THE INFLUENCE OF LOW ATMOSPHERIC PRESSURE OF TIBET ON THE STANDARD TEST FIRES AND FIRE DETECTORS

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ABSTRACT

There are many cultural relic and ancient constructions in Tibet, so how to protect these constructions becomes an important problem. Because of the special geographical location and altitude, the district of Tibet has a very low atmospheric pressure which is 35% less than normal. Measurements were made of the various burning characteristics of the five standard test fires in the standard test rooms in Lhasa and Hefei. At the same time, the responses of various detectors including optical smoke detectors, temperature detectors and carbon monoxide detectors were tested. The results show that low pressure makes the burning rate slower, and the concentration of smoke lower, which make the smoke detectors and temperature detectors respond slower than that in Hefei. Except the wood fire, the maximum of CO concentration was independent of pressure in the other four standard test fires. The study will provide technology support for fire detection and fireproofing of Tibet.

KEYWORDS: Tibet, Standard test fire, Mass loss rate, Carbon monoxide, Fire detectors

INTRODUCTION

There are more than 1000 old historic buildings in Tibet. The Potala Palace was inscribed to the UNESCO world Heritage List in 1994. And in 2000 and 2001, Jokhang Temple and Norbulingka were added to the list as extensions to the sites. How to protect these invaluable constructions in Tibet becomes a new important subject.

The altitude of Tibet is mostly more than three thousand meters, where the atmospheric pressure is 35% lower than normal. The air density of Lhasa is 0.83 $kg\cdot m^{-3}$, while in Hefei it is 1.28 $kg\cdot m^{-3}$. Low atmospheric pressure and air density will have effect on combustion and its product [1], such as gas concentration, smoke particle property, smoke plume movement, temperature, flame radiation and burning sound will also be changed, under the condition of which the response of fire detectors will be changed.

Point-type smoke detectors including ionization smoke detectors and photoelectric smoke detectors are commonly used in normal pressure atmosphere. Previous[2] study showed that the variation of smoke concentration was mainly influenced by the decrease of mass loss rate and the sensitivity of scattered photoelectric point-type detectors at low atmosphere pressure was much lower than that at normal atmosphere pressure, but not the ionization point-type detectors.

Aspiration systems have been successfully used in numerous installations around the world for over 20 years. The system has all but replaced spot detection systems in high-risk and special applications. The carbon monoxide sensors have distinct advantages over the more conventional fire detectors [3].

Measurements were made of the various burning characteristics of the five European standard test fires in the standard test rooms of Lhasa and Hefei. At the same time, the responses of various detectors including carbon monoxide detectors, temperature detectors and aspiration smoke detectors were tested.

MATERIALS AND METHODS

In order to provide the same environment for tests in two different pressures, we did tests in two standard test rooms, one in Hefei and the other in Lhasa, both of which had the same internal dimensions of 10 x 7 x 4 m^3 and also a control room.

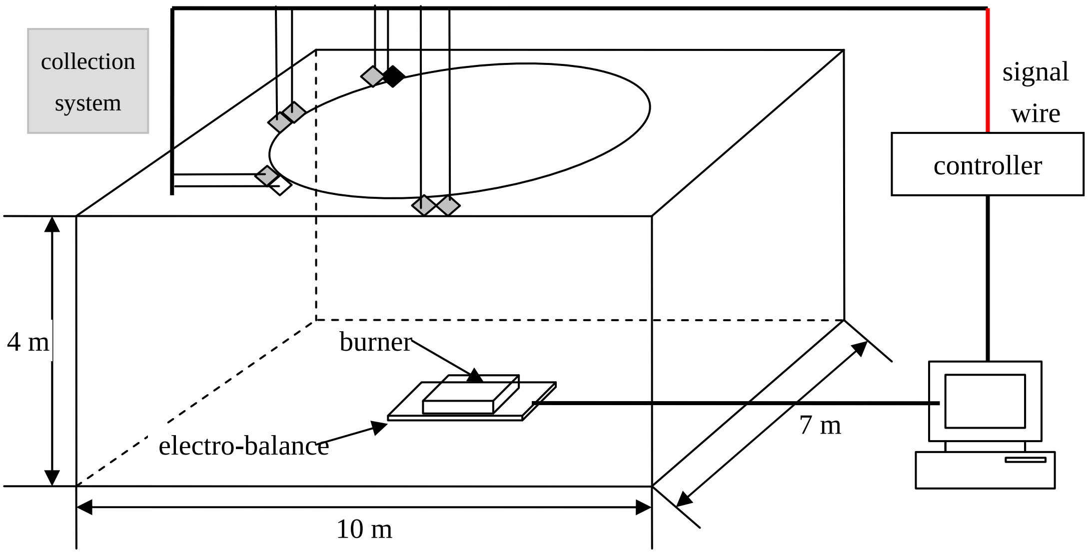

FIGURE 1. A sketch map of standard test room

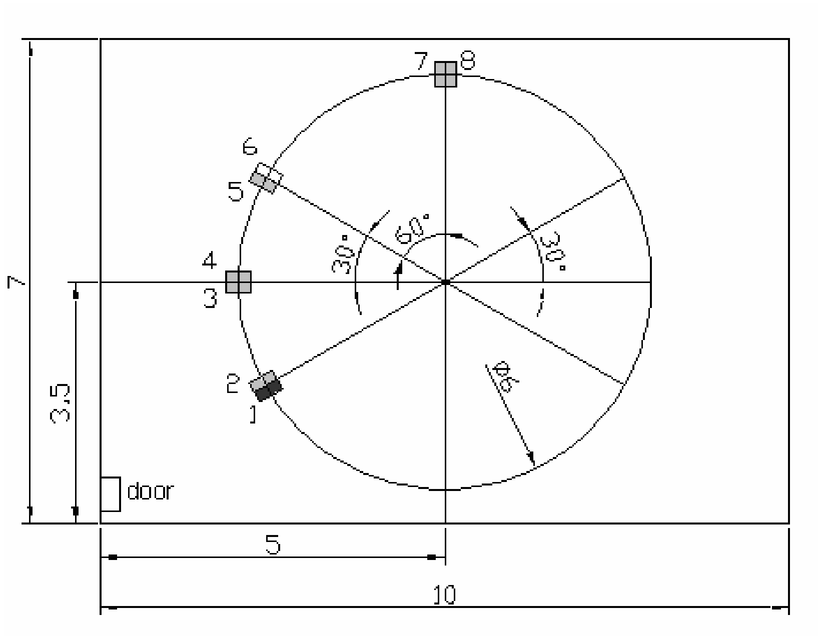

FIGURE 2. Layout of detectors

The detectors were installed on the roof on an arc 3 m from the centre of the room (Fig. 2). No. 1 was an optical / heat detector, and No. 6 was an optical smoke detector, while the others were carbon monoxide – heat detectors.

The sampling points of the MRU gas analyzer and the aspiration smoke detector were installed in the position between No. 3 and No. 4, which is about 4 cm below the ceiling.

For the TF4, TF5 and TF6 fires, the height of burners above the floor were 15.8 cm and the TF1 fire 18.5 cm.

RESULTS

Mass of Material G, Temperature T and the CO Concentration

TABLE 1. In Lhasa

Test fire	CO (ppm)	Temperature T0 (°C)	Pressure (kpa)	Humidity (%)
TF1	352	17.5	65.7	23
TF3	164	5.3	66.0	46
TF4	19	6.8	66.0	39
TF5	21	17.0	65.8	24
TF6		17.8	65.6	20

In all fire tests, the following parameters were measured, the mass of material combusted G using an electronic balance, as well as the increase in temperature T and the CO concentration were recorded in all tests using MRU gas analyser. Furthermore, the atmospheric pressure and the humidity were also recorded before every test. The altitude of Lhasa is 3658 m, while in Hefei it is 50 m. The volume percentage of oxygen in air of Lhasa and Hefei is 20.9%.

The results for the tests are detailed below. Table 1 and 2 summarizes the maximum of carbon monoxide concentration and environment parameters for the five standard test fires.

TABLE 2. In Hefei

Test fire	CO (ppm)	Temperature T0 (°C)	Pressure	Humidity
TF1	202	13.7	101.8	55
TF3	157	13.7	102.0	50
TF4	21	17.4	101.3	65
TF5	19	17.3	101.0	65
TF6	---	17.2	101.1	68

<u>TF1: wood fire</u>

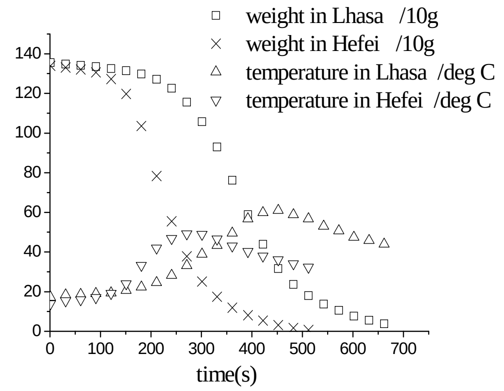

FIGURE 3. Graph of mass of material combusted and temperature (TF1)

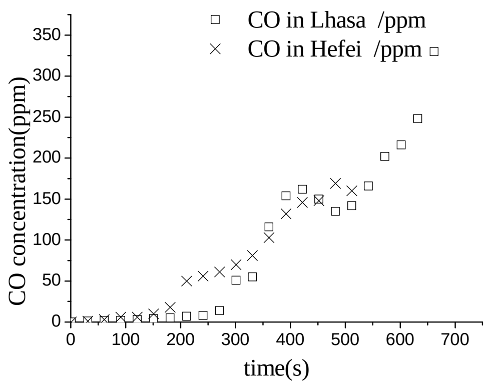

FIGURE 4. Concentration of CO (TF1)

70 dried fir wood sticks (1 × 2 × 25 cm^3) arranged in 7 layers measuring 50 × 50 cm^2 by 8 cm high[4] , using 10 cm of methylated spirits to ignition, which initially produced a slow burning fire generating

small amounts of carbon monoxide. Fig. 3 and Fig. 4 show the temperature, carbon monoxide and the mass of fuel obtained during the wood fires in Lhasa and Hefei. At the beginning of the fire, the development of tests in Lhasa was slower, with a smaller mass loss rate, and temperatures were lower than that of Hefei. But towards the end of the test, the fire in Lhasa became more vigorous and produced more heat. Temperature in Lhasa reached a higher peak. In the fire test of Lhasa, larger quantities of carbon monoxide were produced, more than 300 ppm. But in Hefei, the maximum carbon monoxide concentration was less than 200 ppm. Fig. 4 shows that the graph of carbon monoxide concentration in Lhasa has two peaks, the first of which has the same time when the temperature reaches its peak. But towards end of the fire, although the temperature decreases, the carbon monoxide concentration increases vigorously, even higher than the first peak.

<u>TF4: plastic fire</u>

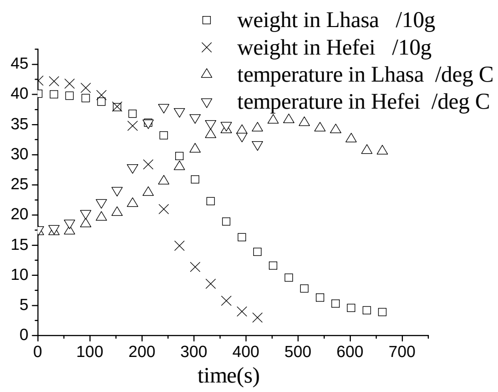

FIGURE 5. Graph of mass of material combusted and temperature (TF4)

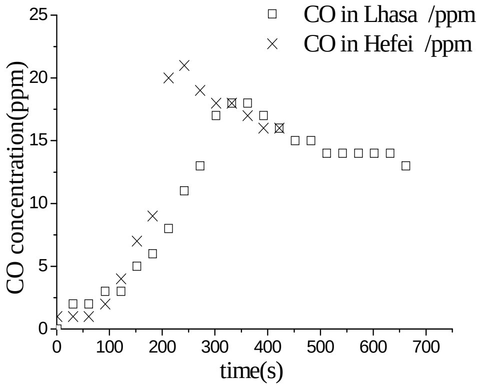

FIGURE 6. Concentration of CO (TF4)

The polyurethane fire (TF4) comprised 3 mats of soft polyurethane foam having a density of approximately 20 kg m^{-3}. Each mat was approximately 50 × 50 × 2 cm^3 and was placed one on top of another on an aluminium base. 5 cm^3 of methylated spirit was used to assist the ignition.

As in Fig. 5 and Fig. 6, TF4 is a slow burning fire generating small amounts of heat. The development of fire tests in Lhasa was slower, and temperature was lower than that of Hefei. But different from the wood fire, the maximum of temperature and carbon monoxide of TF4 in both places were approximate. The carbon monoxide concentration increase significantly, and the concentration of oxygen was seen to decrease.

<u>TF5: Liquid fire (n-heptane)</u>

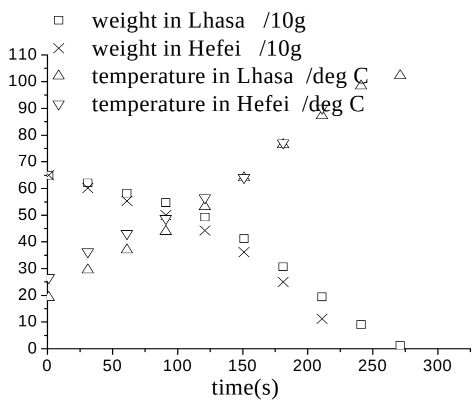

FIGURE 7. Graph of mass of material combusted and temperature (TF5)

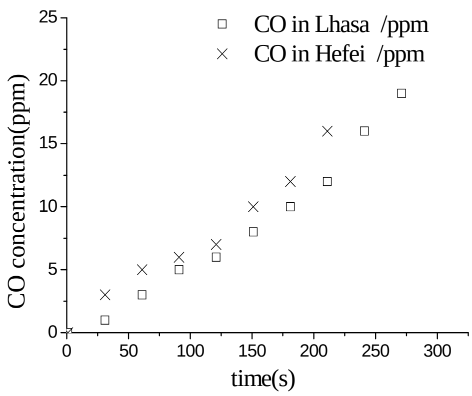

FIGURE 8. Concentration of CO (TF5)

TF5 is fast burning liquid fires. The carbon monoxide concentration and temperature were seen to increase almost linearly. Tests in Lhasa developed slower, and the mass loss rate was a little smaller than in Hefei.

TF6: Liquid fire (methylated spirits)

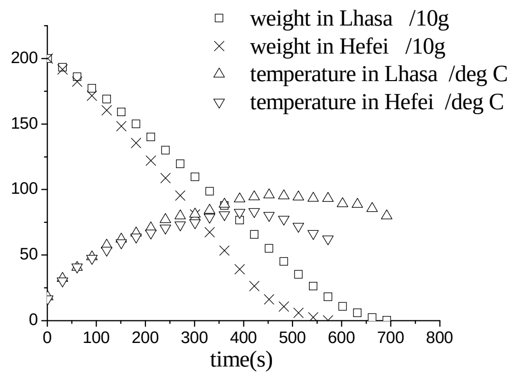

FIGURE 9. Graph of mass of material combusted and temperature (TF6)

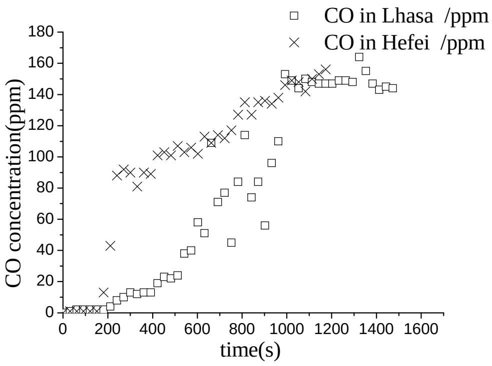

FIGURE 10. Concentration of CO (TF3)

TF6 is also a fast burning fire, but produces small amount of carbon monoxide, less than 10 ppm both in Hefei and Lhasa so the results are not presented here. At the beginning of the fire, the development of tests in Lhasa was slower, with a smaller mass loss rate. Towards the end of the fire, temperature reached a higher peak while the burning rate and temperature decreased slower in Lhasa.

TF3: Smouldering fire (cotton)

The glowing cellulose fire (TF3) was achieved by burning 90 pieces of braided cotton wicks, each approximately 80 cm long and weighing approximately 3 g. The wicks were fastened to a ring 10 cm in diameter and suspended approximately 1 m above a metal plate.

This is a low power output fire that produces large amounts of white smoke. The cotton fire in Hefei developed faster. The carbon monoxide concentration rose to over 80 ppm in 5 minutes in Hefei, but in Lhasa it was about 10 minutes. The burning time of tests in Lhasa was longer, but the maximum of carbon monoxide concentration of tests in Lhasa and Hefei were approximate.

Smoke

Three standard fire tests were performed to investigate the difference between the responses of aspiration smoke detectors in Lhasa and Hefei.

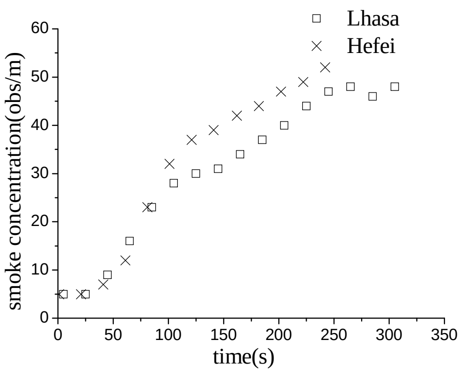

FIGURE 11. Output of aspiration smoke detector (TF5)

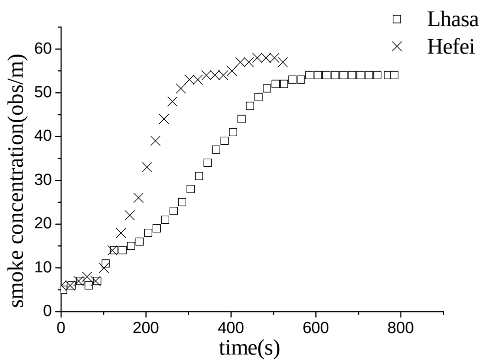

FIGURE 12. Output of aspiration smoke detector (TF4)

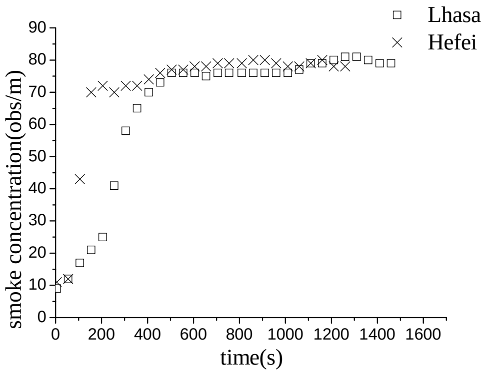

FIGURE 13. Output of aspiration smoke detector (TF3)

The smoke signals of fire tests TF3, TF4 and TF5 increased significantly slower in Lhasa at the beginning. And the aspiration smoke detector responded faster in Hefei.

DISCUSSION

The results show that towards the end of the burning, fire tests in Lhasa produce more carbon monoxide and the temperature is higher. As a result of a higher burning point [5] in high pressure atmosphere of Lhasa, the maximum temperature of the wood fire tests in Lhasa was higher. Local lack of oxygen is caused by the flare-up of the combustible products formed in high temperature pyrolysis which consumed most of the oxygen in the combustion zone. Owing to the relatively low oxygen concentration in Lhasa, the combustion became less vigorous and the temperature and CO concentration decreased for fresh air cannot be delivered to the combustion zone in time. But with the combustion continued the oxygen-controlled combustion released large quality of CO. The wood fire tests needed more time during the process of pyrolysis, so fire tests in Lhasa developed slower at the beginning, which made the response time of CO detectors and temperature detectors longer than that of Hefei.

Test fire 4 produced lots of black smoke in Hefei, and made the smoke detectors to respond. Test fire 4 is a slow burning fire, and the temperature signal and carbon monoxide concentration did not reach the fire alarm threshold both in Lhasa and Hefei. Fire tests in Lhasa developed slower, and produced less smoke, the output of the inspiration detector is lower than that in Hefei at the beginning of the test.

Test fires 5 are fast burning fires. Mass loss rate of burning in Lhasa is smaller than in Hefei, but the development of temperature and the CO concentration in Lhasa and Hefei has not much difference, which is similar to Wieser's work [1]. The tests of the response of the point-type smoke detectors had been done during our previous work [3]. And the response of the aspiration detector showed the same results that tests in Lhasa produced less smoke as a result of lower burning rate. During fire test 5 in Hefei, the carbon monoxide – heat detectors responded faster than that in Hefei.

Test fire 6 produced a lot of heat but little smoke and CO. So the response of carbon monoxide – heat detectors and optical / heat detectors depend more on the temperature signal. The optical smoke detector did not response during the fire tests both in Lhasa and Hefei.

TF3 is the slowest test fire of the five standard test fires and produce little heat. There was little temperature signal. TF3 produced lots of smoke and CO, but as the result showed in aspiration smoke detector, the smoke produced at the beginning of the tests in Lhasa is less than that in Hefei.

The maximum of CO concentration of test fires 3 to 6 in Lhasa and Hefei were approximate, which showed that in these standard test fires, the maximum CO concentration was independent of pressure, as enough oxygen can be delivered to the combustion zone in time in spite of lack of oxygen in Lhasa.

It is noticeable that during test fires 1, 5 and 6, the optical / heat detectors responded faster than that of carbon monoxide – heat detectors in Hefei. But in Lhasa, the results were on the contrary, which showed that when the temperature raised the same during tests both in Lhasa and Hefei, CO concentration changed more in Lhasa.

CONCLUSIONS

1. All five standard fire tests in Lhasa developed slower and spent a longer time for combustion, which shows that low pressure makes the burning rate slower in Lhasa.
2. The concentration of smoke released at the beginning of fire tests is smaller, and the smoke detectors including ionization smoke detectors, photoelectric smoke detectors, and aspiration smoke detectors responded slower in Lhasa.
3. The maximum of CO concentration was independent of pressure in the standard test fires, except the wood fire.

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