

Written opinions by several participants suggested that fighting against fires is not the single function of fire department, and pointed out importance of the promotion of the inspection by fire department at the design and completion of a public building and continuation of surprise inspections after the completion of the building. Promotion of fire safety science with special emphasis on the consideration of local circumstances in building technology, climate and human behaviors, and its penetration to such practitioners such as building regulators, designers and fire fighters should be also an important subject in such countries suffering from rapid increase of fire disasters. In relation to the presentations by Prof. Fan and Mr. Lee, a Thailand diplomat who joined the workshop pointed out need of the transfer of experience and knowledge on the management of building and safety regulations from western world to the newly industrialized countries and districts. He suggests that although many Asian countries have already introduced building and regulations, they do not seem to function so well probably for the lack of experience. Some written comments emphasized needs of the promotion of international communication of fire experts in Asia since the community of science-oriented fire experts in each Asian country is generally too small to cover all aspects of fire safety which is becoming more and more complicated.

In relation to the safety problem raised by Prof. Fan, Mr. Komamiya further pointed out recent notable increase of small to medium scale industrial accidents in Japan. He attributes this increase to the paralysis of people's sensitivity toward danger after one generation since the Japan's high economy growth in the 1960's, which he anticipates as a cause for new types of accidents and disasters in a developed industrial society. Certainly Japanese journalism reports recent increase of significant accidents in medical facilities, which is generally taken as a sign of the paralysis of safety management in the medical world. He also pointed out possible influence of the recent restructuring in industries on the safety management. It is said that some of the recent important industrial disasters including the Japan's first nuclear pollution in 1999 occurred slightly after reduction and/or significant reshuffle of management staffs. There was some consensus in that "cost destruction" in the post cold-war capitalism is likely to generally weaken the social basis for the industrial and urban safety. Technical development in safety management can be essential while it does not have drawn interest of fire scientists.

#### CONCLUDING REMARKS

Presentations and discussions during this workshop seem to reveal several new areas for fire research and its relation with society especially in Asian countries. The following are among such important subjects for the promotion of fire safety and research in Asia.

- (1) Promotion of investigation of actual fire disasters by fire experts and researchers
- (2) Promotion of fire reports and statistics
- (3) Promotion of research in social aspects of fires and other disasters
- (4) Promotion of international exchange of information and ideas for fire safety

Sound scientific fire investigations and statistics are believed to be important not only for local fire experts but also as a valuable window for international fire community to learn what are the central problems in respective countries if they are delivered in international conferences or journals. Transfer of experiences of preceding countries in fire investigation and statistics should be promoted for the development of fire investigations and fire statistics in newly industrialized countries and districts.

## Current Status of Fire Safety and Scope of Fire Safety Measures and Research in China

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#### ABSTRACT

In this paper, the fire statistical data of China from 1986-1995 are analyzed in order to reveal the new features for the fire safety situation along with the China economy growing. The measures taken to improve the fire safety in China are reviewed, and the emphases of the fire researches in the next years are suggested.

**KEYWORDS:** China, Fire Safety, Fire Research

#### 1 INTRODUCTION

The triplet of safety, environment and energy, being closely related to everyday life of people, has been proven to be a major concern of the world civilization. Today fire is still and also would be in the foreseeable future one of the major disasters threatening the life and industrial safety.

Since the policy of reform and opening to the outside world, China has been a developing country with the economy booming fast, and meanwhile the situation of fire safety has been severe during the past decade. In recent years, the increasing fire disasters in China are calling nationwide and even world-wide attention. In 1999, China reported 18,000 fires, resulting in direct property losses of 1440 million yuans, 2744 deaths and 4572 injuries. Compared with the data of 1998, the death due to fires increased by 14.9%, and the direct property losses increased by 26.4%.

The combination of better understanding fire phenomena and new technology for fire

prevention and protection should be the way for us to promote the daily life and industrial fire safety during the new century. In this paper, the current status of fire safety in China is analyzed by inspection into the annual fire data from 1986-1995 reported by the Fire Service Bureau, Ministry of Public Security. We use the data of this decade in respect that during this period China underwent great social and economic changes due to the reform policy put into practice in all its aspects, and accordingly new features and trends for the fire safety situation appeared. The measures taken to improve the fire safety in China are reviewed, and the future research work in this aspect for the coming years is suggested.

## 2 STATISTICS AND ANALYSIS OF FIRE DISASTERS

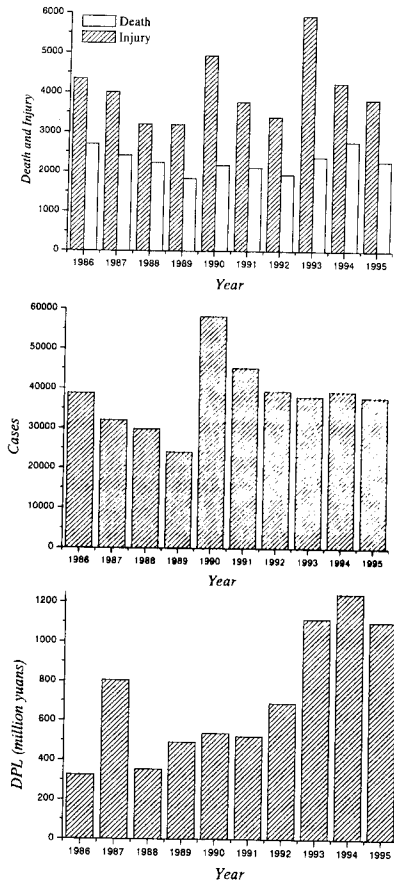


FIGURE 1. Comparison of annual fires in the ten years from 1986-1995.

Annual fire data reported by the Fire Service Bureau, Ministry of Public Security from 1986-1995 are listed in Table 1 [1]. These data don't include those of forest fires and grassland fires. During these 10 years, on average, 38,292 fires occurred each year, 2,281 people died by fires, 4,086 people were injured and annual direct property losses (DPL) were approximately 718.94 million Chinese yuan. On average, every day 105 fires occurred, 6 people died, 11 people were injured, and the direct property losses were about 1.97 million Chinese yuan. The annual fire cases, deaths, injuries and DPL are compared in Figure 1, indicating that during the ten-year period, the fire cases, as well as the deaths and injuries due to fires remained on an average level. There is no obvious trend for any of these three indices to increase or decrease during this period, although the data for one or two years appear much more than those for other years. On the other hand, however, it's obvious that the DPL due to fires in the decade increased by a big margin. Except for 1987, the annual DPL increased by degrees on the whole, and especially from 1992 to 1993, the annual DPL increased greatly and then remained on a new high level up to date (the fire induced DPL in 1998 is about 1448 million yuan, and that in 1999 is about 1440 million yuan, both comparable with the data for 1993-1995). This change implied that with the development of the economy in China, the possible losses due to one

fire case increased greatly on an average.

TABLE 1. Fire Statistics of China from 1986-1995

Year	Cases	Death	Injury	DPL (million yuan)	DPL/GNP (%)
1986	38766	2691	4344	325.85	0.034
1987	32053	2411	4009	805.61	0.073
1988	29852	2234	3206	354.25	0.026
1989	24154	1838	3195	491.26	0.031
1990	58207	2172	4926	536.89	0.031
1991	45167	2105	3771	521.59	0.027
1992	39391	1937	3388	690.26	0.029
1993	38073	2378	5937	1116.58	0.038
1994	39337	2765	4249	1243.91	0.028
1995	37915	2278	3838	1103.16	0.019

Inspection into the fire data leads us to conclude that the fires resulting in heavy property losses are in a large degree due to a few conflagrations. In China, the so called 'conflagration' is defined as a fire which causes ten or more deaths; heavy injuries to more than 20 people; death or heavy injuries to more than 20 people; damages more than 50 residential settlements, or causes direct property losses of more than 500 thousand Chinese yuan. The data in Table 2 indicate that although the annual conflagrations cases remained on a low level, the deaths, injuries and DPL due to the conflagrations accounted for quite a large portion of the total. For

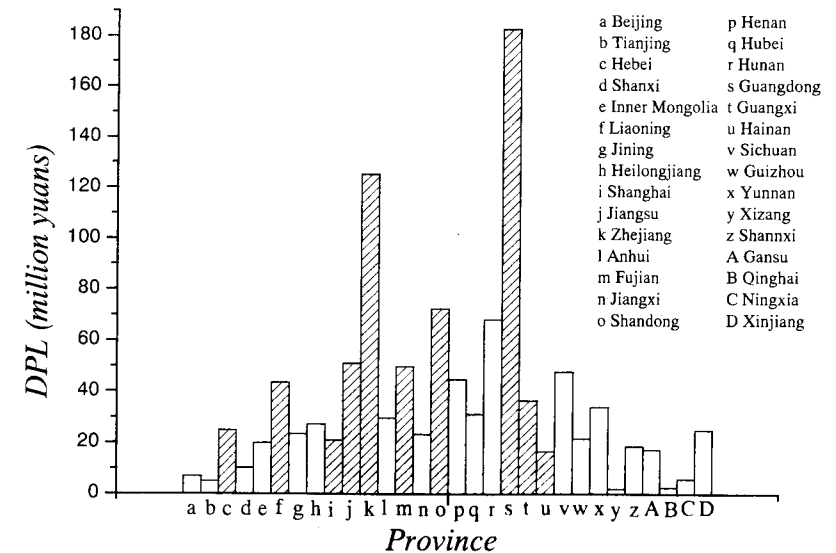


FIGURE 2. Comparison of the fire induced DPL for all provinces in China (from the data of 1995).

instance, in 1993, the conflagrations accounting for only 0.6% of the total fire cases led to more than 50% of the total property losses. In addition, it seems that on the whole there's a trend for the conflagration cases to increase during the ten years, this might be due to the fire service construction and maintenance of cities and towns failing to keep step with the fast growing economy.

TABLE 2. Statistics of Conflagrations during Years from 1986-1995

Year	Cases	Rate of the total	Death	Rate of the total (%)	Injury	Rate of the total (%)	Losses (million yuans)	Rate of the total (%)
1986	117	0.3%	272	10.1	261	6.0	100.69	31.1
1987	114	0.4%	400	16.6	460	11.5	615.75	76.4
1988	146	0.5%	146	6.5	147	4.6	116.36	32.9
1989	144	0.6%	78	4.2	178	5.6	238.52	48.6
1990	114	0.2%	133	6.6	432	8.8	194.30	36.2
1991	124	0.3%	147	7.2	207	5.5	167.69	32.2
1992	177	0.4%	153	7.9	125	3.7	283.26	41.0
1993	205	0.6%	568	23.9	2226	37.5	580.00	52.1
1994	264	0.7%	—	—	—	—	590.61	47.5
1995	206	0.5%	259	11.4	279	7.3	393.89	35.7

In Figure 2 the fire induced DPL for all provinces and municipalities directly under the Central Government in China are compared using the data of 1995 as an example. The data of the later years of this decade shared common characteristics as shown in Figure 2. The shaded columns denote the coastal provinces and coastal large cities which include respectively: Hainan, Guangdong, Guangxi, Fujian, Zhejiang, Shanghai, Jiangsu, Shandong, Hebei and Liaoning. With their leading economic development, fire accidents which have occurred in these places are notable. Figure 2 obviously indicates that the fires in the coastal provinces led to much heavier DPL than other provinces. Altogether 15893 fire accidents were reported in 1995 in the above 10 provinces and cities, resulting in 1064 deaths, 1773 injuries, 624 million yuan direct property losses, making up 46.9%, 46.3% and 57.3% of the total fire accidents in China, respectively. Nearly 60% out of the 206 conflagrations were reported in coastal provinces, which in turn accounts for 63% of the total losses of conflagrations in China. There were 45 cases of conflagrations which took place in Guangdong province, making up 22% of the conflagrations all over the country, with the corresponding direct property losses surpassing 100 million yuans which is over a quarter of the total losses due to conflagrations all over China.

Fires can be induced by many reasons, such as arson, electricity, cigarettes, improperly daily fire use, and so on. Insight into the main reasons resulting in fires in one sense implies the important points which should be paid special attention to for the fire prevention and protection. Figure 3 compares the different causes which resulted in fires during the years of 1986-1995. It can be inferred from this figure that electricity and improperly daily fire use are the two main fire causes all through the ten years, resulting in 46.4% of all the fires during the

decade. Disregarding safety rules and cigarettes make up of the other two secondary main causes leading to about one quarter of the total fire cases.

The statistical data also show that in recent years fires began to strike the high-rise buildings. As shown from the data, before 1994, few fires occurred in high-rise buildings, however, in 1995, 12 conflagrations were reported in high-rise buildings, resulting in 73 deaths, 47 injuries and DPL of 74.55 million yuans. This seems to be related to the lagging of the fire

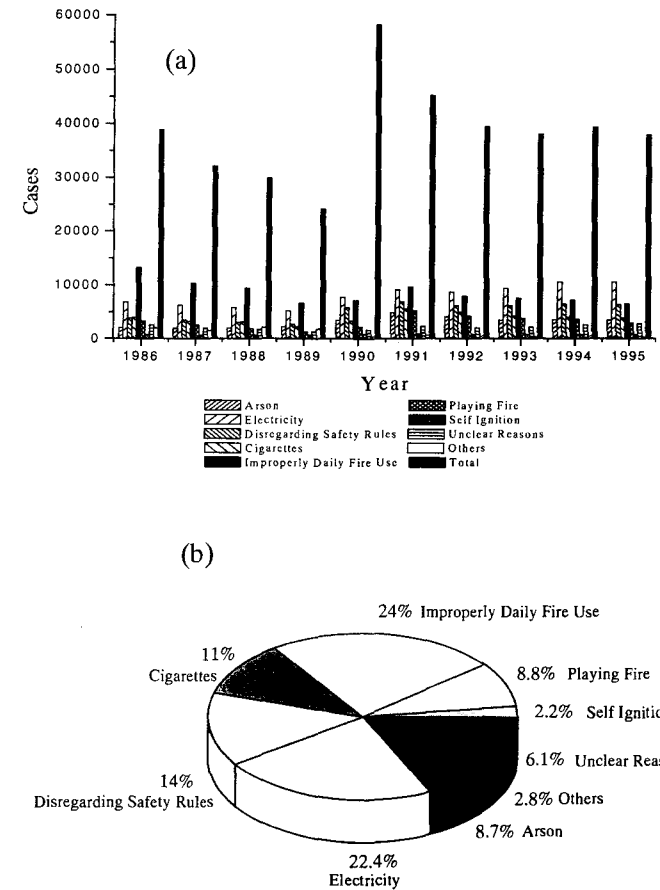


FIGURE 3. The causes of fire occurrence from 1986-1995.

(a) Annual fire classified by causes of occurrence;

(b) Distribution of causes of fire occurrence for the ten years

prevention and protection for the high-rise buildings. Statistics (quoted in [2]) show that high rise buildings in China by 1993 have reached more than 20000, the highest one surpassing 200m in height. At the same time, the total number of high-ladder vehicles concerned with fire fighting is less than 210 and the maximum lifting height is only 50m. Also, so far, there is no helicopter specifically for city fire protection. In addition, as the fire and smoke characteristics in high-rise buildings differ greatly from those in general buildings, the fire protection knowledge for the high-rise building should be enhanced by in depth research.

With the policy of opening to the outside world consistently carried out, more and more foreign-invested enterprises and jointly-invested enterprises are established in China. During the past decade, fire accidents related to these enterprises have been becoming frequent. In 1995, of the 206 conflagrations in the whole country, about 10% of the total are presented in the foreign enterprises, resulting in 35 deaths and 23 injuries, with the DPL being 81.3 million yuans.

Base on the above analysis, the following points can be concluded as for the fire safety features in China during the 10-year period of 1986-1995:

1. With the development of economy, although the fire cases, as well as the deaths and injuries due to fires remained on an average level, the DPL due to fires in the decade increased by a big margin.
2. The fires resulting in heavy property losses are in a large degree due to a few conflagrations.
3. The fires in the coastal provinces led to much heavier deaths, injuries, and DPL than other provinces.
4. Electricity and improperly daily fire use are the two main fire causes all through the ten years, while disregarding safety rules and cigarettes make up of the other two secondary main causes.
5. The fires in high-rise buildings and the foreign-invested or jointly-invested enterprises have began to increase by degrees in recent years.

As a closing of this section, the urbanization and industrialization presently occurring in China have made the fire safety situation severe. With the fast growing economy, more fire protection measures should be taken, and more deep fire researches should be performed, so as to ensure the daily life and industrial fire safety.

### **3 FIRE SAFETY MEASURES IN CHINA**

In past years, China has taken a great deal of measures to improve its ability for fire prevention and protection, which are reviewed as follows.

### **Fire Regulations and Laws**

Since the foundation of the new China, a series of regulations and rules for fire protections have been issued and executed, such as 'Fire Protection Regulations of the People's Republic of China' and 'Fire Protection Standards in Building Construction'. On Sep. 1st, 1998, the 'Fire Protection Law of the People's Republic of China' began to be put into practice, in which the fire safety responsibilities of the governments of different levels were clearly defined. In addition, this law also defined in detail the fire protection responsibilities of the different government units, enterprises, government-sponsored institutions, and the citizens. This law underlies a good social atmosphere and a high efficiency for fire prevention and protection.

### **Fire Protection Administration, Arming and Equipments**

In China, fire prevention and protection are administrated by several ministries separately.

The Ministry of Public Security is in charge of fire suppression and supervision of fire protection excluding forest fire. A special army branch was set up to cope with fires which happened in cities and towns. Up to date, the Fire Service Branch of the People's Liberation Army has a personnel of over 100,000, dispatched all over the country. Every year they put out thousands upon thousands of fires, with help from local amateur firemen and local people at the same time.

The Ministry of Forestry is responsible for the prevention and suppression of fires in forestry 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 the northeast and the inner Mongolia of China.

The Ministry of Construction is in a position to draw up and formally issue the national codes of fire protection design.

The Ministry of Labor (now known as 'State Economic & Trade Commission') is the representative of the Chinese government in labor safety including issue of the regulations related and supervision of their performance in practice. Fire safety of labor is one of the aspects covered by the labor safety.

### **Fire Research**

A system of fire research is being established in China, in which three categories of research are included, respectively known as basic research, applied research and development of new technology for fire prevention and protection. There are different typical organizations

respectively devoted to different categories of study.

The National Science Foundation of China (NSFC) is a main body of coordinating and funding basic research in various areas. Fire science has been given a priority of funding since 1988 soon after the large forest fire in the Great Xingan Mountain. Based on a successful completion of several projects on fire science, a key project, headed by Fan Weicheng, entitled "study of thermophysics in fire processes and fire safety" was formally approved in 1993 and started in 1994. This is the largest key project in the division of Engineering Thermophysics and Energy Utilization during the period of 1991 to 1995. Another key project, entitled "study of special fire phenomena" has recently began to be performed, aimed at better understanding the special fire phenomena such as flashover, backdraft, and gorge fire.

The State Key Laboratory of Fire Science (SKLFS) is a representative institution of basic fire research with a national level in China. The founding of this laboratory marks the beginning of a period when fire research is carried out on a large scale in various complicated areas with many different departments working together for the first time. In the past few years, this laboratory worked in the national or international forefront of fire science and technology. Effective and fruitful research has been carried out in areas such as fire physics and fire chemistry by way of both experiment and computer simulation.

During the past decade, different ministries of the Chinese government have also established relevant fire research institutions devoted to applied research and development of new technology. The Fire Service Bureau under the Ministry of Public Security is a leading body of professional fire brigades as well as four fire research institutes located at cities of Tianjin, Shanghai, Shenyang and province of Sichuan respectively. These four institutes are mainly devoted to the research of applied technology and equipment for fire protection, with different emphasis on various research areas. Sichuan Institute deals mainly with the fire-resistance properties of building materials and structures, and fire proof techniques; Tianjing Institute works on fixed systems for fire extinguishing, and the research and application of technology and equipment for fire fighting with different types of fuels; Shanghai Institute mainly carries out some research and services; Shenyang Fire Institute devotes its efforts mainly to the research of fire alarm systems and communication systems for fire fighting.

Under the China Academy of Building Research, the Ministry of Construction, the Institute of Building Fire Research also carries out fire research, covering the fields such as the thermal properties of materials, tests of fire prevention and fire-resistance of building structures and components, smoke-driven systems for buildings, etc.

Besides, the Institute of Labor Safety Science and Technology of the State Economic & Trade Commission also engages itself in some fire researches. The Ministry of Forestry also has specialized research institutes in forest fire research.

## Fire Protection Education and Training

In China, Nov. 9th is defined as the 'National Fire Prevention and Protection Day'. Every year, many social activities are taken on Nov. 9th in order to help citizens improve their fire prevention and protection knowledge. In universities such as the University of Science and Technology of China and the China University of Mining and Technology, complete fire protection education systems have been built up. Every year, several youths obtain Bachelor, Master, or Ph. D. degrees of fire safety science, due to their excellent achievements in fire researches. Many fire protection troop men are trained in the universities to improve their professional knowledge.

In conclusion, many measures in many aspects have been taken in China to improve its ability for fire prevention and protection. However, it should be clear that there still remain much work to do in order to improve the ability against fire hazards. Especially, as for the fire research, there are still many complex fire phenomena whose mechanisms are unclear up to date. In view of the main characteristics of the typical fires in China, some important fire researches should be emphasized in the following years, which will be outlined in the next section.

## 4 OUTLINE OF THE FUTURE FIRE SAFETY RESEARCHES IN CHINA

In one sense, the basic fire research aimed at better understanding fire phenomena is of the greatest importance for us to promote the daily life and industrial fire safety, for the basic research achievements underlie the new technology for fire prevention and protection. In terms of the main features of the fires in China, several important points are outlined as follows for China fire safety basic research in the next years, which are in fact also the scientific subjects to the common interests of the fire safety scientists and engineers all over the world.

### Fire Disaster Formation Theory of Solid Combustible Dynamic System

This study deals with the transition theory for the solid combustible dynamic system from the nonflame oxidation to fire disaster.

In general, nonflame oxidation can be classified into two categories: the oxidation at normal temperatures and smoldering. China is a country using coal as the major energy source, while the oxidation occurring at normal temperatures results in losses of high-class coal at a speed of about 10 million tons per year. This kind of oxidation is also sometimes the cause of the self-ignition and explosion of large barns in China. However, the mechanism of the oxidation at normal temperatures is not yet clear, and much work should be done in this aspect in order to reveal the conditions which can induce the oxidation at normal temperatures. Compared with the oxidation at normal temperatures, smoldering generally occurs at much

higher temperatures. Smoldering is one of the most frequently reported causes of forest fires in China. Research should be performed so as to find out the factors controlling the occurrence of smoldering and its development, especially its possible transition into fire disaster.

#### **Fire Disaster Formation Theory of Gas or Solid-gas Mixtures**

The background of this study lies on the fact that every year in China great life and property losses result from the coal dust explosion, mill dust explosion, and gas explosion. The conditions controlling the occurrence of the explosions should be revealed by the study.

#### **Prediction of Forest Conflagration**

Forest conflagrations not only result in great life and property losses, but also destroy forestry resources and ecologic balance. The year of 1987 witnessed the forest conflagration of the Great Xingan Mountain in China. According to the survey made by the national expert group, the fire covered the area of 1.33 million hectares, among them 0.89 million hectares were damaged. About 23 thousands hectares became woodless. This forest conflagration destroyed large amount of forest resources as well as houses, electricity transmission grid system, bridges, tunnels, railways, various machines and equipments, resulting in 65 thousands people homeless. The total losses of the forest fire were about 500 million Chinese Yuan.

Although human factor such as cigarette can induce forest conflagration, in general the occurrence of forest conflagration is most closely related to the climate and vegetation features of the forest zone. Prediction of the critical conditions for the occurrence of forest conflagration would be of great importance. It has been shown that forest conflagration has the behavior of self-organization, and the critical conditions for its occurrence are expected to be predicted by the theories of fractal and cellular automata [3]. Many basic researches should be performed in this aspect by means of the modern nonlinear dynamical theories.

#### **Smoke Development in High-Rise Buildings**

As indicated previously, with the high-rise buildings in China more and more built, many problems arose with the fire prevention and protection of high-rise buildings. Especially, the smoke movement in high-rise buildings differs from that in general buildings, and the special characteristics of the smoke movement in high-rise buildings should be studied. A large space fire experimental hall has been built at SKLFS in 1997 which is 22.4m in length, 11.9m in width and 27m in height. From then on, fire safety scientists from Chinese Mainland, Taiwan and Hong Kong have carried out many fruitful experimental studies in the hall.

#### **Nonlinear Fire Dynamics of Special Fire Phenomena**

The special fire phenomena such as flashover, backdraft, as well as the special fire spread

behavior in gorges and the thermal air disorder in the mining fire, should also be the emphases for the Chinese fire researches in the next years. The complex of these special fire phenomena lies on its non-linearity, and the modern nonlinear dynamic theory should be used to perform theoretical and computational studies upon these special fire phenomena. In China, a key project funded by NSFC has began from 2000 devoted mainly to three kinds of special fire phenomena: (a) Flashover and backdraft in compartment buildings; (b) Special behaviors of the gorge fire; and (c) Special air behaviors in the mine fire.

#### **New Method for Fire Risk Analysis and Fire Safety Design**

In the next few years China would proceed with its course of performance based fire risk analysis and fire safety design. Studies should be performed in order to develop the risk analysis and prediction method in combination with the deterministic theory (i.e. fire evolution theory), the statistical theory, and the Chinese residential and industrial characteristics. Performance based fire safety design method and techniques should be developed corresponding to the characteristics of Chinese residential and industrial buildings.

### **5 CONCLUDING REMARKS**

There is no doubt that much progress has been achieved in fire prevention and protection in China since the foundation of the new China. However, with the fast growing economy in China, the present situation of fire hazards is becoming severe. The main cause comes from the fact that fire protection work has failed to keep up with the social development and has turned out to be helpless in solving new problems brought about by the rapid economic development. Therefore, a strategy should be made in China to carry out ahead-of-time fire research work so as to cope with the new challenges of fire hazards in future years. In addition, international cooperation among different countries should be enhanced so as to jointly deal with fire problems with more efficiency.

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