmental noise. Here, a set of features of the micro-explosion was sorted out to identify the micro-explosion noise form background noise using template matching method .

Based on the recognition of the micro-explosion noise, the new concept of OFN (the Occurring Frequency of Noise emission) could be obtained. Theoretically, the micro-explosion noise was emitted only after the interfacial temperature reaches water's boiling point. However, because of the complexity of oil component (e.g. existence of water), the noise is emitted during the entire oil burning process. It is also found from the variation history of the OFN that its value is lower in the quasi-steady period and boilover period, reaches its highest value in the premonitory period and ranges between 0.20-0.5, representing that there is the greatest amount of bubbles formed on the interface in the premonitory period so that the micro-explosion noise is emitted most frequently in this period. As we know, when the amount of bubbles formed is greater, and the micro-explosion occurs more frequently, and the OFN value because larger. Hence, the occurrence of boilover may be predicted based on those knowledge.

Forest Fire Behavior

Experiments study of forest fire is being done in the combustion wind tunnel. Several kinds of fuel and various velocity of incoming flow are used to investigate the effects of fuel type and the velocity on the fire behavior including fire spreading rate and fire intensity, which are similar to the work done in the Intermountain Fire Science Lab located in Missoula, Montana, USA. However, the influence of the pattern of incoming flow is also studied in the SKLFS. A bluff body is placed in the upstream of a fuel bed. Either karma vortex street or a turbulent recalculation attached to the back of the bluff body can be generated by adjustment of the size of the bluff body or the velocity of the incoming flow. Fire vortices have been observed when the karman vortices are generated and shaded on a burning fuel bed. Furthermore, it has been found that the flame goes up along the offside of the bluff body and stays longer in the recalculation zone adjacent to the bluff body. This flame may ignite the combustibles adhered to the back surface of the bluff body, which throws a light on understanding the mechanism of transition from ground fire to crown fire in a forest fire.

Numerical Prediction Of Flame Spread Over Solid Combustibles Under Microgravity

The study of flame spread over solid combustibles under microgravity is essential for the improvement of fundamental combustion understanding and fire safety considerations in nonbuoyant environments[15].

The CFD governing equations for the conservation of mass, species, energy and momentum have been adopted to describe movement in the gas phase. The mathematical treatment of gas-solid interfacial coupling[16] is based on transfer of mass, momentum and energy at the interface. The heat flux balance at the gas-solid interface is directly included in the solid energy balance equation.

The physical problem presented here is flame spread over a vertical wall in an enclosed chamber. In the calculated cases, the initial pressure is 1.5 atm, and the O_2 volume concentration in N_2 is 30%. In Cartesian Coordinates, the thermally thin cellulosic sheet is assumed to be on the y-o-z plane. The computational domain is taken as (x: 0 ~ 0.3m, y: 0 ~ 0.9m, z: 0 ~ 0.9m) with ignition point at the location of (0, 0.45m, 0.30m). It is found from predictions that the buoyancy effect is almost negligible under 10^{-4} g. While under 10^{-2} g the natural induced flow has a significant effect on the flame spread process. The predictions of flame spread rate over a thermally thin cellulosic sheet are found in qualitative agreement with the available experimental data.

Dual-Nature Character of Fire Rules and Its Application

Fire rules have duality in nature: determinability and probability[17,18]. Only when we study not only its determinability but also its probability and furthermore study their combination, can we understand the rules of fire as a whole.

A prime method to study the determinability of fire is modeling including experiment and computer modeling, while statistics analysis is the main method to investigate the probability. It is being tried

to construct a theoretical framework with a single software, which can accommodate various methods of modeling and statistics, and can combine effects of both deterministic and probabilistic factors, and then show the duality of fire rules. The framework is so-called a Combined Modeling of Deterministic and Probabilistic Characters of Fire Rules, called the CDP modeling for short.

The CDP modeling has a great potential of applications in fire science and engineering, which is illustrated here by a fire risk analysis of a furnished rooms with the modeling. As a fire goes on in the room a hazardous state will reach. We would like to know a possibility of arrival at hazard state in a certain time after ignition. According to the CDP modeling the deterministic part includes heat release rate of the furniture, thermal process in the room, and the criterion of hazard, which can all be determined by experiment or computer modeling. The probabilistic part considered in present study is ignition probability of the furniture and its arrangement, which can only be obtained by statistics usually. By combination of the two parts we will know the probability of reaching hazard state at a specified fire duration.

CONCLUDING REMARKS

Many researches have been done on fire safety science and technology for high-rise, underground and atrium buildings, forest and industries in China. Some of the research results are quite interesting. Unfortunately, most of them are not known outside because of difficulties in both language and funding for international activities.

China is a developing country with the largest population and fast-growing economy. Reform is under way in almost all areas including fire safety. In this area technology, management, regulation, education and training as well as fire research are all needed to be improved. Chinese community of fire research is very much interested in joining the international community of fire safety science and technology, and developing exchange and collaboration with the related institutions in the world .

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