NISTIR 6588

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VOLUME 2

Sheilda L. Bryner, Editor

NIST CENTENNIAL 1901-2001

NIST

National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

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Technology Administration
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Research Project on Disaster Prevention in Town Planning

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ABSTRACT

It is introduced that outline of research and development program on the disaster prevention planning in urban area, especially of current research on post-earthquake fires with BRI Fire Research Wind Tunnel (BRI FRWT) within this project.

Research Project on Disaster Prevention in Town Planning

As many countries in the world suffer from forest and wildland fires, Japan has experienced frequent city fires as seen at the Great Hanshin Earthquake (1995). And much effort has been made to redevelop wooden built-up areas in many cities as well as in Kobe. It has been very difficult, however, to realize redevelopment of such areas because of many problems regarding the complicated rights of ownership or impact to existing life conditions.

To take measures to meet this situation, a research and development program on the safety in urban area was initiated with BRI as the core organization in 1998(for five years). The aim of this project is to develop the method to estimate regional safety performance against earthquake fires. With this estimation, residents, landowners, etc. are thought to be easier to discuss on regional safety planning in wooden built-up areas.

In this research program, physically based model of post-earthquake fire is required, that is modeling of the physical growth process of earthquake fire, from single building fire to city fire. And for this modeling, it is essential to quantify the effect of various facilities in earthquake fire: building, road, tree open space and river in wind.

BRI Fire Research Wind Tunnel (BRI FRWT)

Although the importance of wind effects in such fires is often pointed out, there are few quantitative studies on wind-blown fires and firebrands probably because of the lack of appropriate facilities. To meet this circumstance, Building Research Institute constructed in 1998 a large Eiffel-type wind tunnel [1]. It is designed with maximum 10m/s uniform wind velocity from a 5.0m wide and 4.0m tall outlet. Fluctuation of wind velocity is within 1.0%. And it has a 5.0m wide and 15.0m long testing area, which can be fed maximum 15MW propane as the fuel.

These features were determined to cover wide range of Q^*: from so-called low Q^* turbulent fires ($Q^* \bullet 0.05$) which is typical in mass fires, to buoyancy controlled flames typical in structural and furnishing fires, under reasonably strong wind and reduced-to nearly full-scale test conditions. According to the Froude modeling, the capability of this facility is equivalent to approx. 30m/s wind velocity and 5GW heat release rate in a 1/10 scale test, and 250GW heat release rate in a 1/50 scale test, which is almost the limit to achieve the similarity in fire experiments. Also the size of the testing area is believed to allow a full scale or nearly full-scale test on wind effects on fire.

Current Research on City Fire

Current research in progress on city fire are introduced below:

Thermal Plume Behavior in Wind

City fire has caused serious damage particularly under strong winds. The growth and spread of post-earthquake fire is remarkable in this condition. The heat and brands convected by the thermal flow have serious influence even on distant areas from the burning areas. The fire behavior in the gale should be acquired to take effective measures against suffering lots of loss of properties.

A series of outdoor model tests on city fire were carried out with wood cribs as the fuel from late 1960's to early 1970's[2]. These tests and dimensional analysis delivered relations on the trajectory and axial temperature along the plume. However there was considerable limitation in the outdoor tests such as the lack of burning rate measurement and relatively unstable weather during making tests.

With conventional test facilities restricted on scale, repetition of test conditions, etc., general conclusions have not be drawn yet. Therefore in this research, BRI FRWT was used. To reproduce the boundary flow in urban area, roughness blocks and spires were arranged in the test section to control the spatial distribution of wind velocity. A series of tests were conducted under the condition that the fire affecting the windward houses followed a burning house: burning house was modeled with 30cm square propane diffusion burner and the windward buildings were modeled with bricks arranged regularly (Figure 1,2). In the tests the theory of similarity was taken into consideration on heat release rate and wind velocity. Test conditions are shown in Table 1.

The flame shape is different according to a dimensionless number of a Froude number. The axis temperature along the flame and thermal flow was indicated on the basis of a series of experiments lead by Saga (1997)[3]. Although our test scale (1/30) and fire source (propane burner) are different from previous study (1/200,1/140; Methanol) but the same result obtained that the axial temperature is proportional to the negative 4/3 power of the Froude number (Figure 3).

The fire behavior near the flame has not been mentioned before. The result of our tests show the axial temperature is in proportion to the negative 1.0 power of the Froude number. Assuming that the thermal flow comes from a line heat source rather than a square heat source in the adjoining area of the flame as in Yokoi's study [4], the said result can be theoretically proved. Temperature distribution in the leeward was observed (Figure 4). The equation predicting the temperature was proposed using the relation between the Froude number and another dominant dimensionless number. These results on the temperature distribution in the leeward were also similar to Saga's smaller scale test [3].

The effect of a fireproof building blocking the fire spread was also tested. It depends on the length and height of the building models. In some cases, the heat was unexpectedly convected by the downward flow behind the building model, and consequently the temperature at the ground level increased in comparison with the one of the area consisted of low building models.

Critical Conditions for Merging and Disintegration of Low Q* Fires

The principal aim of this test is to generate quantitative information on mass fires as a basis for the sound technical countermeasures against mass fires. Mass fires whether in urban areas, in wildland or in forests are characterized by the low heat release rate per unit area, namely by low

Q* values. The Q* value of city fire is said to be below 0.1[1].
Flame heating due to a city fire is controlled essentially by the length and inclination of the flame from the burning area. There are considerable experimental and modeling works on the flame behavior affected by wind. However, most of which deal with large or medium Q* flames or far field from the flame [5]. And it should be noteworthy that there are relatively few experimental works on low Q* fires compared with ones on large or medium Q* fires [6-8] even in quiescent environment.
However, the near field of windblown diffusion flames from low Q* fires are of the primary importance for the engineering treatment of fire spread in mass fires. Few laboratory studies deal with such flames [9]; it is probably because near field of windblown fire is generally much more difficult to model than a diffusion flame in quiescent unconfined environment, and turbulent low Q* fires are generally difficult to reproduce in laboratory. But it is very important to decide to critical conditions for merging and disintegration of low Q* fires for fire prevention town planning, especially for density control of buildings.
The test that we are carrying out used 15cmx15cm square and 24cm tall porous propane diffusion burners as heat sources. In this testing apparatus, we can set number of burners (1-25), distance between heat sources and mass flow of propane gas, that is, we can control heat release rate in order to reproduce various Q* fires. In this test, we are measuring flame height and temperature distribution above heat sources in order to define "merging" or "disintegration" of fires quantitatively. This quantitative definition is thought to be necessary for windblown test conditions (Figure 5).
Some tentative test results are shown in Figure 6. This test condition is planned to reproduces $Q^* \approx 1$ fire. Now we are tuning this testing apparatus so that we can exactly control heat release rate in order to make various test conditions.

Research Plans on City Fire

Results of current research presented are tentative, and further consideration and additional tests are required. This research and development program started in 1998 has been carried out for five years. And within this program, following subjects are studied in progress:

- Modeling of flame behaviors in wind
- Properties of fire brands: drag coefficient, burning behavior, etc.,
- Effectiveness of fire resistive buildings and greens as barriers against spread of city fires
- CFD modeling of spread of city fire

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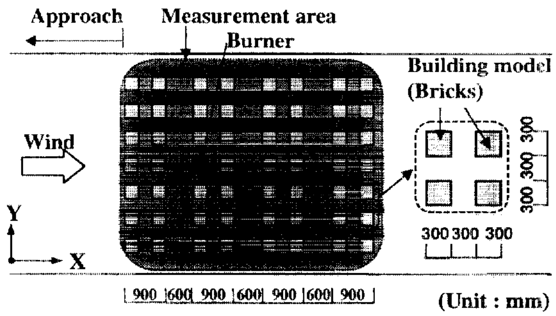


Figure 1 Test area (plan)

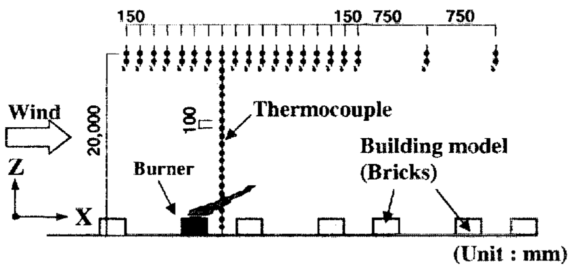
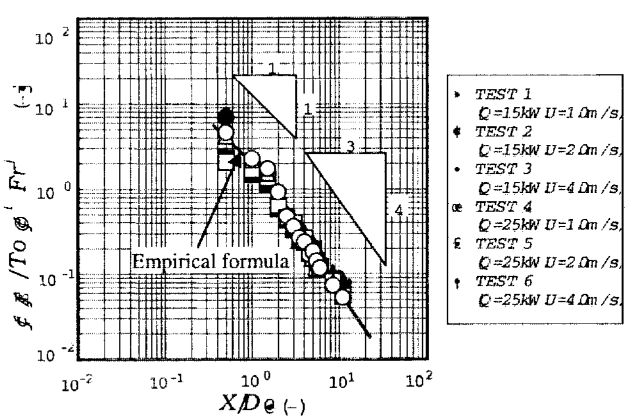


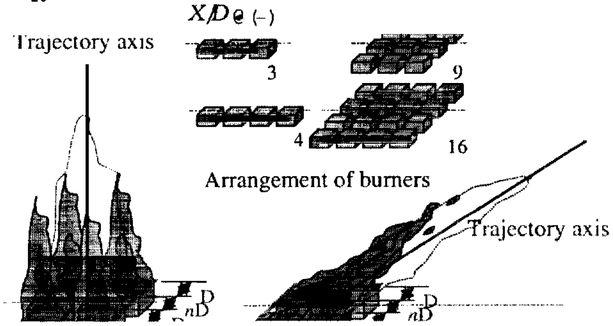
Figure 2 Test area (cross section)

Table 1 Test conditions

Test Number	1	2	3	4	5	6
Wind velocity* (m/s)	0.63	1.26	2.52	0.63	1.26	2.52
Heat Release Rate (kW)	15.0			25.0		

*converted value at 0.3m above the floor





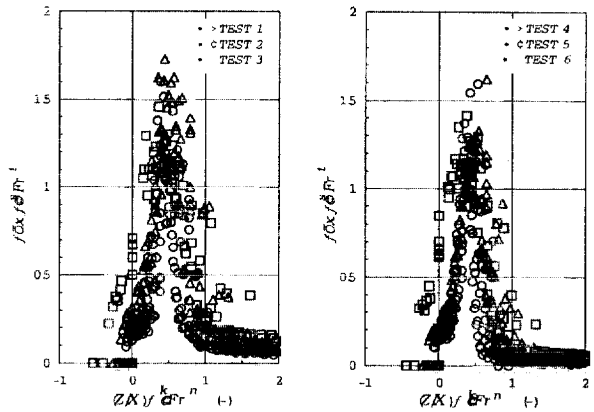


Figure 3 Axial Temperature along the flame

Figure 4 Temperature distribution in the leeward

Figure 5 Arrangement of burners

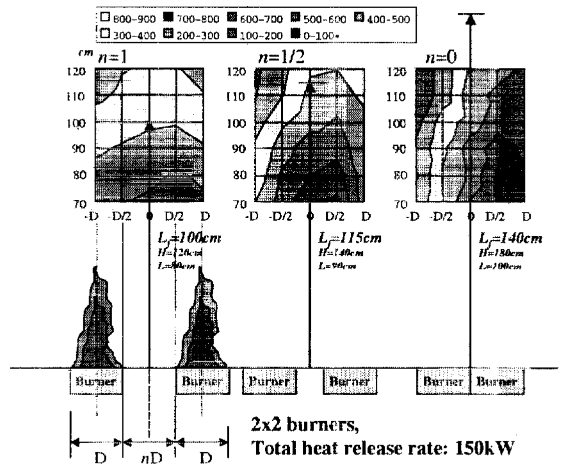


Figure 6 Tentative test results of merging of fires ($Q^* \approx 1$)