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The Reduction in Fire Hazard in Corridors and Areas Adjoining Corridors Provided by Sprinklers

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Public Buildings Service
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THE REDUCTION IN FIRE HAZARD IN CORRIDORS AND AREAS ADJOINING CORRIDORS PROVIDED BY SPRINKLERS

Daniel Madrzykowski

ABSTRACT

A study was conducted for the General Services Administration to investigate and quantify sprinklered fire exposure on an exit corridor and spaces adjacent to that corridor. The study compares the conditions in the test facility due to a 1 MW crib fire with those of a fire under control by a sprinkler. The effect of a sprinkler positioned in the corridor, outside of the burn room, was also examined. The test facility consisted of a burn room, a target room and a corridor connecting the two rooms. The burn room was a 2.44 m square with a 2.44 m high ceiling. The corridor was 12.8 m long, 2.44 m wide and 2.44 m high. The target room consisted of an entry alcove and a rectangular room with a total volume of 15 m^3. The target room was protected using a simulated "standard door" (6 mm top cut, 6 mm side cut and a 13 mm undercut). Gas temperatures and concentrations of oxygen, carbon dioxide, and carbon monoxide were measured at selected points in the three rooms. Tenability was assessed using both temperature and gas toxicity criteria. This assessment showed that sprinklers maintained tenable conditions outside the room of fire origin.

Key words: corridor tests; crib tests; large scale fire tests; life safety; refuge; room fires; sprinklers; tenability limits.

1. INTRODUCTION

Under the sponsorship of the General Services Administration (GSA), the Building and Fire Research Laboratory (BFRL) at the National Institute of Standards and Technology has been working on a multi-phase research project addressing the analysis and assessment of the fire safety in GSA buildings. As part of this project, a better understanding of the critical factors that determine the impact of sprinklered fire exposure on exit corridors and on spaces adjacent to these corridors was developed. The information gathered in this study will be used by GSA, along with other research data, for evaluation of the life safety provided in staging areas.

The data obtained from this study provides information to support the appraisal of conditions in building corridors and to assess exposures for occupants who may be unable to evacuate the fire floor and have to take refuge in their offices or other spaces on the fire floor. In many instances, particularly in high rise buildings, designated "safe areas" are established as part of the building safety plan. In the event of fire, the occupants would move through the building to these spaces which have been specifically designed to provide an area safe from the effects of the fire and its toxic gases for some period of time. These areas would also serve as staging areas for evacuation of people to another part of the building or the outside. These results, in combination with other engineering methods including the Engineering Fire Hazard Assessment Model [1][1], can assist fire protection professionals in making design decisions for the location of staging areas and specifications for methods to protect staging area occupants in a variety of situations.

To quantify sprinklered fire exposure on an exit corridor and spaces adjacent to that corridor, the Building and Fire Research Laboratory conducted full-scale fire tests in a simulation of a portion of a building corridor system. The test series involved exposure of a corridor and a target room, a room adjoining the corridor, to a developing room fire. In control tests, the fire was allowed to develop to its fullest extent in the space without sprinkler protection. In the test cases, a sprinkler positioned either in the burn room itself or outside of the burn room in the corridor activated automatically. Measurements of conditions in the corridor and target room were used to assess the reduction in fire hazard provided by the sprinklers.

2. EXPERIMENTAL APPROACH

Full-scale fire tests were conducted in a noncombustible burn room - corridor - target room test facility (Figure 1) using wooden cribs as the fuel load. The facility was instrumented to measure gas temperatures and concentrations of oxygen, carbon dioxide and carbon monoxide (Figure 2). The combustion products were sampled at 1.5 m (5 ft) above the floor. This elevation is considered as a characteristic head height. Sprinklers were installed in the burn room and along the corridor as shown in Figure 3. The sprinkler lines were instrumented with pressure switches and clocks to detect the activation time of the sprinklers. Depending on the test configuration, sprinklers were pressurized either with water for suppression ("wet") or air for measurement of activation time ("dry"). The sprinklers were allowed to activate automatically during the suppression tests.

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[1]Numbers in brackets indicate literature references at the end of the paper.

2.1 Description of the Test Facility

The test facility (Figure 1) consisted of a "burn room" containing the fire source, a "target room" and a 12.8 m (42 ft) long corridor connecting the two rooms. The "burn room" was a 2.44 m (8 ft) square with a 2.44 m ceiling. The burn room was lined with two layers of calcium silicate board for a total thickness of 25.4 mm (1 in).

The burn room was provided with two door openings. The first opening was 0.76 m (2.5 ft) wide by 1.52 m (5 ft) high. This opening vented out of the test area to an overhead exhaust hood. The other opening, between the burn room and the corridor, was 0.46 m (1.5 ft) by 1.52 m (5 ft) high. The size of the openings were the same as those used in a study of post flashover fire hazards [2] to allow for comparison of corridor flow data.

The total volume of the "target room", 15 m^3 (528 ft^3), was composed of two parts, a rectangular main room area and an entry alcove. The main room is 2.2 m (7.1 ft) high, 2.6 m (8.5 ft) long and 2.4 m (7.75 ft) wide. The entry alcove is 2 m (6.6 ft) high, 0.8 m (2.7 ft) long and 1.1 m (3.5 ft) wide. The overall dimensions of the door opening between the target room and the corridor were 2.0 m (6.6 ft) high by 1.1 m (3.6 ft) wide.

A simulated door, constructed using a 2.0 m (6.5 ft) by 1.0 m (3.3 ft) wide sheet of 13 mm (0.5 in) thick calcium silicate board, was used for all of the tests. The simulated door was placed in the target room opening with a 13 mm (0.5 in) undercut, a 6 mm (0.25 in) top cut, and a 6 mm (0.25 in) side cut. The side cut was located along the west edge of the door. These cut dimensions were chosen to be representative of typical door crack sizes based on available information [3, 4].

Wood cribs were used as the fuel source in these tests, since they provide a repeatable fire load. The cribs used in this study were similar to those used by Walton [5]. They were constructed of fir sticks 38 mm (1.5 in) high by 38 mm (1.5 in) wide and 0.61 m (2 ft) long. The sticks were fastened together by 8d common nails at both ends. The cribs were 16 layers high with 6 sticks per layer. The 16 layer or 0.61 m (2 ft) high cribs, shown in Figure 4, were the only type used in these tests.

The fuel load consisted of two cribs positioned next to each other in the center of the burn room (Figure 5). Each crib was elevated approximately 0.13 m (5 in) above the floor. The shield was composed of a 1.21 m (4 ft) by 1.21 m (4 ft) by 13 mm (0.5 in) thick sheet of calcium silicate board. The shield was positioned 0.20 m (8 in) above the top of the cribs. The cribs were ignited using a 0.15 m (6 in) diameter circular pan 0.05 m (2 in) tall containing 350 ml (10.5 oz) of heptane centered under the cribs. The heptane was ignited using an electrically activated match. The cribs had an average weight of 36 kg (80 lbs) each and a moisture content of between 5 and 10 percent. The maximum heat release rate (HRR) for the two cribs in a free burn condition is approximately 1 MW (Figure 6).

2.2 Instrumentation and Data Acquisition

Measurements were taken in the burn room, corridor, target room, and exhaust hood. The general locations of the measurement devices are shown in Figure 2. Their placement and distribution is summarized in Table 1. A thermocouple array was located 0.3 m (1 ft) out from the corner of the burn room. All thermocouples were 0.5 mm (20 mil) chromel-alumel bare bead thermocouples. A gas sampling pickup tube was located adjacent to the thermocouple array, in the burn room, 1.5 m (5 ft) above the floor. Combustion products were sampled through the horizontal 9.4 mm (3/8 in) I.D. stainless steel tube. The tube was connected to 9.4 mm (3/8 in) polyethylene tubing, which delivered the gas samples to the oxygen, carbon dioxide, and carbon monoxide gas analyzers via two glass wool filter-moisture cold traps, a pump, and flow metering system.

In the corridor, floor to ceiling thermocouple arrays were located at 3 m (10 ft) intervals from the burn room doorway, along the axis centerline. Thermocouple pairs (ceiling surface and 51 mm (2 in) below the ceiling) were placed at intermediate 1.5 m (5 ft) intervals. A gas sampling tube inlet was located in the center of the corridor, 6 m (20 ft) from the burn room and 1.5 m (5 ft) above the floor. The concentrations of oxygen and carbon dioxide were measured from gas samples drawn at this location.

Another gas sampling tube and thermocouple array were located in the target room. Oxygen, carbon dioxide, and carbon monoxide were measured from gas sampled in the target room.

Temperatures, velocities, and oxygen, carbon dioxide, and carbon monoxide concentrations in the exhaust gases in the test facility exhaust stack were monitored. These data were used to determine the mass flow rate through the stack and the total rate of heat production by the fire using oxygen consumption calorimetry [6].

Immediately prior to each test, the cribs were weighed and their moisture content measured. After the data acquisition system was started, the heptane was ignited. The measurements obtained from the instruments were recorded at a rate of one scan every fifteen seconds on a computerized data acquisition system. Techniques for the analysis of the data have been documented [7].

3. DISCUSSION OF TEST RESULTS

Nine fire tests were conducted in the burn room-corridor-target room test facility. A listing of the test parameters is given in Table 2. The first, second, and third tests were free burn tests to determine the conditions in the test area resulting from an unmitigated fire development. The fourth and fifth tests utilized a standard pendent sprinkler (S.S.) and a quick response pendent sprinkler (Q.R.S.), respectively, positioned outside of the burn room in the corridor. The sixth and seventh tests utilized a S.S. and a Q.R.S., respectively, positioned in the burn room over a shielded fire. The eighth and ninth tests utilized a S.S. and a Q.R.S., respectively, positioned in the burn room over an unshielded fire.

The nine tests will be reviewed in three categories; 1) Non-Sprinklered, 2) Sprinklers in the Corridor, and 3) Sprinkler in the Burn Room. A summary of the test results are given in Tables 3, 4 and 5. A set of data plots for each of the nine tests can be found in Appendix A.

3.1 Non-Sprinklered

A summary of the Non-Sprinklered test measurements, which effect the tenability of the test areas, is given in Table 3. Figure 6 exhibits the heat release rate plots for Tests 1 through 3 as well as a free burn heat release rate curve for the fuel package under a calorimetry hood. The average peak heat release rate is approximately 900 kW. It can be seen from Table 3 that the measured conditions in the corridor and the target room are similar for all of the Non-Sprinklered tests. Hence, the shielding of the fire did not make a significant difference in measured conditions in the corridor or the target room. Since the results of the Non-Sprinklered tests were so similar, with regard to measured conditions in the corridor and target room, they will be discussed as one.

Figure 7 presents the graphs of gas temperature for Test 2 at 1.5 m (5 ft) above the floor for the burn room, the corridor and the target room as a function of time. The temperature in the burn room was approximately 500°C (932°F) for more than 10 minutes. The temperature curves shown for the corridor exhibit peak temperatures of 130°C (266°F). The measured temperatures at different distances from the burn room indicate a uniform increase (± 10°C) in temperature at the 1.5 m (5 ft) elevation throughout the entire corridor. The peak temperature in the target room was 61°C (142°F). Figures 8 through 10 show the measured concentrations of oxygen, carbon dioxide, and carbon monoxide during Test 2 in the burn room, corridor, and target room respectively. The carbon monoxide data for the corridor is not available for Test 2 due to instrument failure. Instrumentation failures occurred during the other tests as noted on Tables 3 - 5, hence the data is not available.

3.2 Sprinkler in the Corridor

The corridor sprinkler tests utilized three sprinkler heads installed 1.8 m (6 ft), 5.5 m (18 ft) and 9 m (30 ft) from the burn room/corridor vent on the centerline of the corridor ceiling. All of the sprinklers used in this test series are commercially available pendent heads with a activation temperature rating of 74 °C (165 °F). The sprinklers were installed so their deflectors were 57 ± 6 mm (2.25 ± 0.25 in) below the ceiling. The water supply was set to allow the sprinklers to flow 95 lpm (25 gpm) with a line pressure near the head of 172 kPa (25 psig). During these tests, only the sprinkler closest to the burn room/corridor vent activated. Both of these tests utilized a shielded fire.

A summary of the test measurements, which effect the tenability of the test areas, is given in Table 4. It can be seen from Table 4 that the measured conditions in the corridor and the target room are similar for both of the tests. Given the similarity, only data from Test 4 will be reviewed.

In the test under discussion, standard response sprinklers were used. Figure 11 presents the graphs of gas temperature at 1.5 m (5 ft) above the floor for the burn room, the corridor and the target room as a function of time. The sprinkler activated at 427 seconds after ignition. The temperature curves shown for the corridor exhibit peak temperatures of approximately 70°C (160°F) at the 1.5 m (5 ft) level just prior to sprinkler activation. The peak temperature in the target room was 31°C (86°F). Figures 12 through 14 show the measured concentrations of oxygen, carbon dioxide, and carbon monoxide in the burn room, corridor, and target room respectively.

3.3 Sprinkler in Burn Room

A summary of the sprinkler in burn room test measurements, which affect the tenability of the test areas, is given in Table 5. It can be seen from Table 5 that the measured conditions in the corridor and the target room are similar for both of the tests. Shielding does not have an effect on the conditions in the corridor and target room. Given the similarity, only data from Test 6 will be reviewed.

In the test under discussion, standard response sprinklers were used with a shielded fire. Figure 15 presents the graphs of gas temperature at 1.5 m (5 ft) above the floor for the burn room, the corridor and the target room as a function of time. The sprinkler activated at 265 seconds. The sprinkler in the burn room significantly limited the temperature rise throughout the test space. The temperature curves shown for the corridor exhibit a peak temperature of 40°C (105°F) at the 1.5 m (5 ft) level just prior to sprinkler activation. The temperature in the target room remained constant at approximately 24°C (75°F) throughout the test. Figures 16 through 18 show the measured concentrations of oxygen, carbon dioxide, and carbon monoxide in the burn room, corridor, and target room respectively.

4. ANALYSIS OF TEST RESULTS

The tenability of a space, exposed to a fire environment, is based on several factors including: high temperature, oxygen depletion, irritating or toxic combustion products and loss of visibility. Even if these factors were working individually, and in many cases they do not, an exact threshold of tenability could not be identified due to differences in individuals and the different circumstances under which they are exposed to the hazard. To complicate matters further, the synergy with which these individual hazards work in combined exposures has not been quantified. Methods have been developed to evaluate tenability in fire situations. The tenability criteria and analysis for temperature and combustion gas exposure used in this study are those approximated in HAZARD I [8].

The smoke toxicity associated with a given combustion product is related to the concentration of the fire gases and the duration of exposure to the specified concentration. Criteria are available in the literature for assessing the toxic hazard presented by the concentrations of oxygen, carbon dioxide, and carbon monoxide measured during these full scale tests. In the HAZARD I tenability evaluation routine (TENAB), the N-Gas Model is utilized to provide a dimensionless toxic gas hazard parameter called Fractional Exposure

Dose (FED). FED is the combination of the effects of each of the toxic gases toward the total effect on the exposed person. Table 6 presents tenability limits for incapacitation and death due to temperature and FED due to low oxygen concentrations, high carbon dioxide concentrations and high carbon monoxide concentrations over time [8]. The gas concentration data from tests 2, 4 and 6 were analyzed with the N-Gas Model equation, and the results are shown in Tables 7 through 9 respectively.

4.1 Comparison of Sprinklered vs Non-Sprinklered Results

Figure 19 illustrates the reduction in the fire's heat release rate due to sprinkler activation. This indicates that the heat introduced into the corridor, for the sprinklered burn room case, is reduced by a factor of 10 compared to the non-sprinklered case. By examining Figures 20 and 21, which show the 1.5 m (5 ft) level temperatures at the center of the corridor and in the target room, it can be seen that the temperatures were reduced by at least 50 % regardless of sprinkler location. With a sprinkler in the burn room, temperatures in the corridor were reduced from an untenable condition in excess of 100°C (212°F) with no sprinklers to a tenable 40°C (104°F). Temperatures near the ceiling of the corridor exceeded 200°C (392°F) in the non-sprinklered case. In the target room, the temperatures under sprinklered conditions were kept within 5°C (9°F) of initial ambient conditions.

Oxygen depletion never reached lethal levels (5%) in the corridor or the target room. However, the levels of oxygen depletion shown in Figure 22 for the non-sprinklered test are below the level which would incapacitate an occupant within 5 minutes [8]. Figure 23 exhibits that the oxygen concentration in the target room remained virtually unaffected by the fire in the sprinklered tests.

Figures 24 and 25 exhibit the decrease in carbon dioxide generation for the tests in which "wet" sprinklers were installed in the corridor and the target room respectively. Figure 26 presents a comparison of the carbon monoxide measured in the target room under the three different test conditions. The combined effects of increased carbon dioxide and carbon monoxide and reduced oxygen were used in the FED calculations.

A summary of the tenability analyses is given in Tables 7 through 9 for Tests 2,4,and 6 respectively. In the tables, conditions are noted for the burn room, corridor and target room. The primary areas of concern to this study are the corridor and target room. Untenable conditions due to temperature and FED existed in the corridor for the "Non-Sprinklered" case. Incapacitating conditions were evident in the target room for the "Non-Sprinklered" case and in the corridor in the "Sprinklers in Corridor" case. Tenable conditions were maintained in the corridor and target room throughout the test which had a sprinkler in the burn room.

4.2 Comparison of Standard Sprinkler To Quick Response Sprinkler

The response times of the sprinklers are listed in Table 10. For the non-sprinklered cases, sprinkler activation times are given for sprinklers charged with air. Similarly, the sprinkler in the burn room, during the "Sprinklers in Corridor" tests, was charged only with air. Quick response sprinklers consistently activated sooner than the standard sprinklers, resulting in lower maximum temperatures in the burn room.

Both standard and quick response sprinklers maintained tenable conditions in the corridor and target room (Tables 8 and 9).

5. CONCLUSIONS

This study has shown that water spray from sprinklers can reduce the hazardous conditions in egress ways and staging areas in close proximity to the source of the fire. The conditions in the corridor during the non-sprinklered tests were lethal due to the temperature and combined effects of the combustion gases. The conditions in the target room during the non-sprinklered tests were incapacitating due to the combined effects of the combustion gases only.

The conditions in the corridor and the target room remained tenable in all tests in which sprinklers operated either in the burn room or the corridor. The sprinkler installed in the burn room was more effective than the sprinkler in the corridor at mitigating the hazardous conditions due to heat and products of combustion in the corridor and target room.

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Table 1. Location of Instrumentation

GSA CORRIDOR AND SIMULATED STAGING AREA FIRE TEST SERIES

I. Instrumentation in the Burn Room, Corridor, and Target Room

A. Thermocouple Trees, Gas Temperature

Array 1 in burn room, Northwest quadrant - 9 thermocouples at 0.26, 0.66, 1.07, 1.47, 1.88, 2.19, 2.34, 2.39, and 2.44 m from floor.

Array 2 in doorway between burn room and corridor - 8 thermocouples at 0.51, 0.61, 0.91, 1.22, 1.37, 1.52, 1.83, and 2.29 m from floor.

Array 3 in corridor, 3 m from burn room doorway - 9 thermocouples at 0.26, 0.66, 1.07, 1.47, 1.88, 2.19, 2.34, 2.39, and 2.44 m from floor.

Array 4 in corridor, 4.6 m from burn room doorway - 2 thermocouples at 2.39 and 2.44 m from floor.

Array 5 in corridor, 6.1 m from burn room doorway (center of corridor) - 9 thermocouples at 0.26, 0.66, 1.07, 1.47, 1.88, 2.19, 2.34, 2.39, and 2.44 m from floor.

Array 6 in corridor, 7.6 m from burn room doorway - 2 thermocouples at 2.39 and 2.44 m from floor.

Array 7 in corridor, 9.1 m from burn room doorway - 9 thermocouples at 0.26, 0.66, 1.07, 1.47, 1.88, 2.19, 2.34, 2.39, and 2.44 m from floor.

Array 8 in corridor, 10.6 m from burn room doorway - 2 thermocouples at 2.39 and 2.44 m from floor.

Array 9 in target room, 1.5 m from doorway - 8 thermocouples at 0.35, 0.76, 1.16, 1.57, 1.88, 2.03, 2.08, and 2.13 m from floor.

C. Gas Analysis

Burn Room probe, 0.46 m horizontally from the Northwest corner, 1.53 m from the floor - oxygen, carbon dioxide, and carbon monoxide concentrations.

Corridor probe, center of corridor, 1.53 m from the floor - oxygen, carbon dioxide, and carbon monoxide concentrations.

Target Room probe, 0.3 m horizontally from the East and South walls and 1.53 m from the floor - oxygen, carbon dioxide, and carbon monoxide concentrations.

II. Exhaust Hood

1 smoke meter

1 probe for sampling oxygen, carbon dioxide, and carbon monoxide.

9 pitot static probes.

9 thermocouples.

Table 2.Summary of Test Configurations

Test No.	Shielded Fire	Sprinkler(s)	Location
1	Yes	None (Std)*	n/a
2	Yes	None (QR)*	n/a
3	No	None (Std)*	n/a
4	Yes	Standard	Corridor
5	Yes	Quick Response	Corridor
6	Yes	Standard	Burn Room
[illegible]	Yes	Quick Response	Burn Room
8	No	Standard	Burn Room
9	No	Quick Response	Burn Room

* "Dry" Sprinklers were used to measure activation times.

Table 3. Summary of Test Results - Non-Sprinklered

NON-SPRINKLERED			
TEST NO.	**1**	**2**	**3**
BURN ROOM	**SHIELDED FIRE**		**UNSHIELDED**
O_2 (MIN)	1.1 %	2.7 %	*
CO_2 (MAX)	24.1 %	16.8 %	*
CO (MAX)	0.5 %	1.7 %	*
Temp @ 1.5 m (MAX)	790°C	520°C	820°C
CORRIDOR	**SHIELDED FIRE**		**UNSHIELDED**
O_2 (MIN)	8.0 %	8.6 %	8.4 %
CO_2 (MAX)	11.9 %	10.5 %	11.1 %
CO (MAX)	*	*	*
Temp @ 1.5 m (MAX)	184°C	130°C	151°C
TARGET ROOM	**SHIELDED FIRE**		**UNSHIELDED**
O_2 (MIN)	12.9 %	13.3 %	12.4 %
CO_2 (MAX)	6.4 %	5.9 %	7.5 %
CO (MAX)	0.4 %	0.6 %	0.4 %
Temp @ 1.5 m (MAX)	63°C	61°C	63°C

* Data not available

Table 4. Summary of Test Results - Sprinklers in Corridor

SPRINKLERS IN CORRIDOR		
TEST No.	4	5
BURN ROOM	S.S	Q.R.S.
O_2 (MIN)	1.0 %	3.7 %
CO_2 (MAX)	19.3 %	17.1 %
CO (MAX)	*	*
Temp @ 1.5 m (MAX)	628°C	584°C
CORRIDOR	S.S.	Q.R.S.
O_2 (MIN)	11.2 %	11.9 %
CO_2 (MAX)	8.4 %	7.9 %
CO (MAX)	*	*
Temp @ 1.5 m (MAX)	73°C	52°C
TARGET ROOM	S.S.	Q.R.S.
O_2 (MIN)	18.2 %	17.9 %
CO_2 (MAX)	1.5 %	2.5 %
CO (MAX)	0.3 %	0.1 %
Temp @ 1.5 m MAX)	31°C	30°C

* Data not available

Table 5. Summary of Test Results - Sprinkler in Burn Room

SPRINKLER IN BURN ROOM				
TEST No.	6	7	8	9
BURN ROOM	SHIELDED FIRE		UNSHIELDED FIRE	
	S.S.	Q.R.S.	S.S.	Q.R.S.
O_2 (MIN)	12.9 %	13.3 %	*	15.5 %
CO_2 (MAX)	7.2 %	6.7 %	*	4.1 %
CO (MAX)	0.6 %	0.5 %	*	*
Temp @ 1.5m (MAX)	202°C	140°C	95°C	48°C
CORRIDOR	SHIELDED FIRE		UNSHIELDED FIRE	
	S.S.	Q.R.S.	S.S.	Q.R.S.
O_2 (MIN)	17.8 %	17.7 %	18.6 %	18.2 %
CO_2 (MAX)	2.4 %	2.5 %	1.8 %	2.3 %
CO (MAX)	*	*	*	*
Temp @ 1.5m (MAX)	40°C	28°C	23°C	22°C
TARGET ROOM	SHIELDED FIRE		UNSHIELDED FIRE	
	S.S.	Q.R.S.	S.S.	Q.R.S.
O_2 (MIN)	20.7 %	20.8 %	20.9 %	20.8 %
CO_2 (MAX)	0.4 %	0.3 %	0.2 %	0.2 %
CO (MAX)	< 0.1 %	< 0.1 %	< 0.1 %	< 0.1 %
Temp @ 1.5m (MAX)	25°C	25°C	25°C	24°C

* Data not available

Table 6. Tenability Limits Used in Hazard I

Cause	Incapacitation Level	Lethal Level
Temperature	65°C	100°C
Toxic Gases*	0.50	1.00

* Fractional Exposure Dose (FED) due to CO, CO_2, and O_2.

Table 7. Tenability Results - Non-Sprinklered, Test 2

AREA	TIME (s)	CONDITION	CAUSE	TEMP (°C)	FED
BURN RM	153	Incapac.	Temp	69	0.00
	198	Dead	Temp	118	0.00
	489	Incapac.	FED	480	0.58
	564	Dead	FED	474	1.04
CORRIDOR	350	Incapac.	Temp	68	0.50
	489	Dead	Temp	480	0.00
	1236	Incapac.	FED	122	0.51
	1630	Dead	FED	97	1.00
TARGET RM	1372	Incapac.	FED	60	0.50

Table 8. Tenability Results - Sprinklers in Corridor, Test 4

AREA	TIME (s)	CONDITION	CAUSE	TEMP (°C)	FED
BURN RM	349	Incapac.	Temp	73	0.0
	349	Dead	Temp	110	0.0
	805	Incapac.	FED	584	0.52
	866	Dead	FED	616	1.02
CORRIDOR	501	Incapac.	Temp	68	0.00
TARGET RM	1470	Tenable	n/a	29	0.05

Table 9. Tenability Results - Sprinkler in Burn Room, Test 6

AREA	TIME (s)	CONDITION	CAUSE	TEMP (°C)	FED
BURN RM	167	Incapac.	Temp	71	0.00
	198	Dead	Temp	100	0.00
	1553	Incapac.	FED	36	0.50
CORRIDOR	1690	Tenable	n/a	24	0.00
TARGET RM	1690	Tenable	n/a	25	0.00

Table 10. Summary of Sprinkler Response Times (seconds)

NO SPRINKLERS					
		BR	**1.8 m**	**5.5 m**	**9.0 m**
S.S.	**Shielded**	259	350	439	475
	Unshielded	132	373	463	516
Q.R.S.	**Shielded**	173	291	357	411
SPRINKLERS in CORRIDOR					
		BR	**1.8 m**	**5.5 m**	**9.0 m**
S.S.	**Shielded**	243 #	427	*	*
Q.R.S.	**Shielded**	190	316	*	*
SPRINKLER in BURN ROOM					
		BR	**1.8 m**	**5.5 m**	**9.0 m**
S.S.	**Shielded**	265	*	*	*
	Unshielded	190	*	*	*
Q.R.S.	**Shielded**	259	*	*	*
	Unshielded	90	*	*	*

\# Q.R.S. used in the burn room in place of a S.S.
* No activation

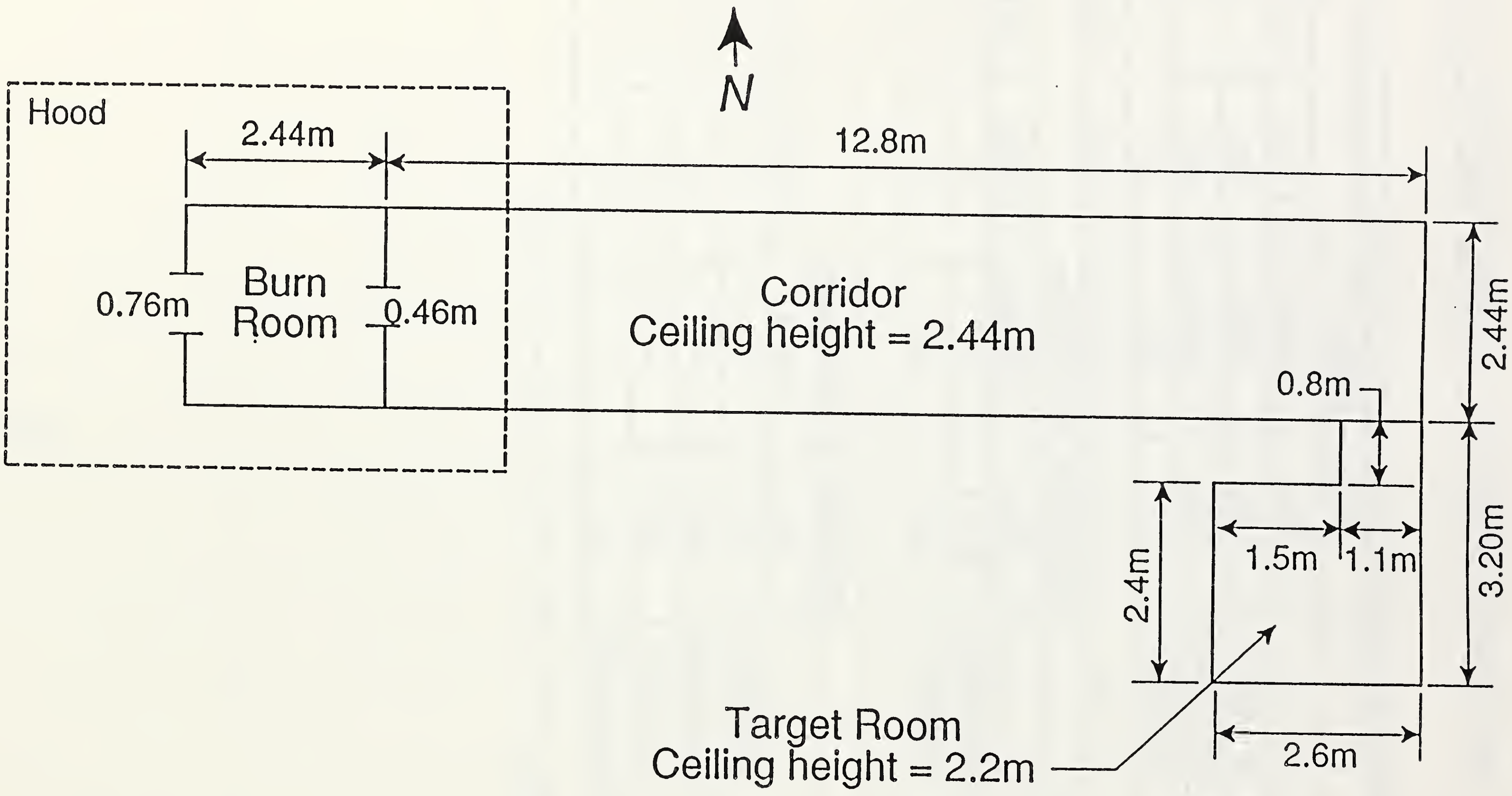

Figure 1. Test Configuration

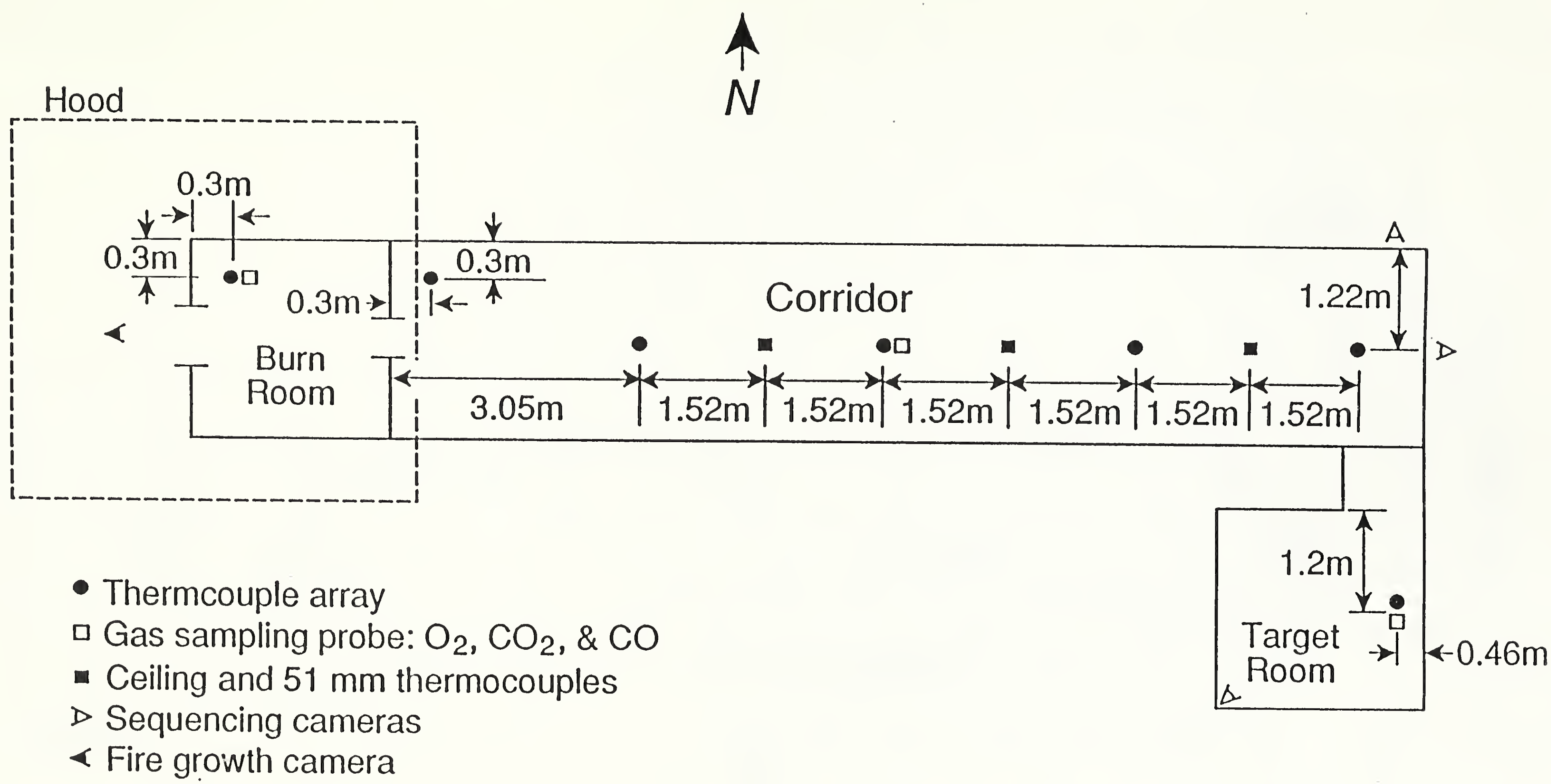

Figure 2. Test Configuration (Instrument Locations)

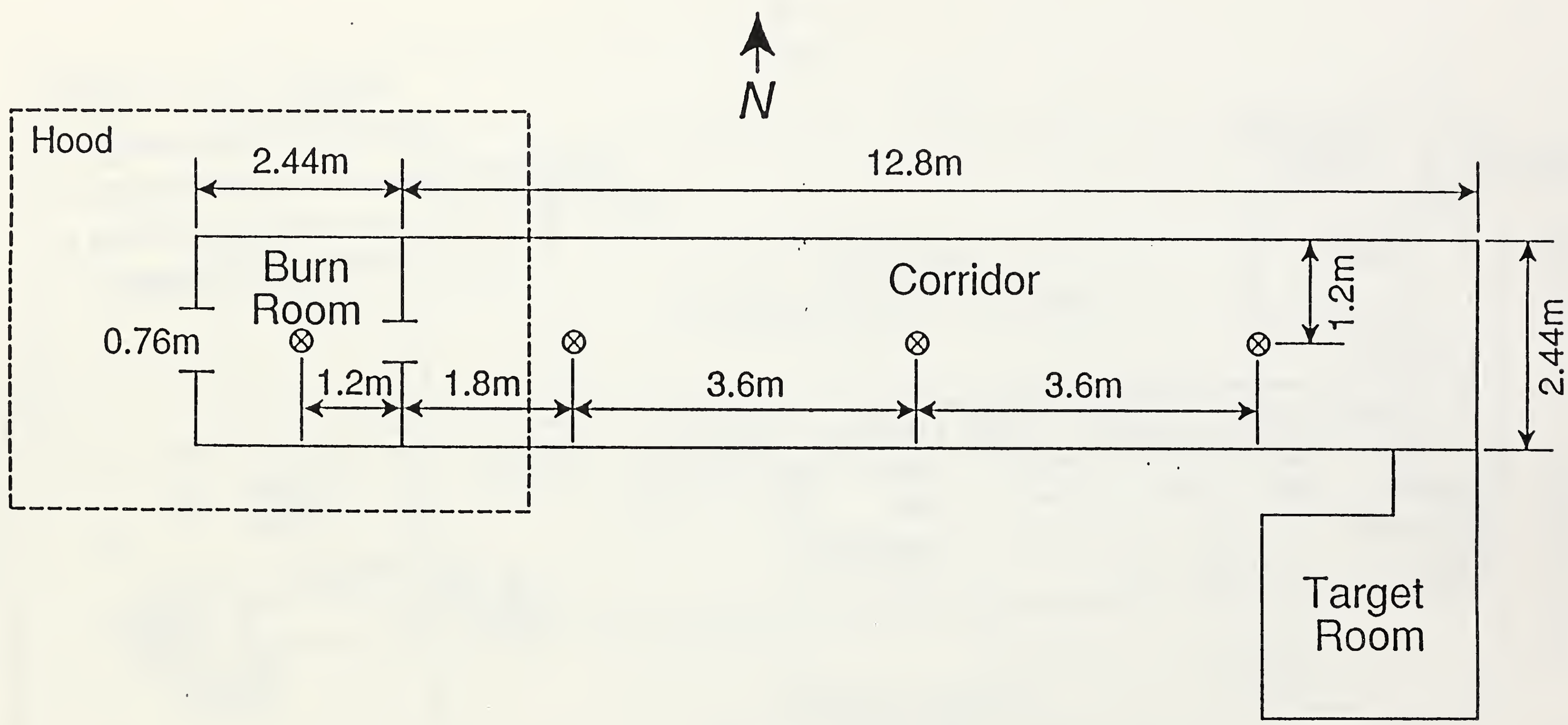

Figure 3. Sprinkler Locations

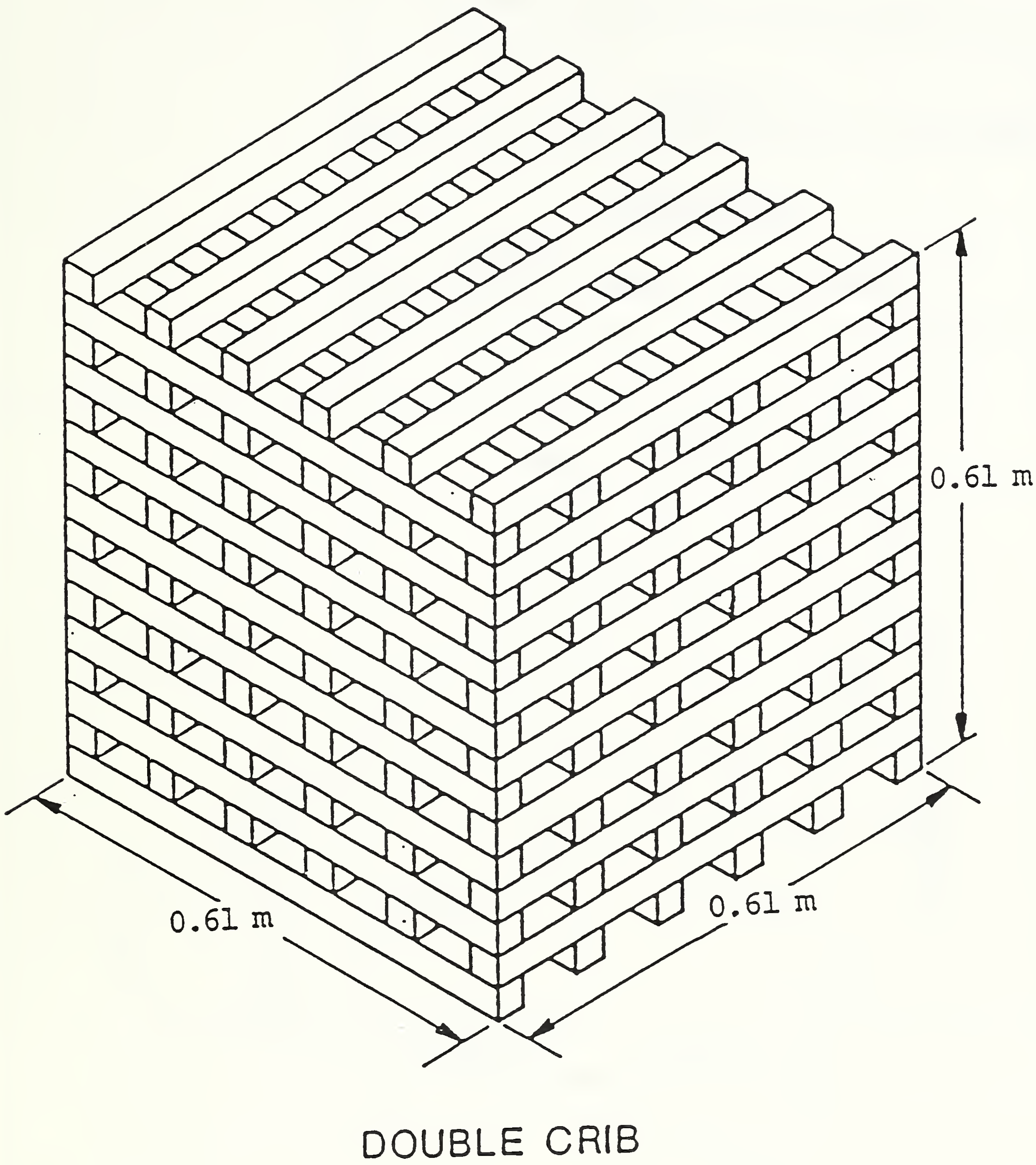

Figure 4. Diagram of Crib

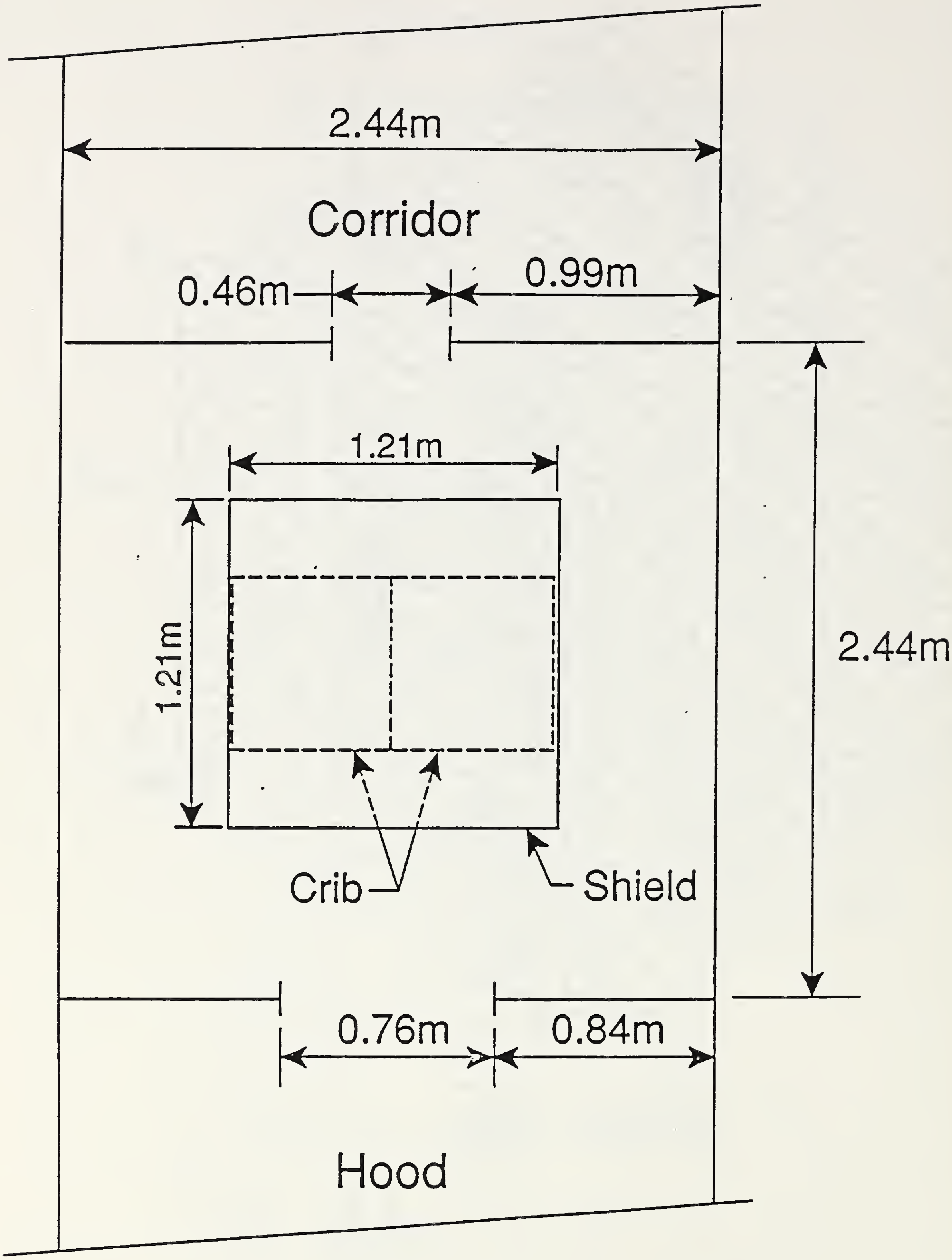

Figure 5. Crib Placement Diagram

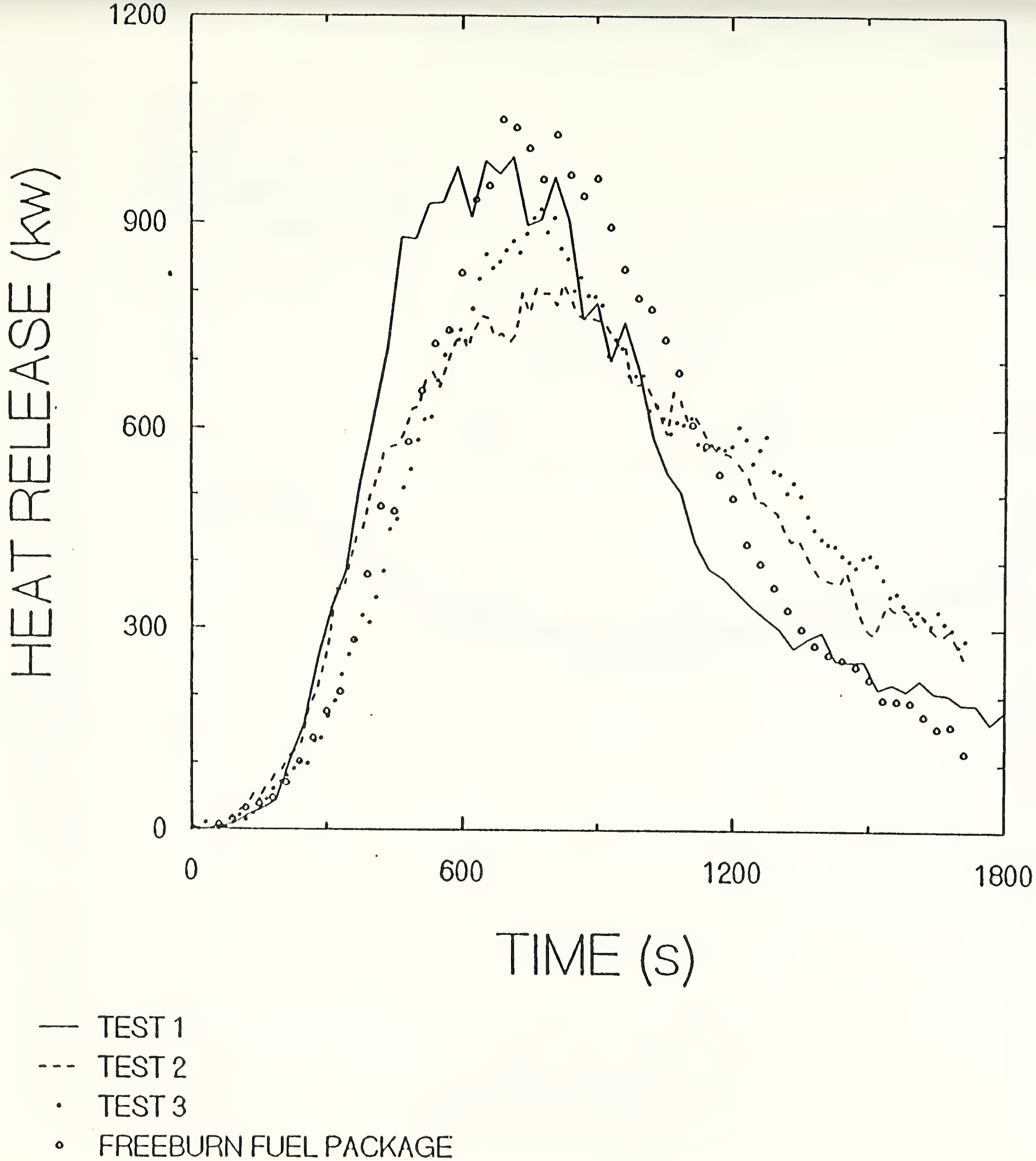

Figure 6. Heat Release Rate Comparison - Non-Sprinklered

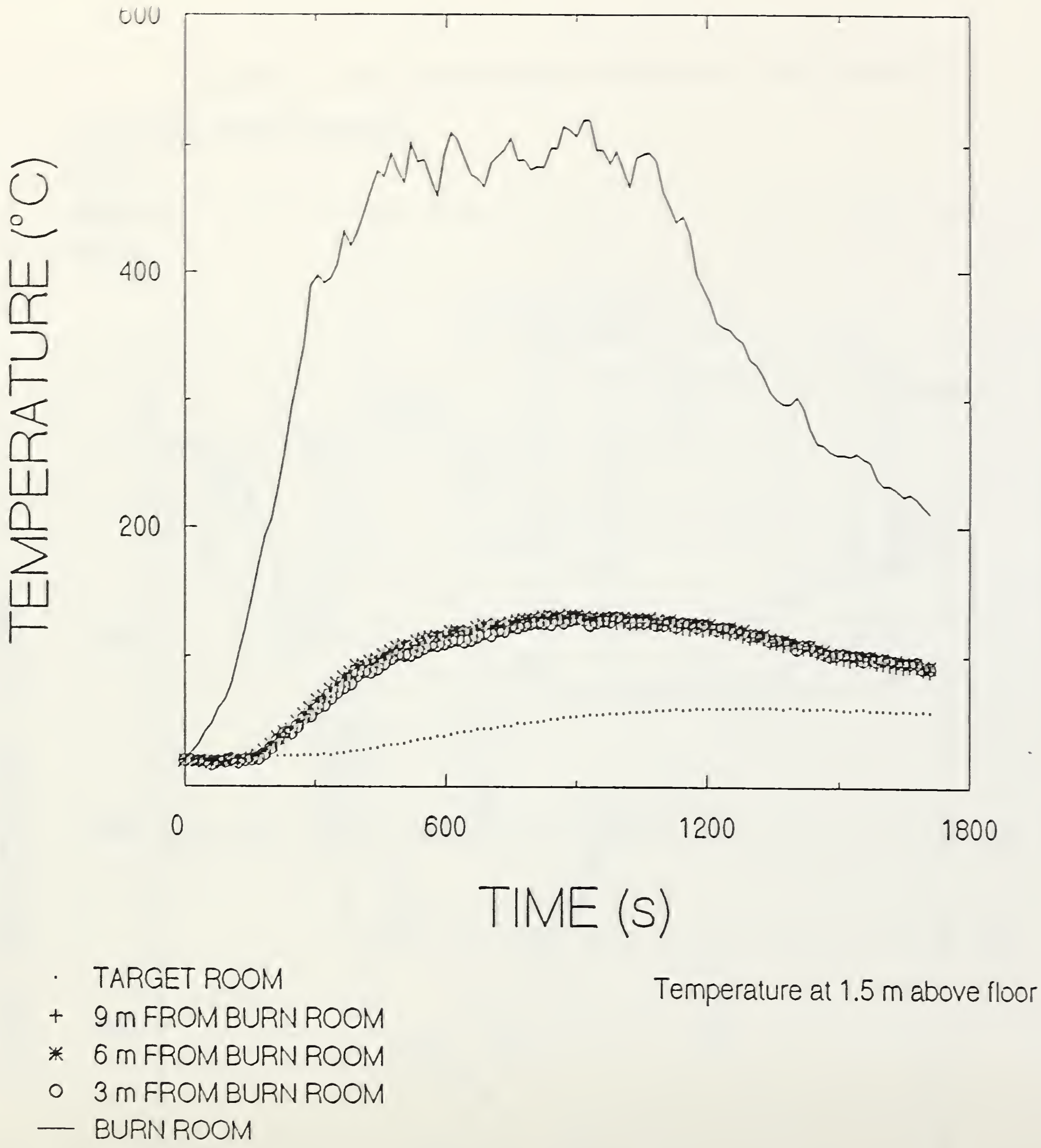

Figure 7. Temperatures in Burn Room, Corridor & Target Room - Non-Sprinklered

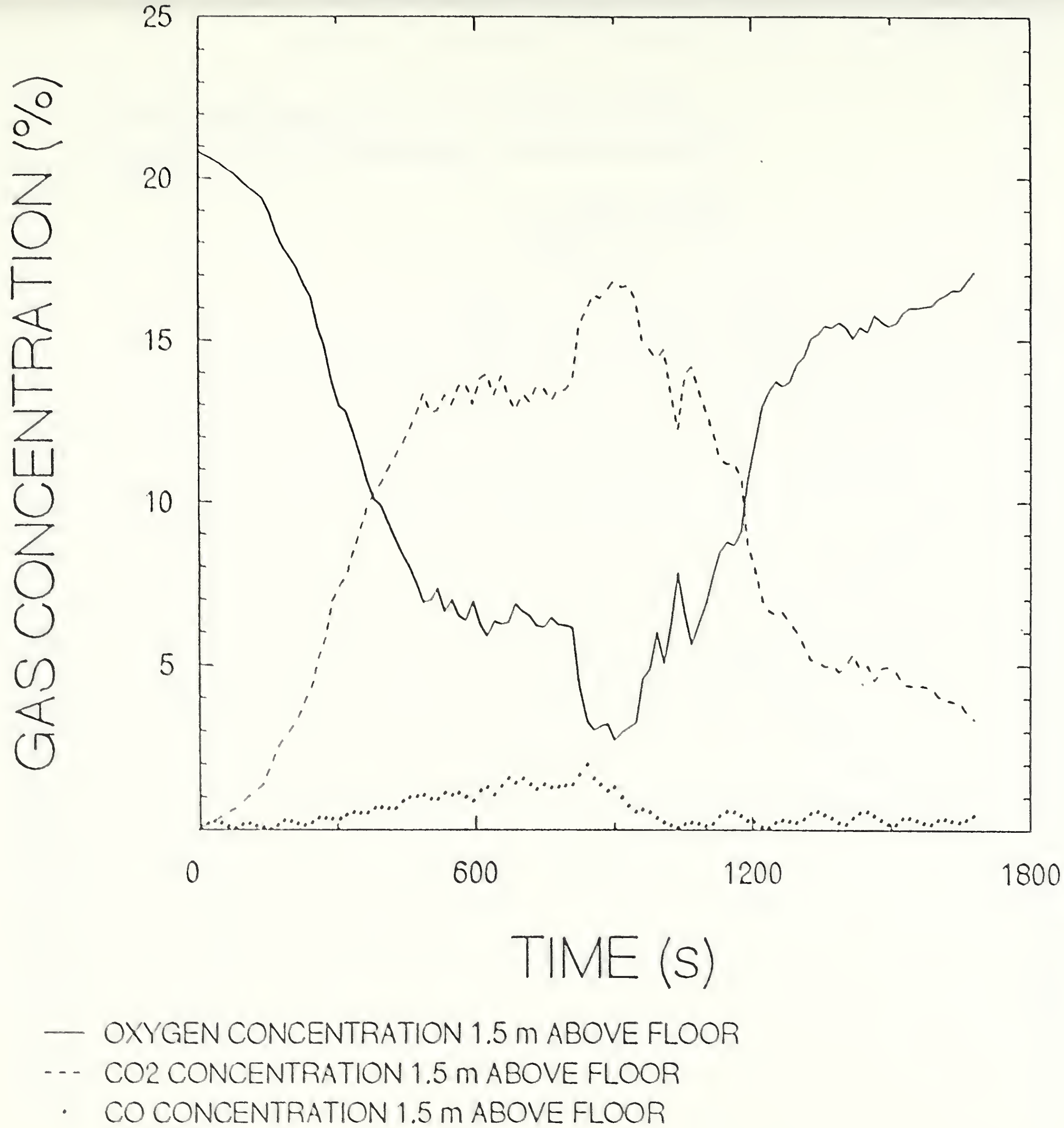

Figure 8. Burn Room Gas Concentrations - Non-Sprinklered

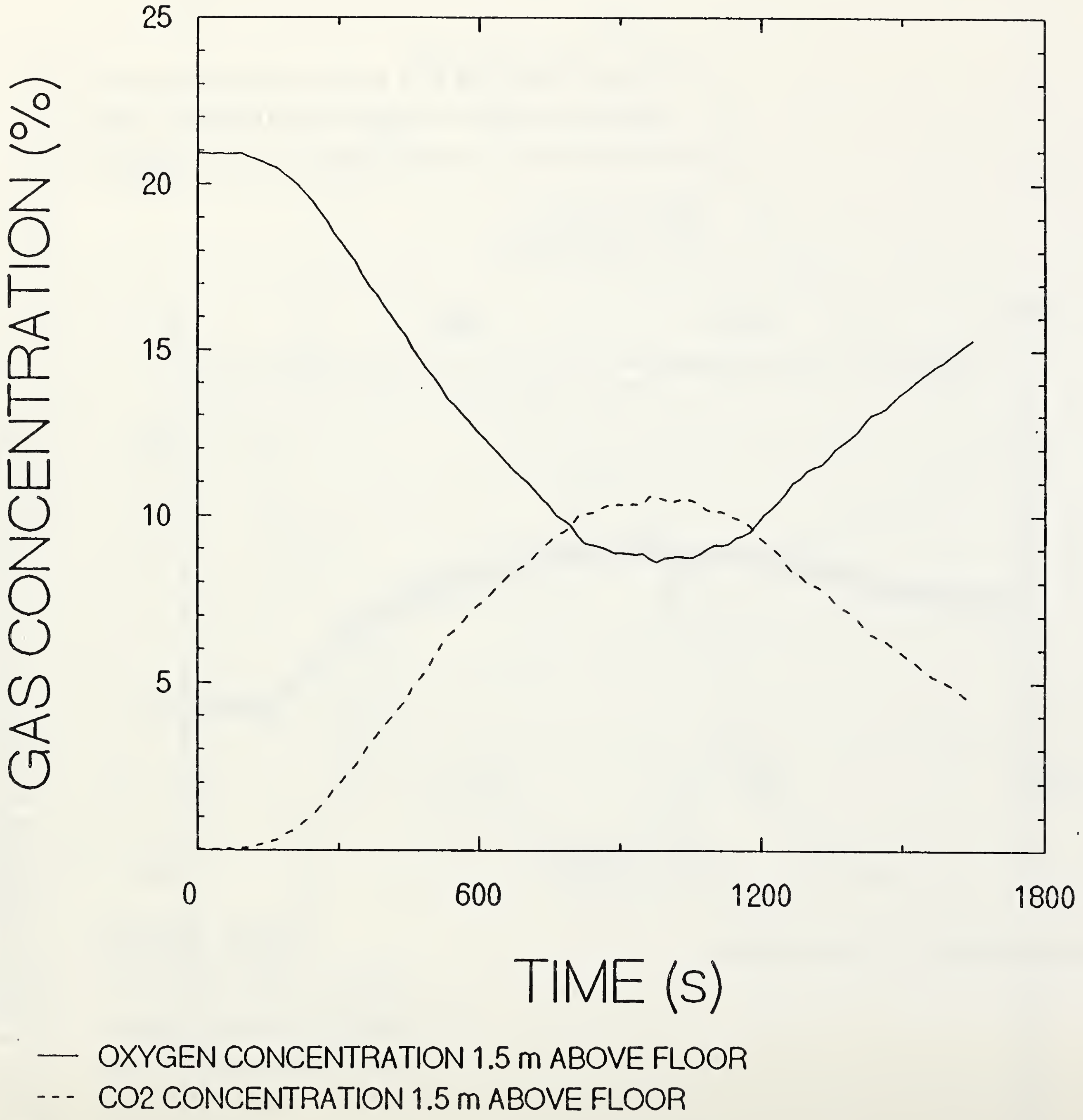

Figure 9. Corridor Gas Concentrations - Non-Sprinklered

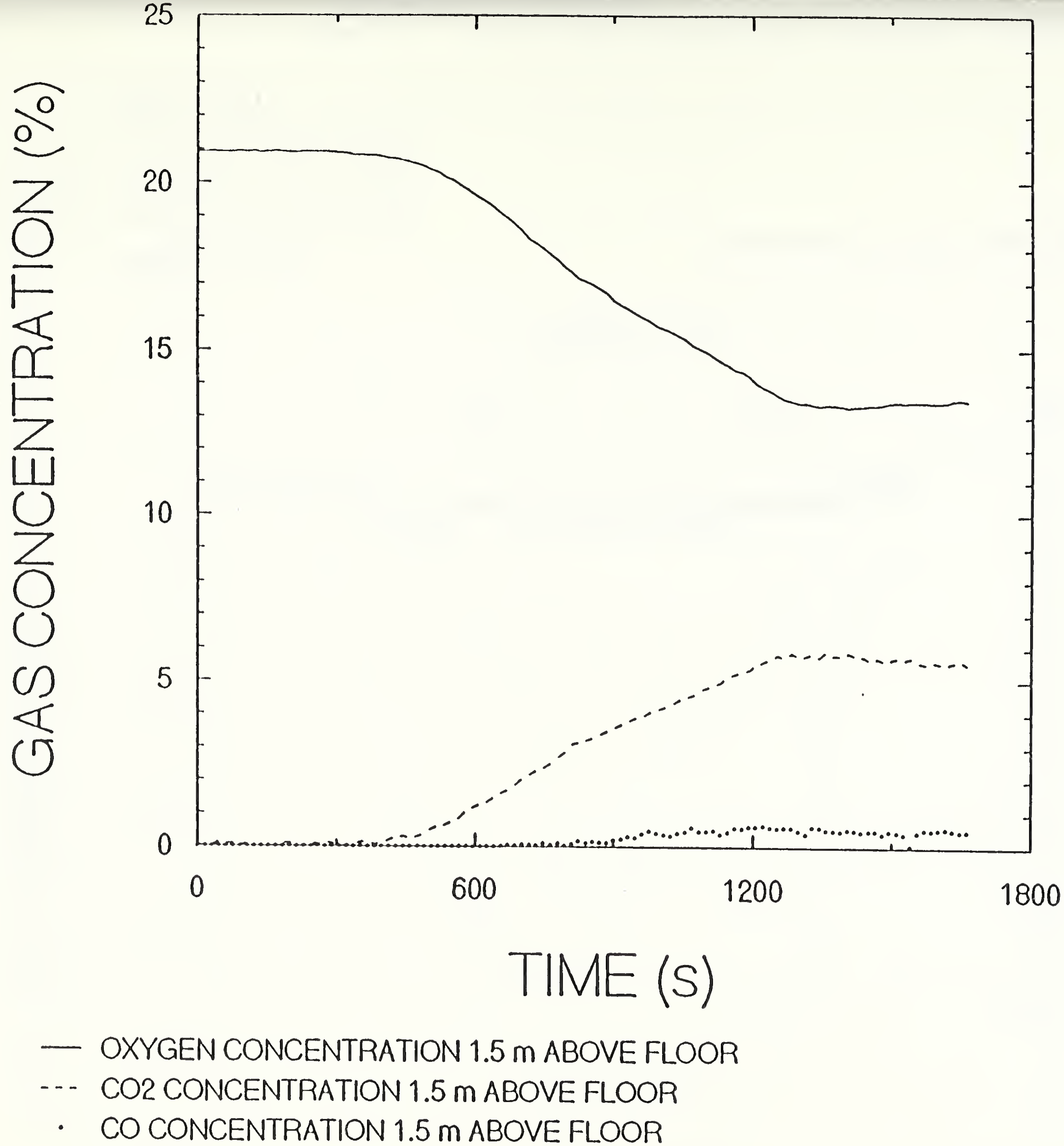

Figure 10. Target Room Gas Concentrations - Non-Sprinklered

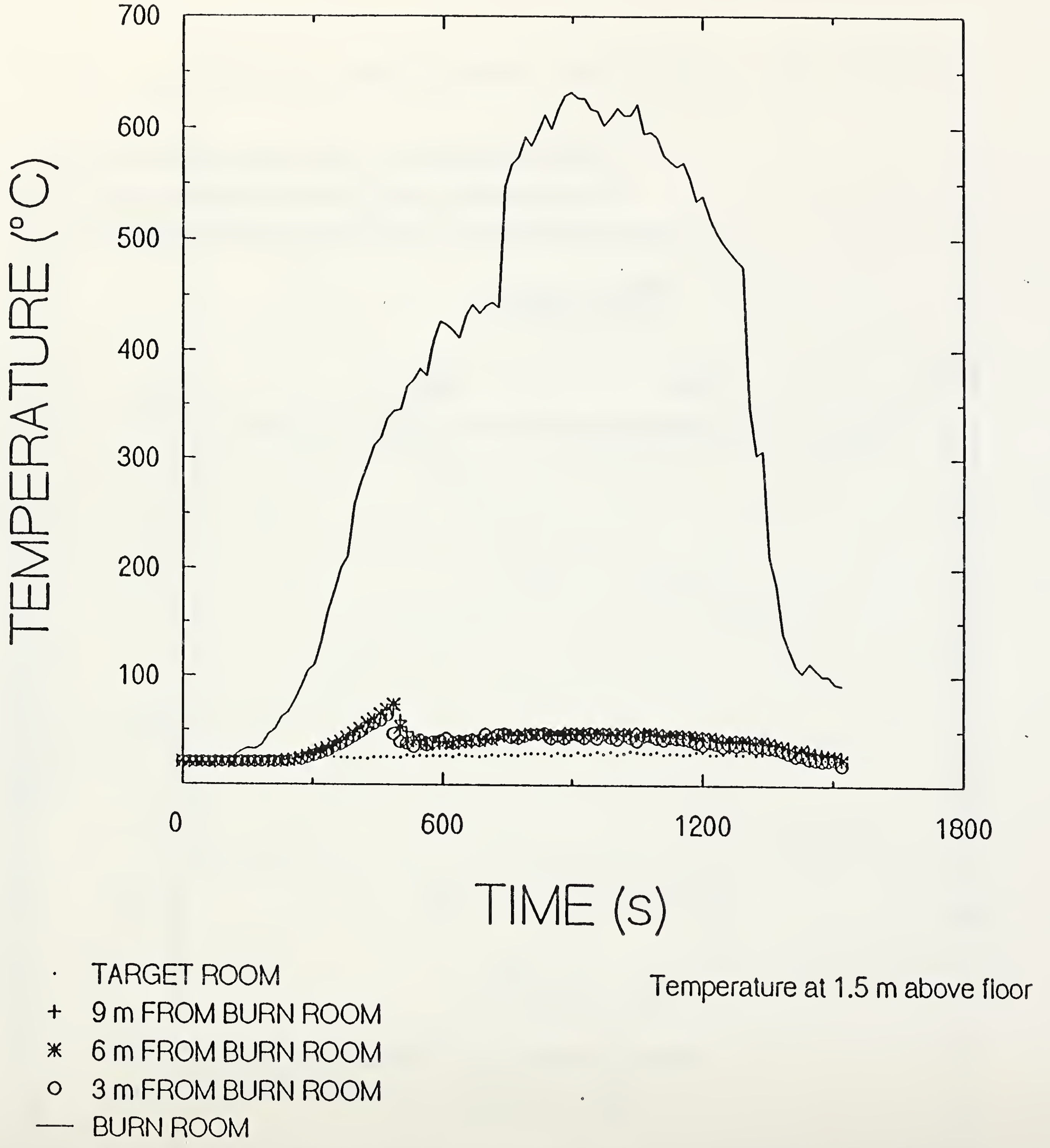

Figure 11. Temperatures in Burn Room, Corridor & Target Room
Sprinklers in Corridor

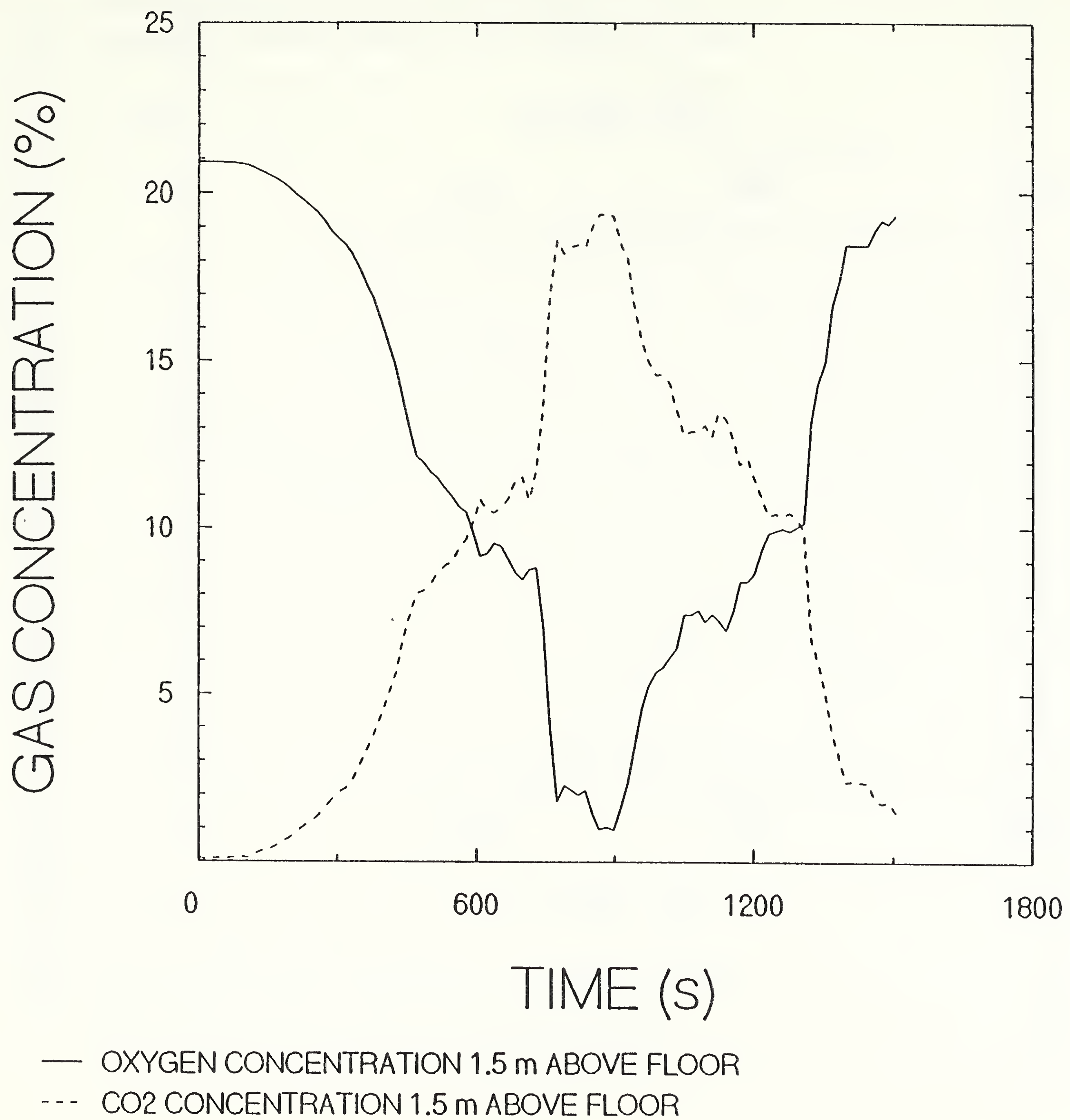

Figure 12. Burn Room Gas Concentrations - Sprinklers in Corridor

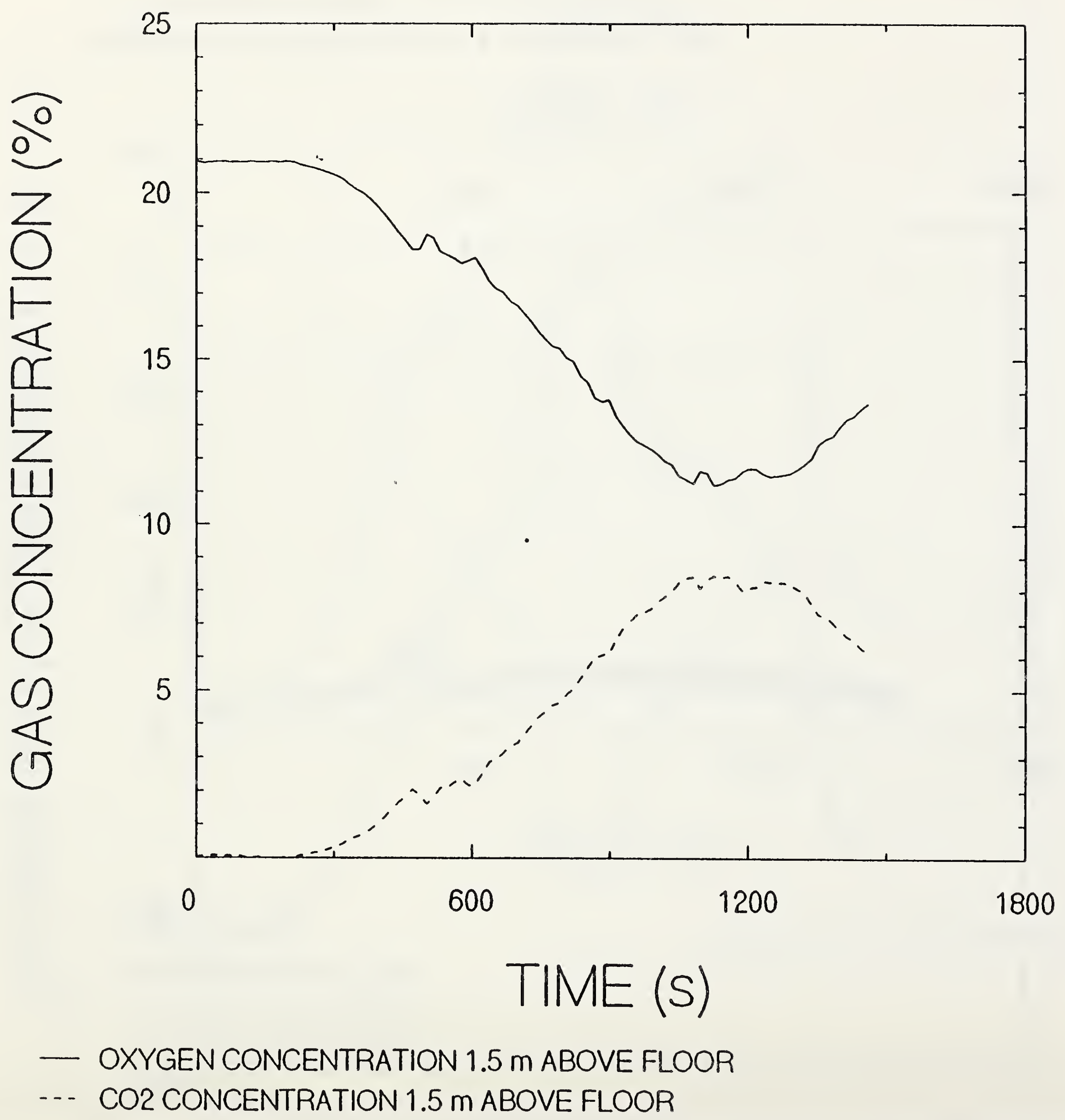

Figure 13. Corridor Gas Concentrations - Sprinklers in Corridor

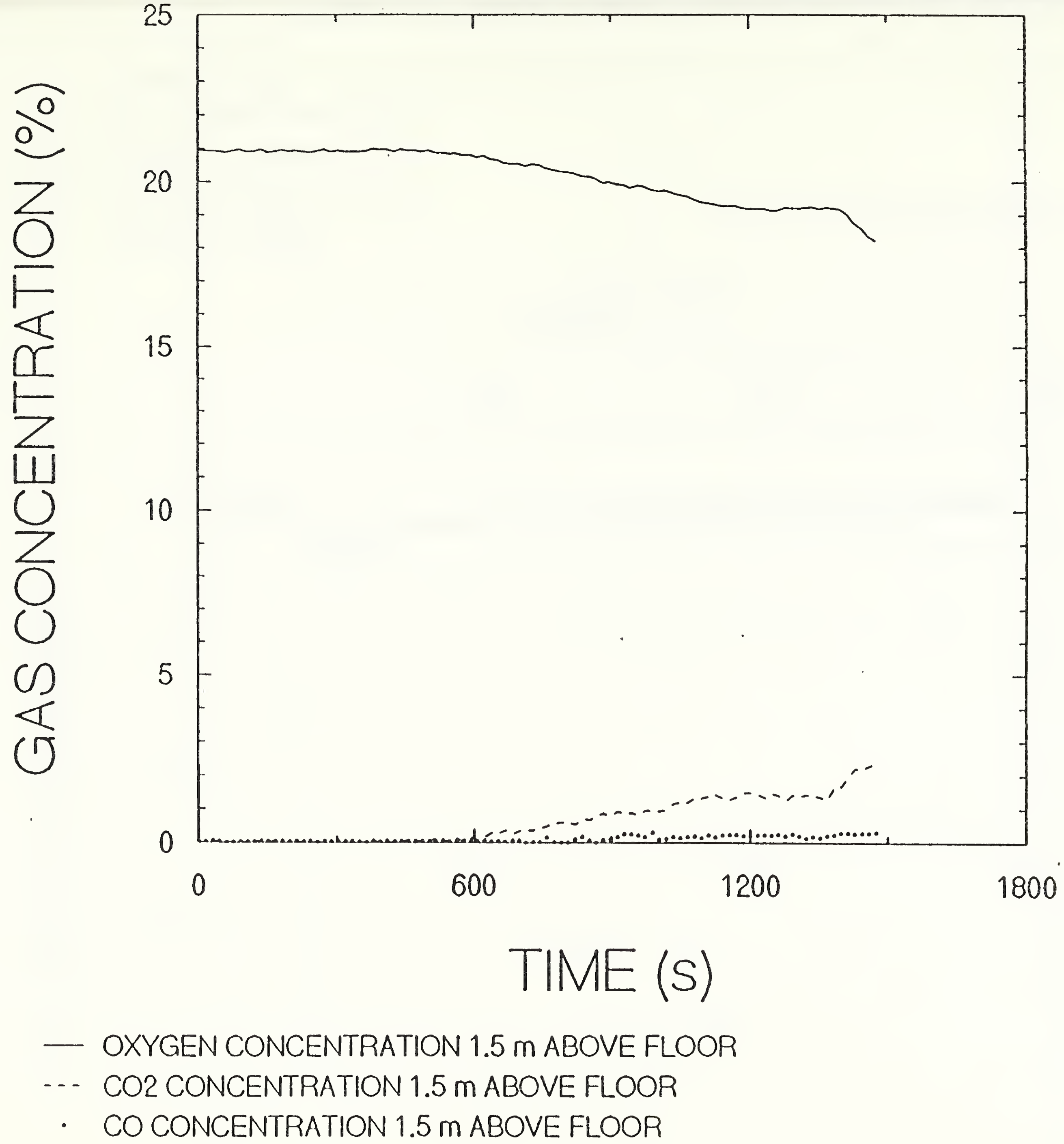

Figure 14. Target Room Gas Concentrations - Sprinklers in Corridor

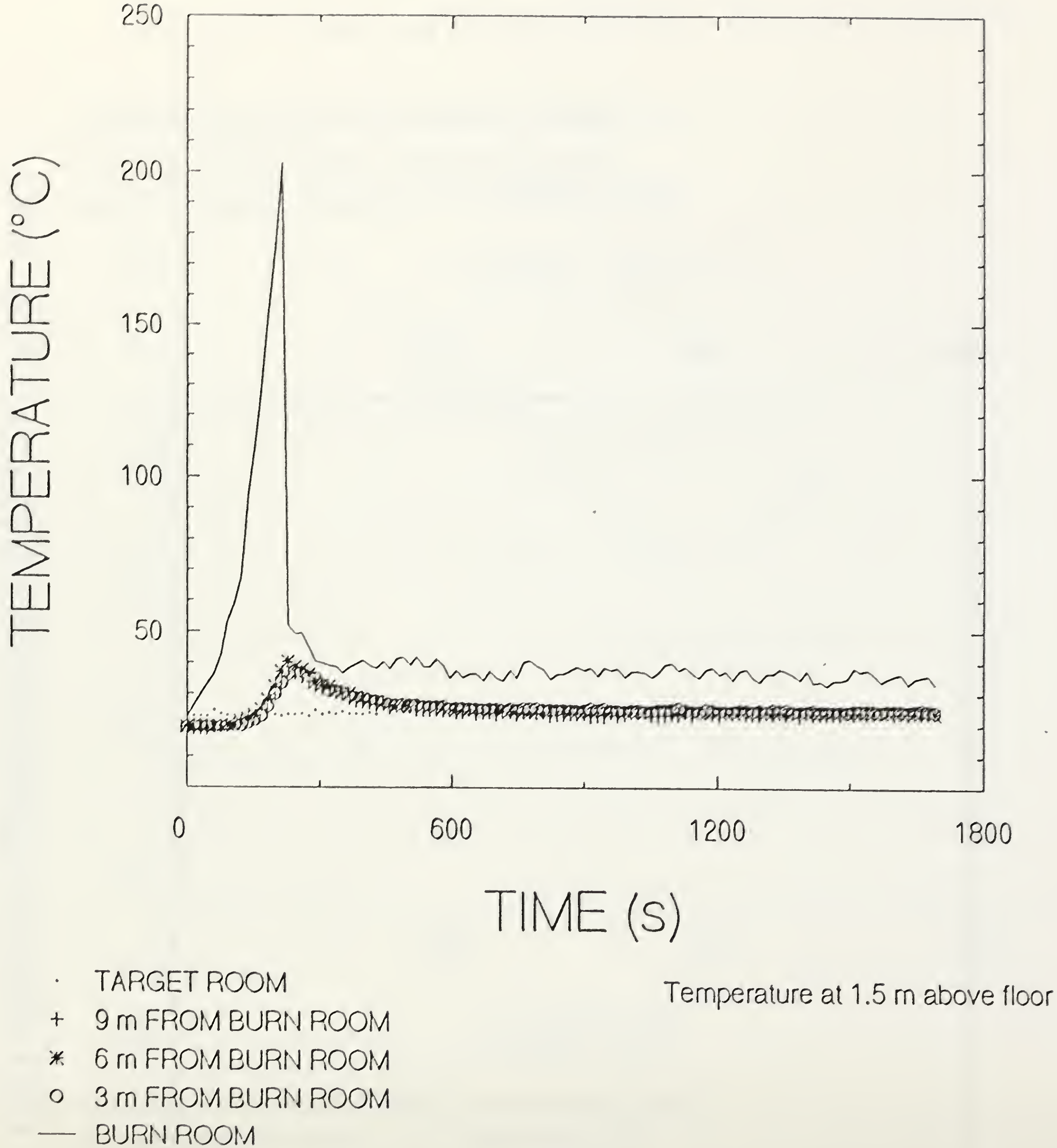

Figure 15. Temperatures in Burn Room, Corridor & Target Room Sprinkler in Burn Room

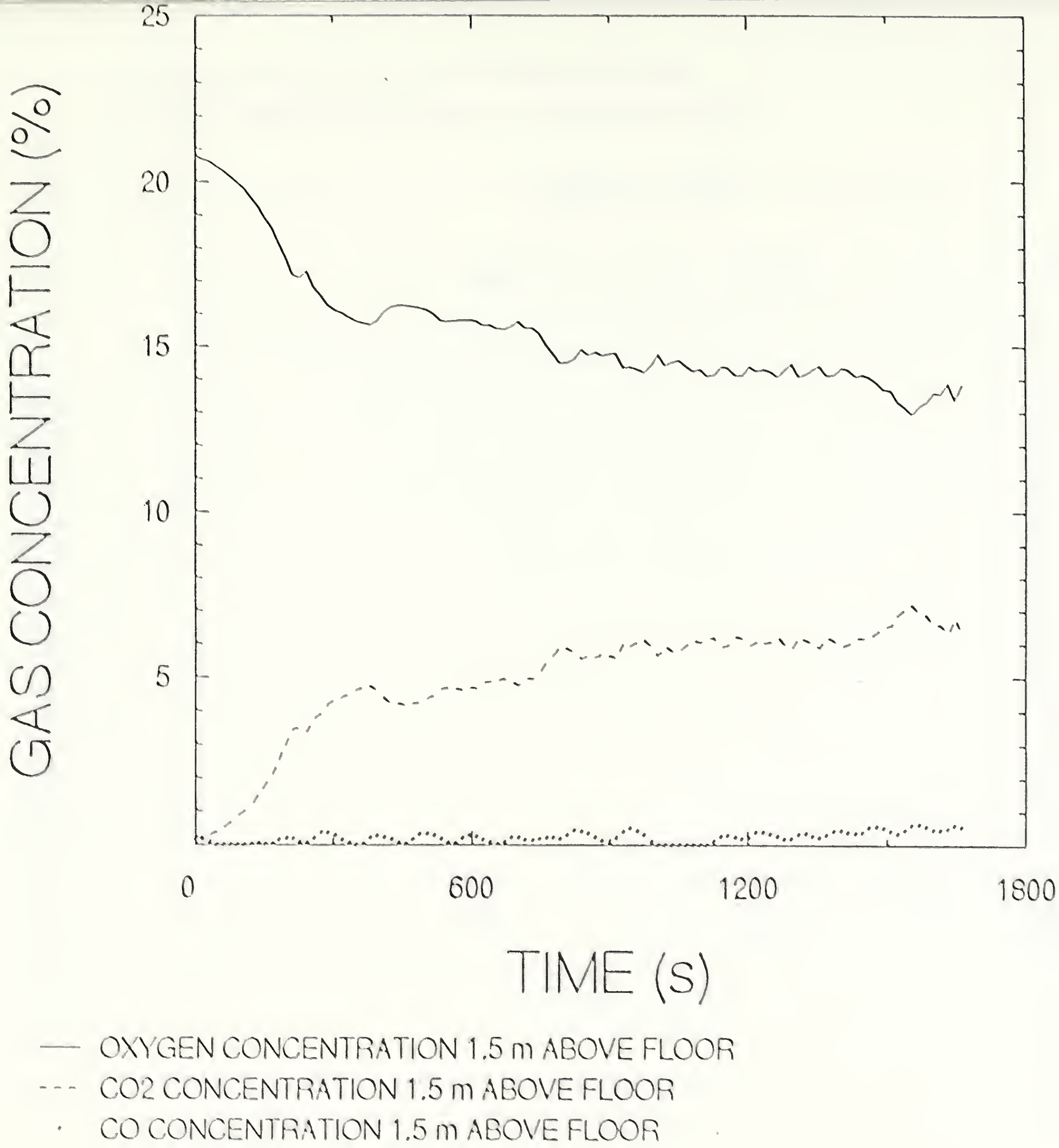

Figure 16. Burn Room Gas Concentrations - Sprinkler in Burn Room

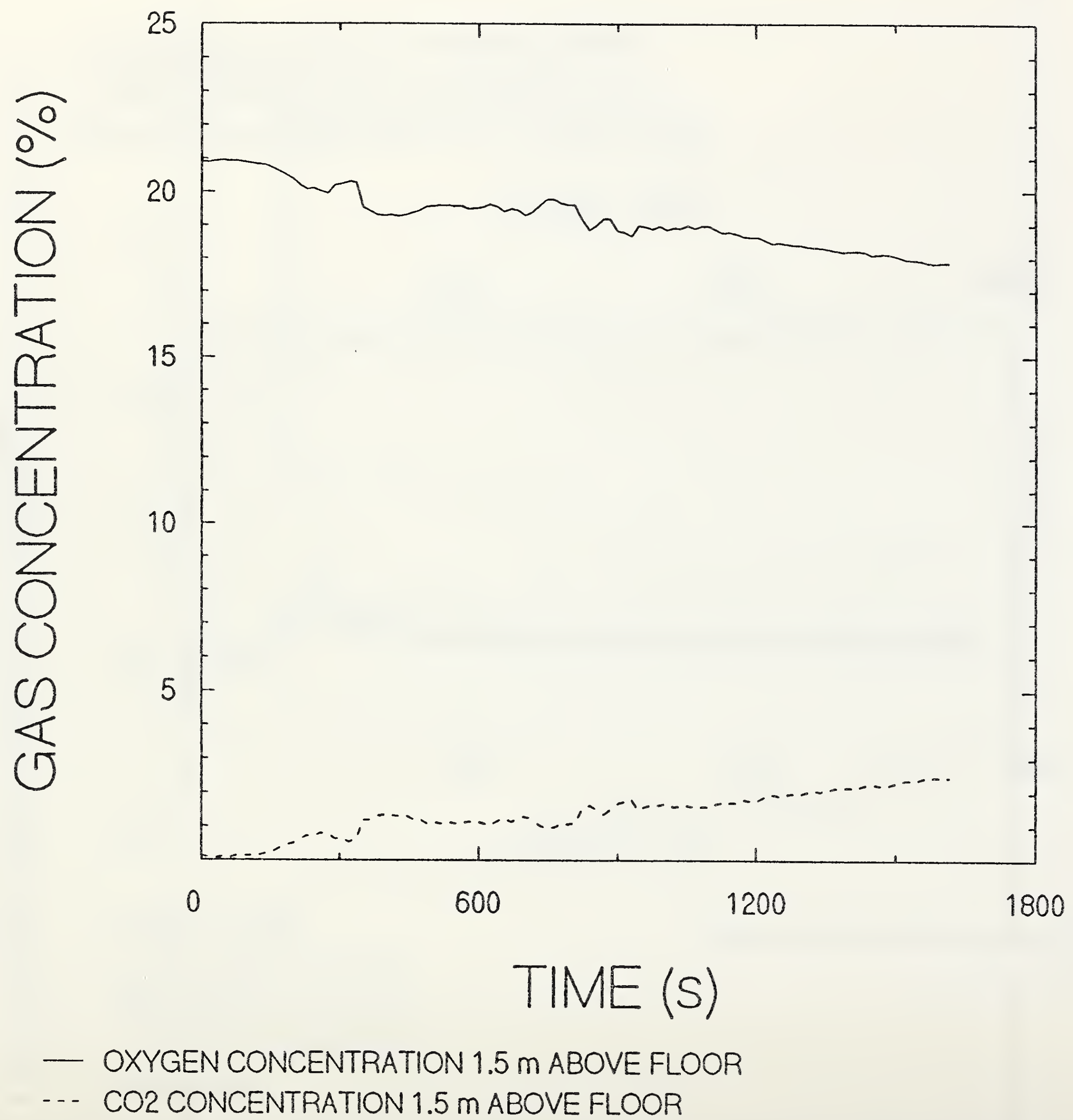

Figure 17. Corridor Gas Concentrations - Sprinkler in Burn Room

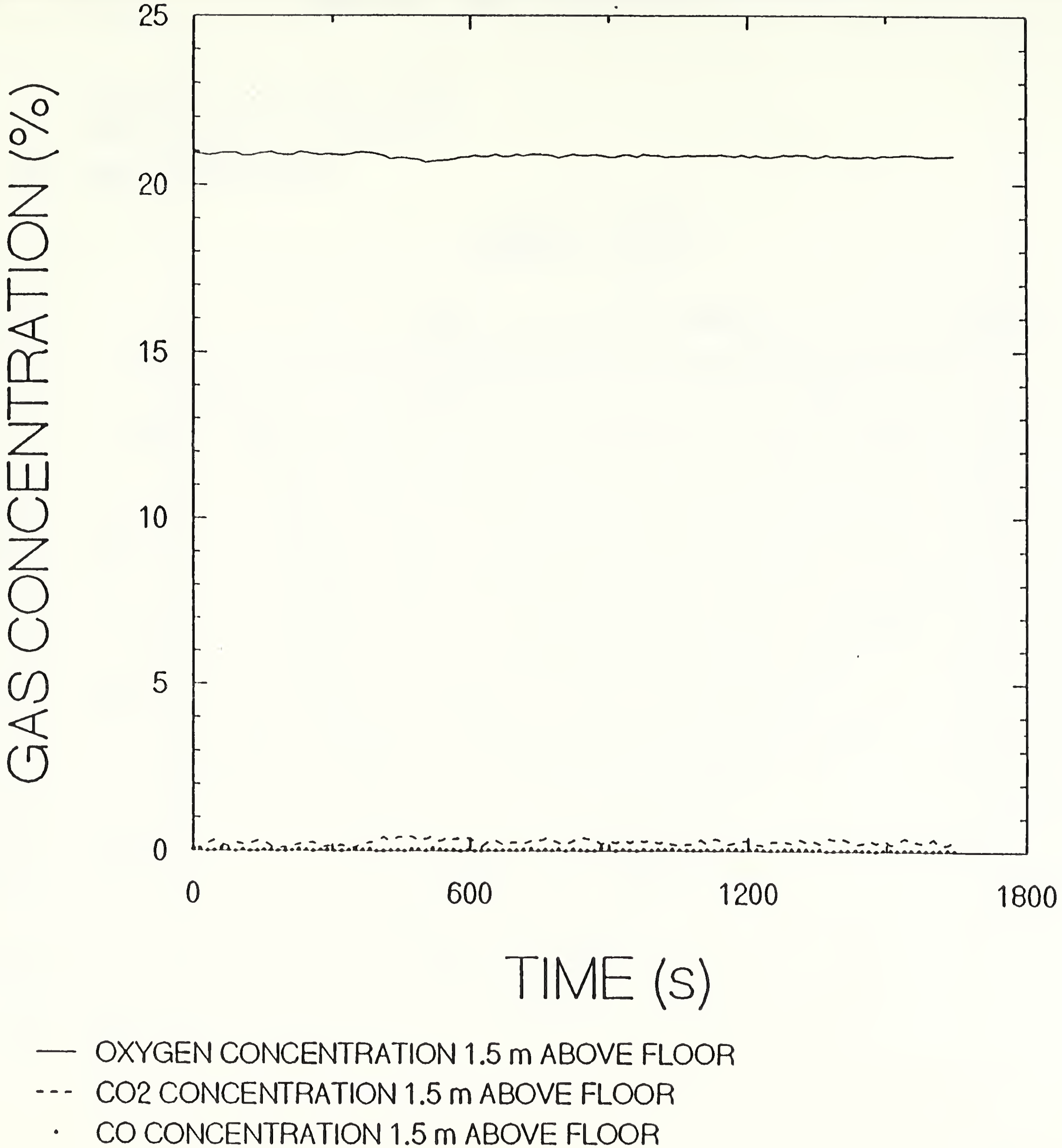

Figure 18. Target Room Gas Concentrations - Sprinkler in Burn Room

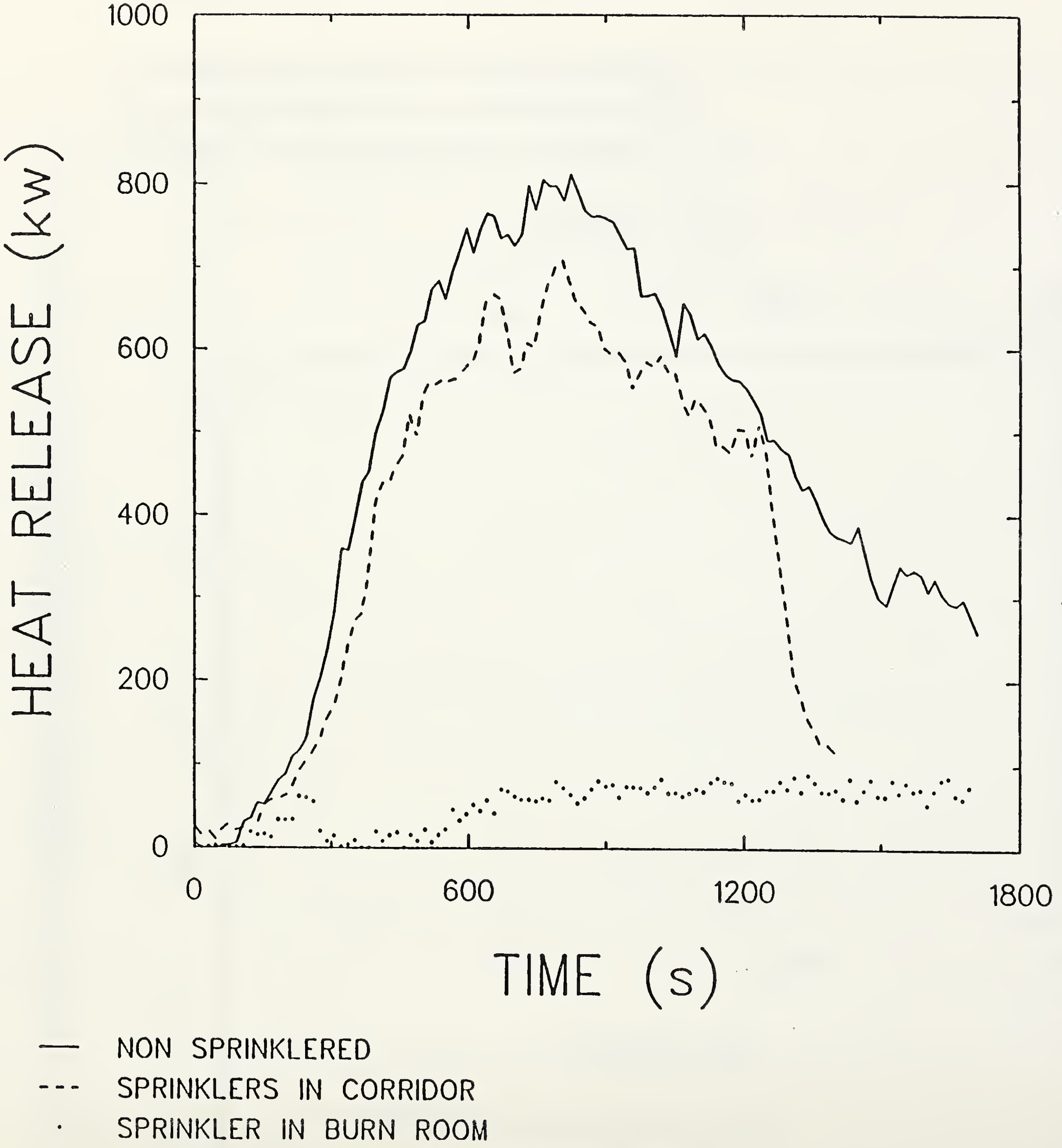

Figure 19. Heat Release Rate Comparison

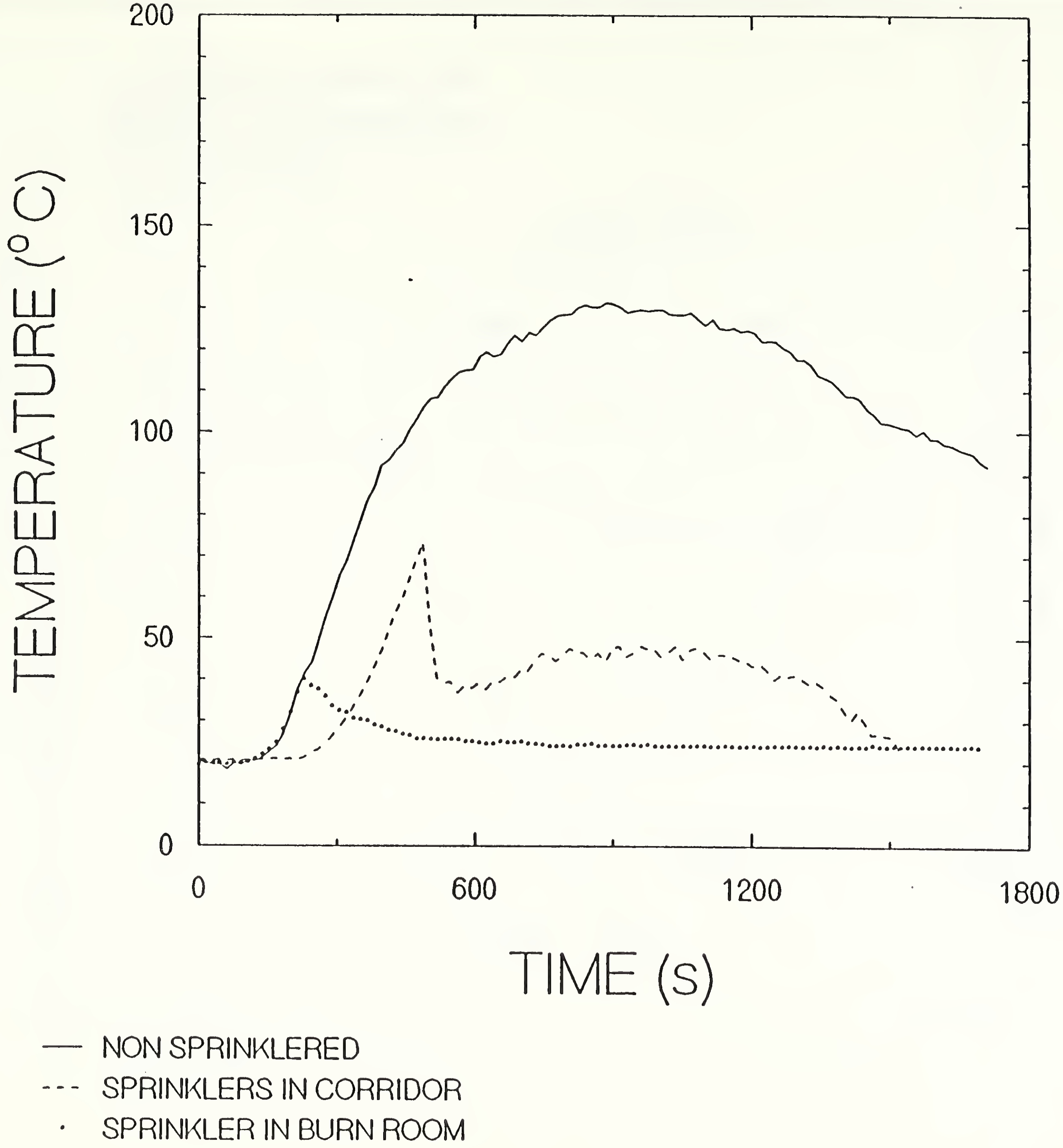

Figure 20. Temperature Comparison - Corridor

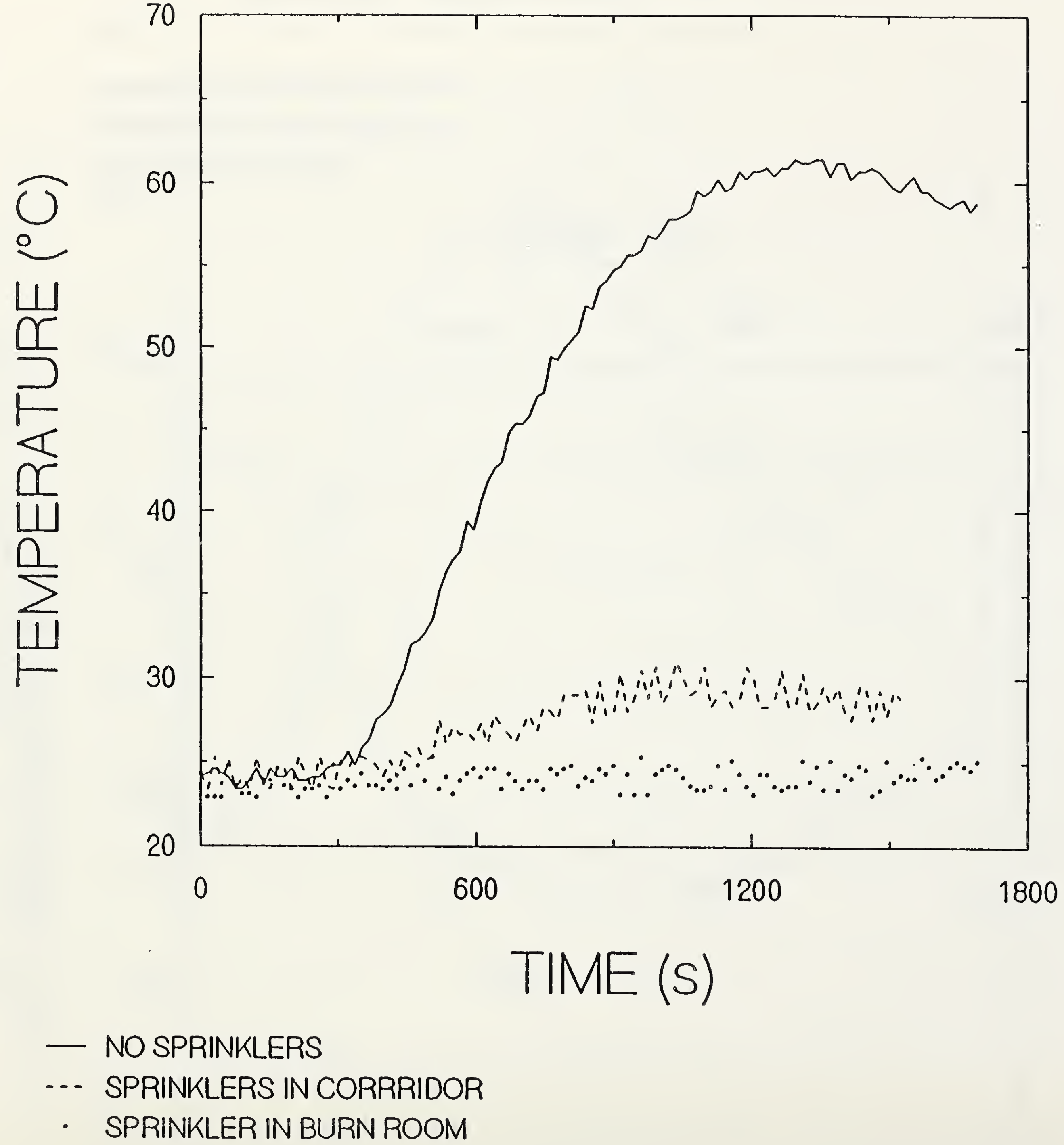

Figure 21. Temperature Comparison - Target Room

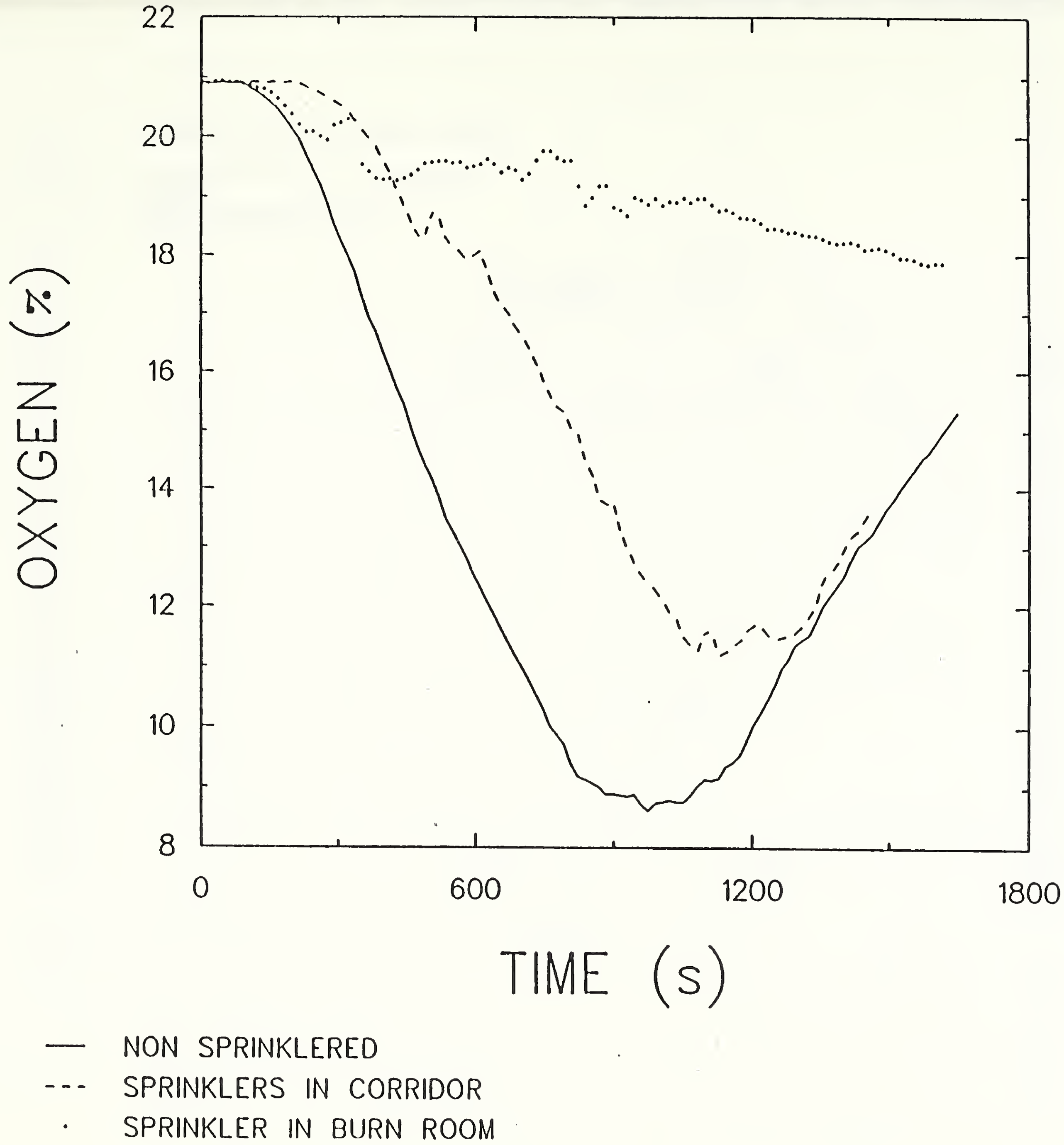

Figure 22. Oxygen Concentration Comparison - Corridor

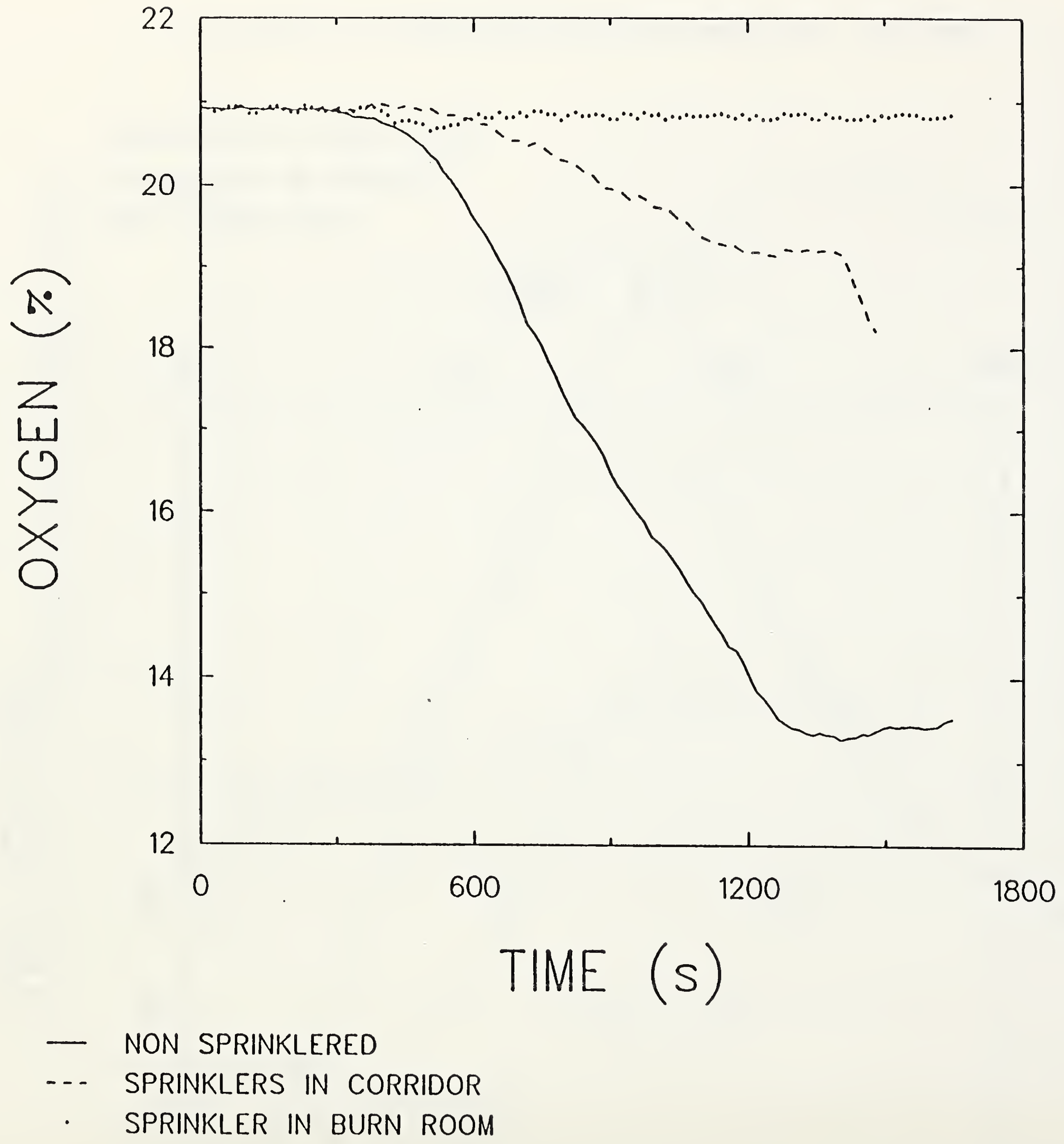

Figure 23. Oxygen Concentration Comparison - Target Room

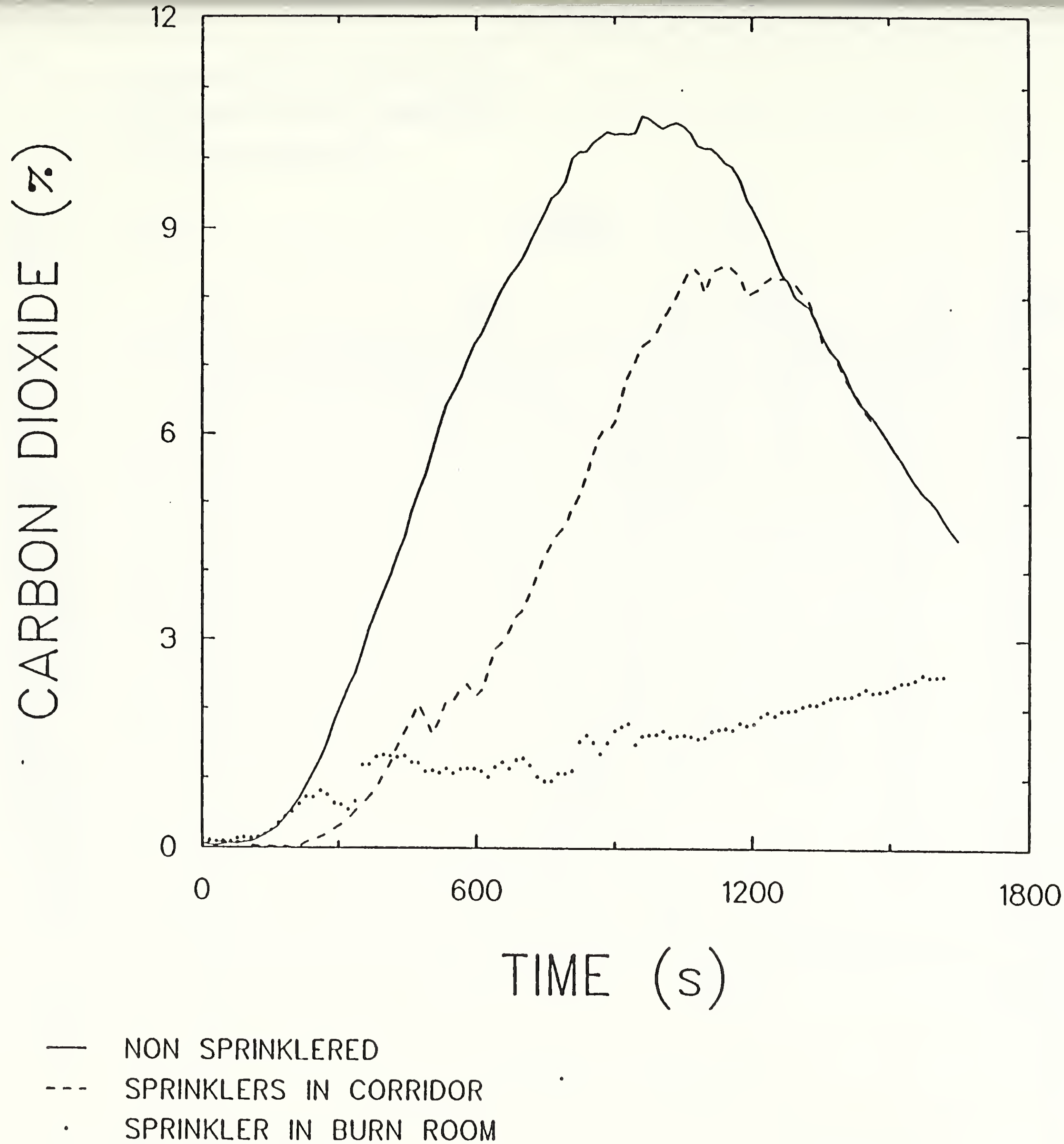

Figure 24. Carbon Dioxide Comparison - Corridor

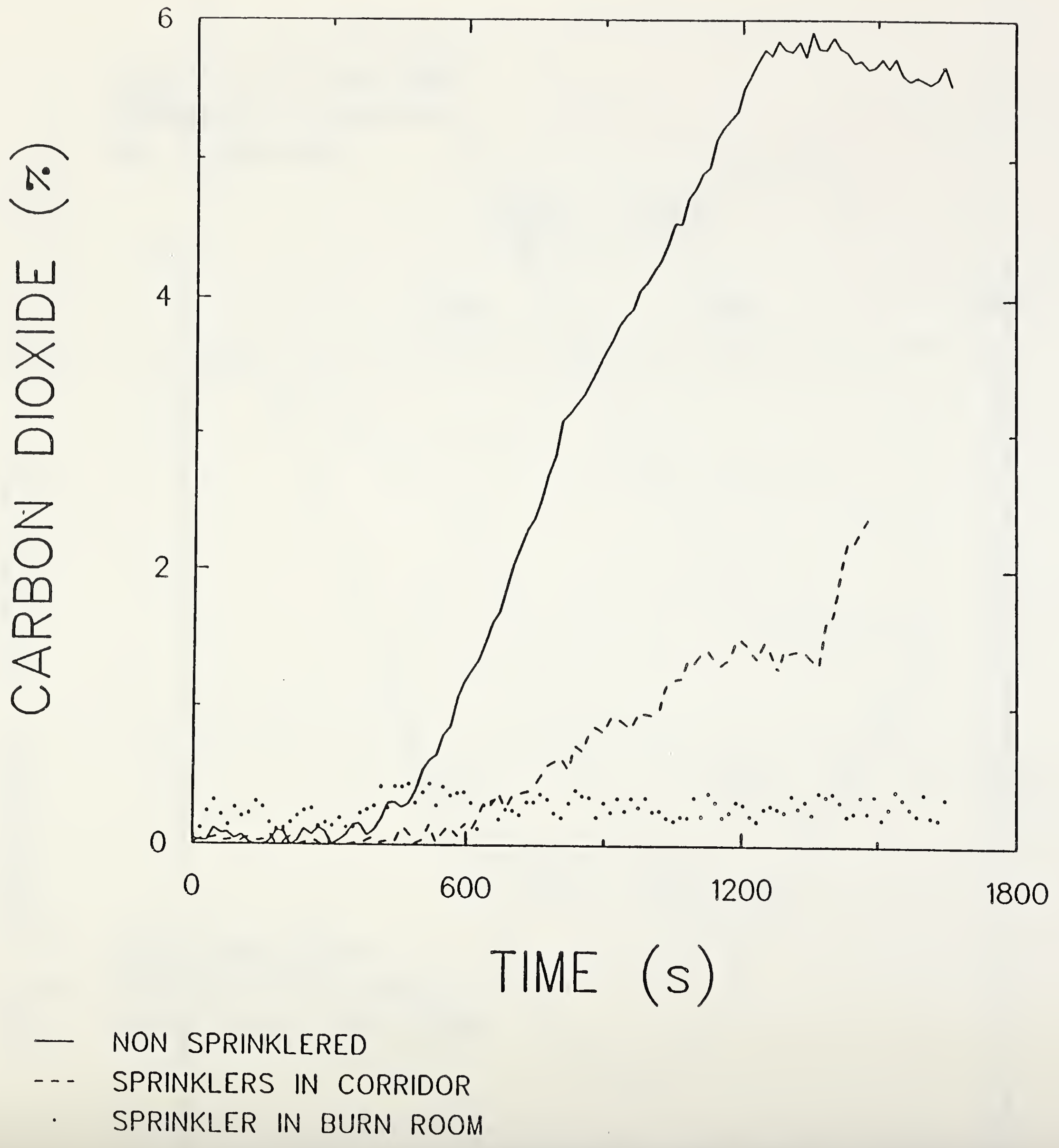

Figure 25. Carbon Dioxide Comparison - Target Room

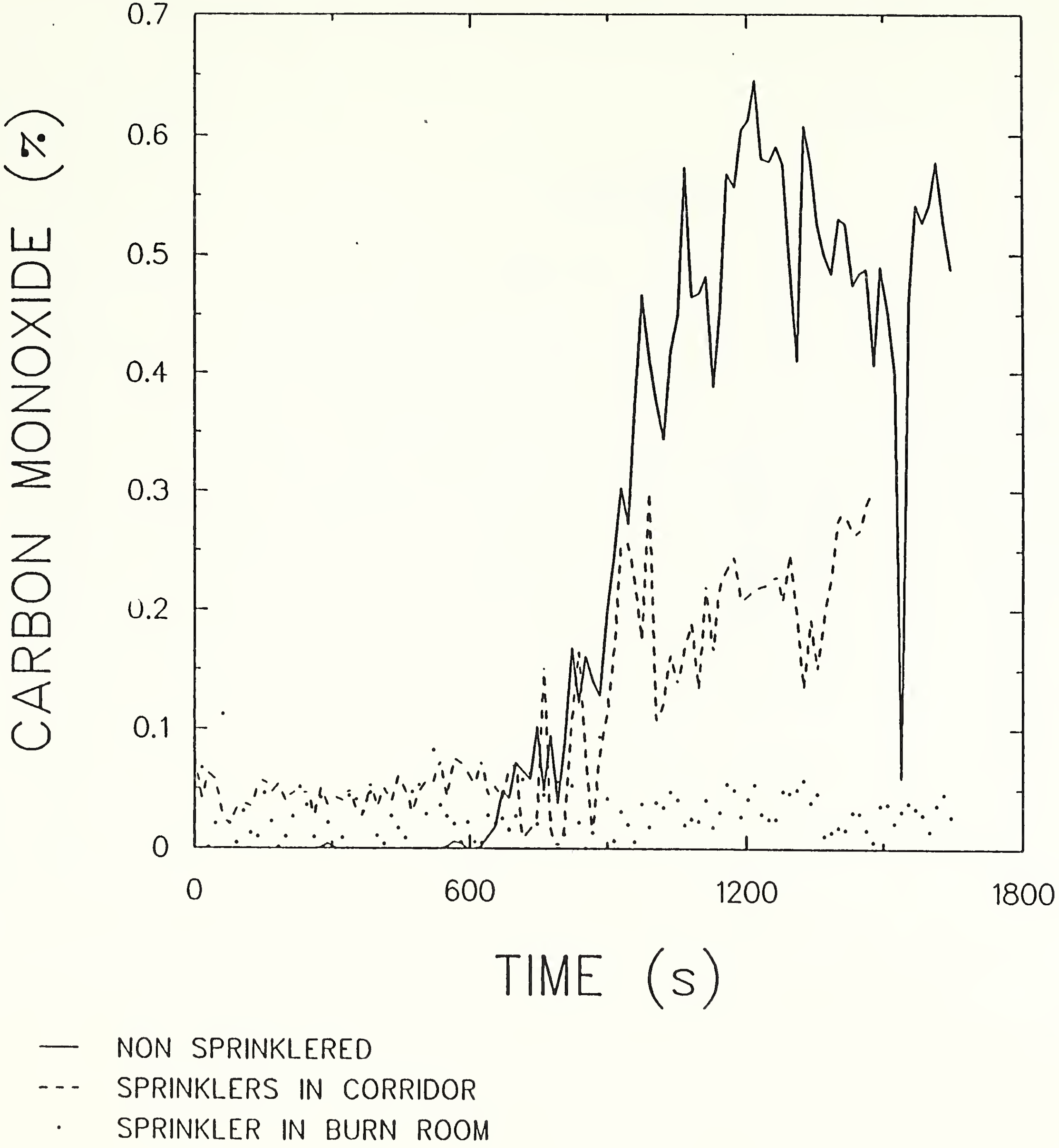

Figure 26. Carbon Monoxide Comparison - Target Room

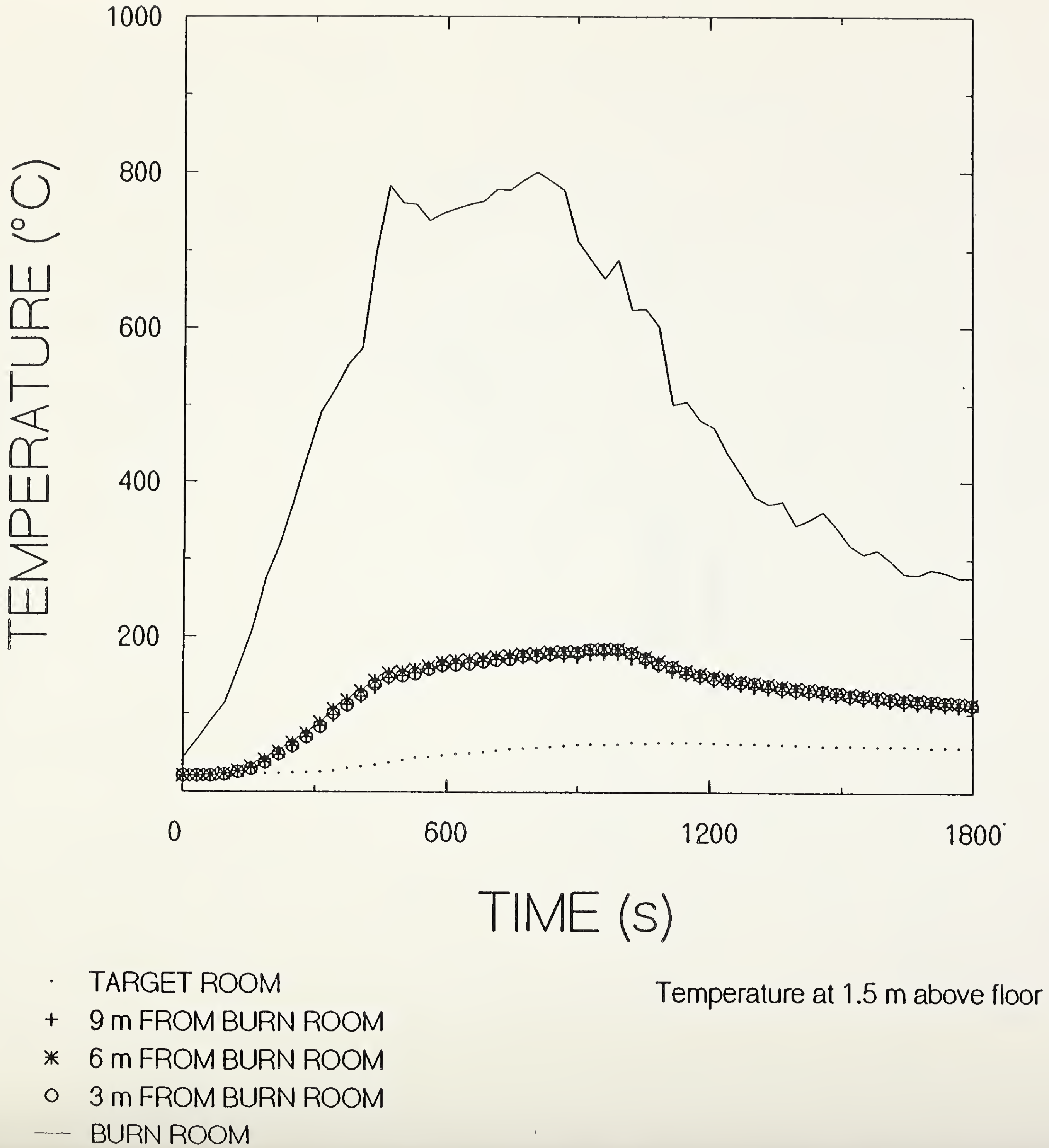

Figure A-1. Temperatures in Burn Room, Corridor, & Target Room - Test 1

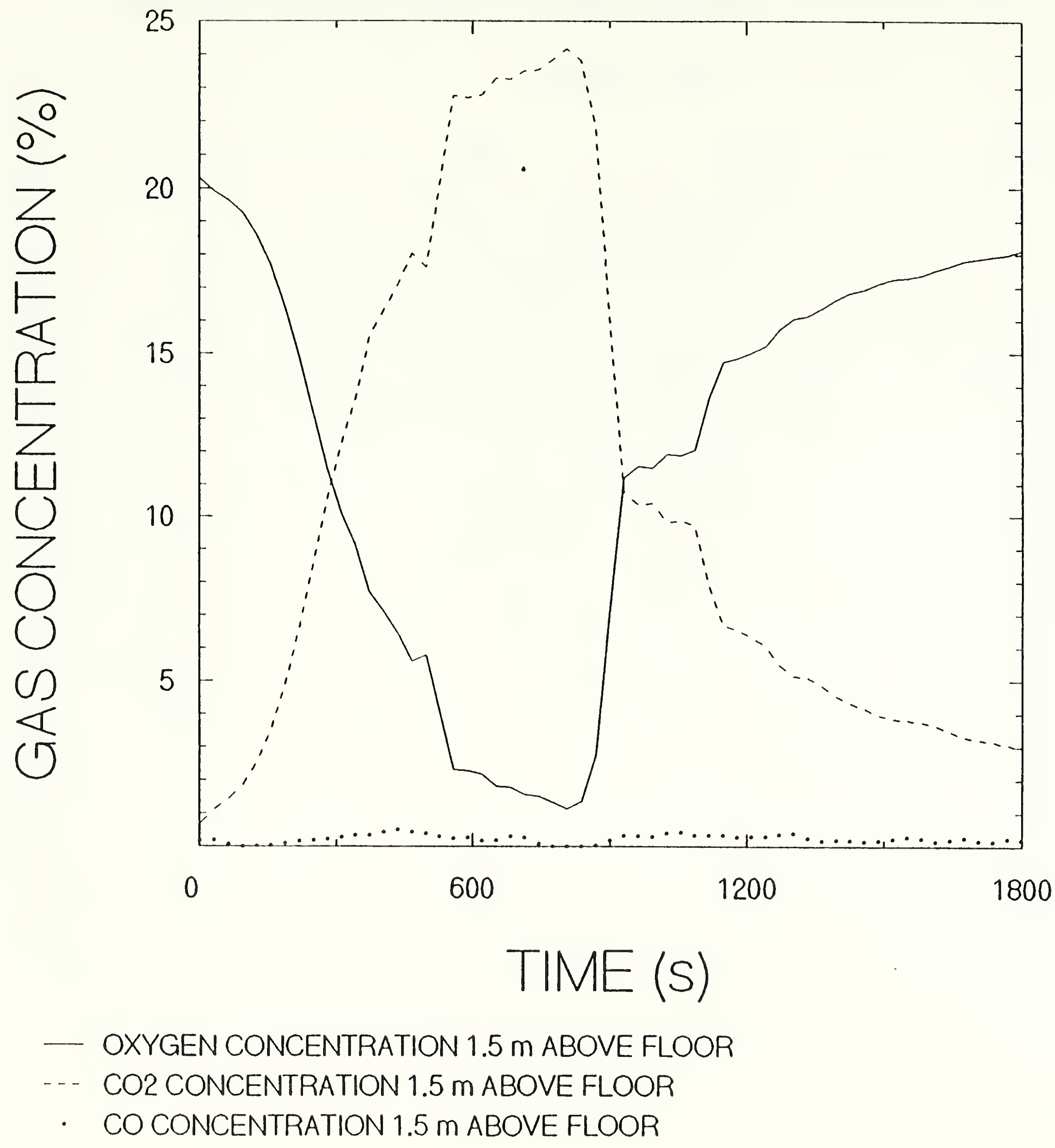

Figure A-2. Burn Room Gas Concentrations - Test 1

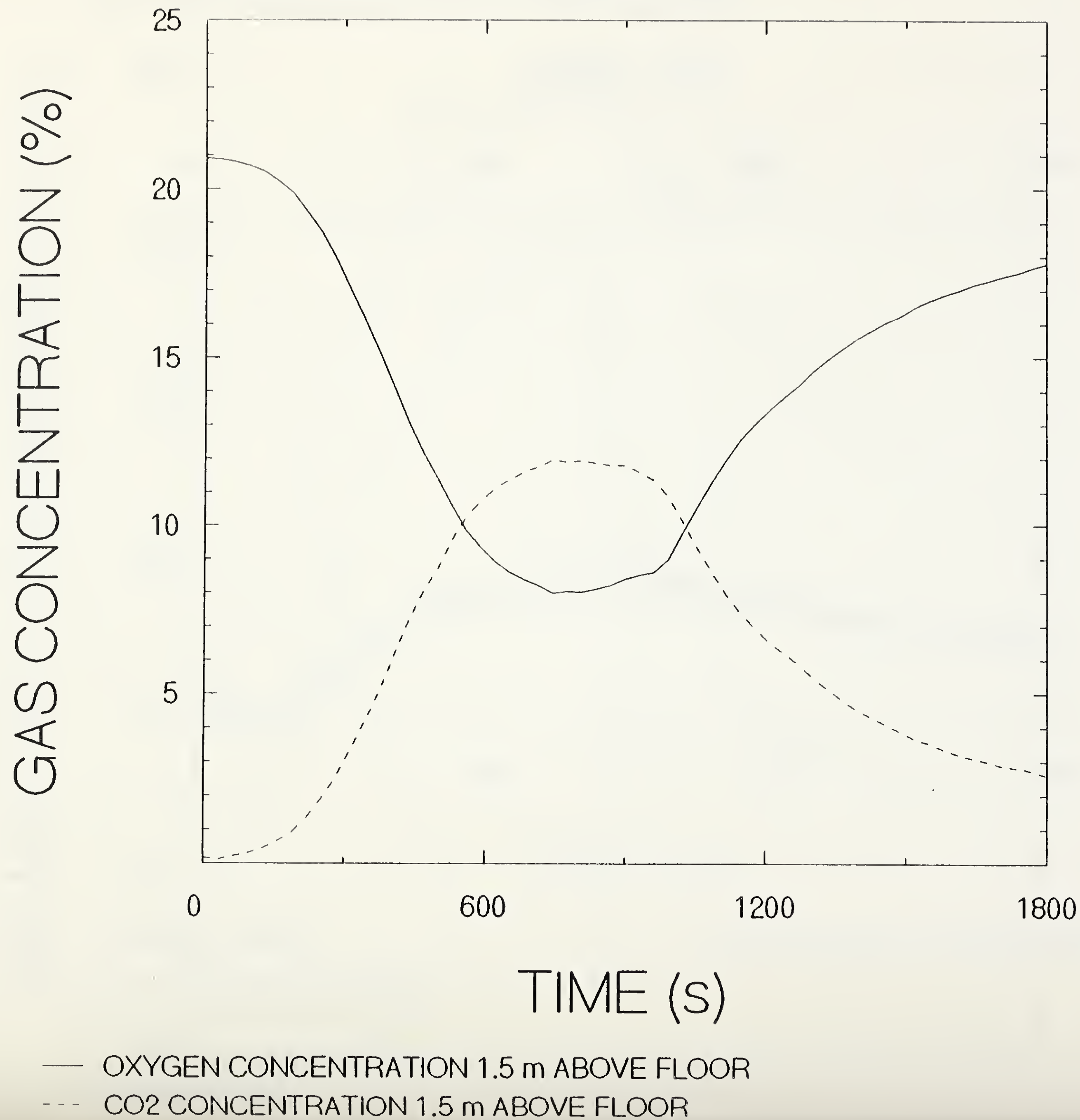

Figure A-3. Corridor Gas Concentrations - Test 1

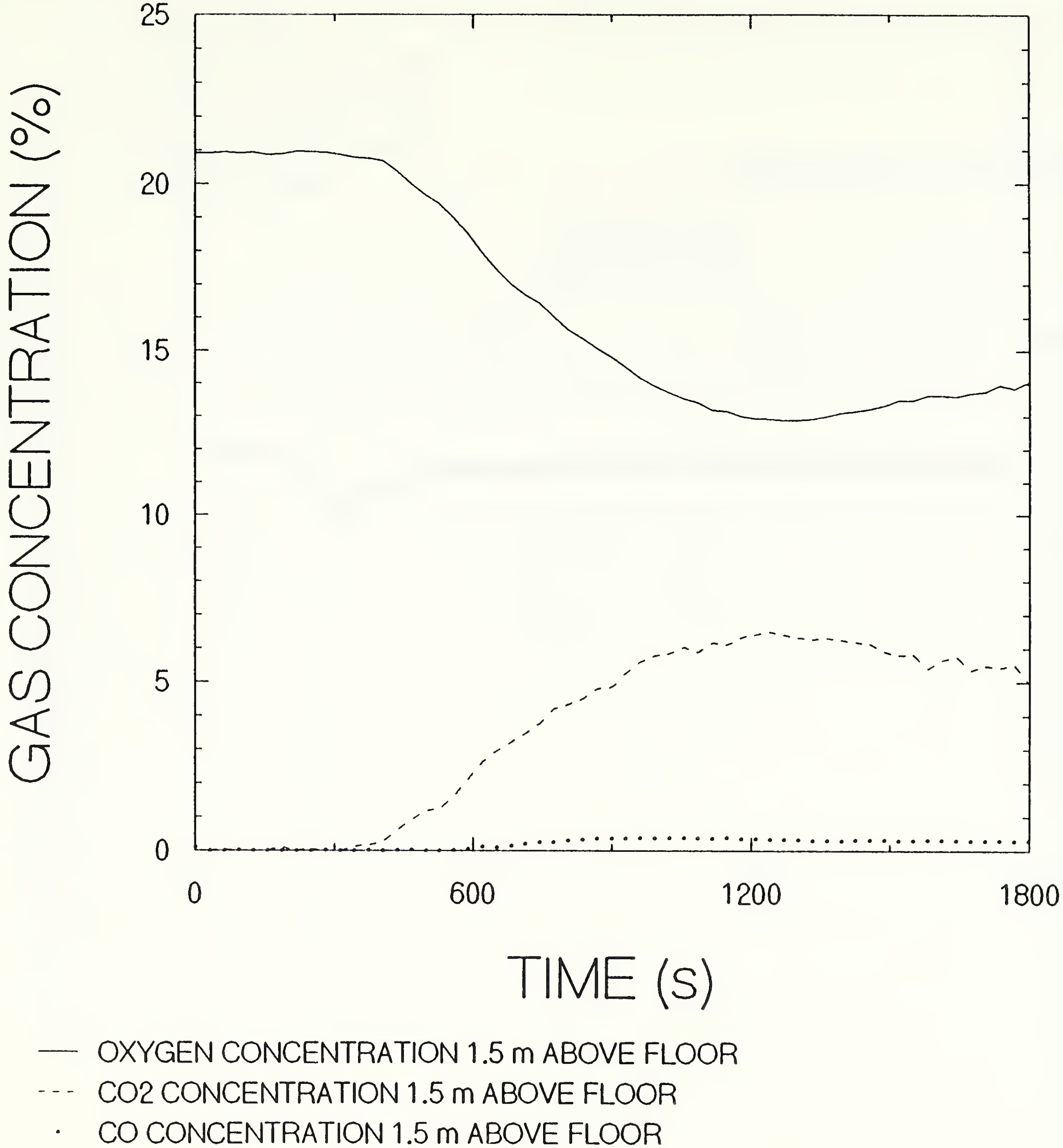

Figure A-4. Target Room Gas Concentrations - Test 1

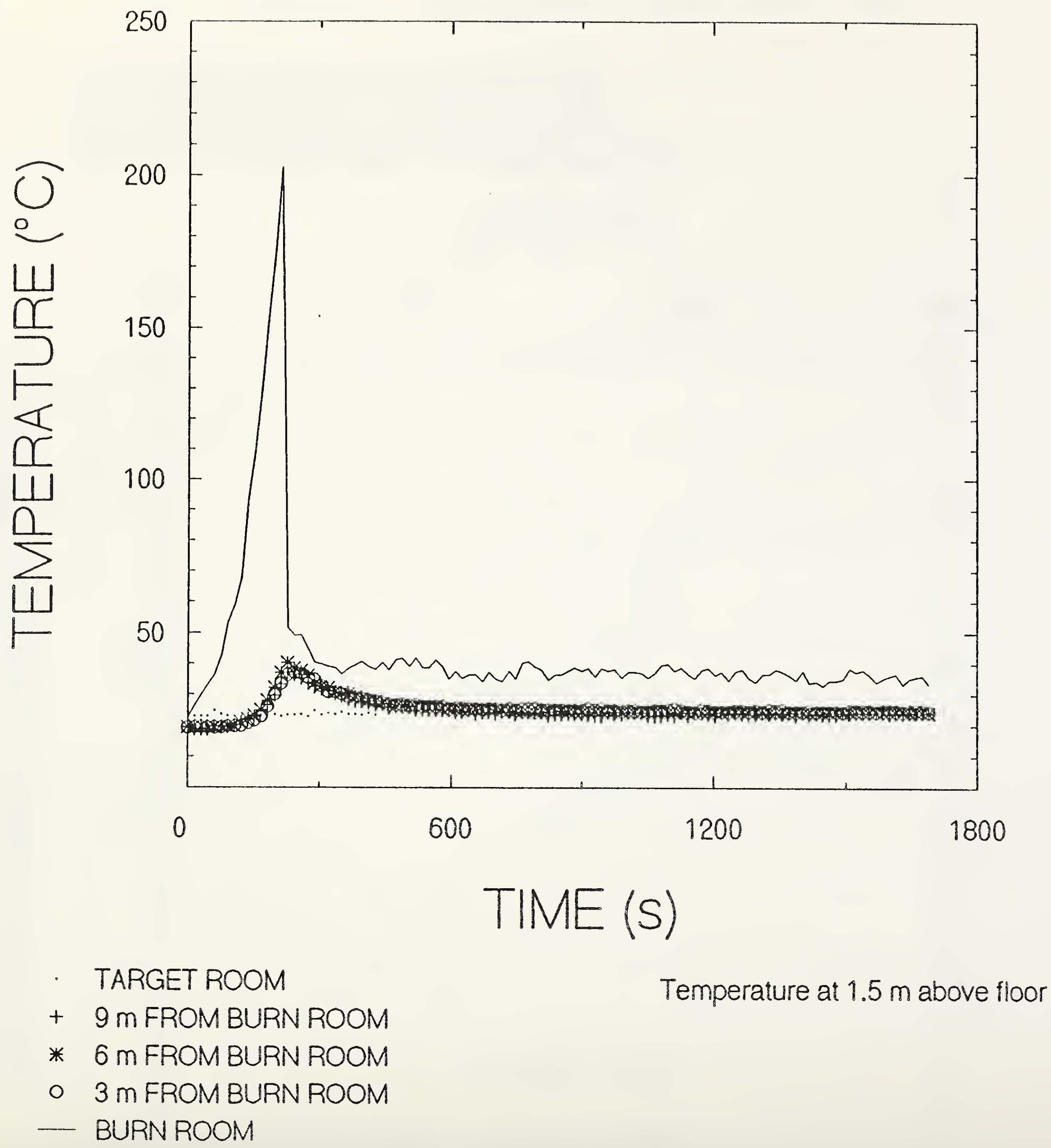

Figure A-5. Temperatures in Burn Room, Corridor, & Target Room - Test 2

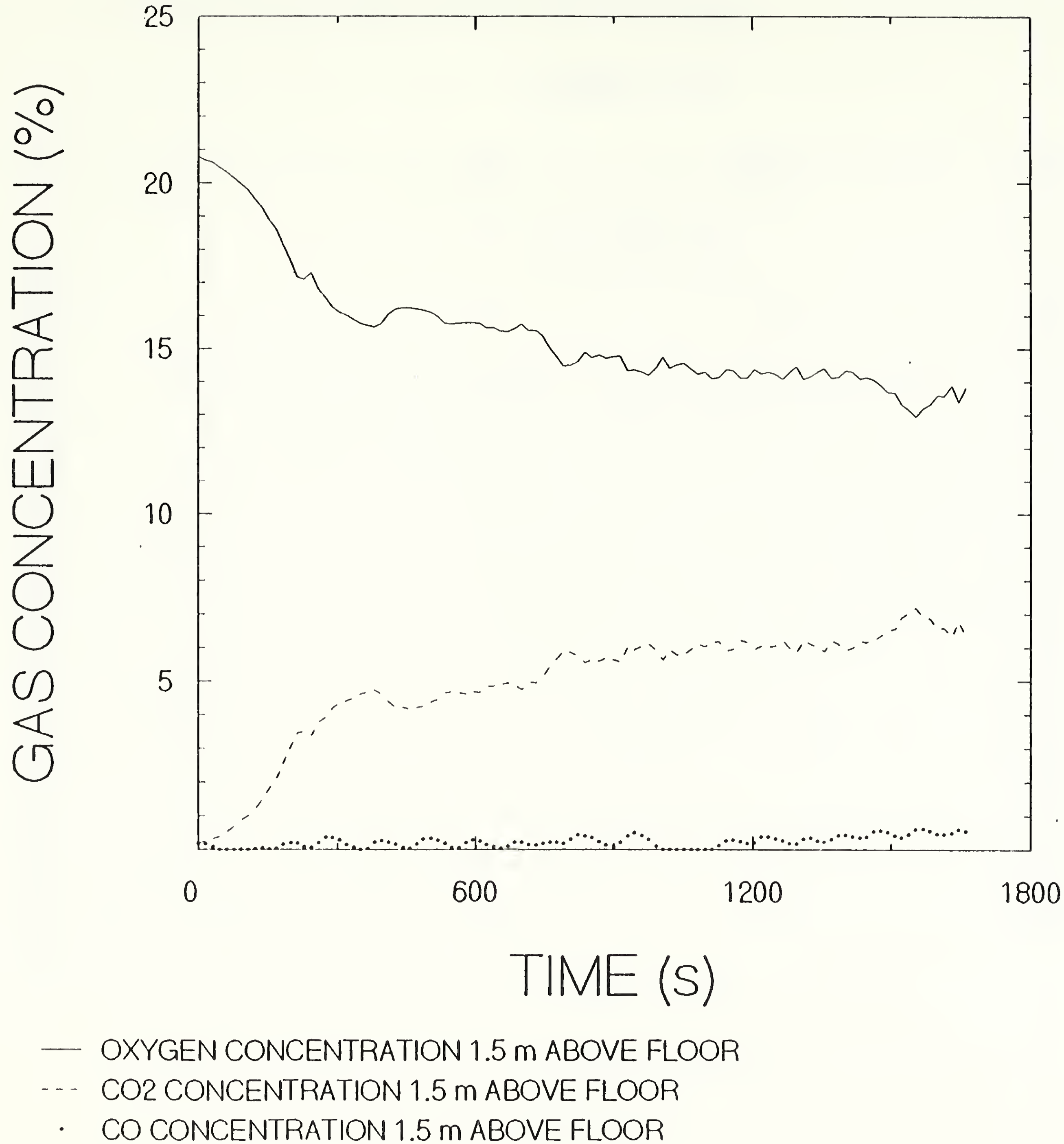

Figure A-6. Burn Room Gas Concentrations - Test 2

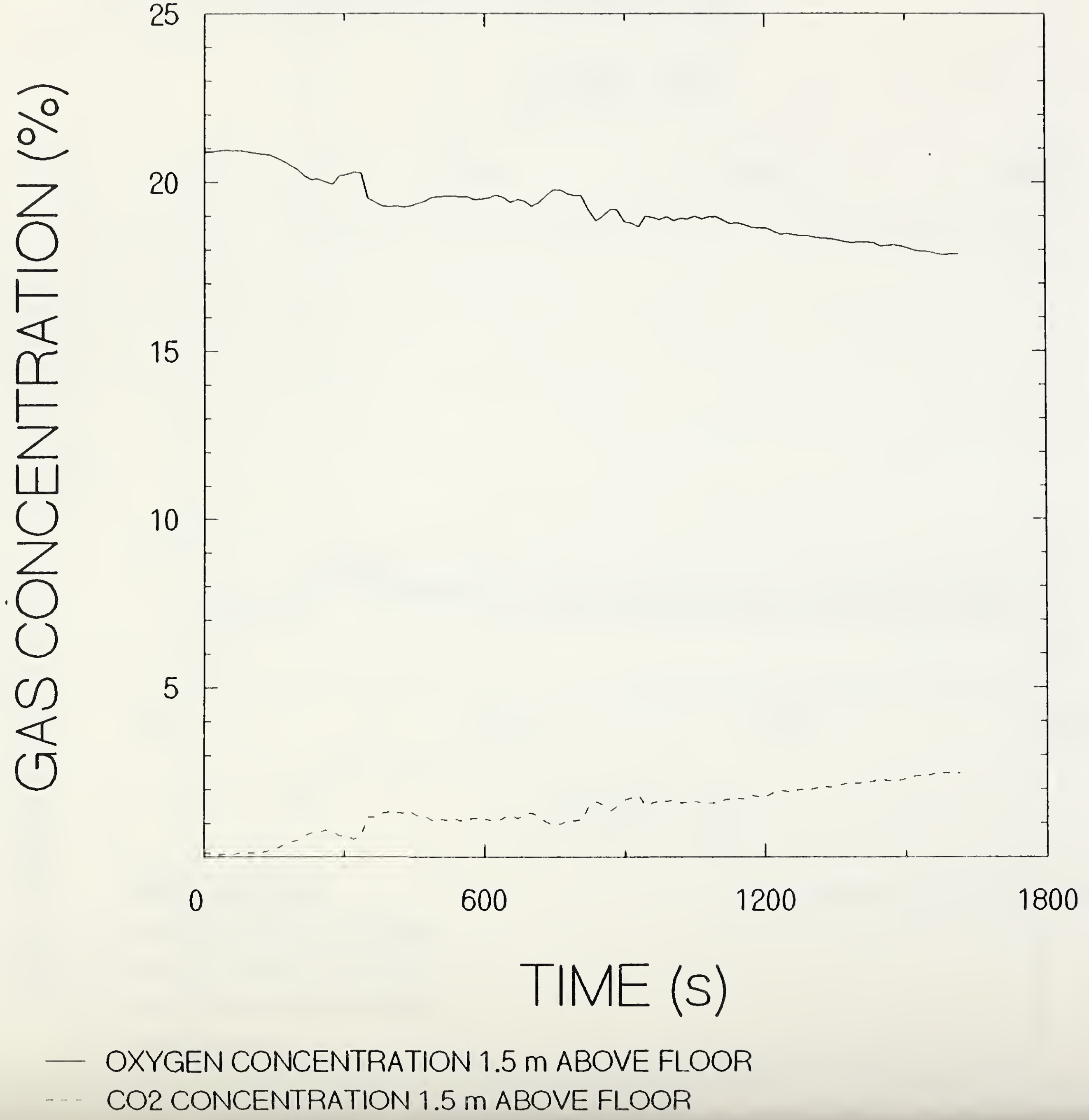

Figure A-7. Corridor Gas Concentrations - Test 2

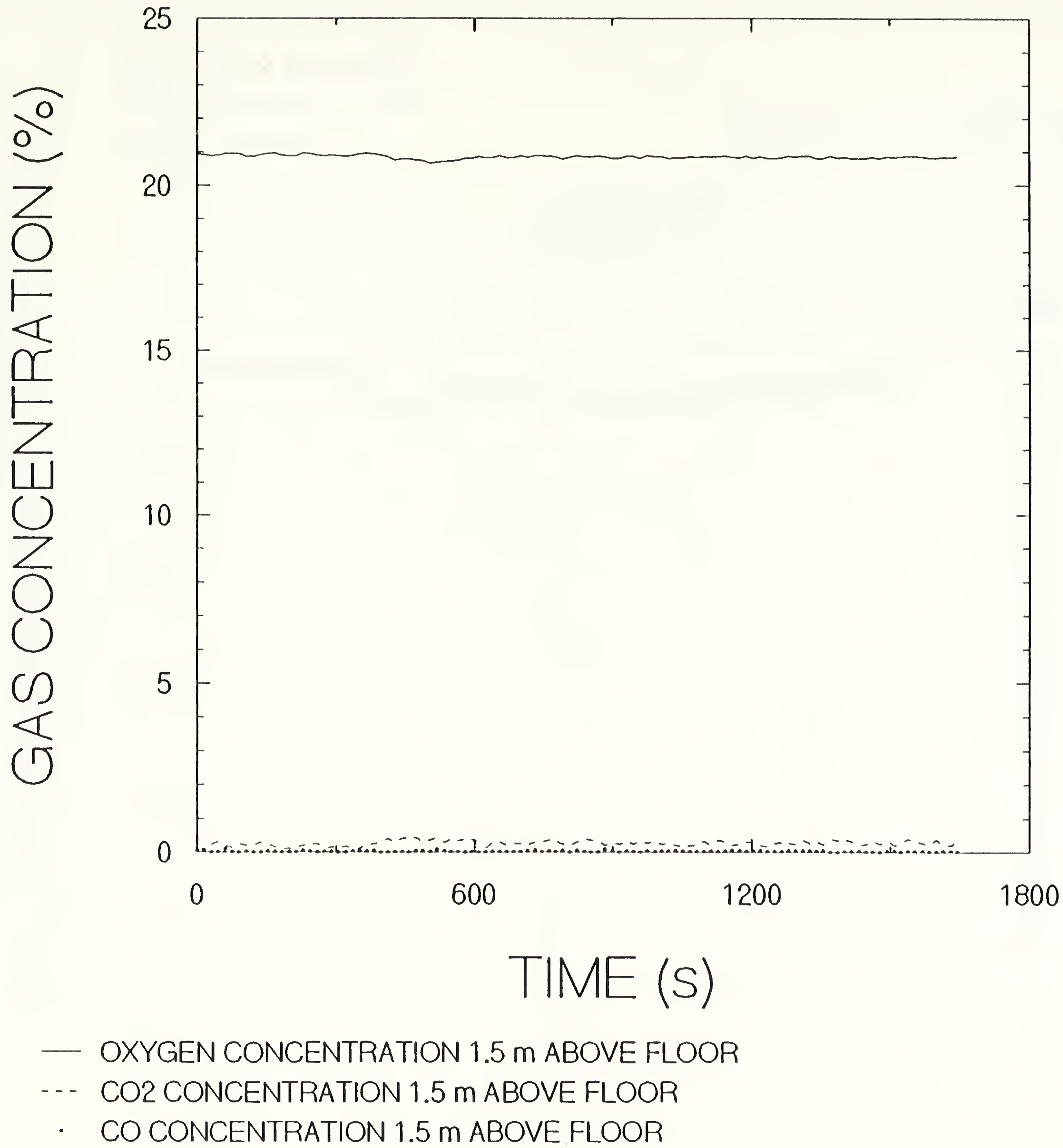

Figure A-8. Target Room Gas Concentrations - Test 2

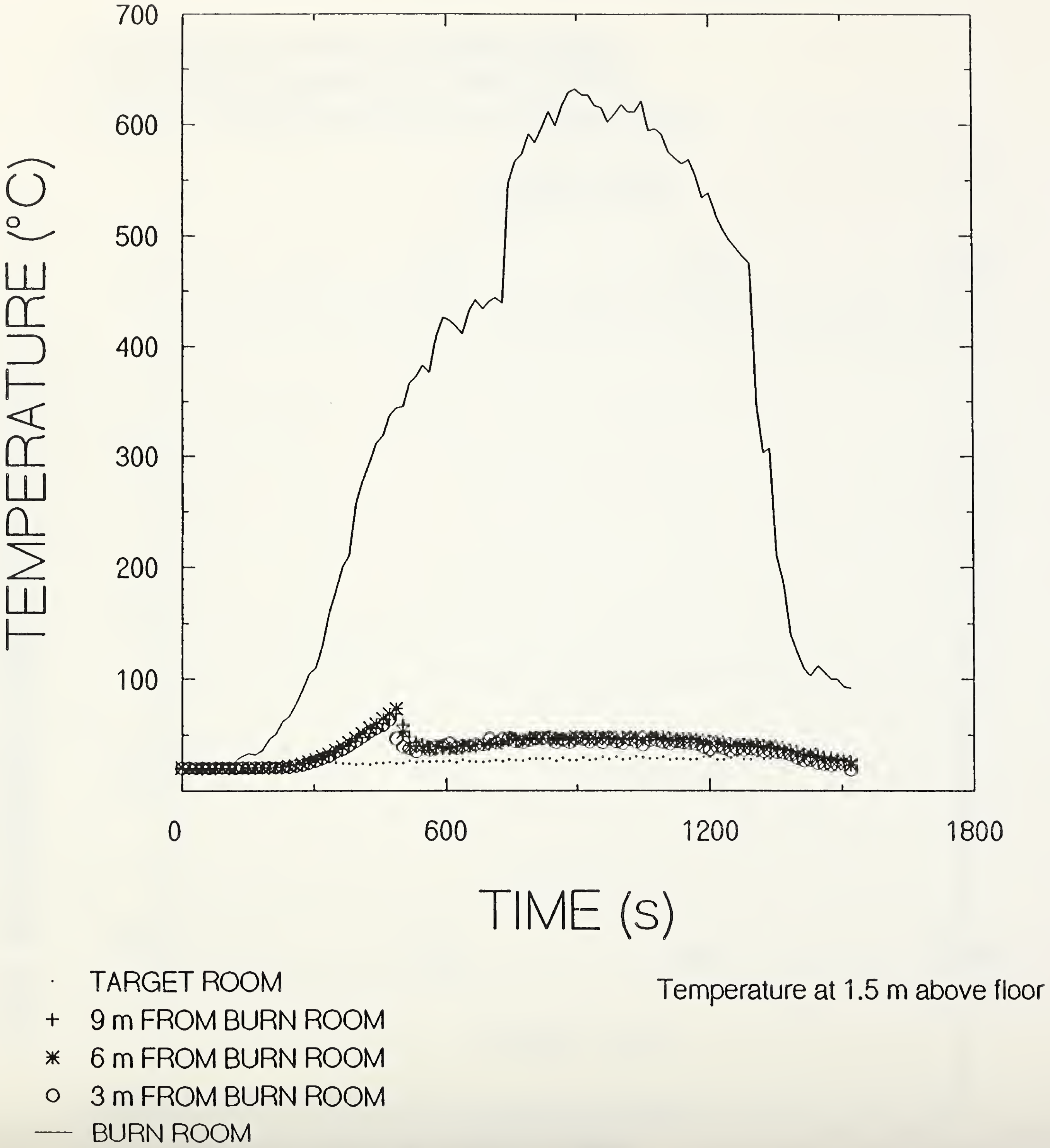

Figure A-9. Temperatures in Burn Room, Corridor, & Target Room - Test 3

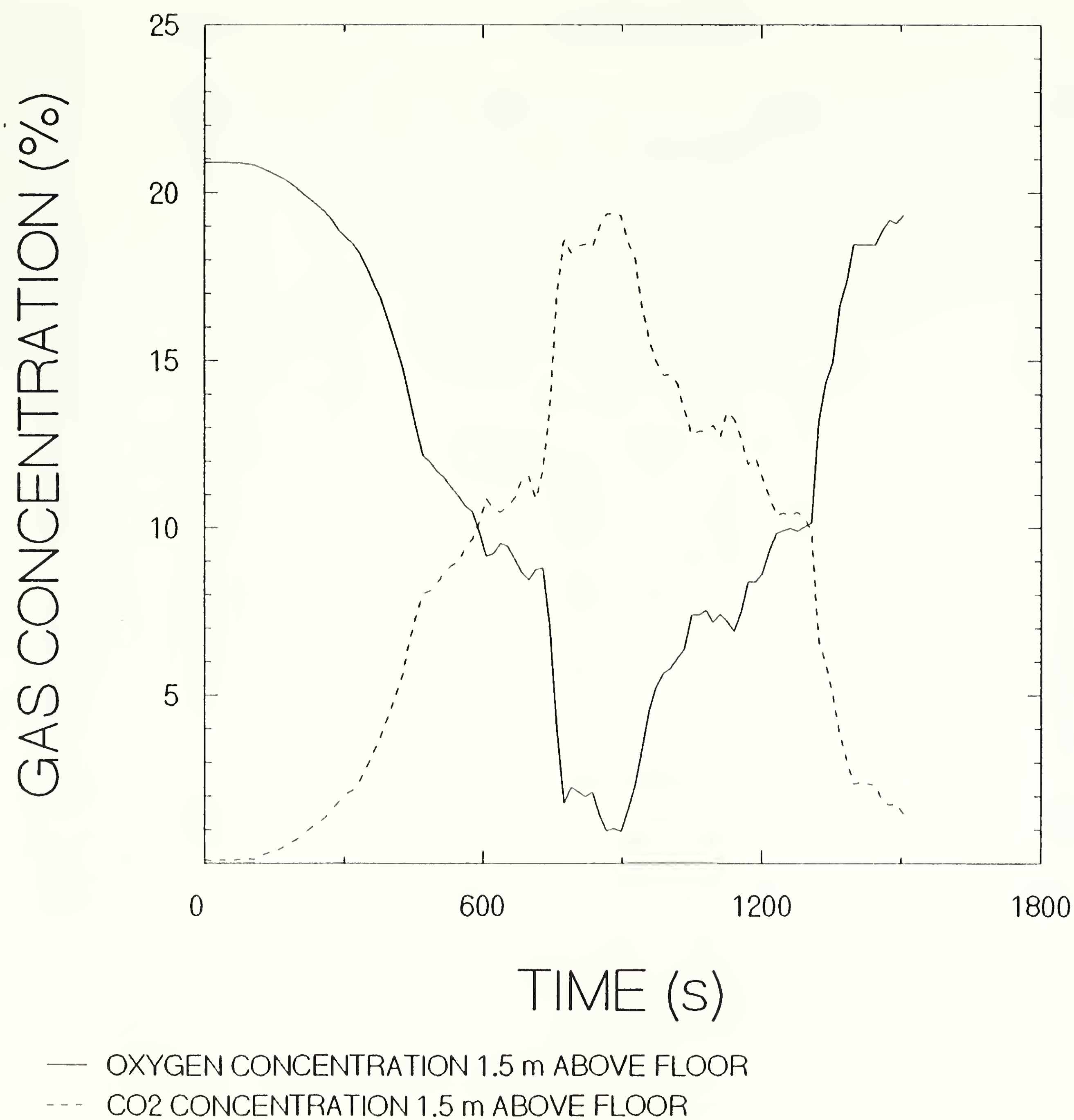

Figure A-10. Burn Room Gas Concentrations - Test 3

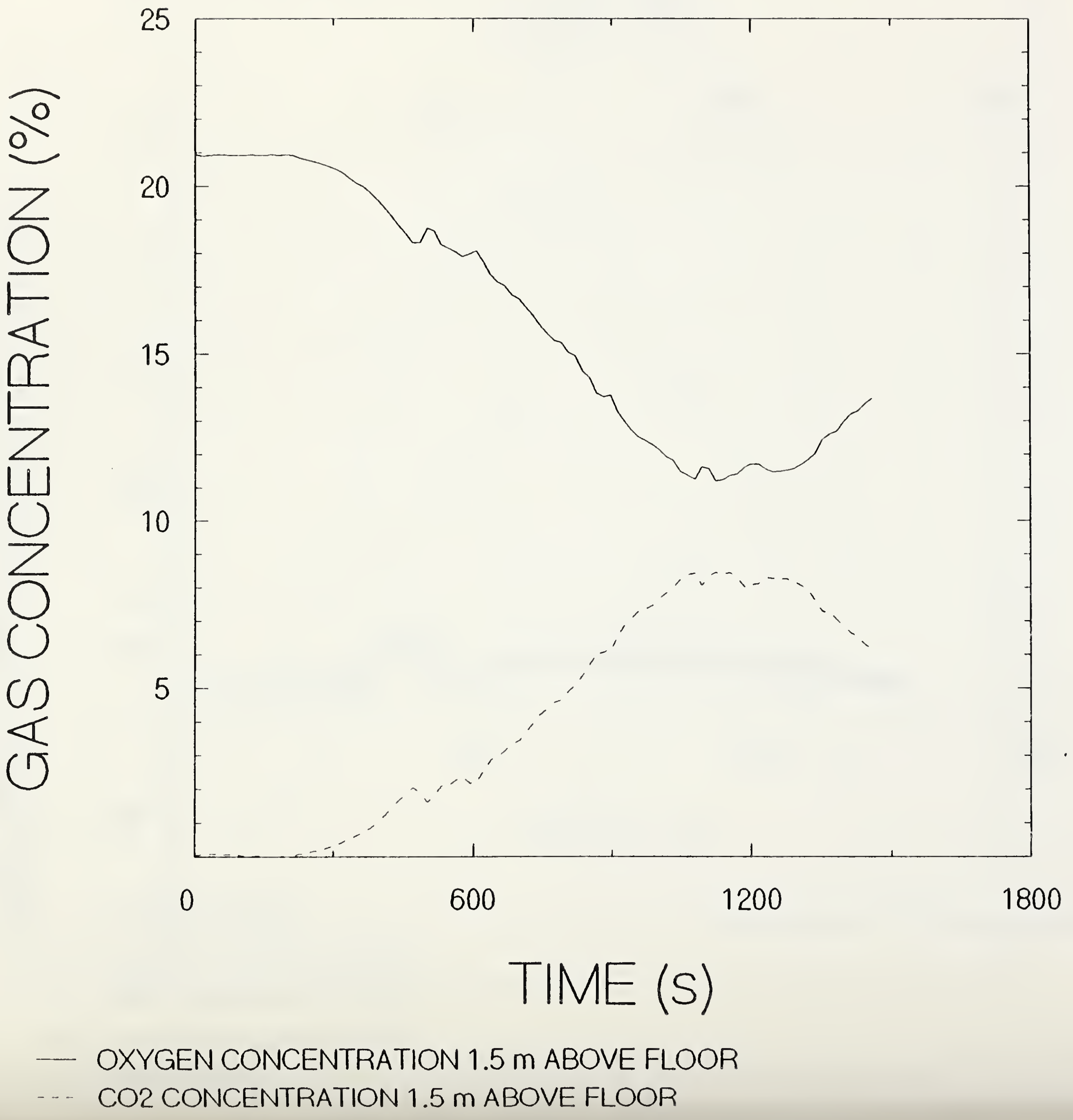

Figure A-11. Corridor Gas Concentrations - Test 3

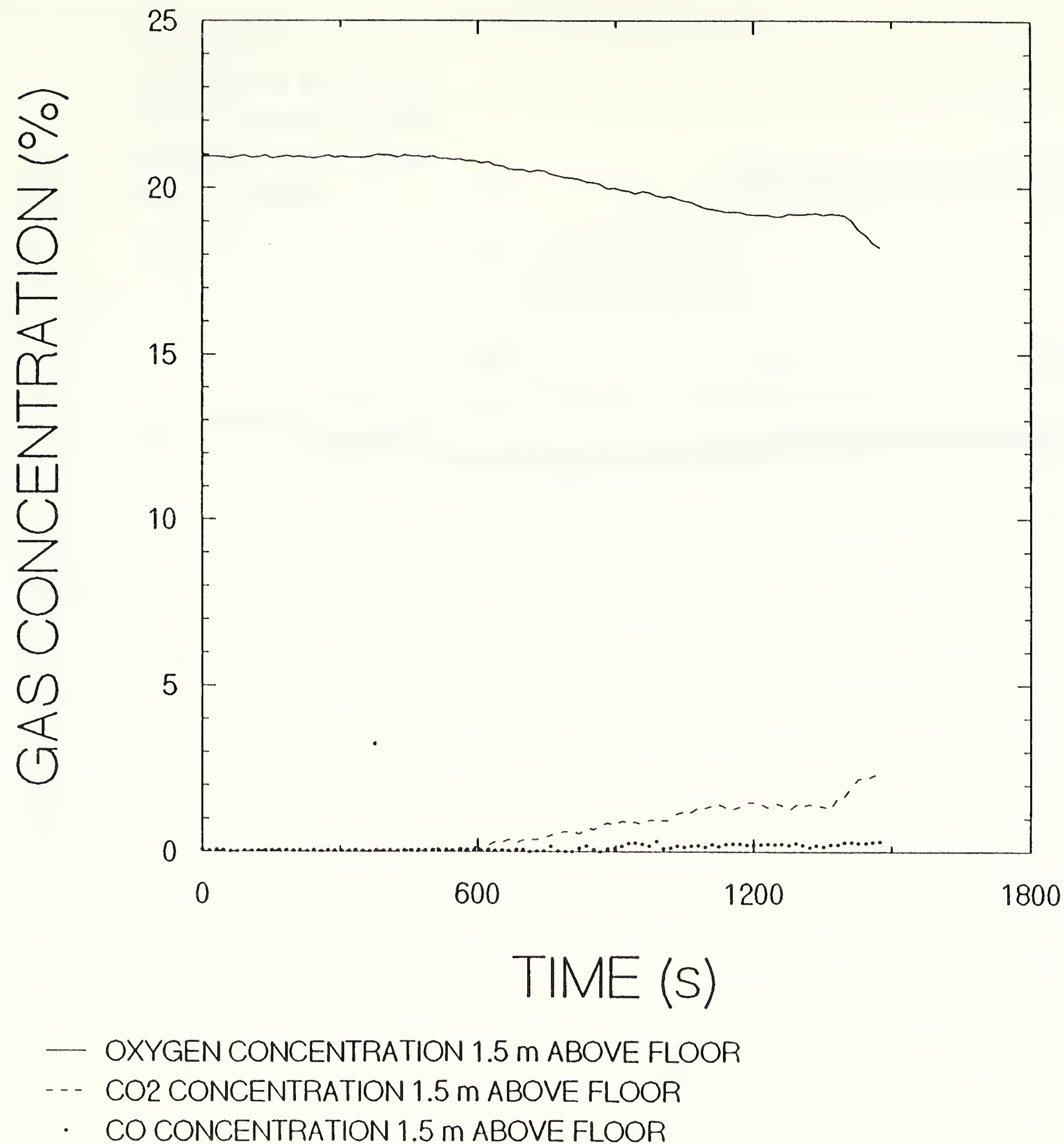

Figure A-12. Target Room Gas Concentrations - Test 3

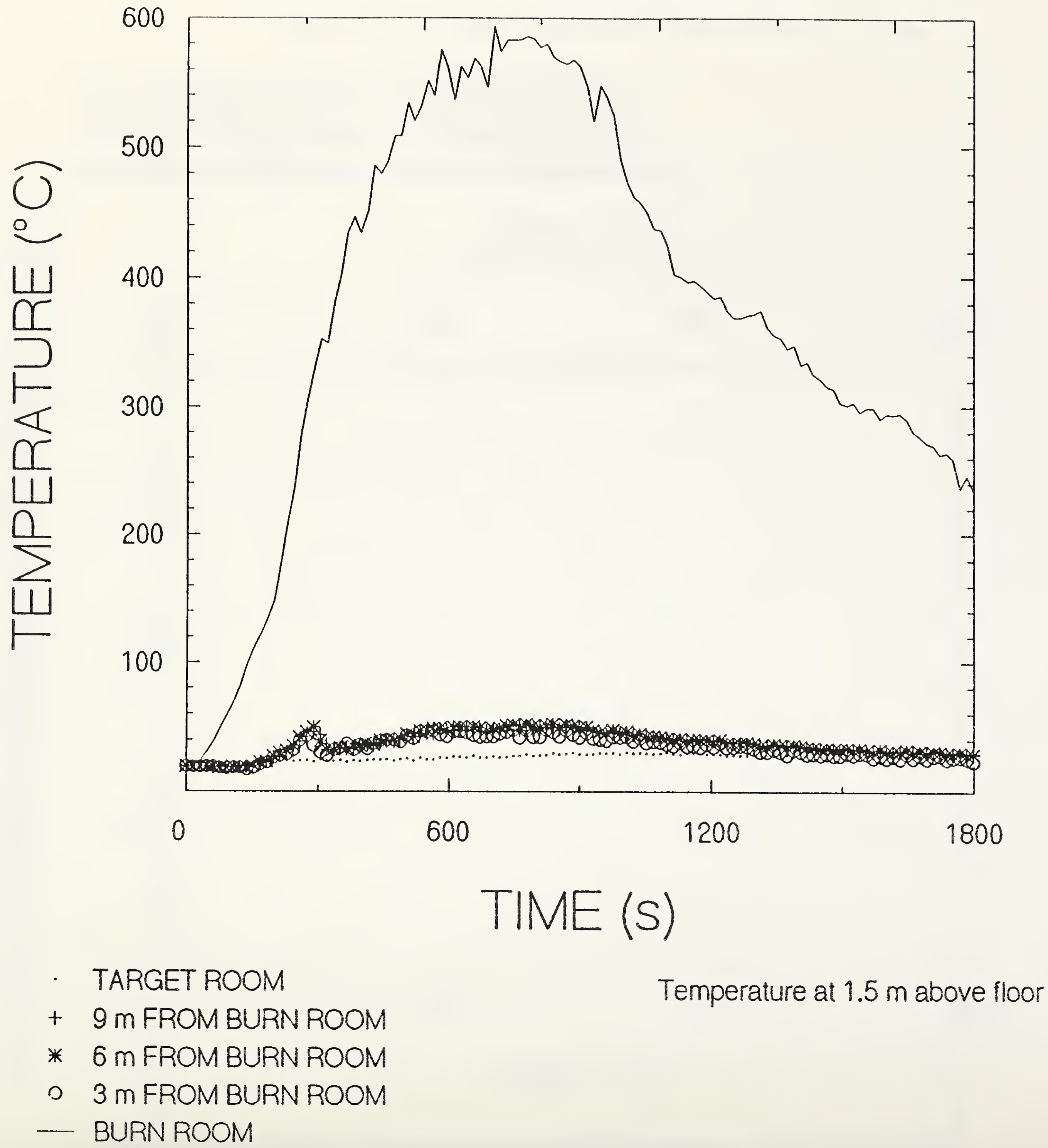

Figure A-13. Temperatures in Burn Room, Corridor, & Target Room - Test 4

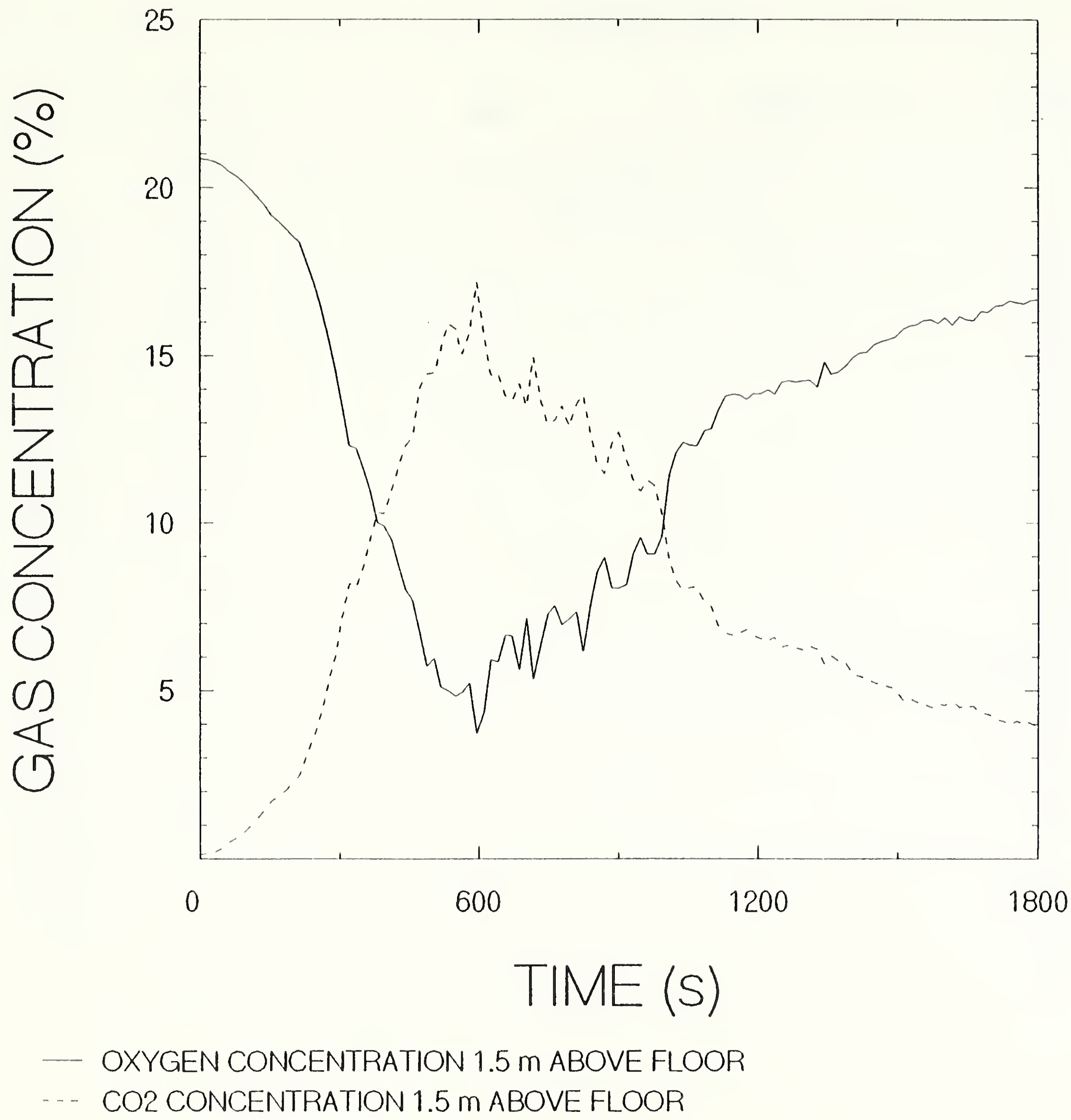

Figure A-14. Burn Room Gas Concentrations - Test 4

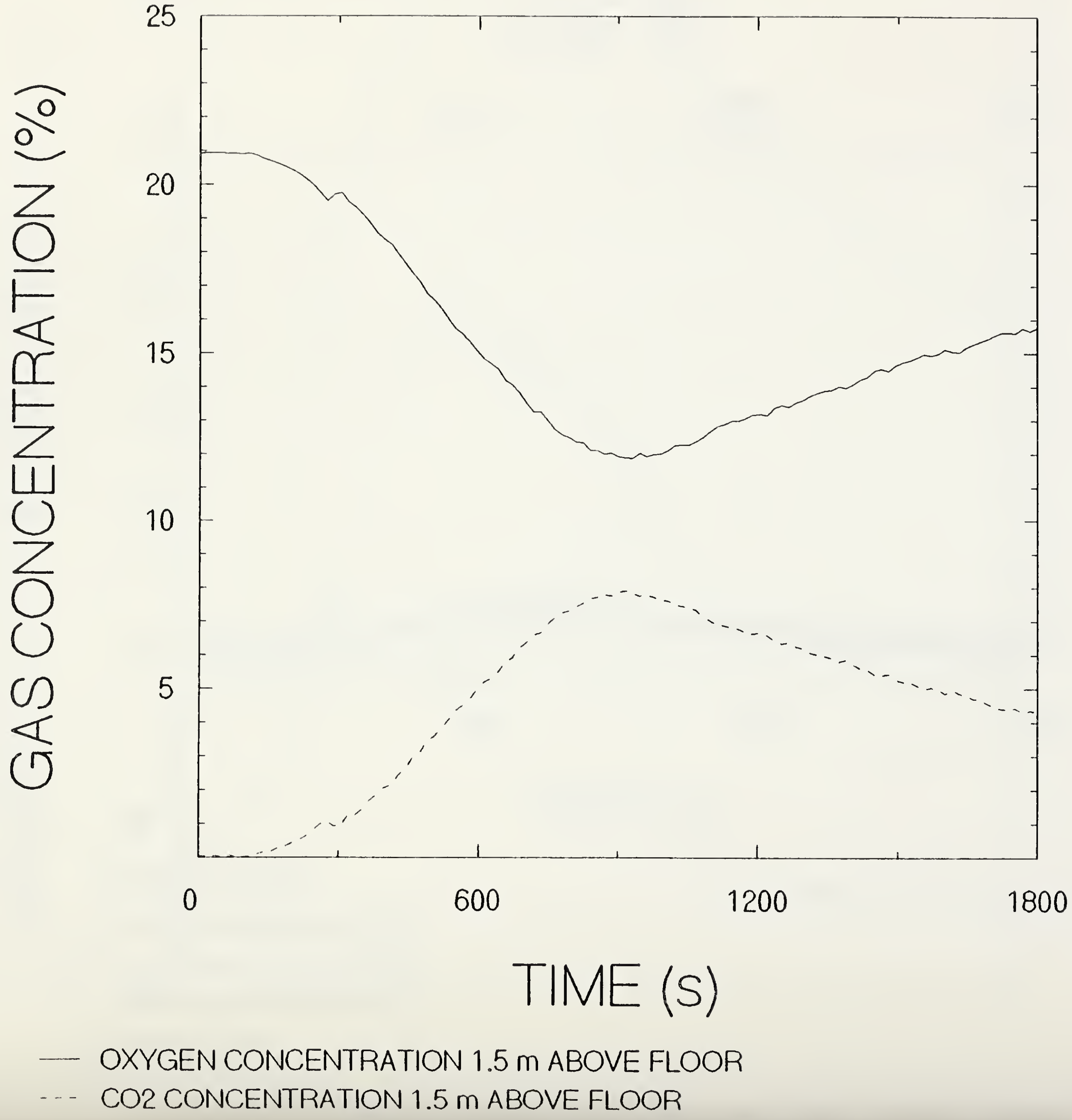

Figure A-15. Corridor Gas Concentrations - Test 4

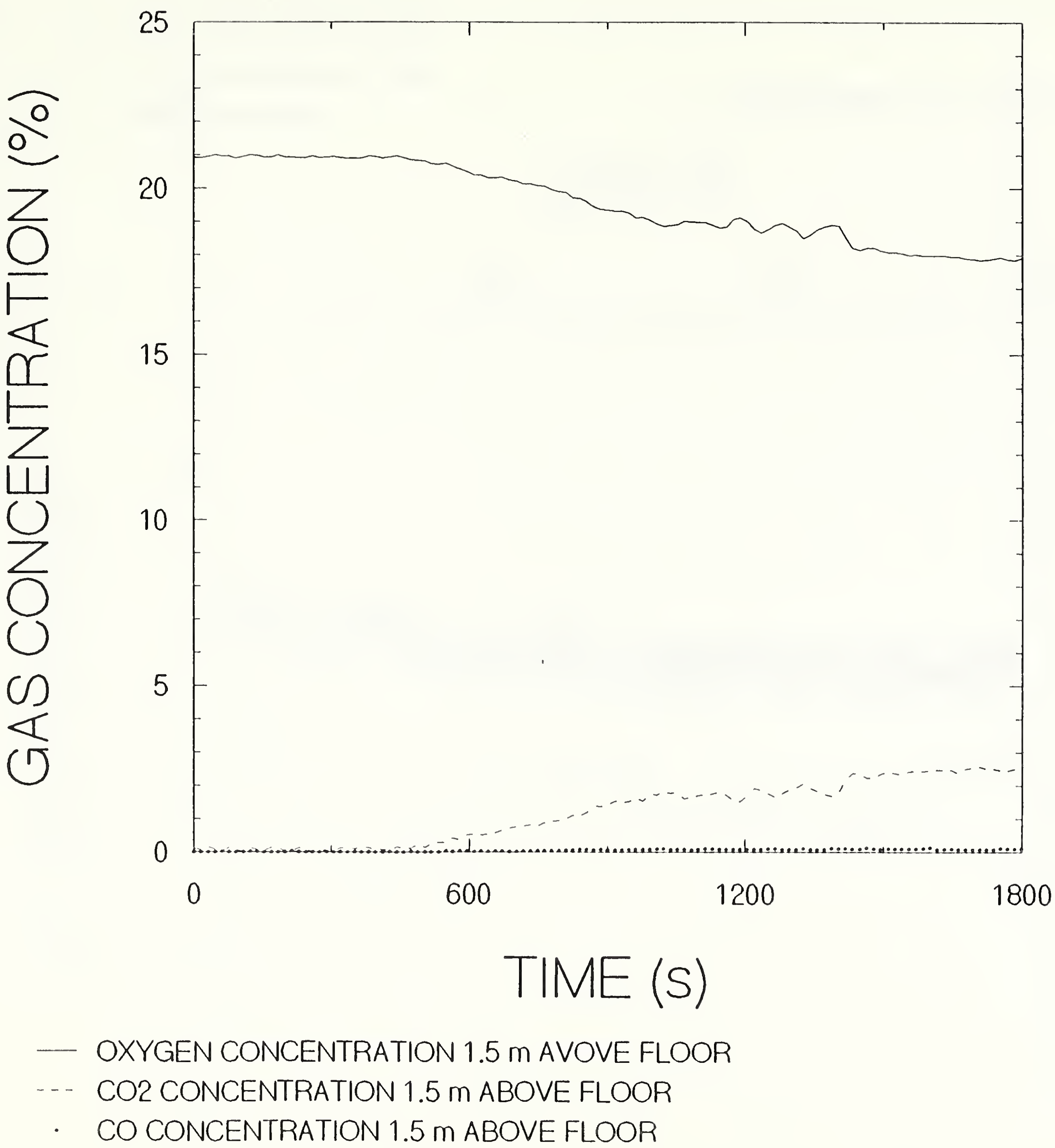

Figure A-16. Target Room Gas Concentrations - Test 4

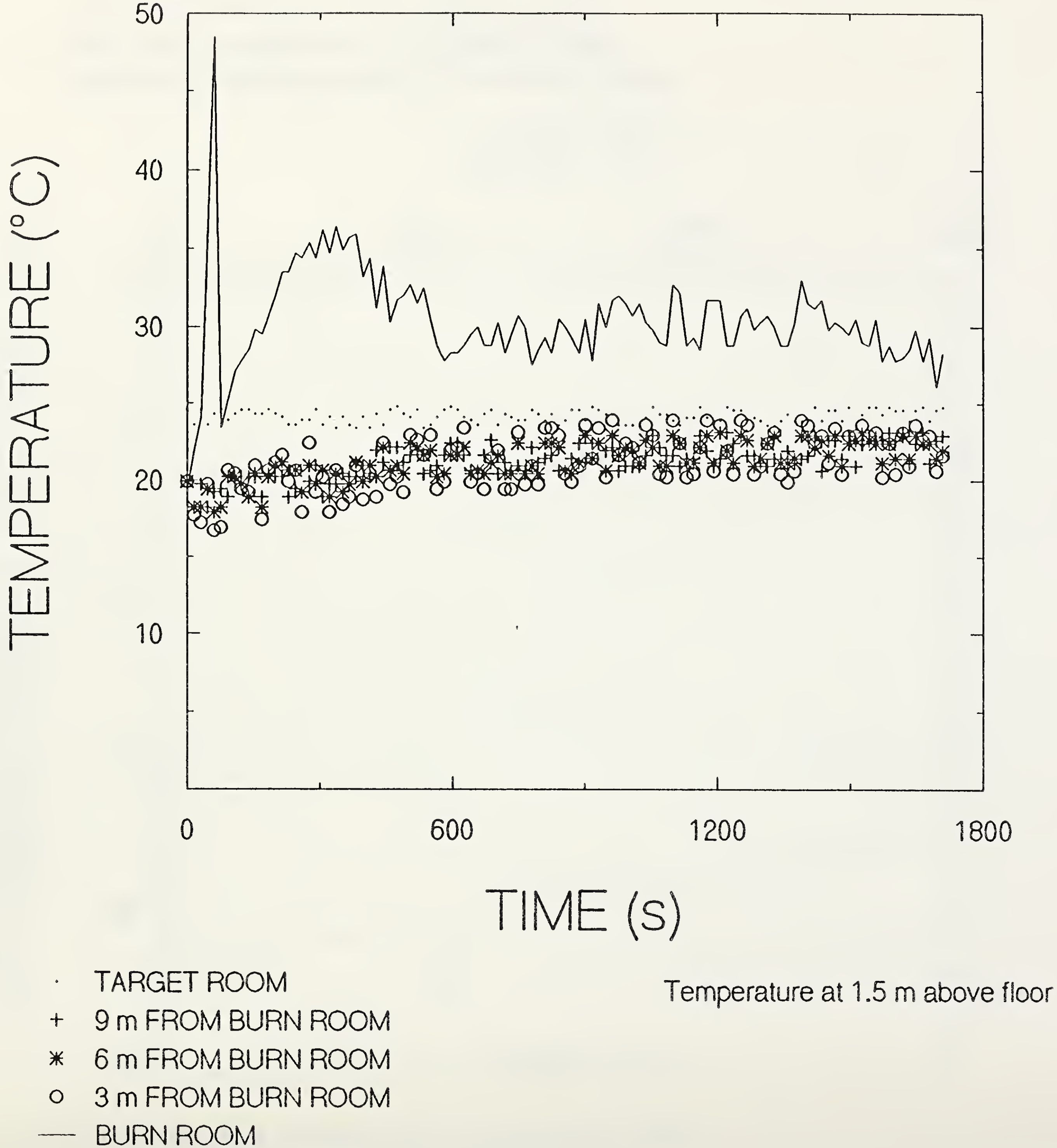

Figure A-17. Temperatures in Burn Room, Corridor, & Target Room - Test 5

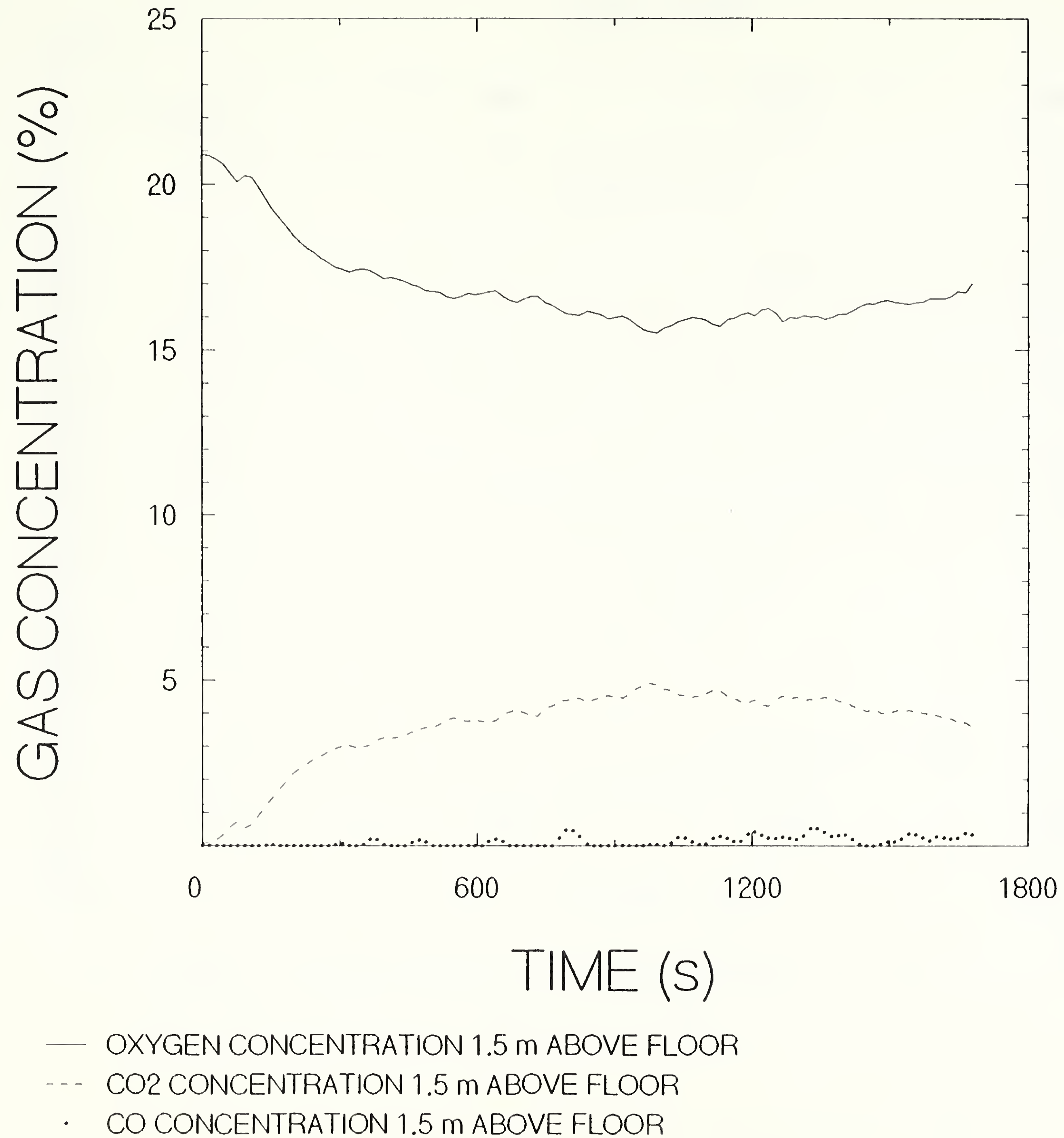

Figure A-18. Burn Room Gas Concentrations - Test 5

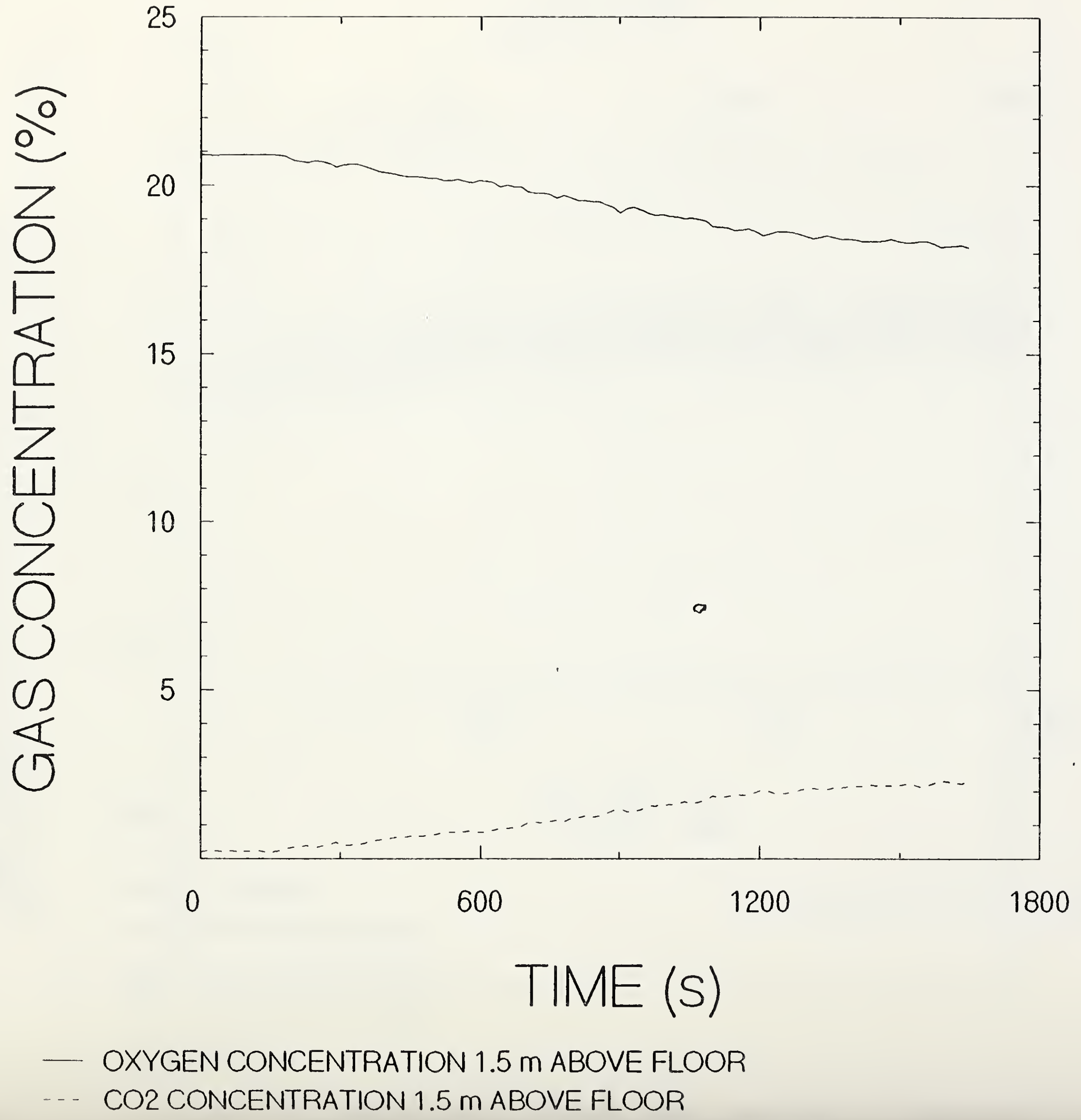

Figure A-19. Corridor Gas Concentrations - Test 5

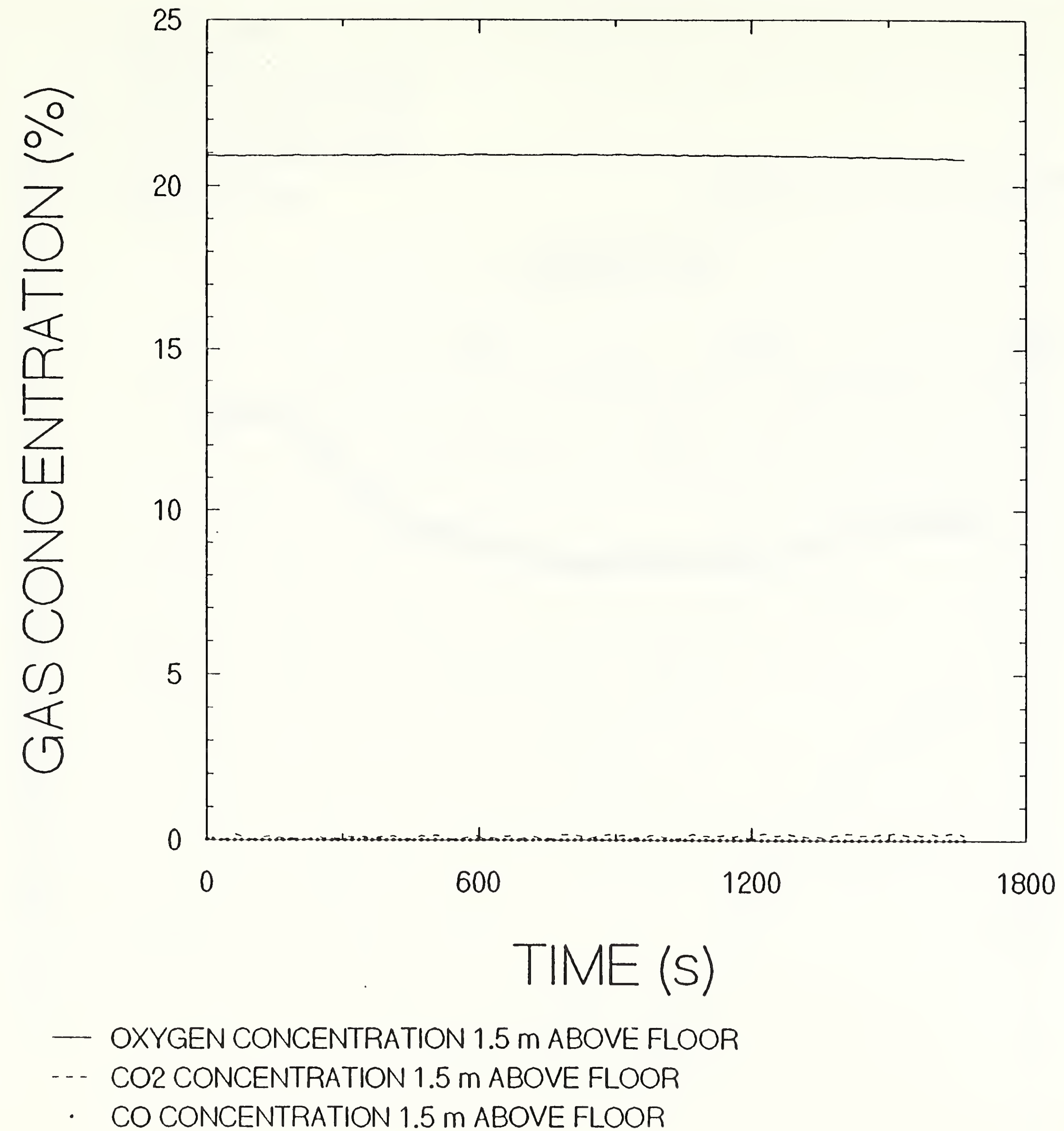

Figure A-20. Target Room Gas Concentrations - Test 5

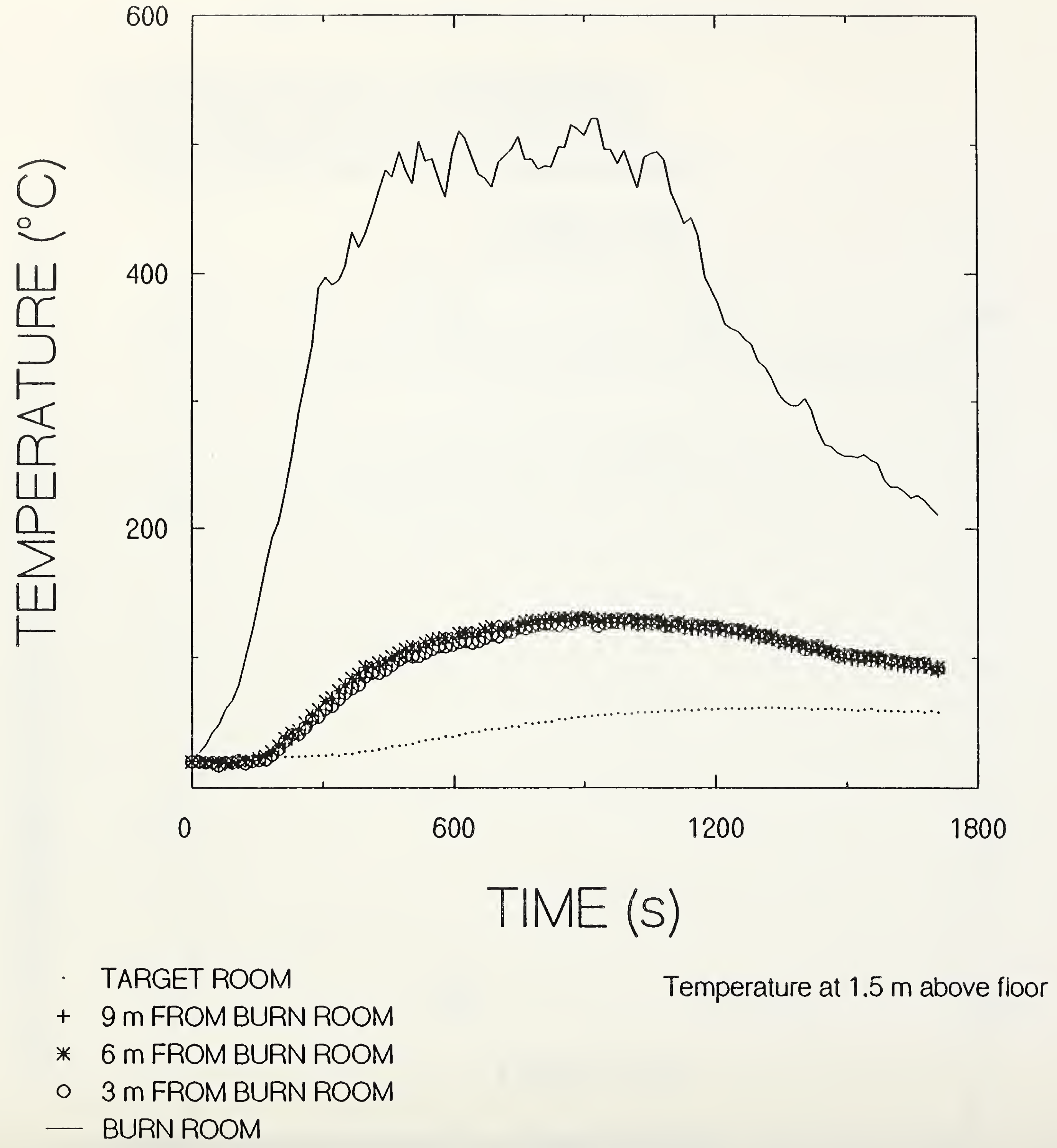

Figure A-21. Temperatures in Burn Room, Corridor, & Target Room - Test 6

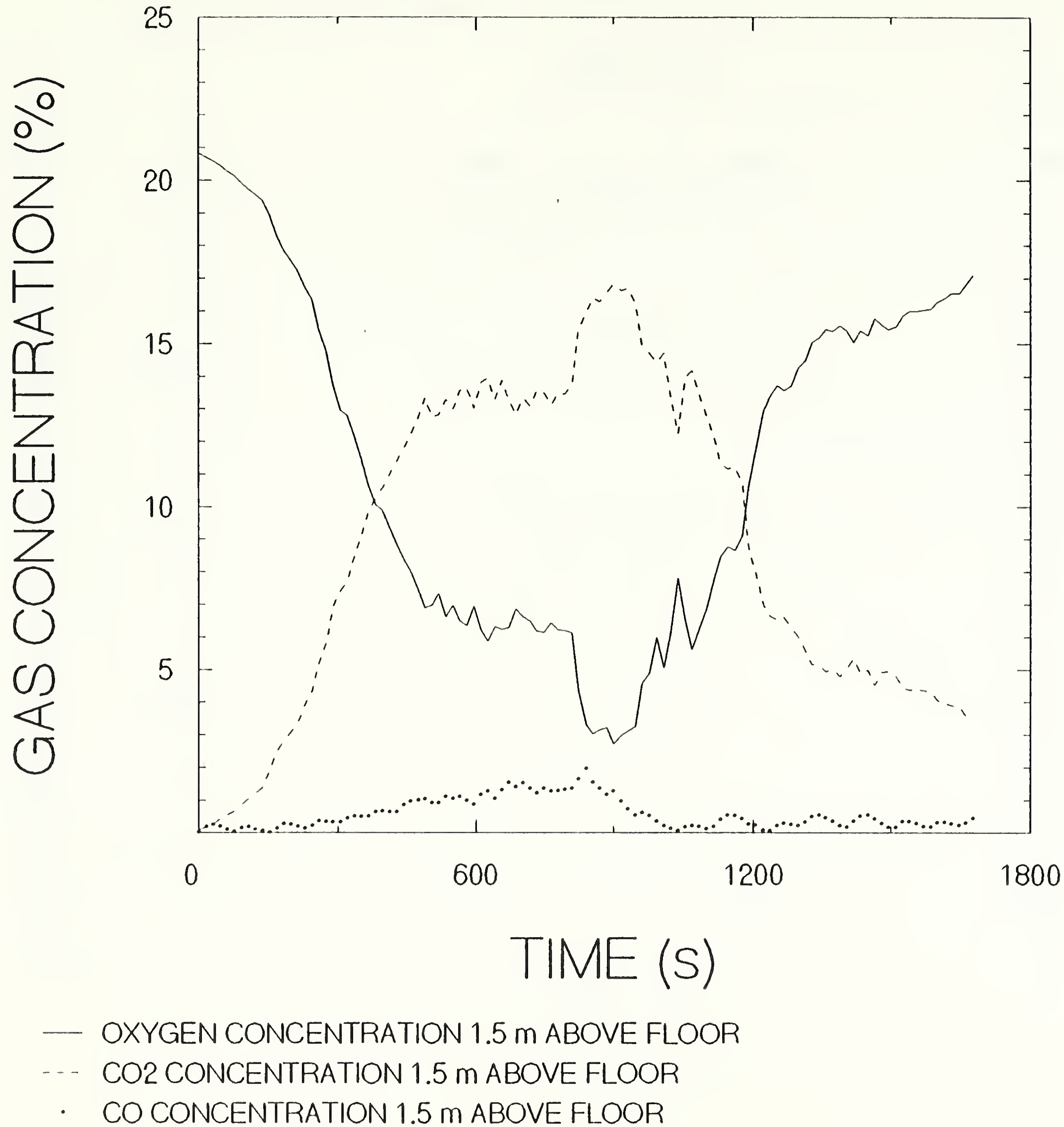

Figure A-22. Burn Room Gas Concentrations - Test 6

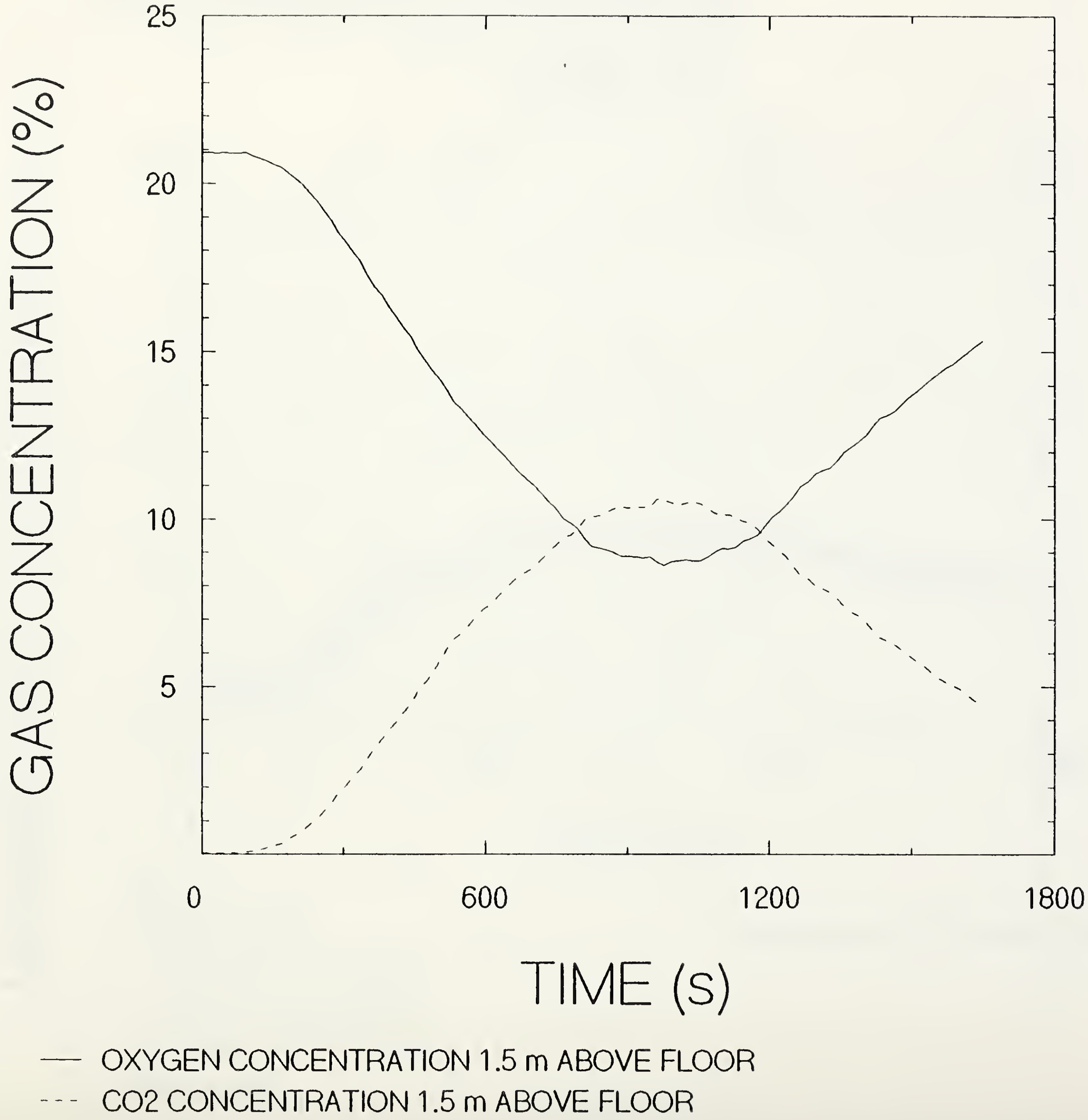

Figure A-23. Corridor Gas Concentrations - Test 6

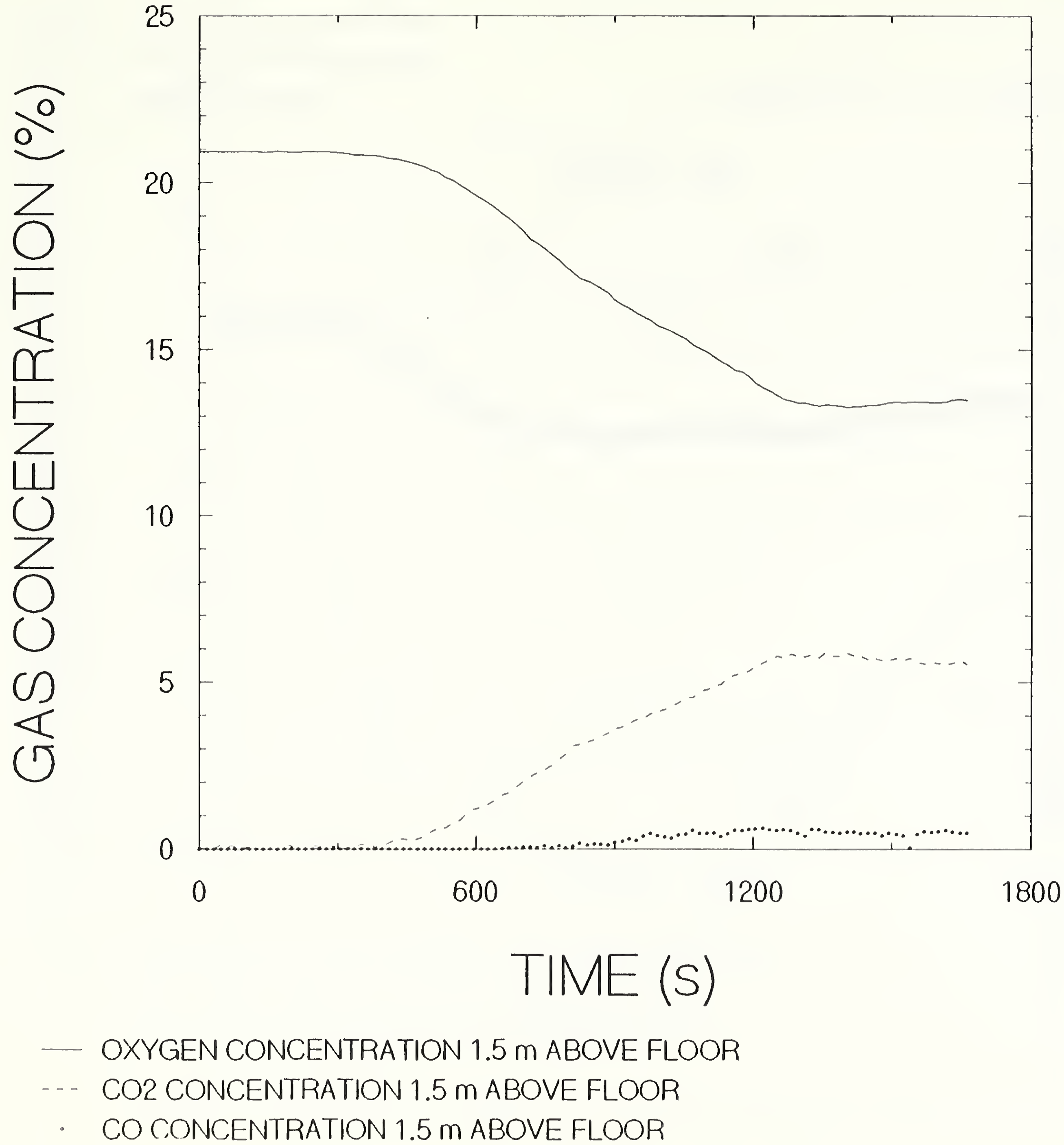

Figure A-24. Target Room Gas Concentrations - Test 6

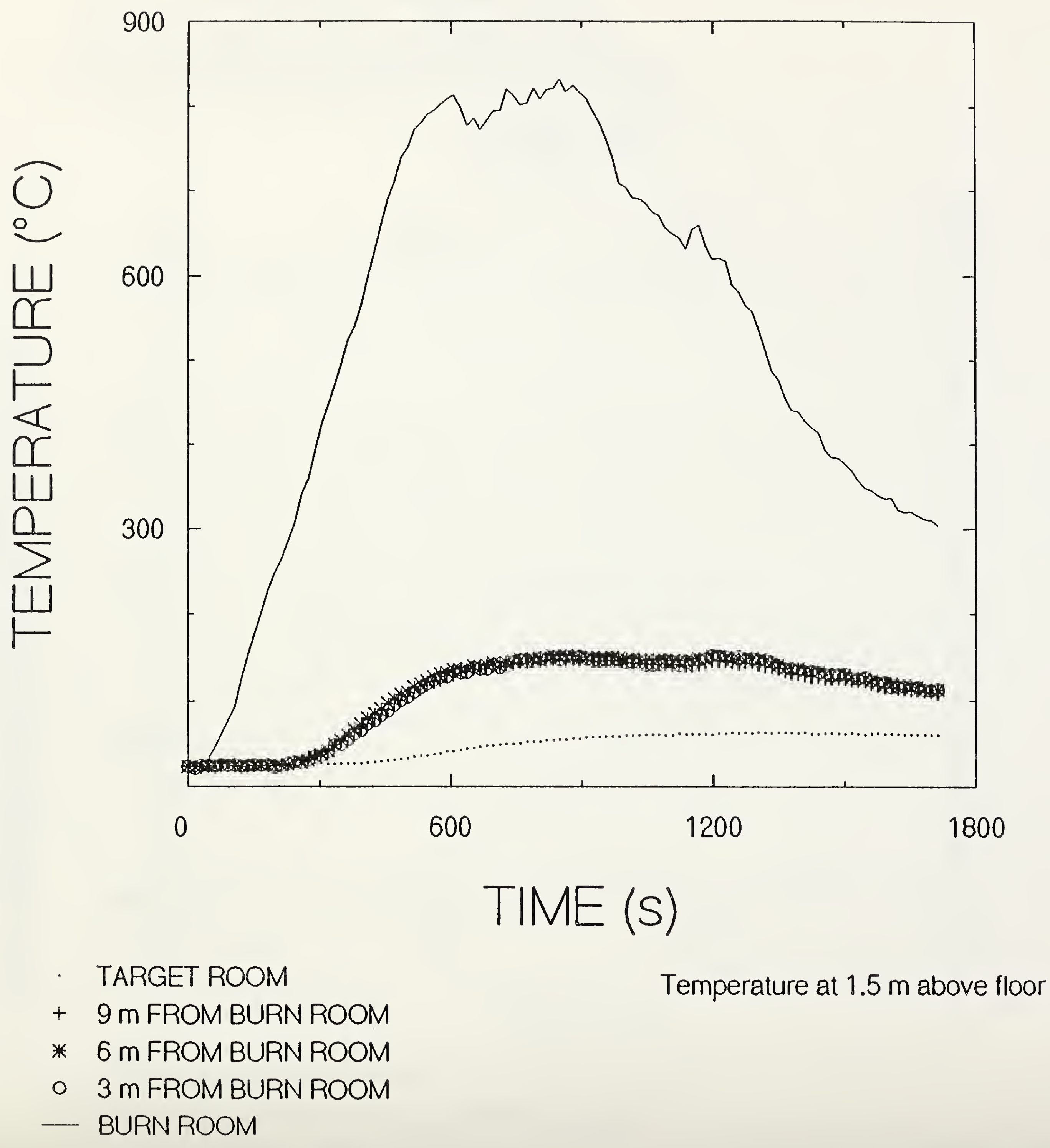

Figure A-25. Temperatures in Burn Room, Corridor, & Target Room - Test 7

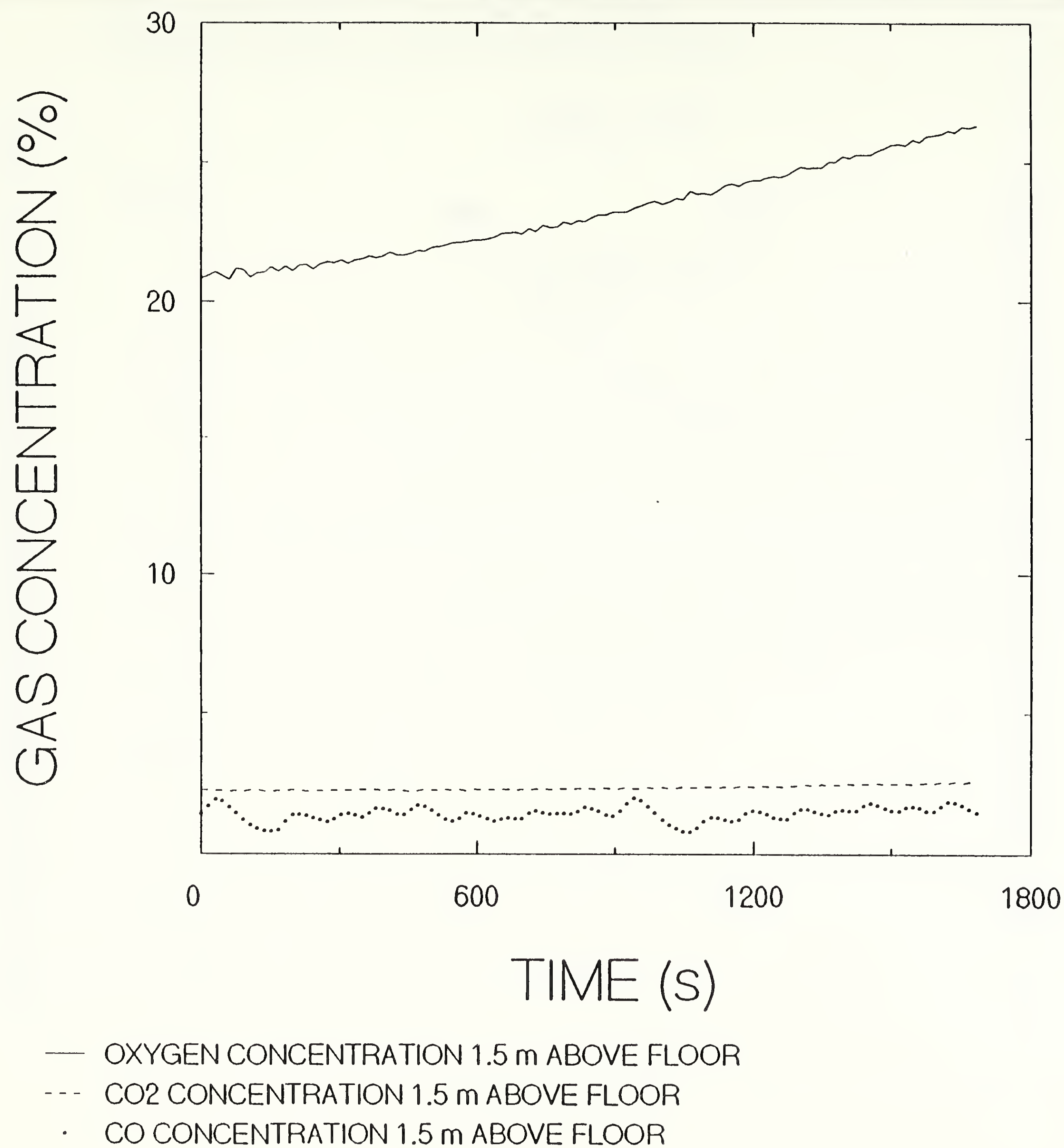

Figure A-26. Burn Room Gas Concentrations - Test 7

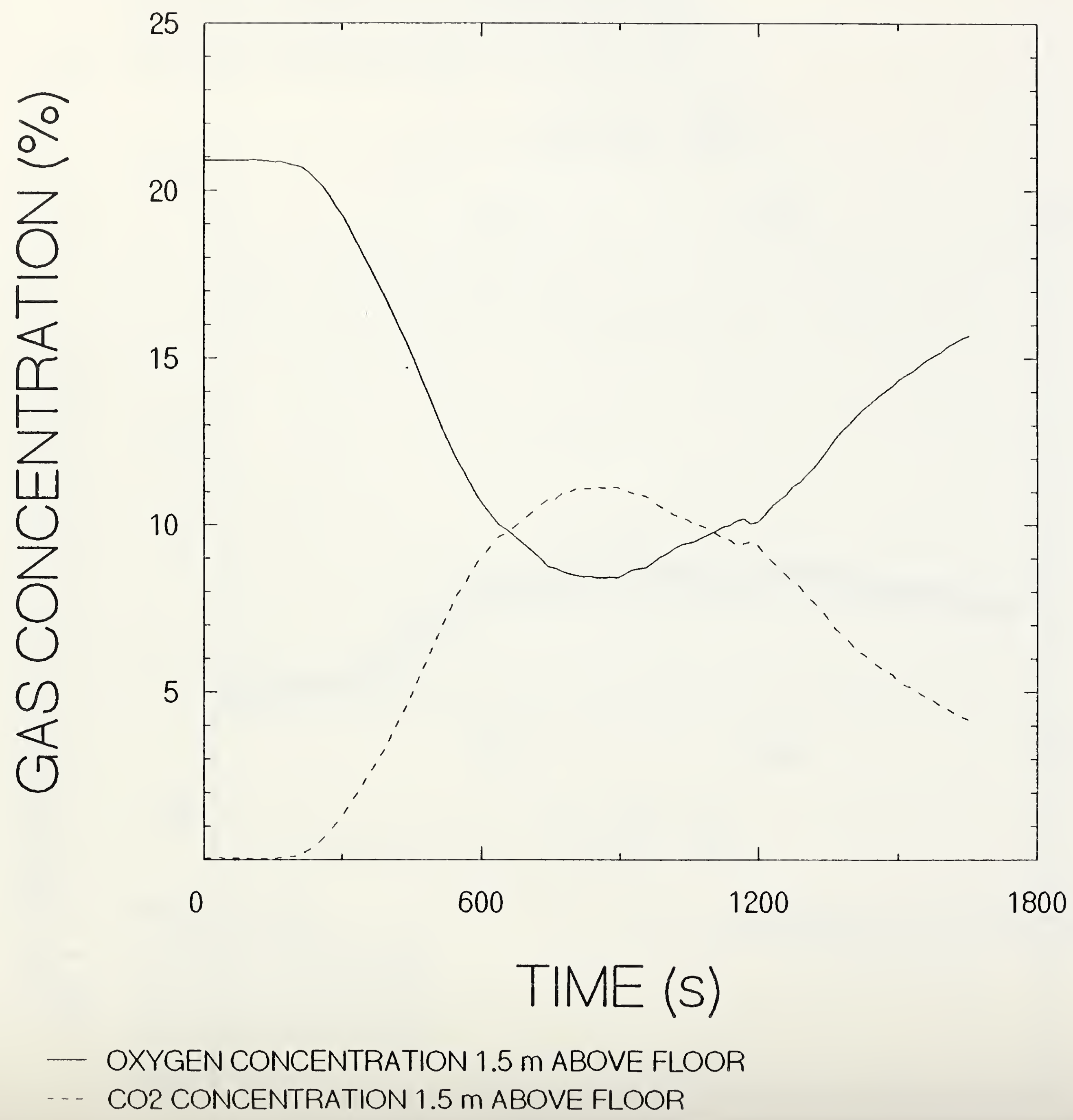

Figure A-27. Corridor Gas Concentrations - Test 7

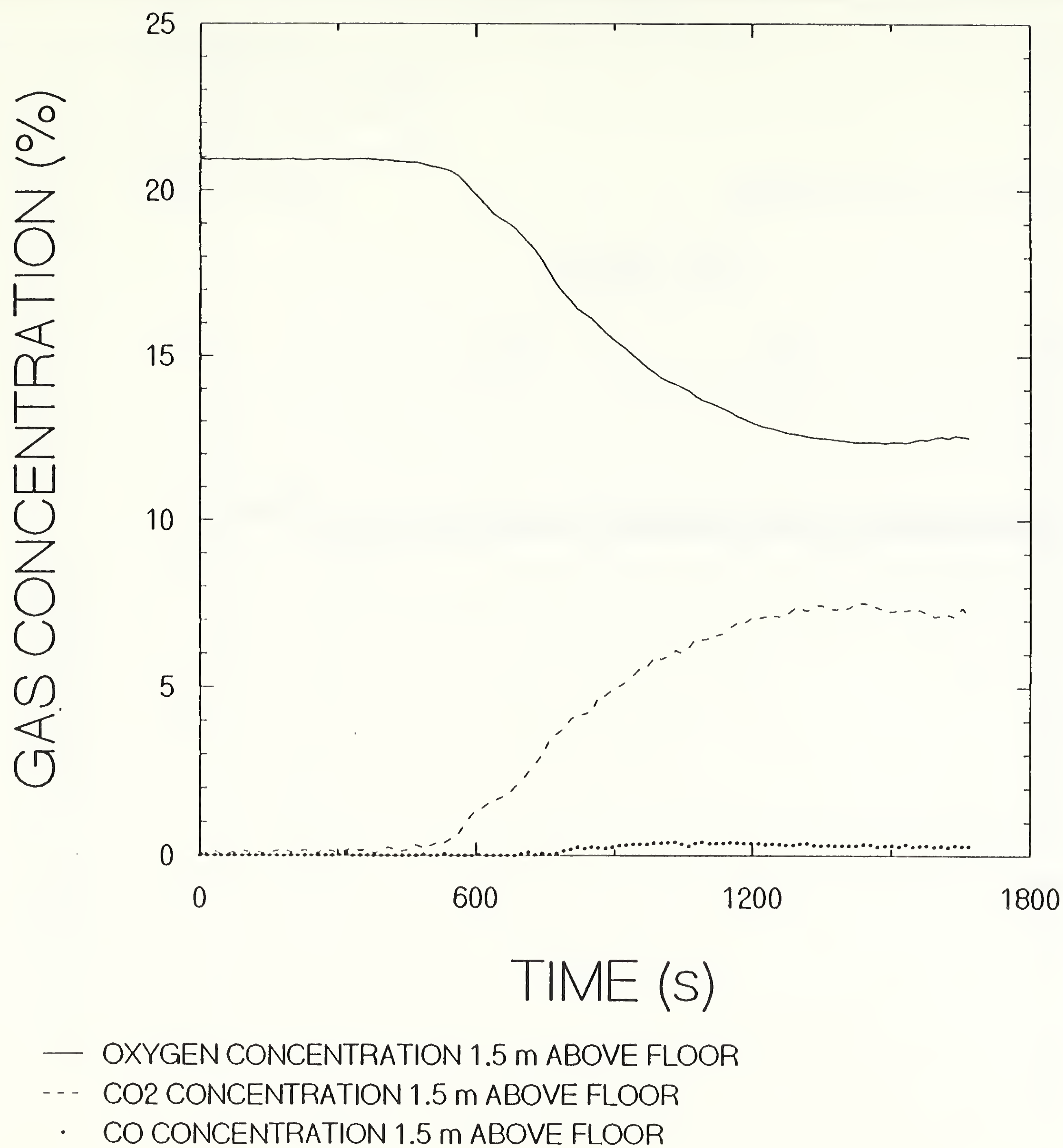

Figure A-28. Target Room Gas Concentrations - Test 7

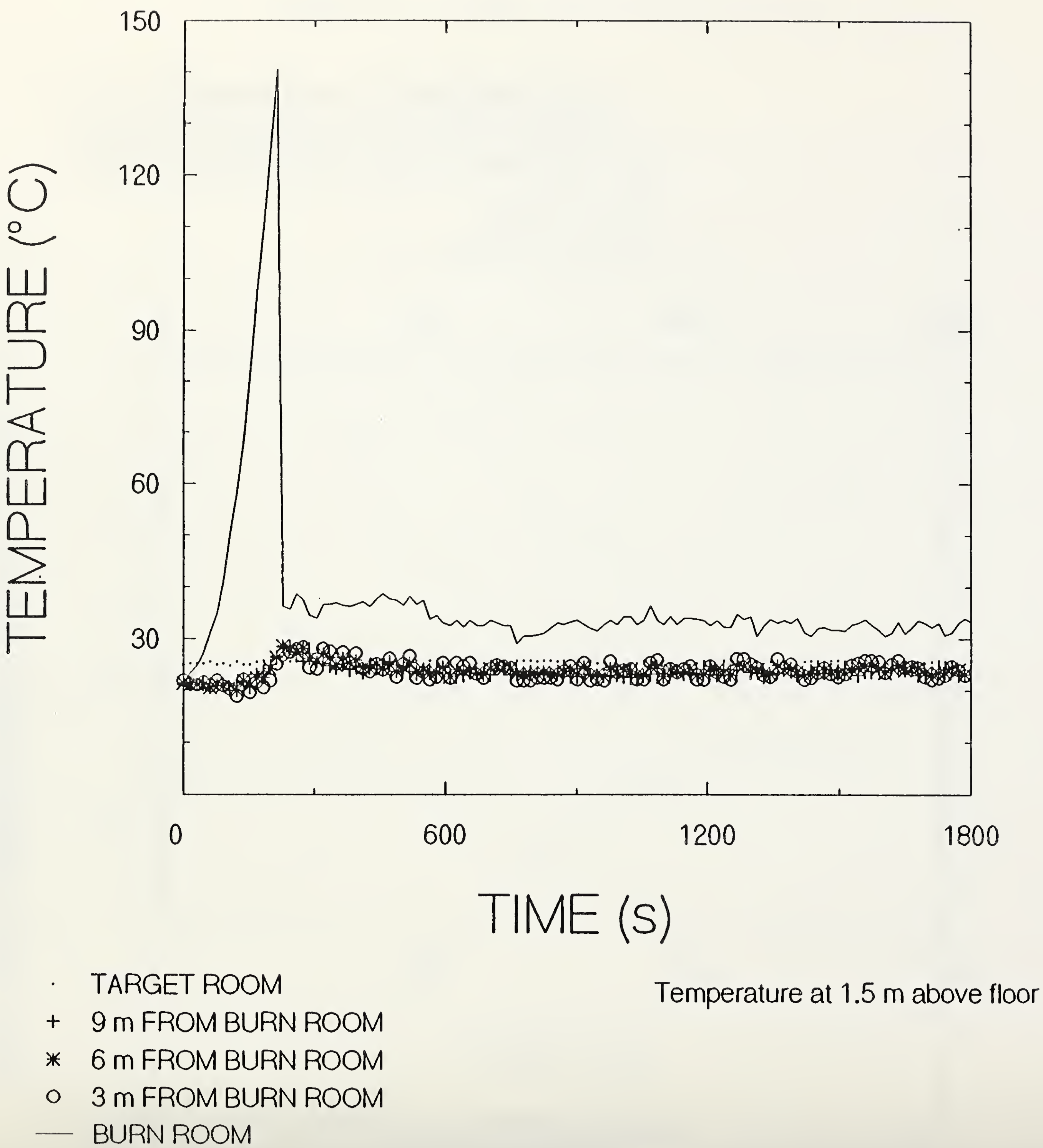

Figure A-29. Temperatures in Burn Room, Corridor, & Target Room - Test 8

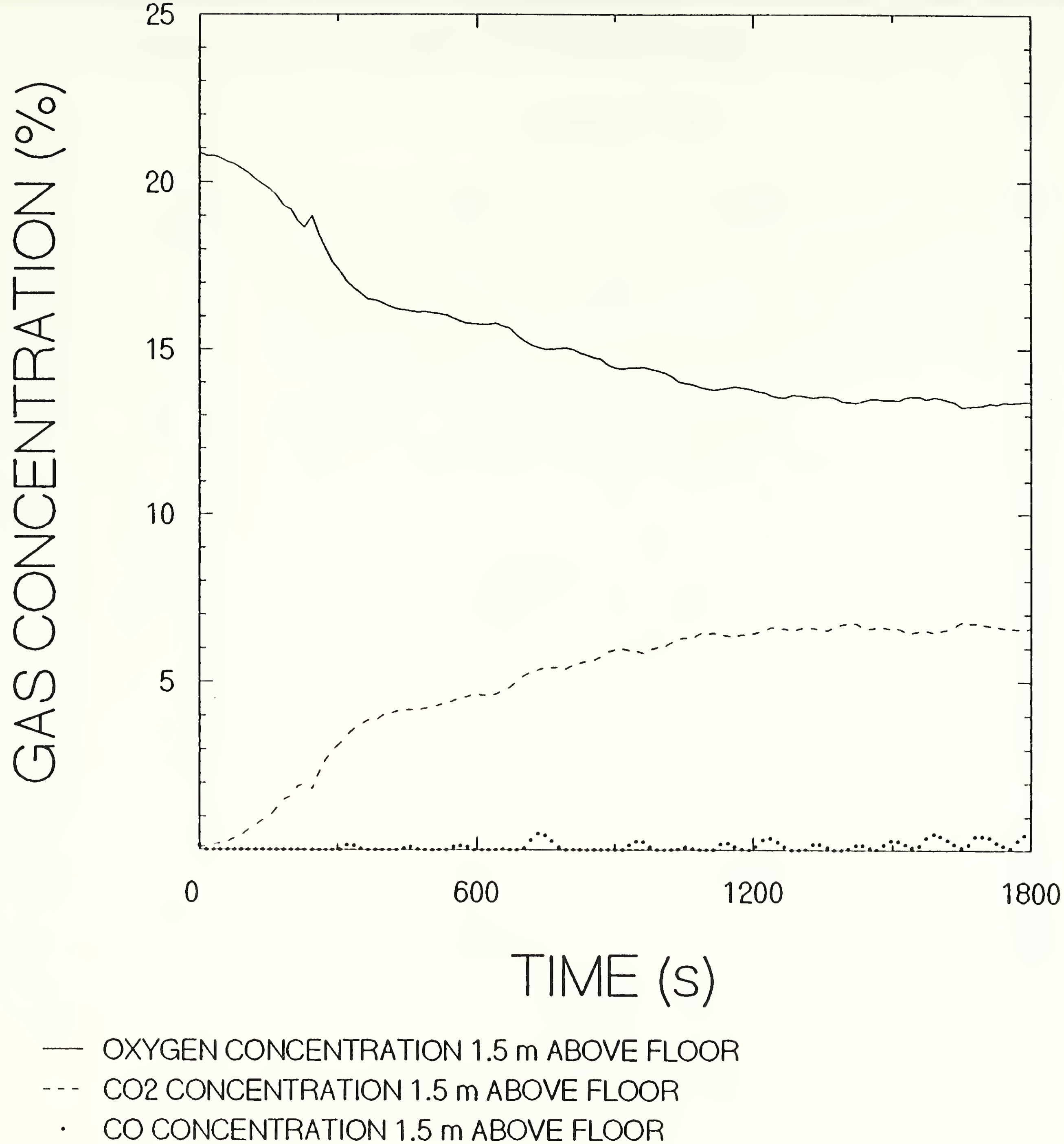

Figure A-30. Burn Room Gas Concentrations - Test 8

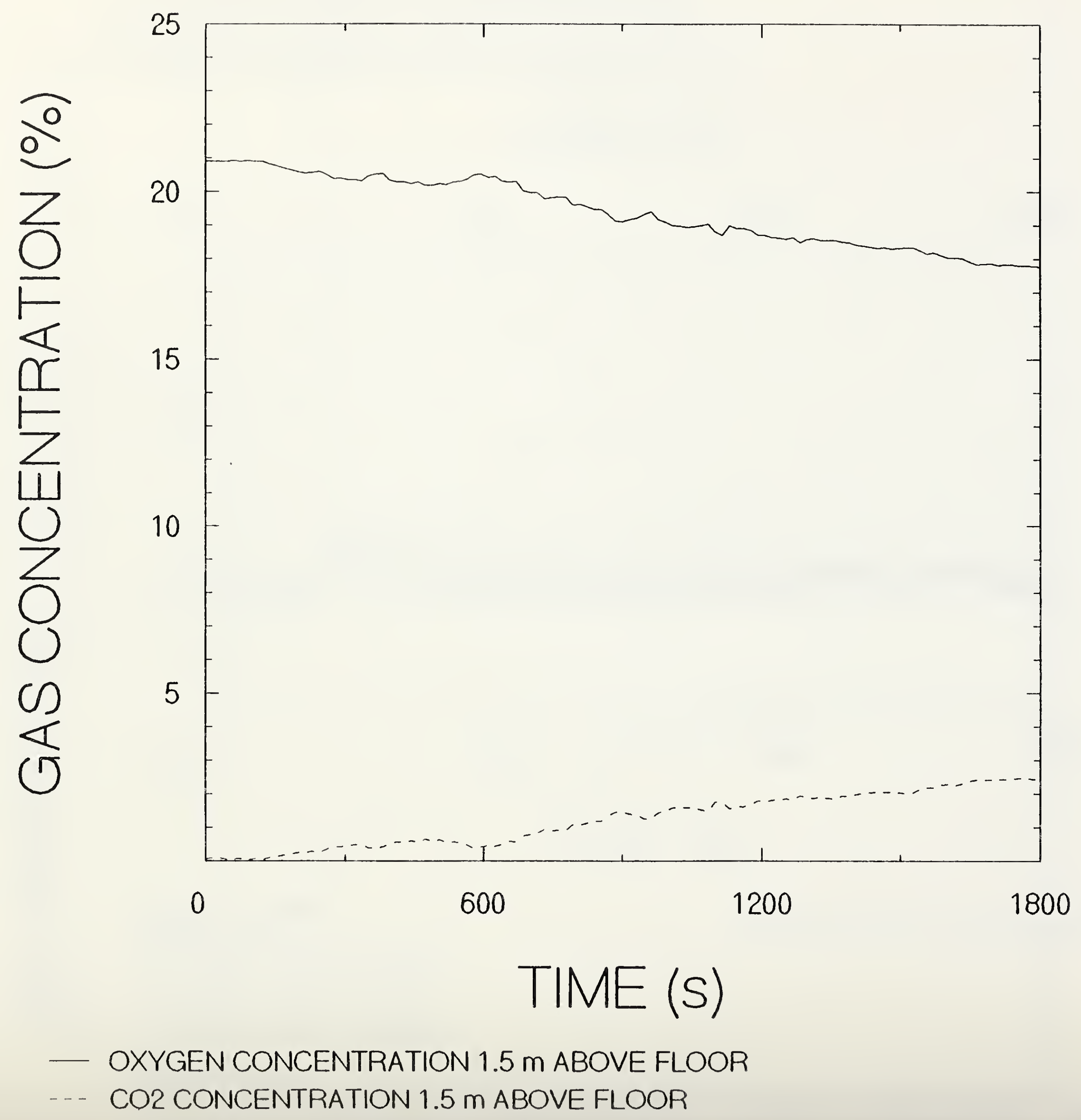

Figure A-31. Corridor Gas Concentrations - Test 8

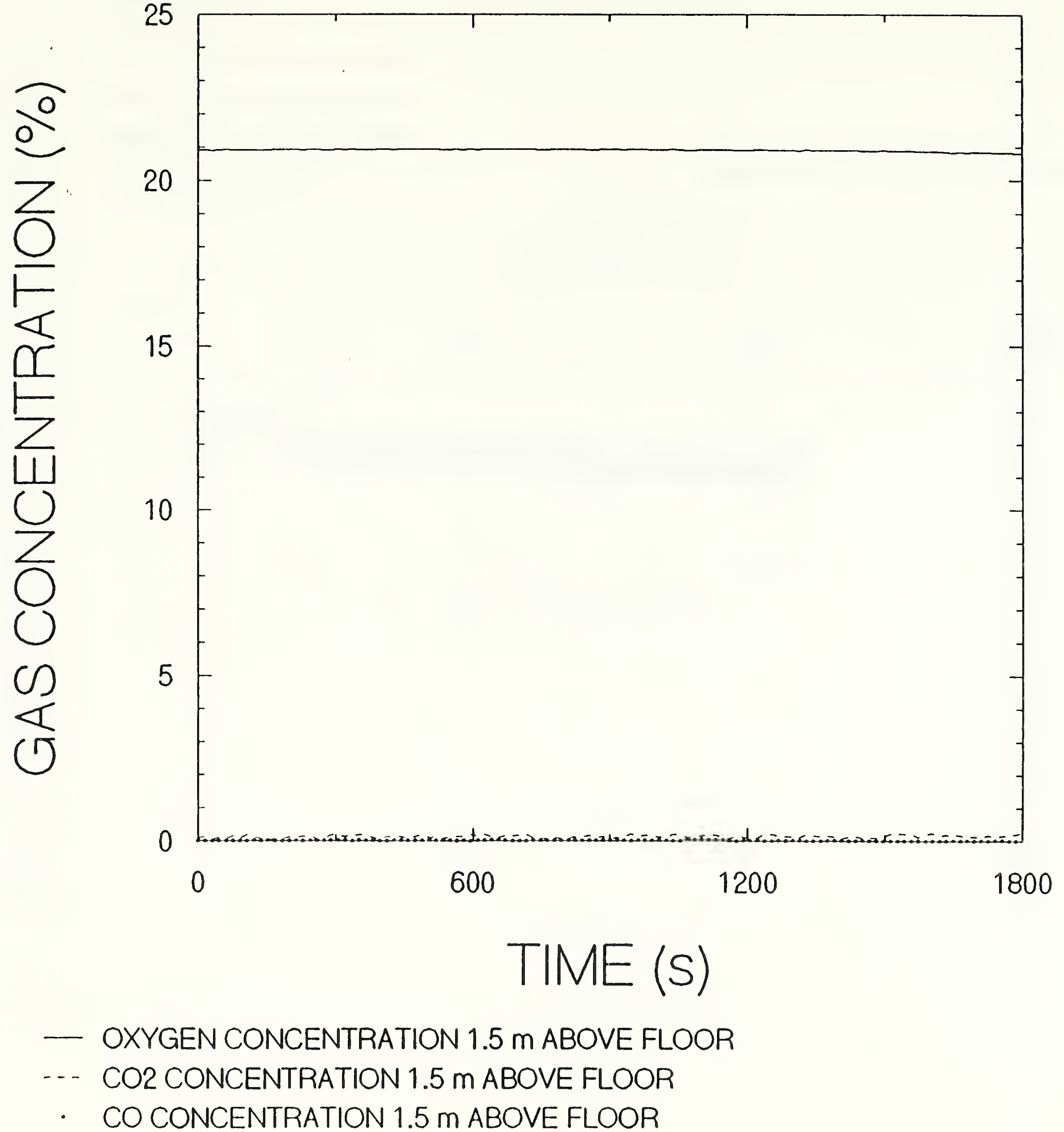

Figure A-32. Target Room Gas Concentrations - Test 8

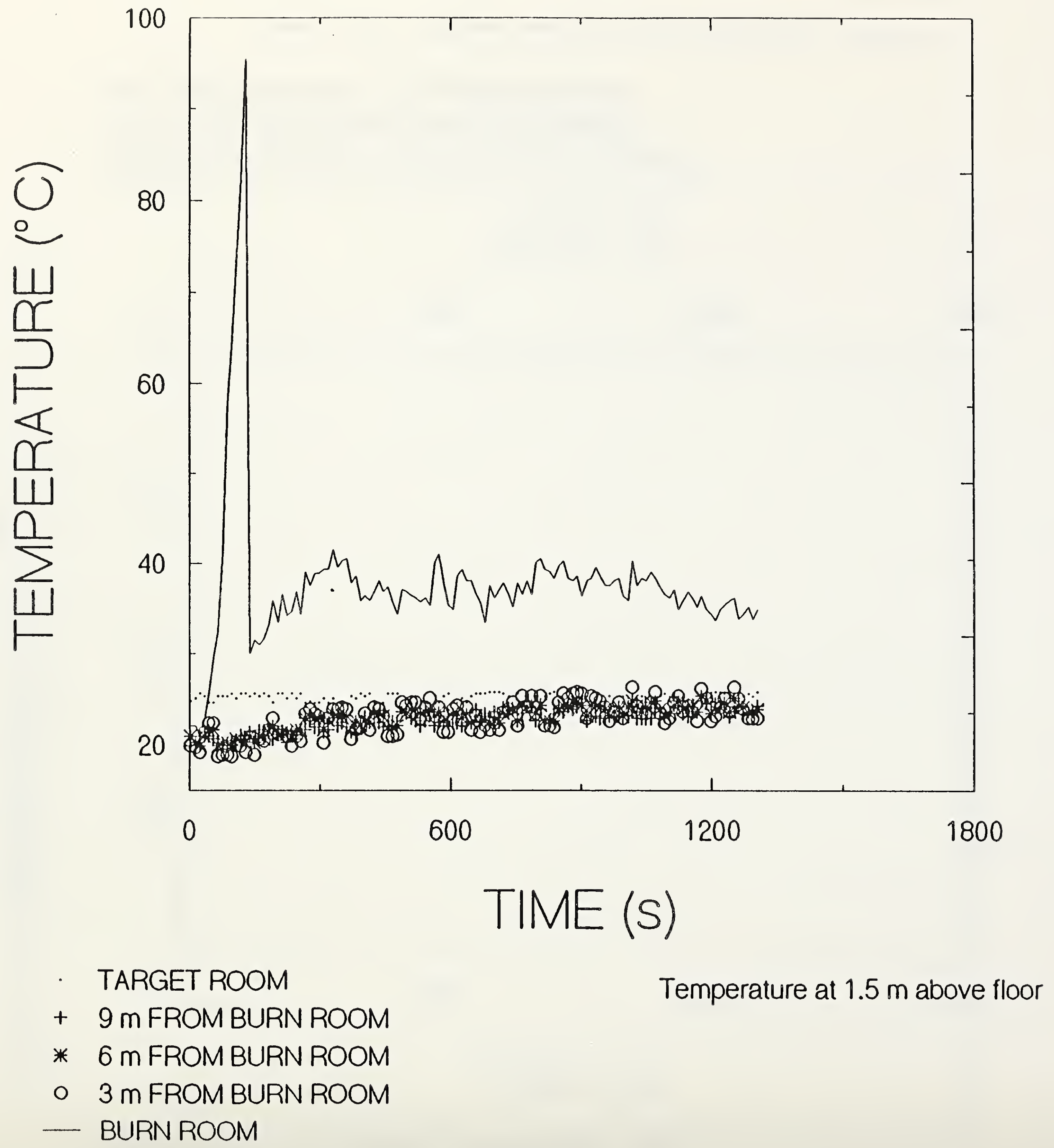

Figure A-33. Temperatures in Burn Room, Corridor, & Target Room - Test 9

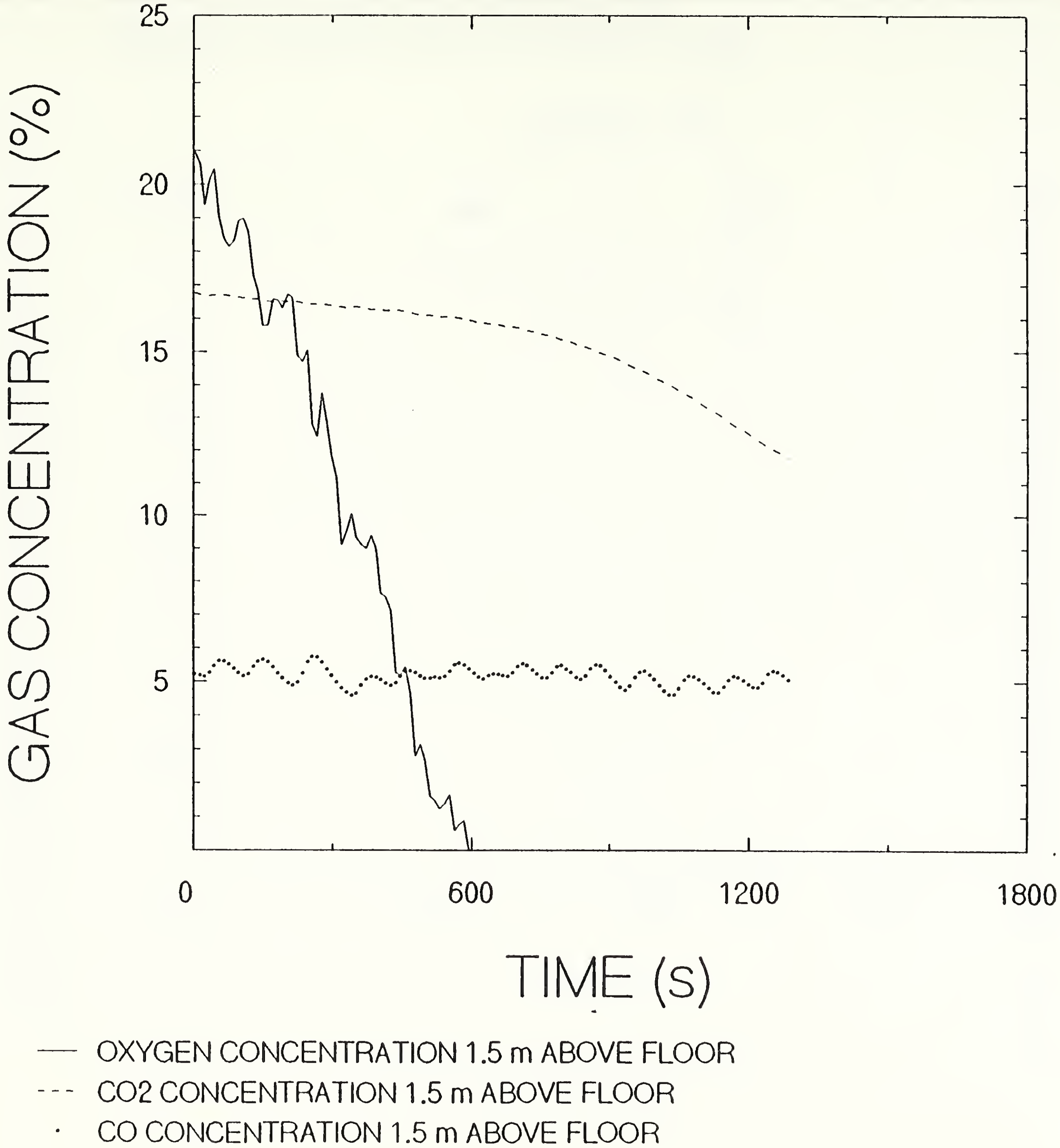

Figure A-34. Burn Room Gas Concentrations - Test 9

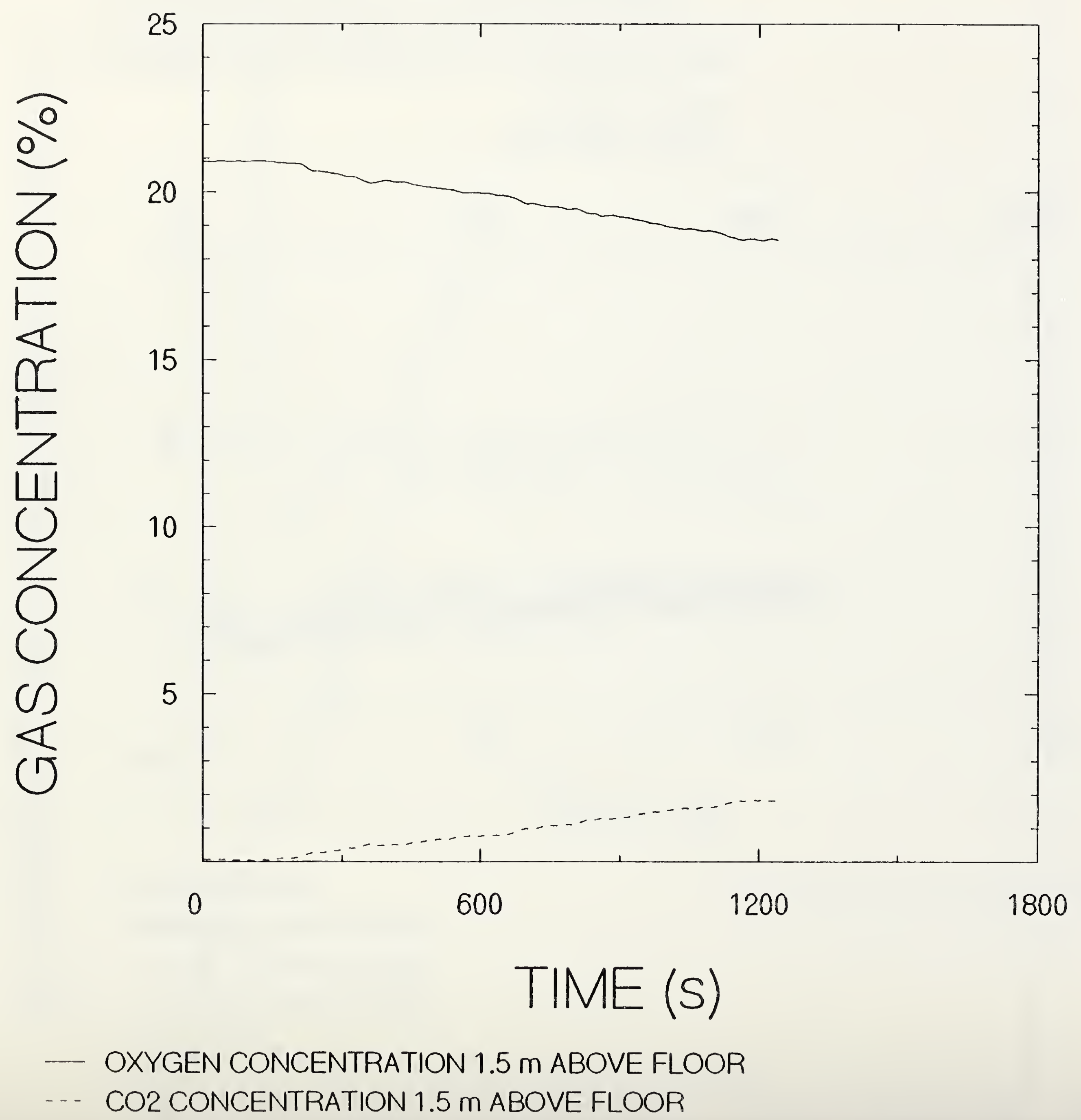

Figure A-35. Corridor Gas Concentrations - Test 9

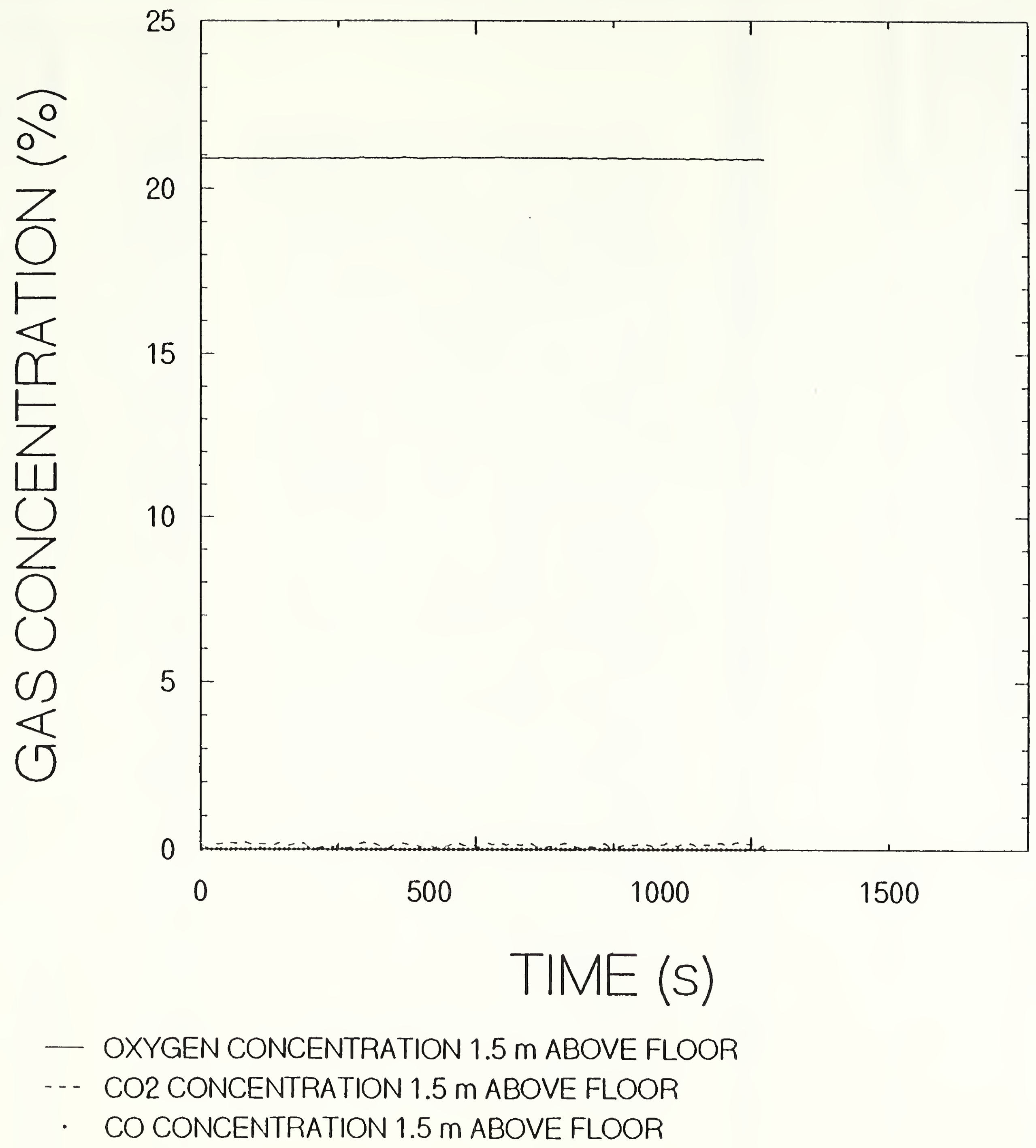

Figure A-36. Target Room Gas Concentrations - Test 9

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5. AUTHOR(S)

Daniel Madrzykowski

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General Services Administration
Office of Real Property Management and Safety
Washington, DC 20405

10. SUPPLEMENTARY NOTES

11. ABSTRACT (A 200-WORD OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, MENTION IT HERE.)

A study was conducted for the General Services Administration to investigate and quantify sprinklered fire exposure on an exit corridor and spaces adjacent to that corridor. The study compares the conditions in the test facility due to a 1 MW crib fire with those of a fire under control by a sprinkler. The effect of a sprinkler positioned in the corridor, outside of the burn room, was also examined. The test facility consisted of a burn room, a target room and a corridor connecting the two rooms. The burn room was a 2.44 m square with a 2.44 m high ceiling. The corridor was 12.8 m long, 2.44 m wide and 2.44 m high. The target room consisted of an entry alcove and a rectangular room with a total volume of 15 m^3. The target room was protected using a simulated "standard door" (6 mm top cut, 6 mm side cut and a 13 mm undercut). Gas temperatures and concentrations of oxygen, carbon dioxide, and carbon monoxide were measured at selected points in the three rooms. Tenability was assessed using both temperature and gas toxicity criteria. This assessment showed that sprinklers maintained tenable conditions outside the room of fire origin.

12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)

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