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Heat Response Characteristics in Automatic Fire Extinguisher

Yong H. Park*

Department of Fire Protection Engineering, Hoseo University, Asan, Korea

Abstract

Apartments and housings without sprinklers are very susceptible to fire damages during the absence of human being or only in the presence of the children and the elders. New automatic fire extinguishers can play a very important role to reduce this kind of fire damages. This study revealed that the reaction temperature and response time of the heat detectors are greatly influenced by fusible metal thickness and heating rates. Reaction time varied from 139 seconds to 490 seconds depending upon the room sizes and detector positions. Response time less than 60 seconds requires fusible metals with lower melting point and higher position of the extinguisher. Fusible metal was shown to be more sensitive to the lower heating rate. The thickness of the fusible metal with 0.2mm and the cap thickness of 0.7mm was found to reduce the response time to 40 seconds.

1. Introduction

In general, small buildings and residence housings rely on manual fire extinguishers instead of automatic fire suppression systems like springklers. In the absence of human-beings or in the presence of just children and the elders, even small fires can cause bigger disasters. Since fire suppression at the early stage is very important, there is no doubt that the use of automatic fire extinguisher will definitely reduce the fire damages. For this reason, simple structured and low-cost automatic fire extinguisher using fusible metal as heat detector was newly developed and tested.

Author: Tel.: +82-41-540-5733;
Fax: +82-41-540-5728
E-mail address: yhpark@office.hoseo.ac.kr

2. Experimental

2.1 Samples

New automatic fire extinguisher was developed adopting fusible metal type heat detector which responds to the heat generated by the fire. Spread nozzle was employed for hydrant ejection instead of hose of the manual fire extinguisher. The vessel and the hydrant uses the same as the manual fire extinguisher with the pressure of 9.8kg/cm^2 and the ABC hydrant.

Figure 1 shows the shape of the automatic fire extinguisher and heat detector parts.

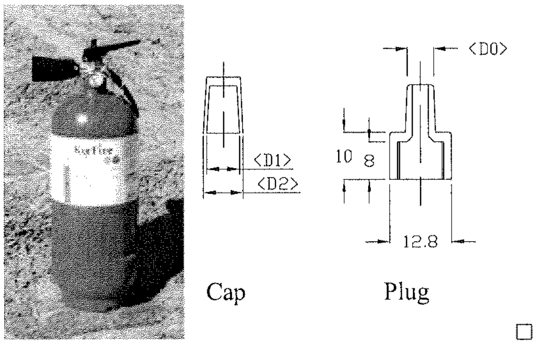


Figure 1. Automatic fire extinguisher and shape of heat detectors(cap and plug)

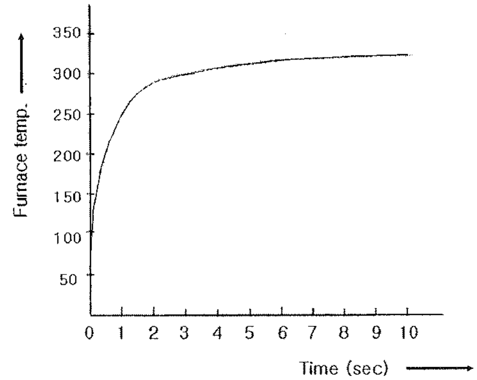


Figure 2. Heating rate for the reaction time test

3. Performance Tests

To evaluate the performance of the automatic fire extinguisher, five tests such as leak test, reaction time test, injection rate test, impact test, fire suppression test were conducted with pilot samples.

3.1 Leak test

Leak tests were conducted to investigate the leakage of the cylinder under the fill-up pressure. Test procedures are;

1. The cylinder was filled with air or nitrogen gas to the designated pressure at 20±2°C and left 24 hours at room temperature. Check the pressure gage if there is a change or not.
2. Conduct thermal cycling of the detectors for 24 hours at maximum allowable temperature and for 24 hours at minimum allowable temperature.
3. Leave the detectors in the hot water at maximum allowable temperature for two hours, and check the bubbles.

3.2 Reaction time test

To investigate the reaction time at the designated nominal temperature, the detector was put into the hot oven and heated at the heating rate of Figure 2.

Table 1 Reaction time

Nominal temperature	Reaction time
~ 75°C	< 1 min
75 °C ~ 121 °C	< 1 min 45 sec
121 °C ~ 162 °C	< 3 min
162 °C ~ 204 °C	< 5 min
204 °C ~	< 10 min

3.3 Fire suppression test

To evaluate the performance of the automatic fire extinguisher, field tests for fire suppression of fire class A and B were performed for the room size of $12m^2$(R1) and $4m^2$(R2). Table 2 represents the summary of the field tests

Table 2 Summary of fire model tests

	Test-1	Test-2	Test-3
Fire class	A	A	B
Combus-tables	plywood wall/ wood lattice	Wood lattice	Wood lattice
No. of models	2	1	2
Ignition	ethanol 100 ℓ	n-epthane 1.5 ℓ	n-hepthane
Detector position	1.5 M, 2.6M,		
Reaction time limit	< 6 min	< 3 min	< 3 min

Table 3 Thickness variation of fusible metal(Tcap=0.7mm)

(unit:mm)

Specimen No.		D1	Tfm	D2
Group A	N1	6.8	0.2	8.2
	N2	7.0	0.3	8.4
	N3	7.2	0.4	8.6
	N4	7.4	0.5	8.8

* Tfm=(D1-D0)/2, D0=6.4

* Tcap=(D2-D1)/2

Table 4 Thickness variation of caps (Tfm= 0.2mm)

(unit:mm)

Specimen No.		D1	D2	Tcap
GroupB	N5	6.8	8.2	0.7
	N6	6.8	8.4	0.8
	N7	6.8	8.6	0.9
	N8	6.8	8.8	1.0

Table 5 Chemical composition and thermal property of fusible metal

Metal	Compo-sition	Percent (%)	Density (kg/m^3)	Thermal conductivity (W/m□)
Fusible metal	Bi	50	9.8	33
	Pb	26.6	11.36	
	Sn	13.4	7.35	
	Cd	10	8.65	
Copper-alloy	-	-	-	149

4. Results and discussions

In reaction time test, the fusible metal detector responded in 72seconds at oven temperature of 106□, which is less than that for the nominal reaction temperature range of 75°C ~ 121°C.

Fire model test-1 for room-1 revealed that the reaction time for the detector at the height of 1.5M was 7min 20sec which exceeded the limit of 6 min. However, fire model test-1 for room-2 revealed that the reaction time for the detector at the height of 1.5M was 5min 39sec and the reaction time for the detector at the height of 2.6M was 3min 40sec, both of which are within the limits. This test results showed that room-1 is so spacious that the heating rate is not enough for the detector. It also showed that the higher installation of the fire extinguisher could greatly reduce the reaction time.

Figure 3 and Figure 4 represent temperature increase for each room type. In all fire test-1, re-ignition from the fire model was not observed in 2 minutes after the fire suppression. Figure 5 shows the result of fire test-1 representing the successful fire suppression after the automatic fire extinguisher was used.

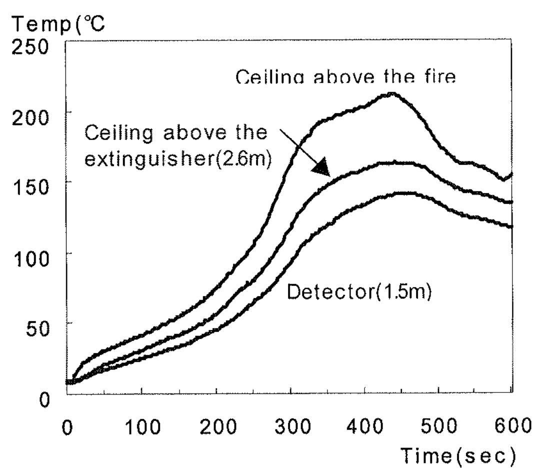


Figure 3. Fire test-1 for room-1

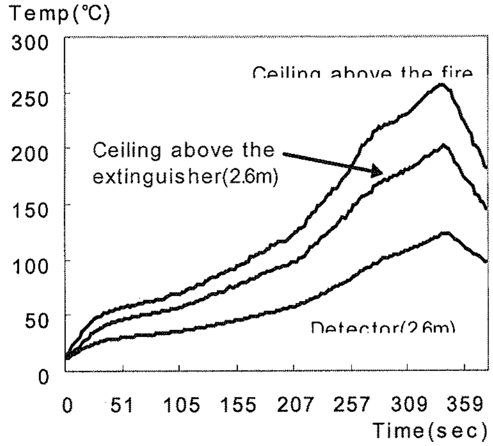


Figure 4. Fire test-1 for room-2

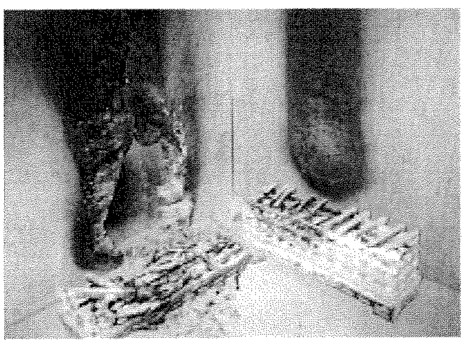


Figure 5. Result of fire test-1

In fire model test-2 for room-1, the reaction time for the detector at the height of 2.6M was 2min 40sec which is below the limit. The reason for this is the higher heating rate of the room due to the use of n-heptane.

Fire model test-3 for Room-1 revealed that the reaction time for the detector at the height of 2.6M was 2min 19sec which is also below the limit. The reason for this is the higher heating rate of the detectors due to the location of the detector and the use of n-heptane. In this test, the location of the extinguisher was middle top of the fire models. Figure 6 and Figure 7 are heating curves in the Room-1 for the fire test-2 and fire test-3.

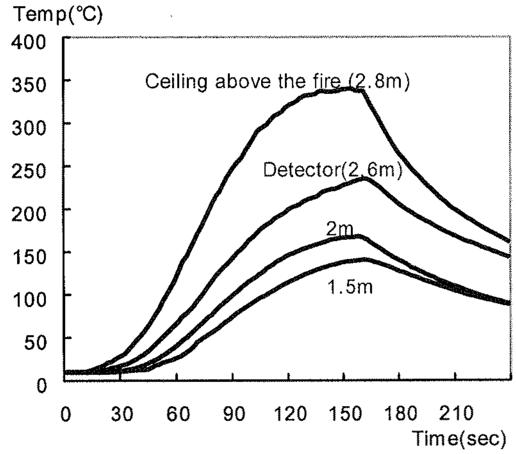


Figure 6. Fire test-2 for Room-1

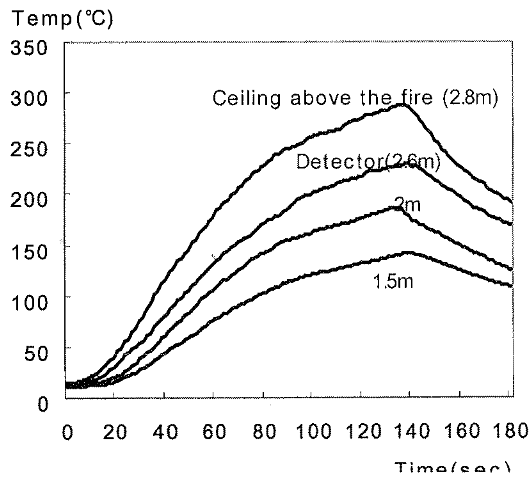
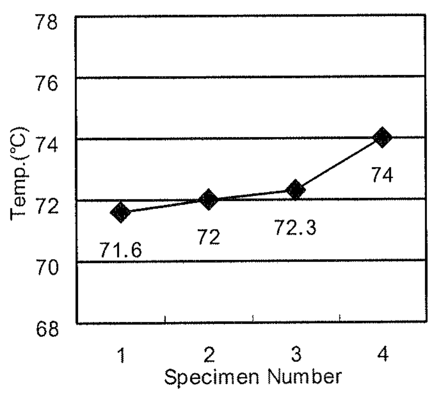


Figure 7. Fire test-3 for Room-1

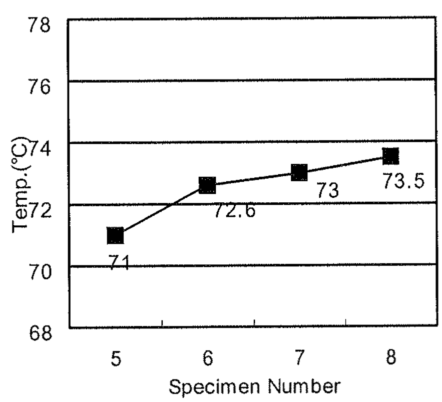
Although all fire test results revealed that the automatic fire extinguisher should be located at least 2.6M which is near the ceiling of the room to meet the reaction time requirements, it would be more desirable if the detector shows much shorter the reaction time.

Figure 8 shows the results of the reaction temperature depending upon the thickness variation of the fusible metal. The minor increase of the cap thickness or fusible metals resulted in the increase of the reaction temperature of the detectors. However considering the requirement for the temperature deviation of the detector is ±3% of the nominal operation temperature, all the data are within the range regardless of the thickness variation.

Figure 9 shows two different heating rate for the detectors. Heating rate (A) represents that of the nominal laboratory tests and heating rate (B) represents that of the real Room-1. Figure 10 -13 represents the results of the reaction time with the variation in the thickness of the cap and fusible metal depending upon the different heating rates as in Fig. 9.



a) fusible metal thickness variation



b) cap thickness variation

Figure 8. Reaction temperature of the samples

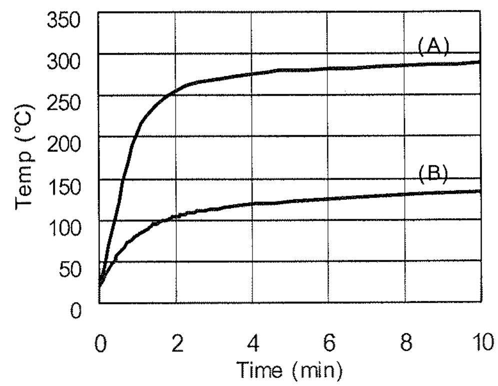


Figure 9. Heating curves for detectors

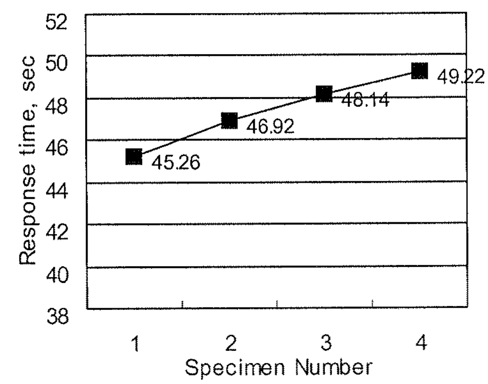


Figure 10. Response time of Group-A under heating curve (A)

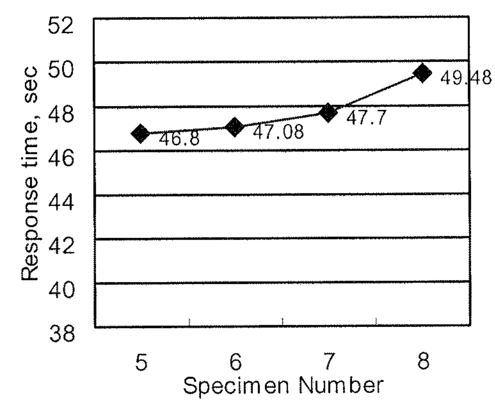


Figure 11. Response time of Group-B under heating curve (A)

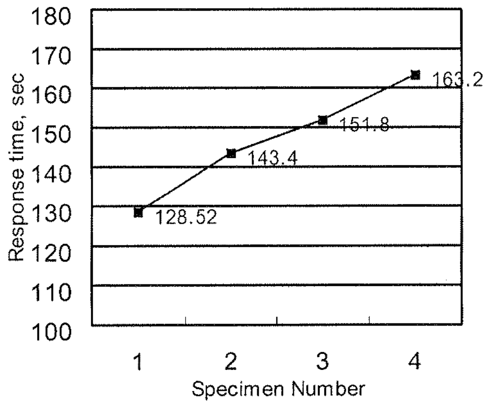


Figure 12. Response time of Group-A under heating curve (B)

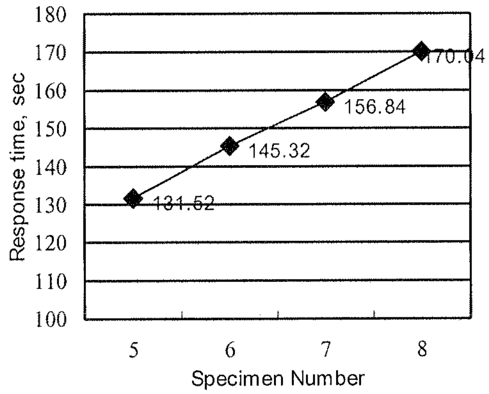


Figure 13. Response time of Group-B under heating curve (B)

5. Conclusion

Followings are the results of this study.

1) The reaction time due to the change in the thickness of the detector are more susceptible to the slower heating rate of the atmosphere.
2) The optimal thicknesses for the detector were found to be 0.7mm for the cap and 0.2mm for the fusible metal.
3) The above thickness can provide reaction time of 40seconds, but fusible metals with lower melting point should be adopted for larger spaces.