CANMET

Canada Centre for Mineral and Energy Technology

Centre canadien de la technologie des minéraux et de l'énergie

Mining Research Laboratories

Laboratoires de recherche minière

Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

Canada

THE ENERGY OF OUR RESOURCES - THE POWER OF OUR IDEAS

L'ÉNERGIE DE NOS RESSOURCES - NOTRE FORCE CRÉATRICE

EVALUATION OF THE U.S.MID-SCALE APPARATUS FOR MEASURING THE FLAMMABILITY OF CONVEYOR BELTING: PART II

K.J. Mintz

MRL 92-089(TR)

March 1993

Pr. 14.67.01.02-1

EVALUATION OF THE U.S. MID-SCALE APPARATUS FOR MEASURING THE FLAMMABILITY OF CONVEYOR BELTING: PART II

by

K.J. Mintz*

ABSTRACT

This report is the second phase of the evaluation of the U.S. Mine Safety and Health Administration (MSHA) "BELT" test for possible incorporation into the Canadian Standard, replacing the present flame propagation (propane gallery) test. Good correlation with MSHA was obtained on a series of three rubber/fabric belts. Tests on rubber/steel cord belts and PVC belts showed that the same formulation belt could either pass or fail depending on the thickness of the belt. A series of tests on various formulations of rubber/fabric belts showed that polychloroprene belts were more fire-retardant than SBR or SBR/polychloroprene blends, but that even SBR belts can be formulated to pass the BELT test. Finally, a simple model was developed that shows that the heat capacity of the belting is a critical factor in determining performance in the test: the BELT test as presently constituted is more severe the thinner the belt, for a given formulation. Thus, there will be a minimum thickness required for most products.

*Research Scientist, Canadian Explosives Research Laboratory, Explosives Branch, CANMET, Energy, Mines and Resources Canada, Ottawa

DEUXIÈME PARTIE DE L'ÉVALUATION DE L'APPAREIL AMÉRICAIN À ÉCHELLE MOYENNE DE MESURE DE L'INFLAMMABILITÉ DE COURROIES TRANSPORTEUSES

par

K.J. Mintz*

RÉSUMÉ

Le présent rapport décrit la deuxième phase de l'évaluation de l'essai "BELT" de l'U.S. Mine Safety and Health Administration (MSHA) en vue de son incorporation possible dans la norme canadienne, en remplacement de l'essai actuel de propagation de la flamme (propane en galerie). Une bonne corrélation a été obtenue avec les résultats de la MSHA pour une série de trois courroies en caoutchouc/textile. Les essais effectués sur des courroies en caoutchouc/câble d'acier et des courroies en PVC ont montré que pour une composition donnée, une courroie pouvait, selon son épaisseur, satisfaire ou non aux critères de l'essai. Une série d'essais effectués sur des courroies en caoutchouc/textile de diverses compositions a montré que les courroies en polychloroprène étaient plus ignifuges que les courroies constituées de SBR ou d'un mélange SBR/polychloroprène, mais même les courroies en SBR peuvent être fabriquées avec une composition telle qu'elles satisfont aux critères de l'essai BELT. Enfin, on a élaboré un modèle simple montrant que la capacité calorifique des courroies est un facteur critique dans la détermination de la tenue à l'essai : pour une composition donnée, plus une courroie est mince, plus il lui est difficile de satisfaire aux critères de l'essai BELT dans sa forme actuelle. Par conséquent, une épaisseur minimale est requise pour la plupart des produits.

---

*Chercheur scientifique, Laboratoire canadien de recherche sur les explosifs, Direction des explosifs, CANMET, Énergie, Mines et Ressources Canada, Ottawa

CONTENTS

TABLES

FIGURES

INTRODUCTION

The present report is a continuation of MRL 91-076(TR) (1), in which four different beltings, PVC, rubber/fabric (2 types), and rubber/steel cord, were studied experimentally in the U.S. Bureau of Mines (USBM) / Mine Safety and Health Administration (MSHA) new mid-scale flammability apparatus (2,3), which they call BELT (***Belt Evaluation Laboratory Test***). Temperature-time traces were generated at various points in the apparatus for each trial. The main conclusions reached were: (1) the BELT test appears to be a sufficiently stringent test; (2) qualitative correlation seems to exist between passing the flame propagation test (as described in the Canadian Standard (4)) and passing the BELT test; (3) the burner time is the independent relevant variable, rather than the length burned or the flameout time; (4) any belt will burn in the BELT test if the burner time is made sufficiently long; and (5) belts with asymmetric covers should be tested separately with the thin side up and the thin side down. In the present study, additional tests were carried out to correlate with results obtained by MSHA, to extend the testing to other types of belts, and to use a simple model to try to understand the processes involved.

After the experimental portion of this study had been carried out, MSHA issued a formal proposal (5) for adoption of the BELT test. The steel rack and the position of the burner relative to the sample are specified more precisely than in the earlier versions, the burner time is 5.0 - 5.1 min., rather than 5 ± .1 min.; the temperature of the ventilating air is restricted to a minimum 10°C, the temperature of the apparatus is restricted to a maximum of 35°C, and only the load-bearing side of the belt (normally the thicker side) is placed up. These changes were instituted as a result of further testing at MSHA and elsewhere in order to improve the repeatability of the test.

APPARATUS

The equipment and methodology were exactly the same as in Part I (1).

RESULTS

Belts #5 - 7: Rubber/Fabric Types

A series of three 3-ply rubber/fabric belts formulated by a manufacturer to provide a range of flammability had been tested by MSHA in their Trialdelphia, W. Va. facility. Belts #5 and 6 passed in each of their three tests, with belt #5 performing better (36 cm burnt compared to 43 cm burnt for belt #6). Belt #7 failed in a single trial. The results of the tests performed here are shown in Table 1; the temperature-time traces are shown in Figures 1 - 7.

Belt #5 started producing crackling noises between 45 and 60 s; a few small, smoking pieces fell onto the floor at about 3 minutes; after the burner was removed and the flames went out, there was some glowing and heavy smoke for a few minutes. The plies did not separate appreciably. Figures 1 - 3 show that the temperature remains fairly constant after the initial rise until the burner is removed. The higher temperatures at all stations may be associated with a slight change in placement of the burner or the higher ambient temperature in that trial may have contributed to the increased temperature.

The crackling noises started sooner for belt #6, about 35 - 40 s. Glowing particles started falling on the floor of the apparatus at about 2 - 2.5 minutes. Later, at about 3.4 minutes, large chunks fell onto the floor. In trial #1, although the actual flameout time (after the burner was removed) was short, the belt continued to have considerable glow; when the door to the room was opened about 3 minutes later, thus increasing the ventilation air, the sample burst into flames again. In trials 2 and 3, the flames took much longer to go out, the strong glow and heavy smoke persisted for some time. Fig. 4 - 6 show that the temperature started climbing at about 4 minutes. All these factors indicate that belt #6 is significantly less fire-retardant than belt #5, and might be rather marginal in terms of passing this test.

The crackling noises started even earlier for belt #7, at about 30 s. By 2 minutes, the fire on the belt seemed to be well-established. A few burning pieces fell on the floor starting at about 3 minutes, and at 4.5 minutes, there was a strong fire on the floor as well as on the belt. The belt had to be extinguished, but kept re-igniting. Figure 7 shows that there was hardly any drop in temperature when the burner was removed because the fire had become completely self-propagating by that time. The small dip in the temperature curves at about 3 minutes may be associated with the burning pieces falling off the sample. There can be no doubt that this product does not pass the BELT test.

Table 1. Results from BELT tests on belts #5 - 7

Belt No.	Trial No.	Temp. (°C)	R.H. (%)	Air Velocity (m/s)	Burner Time (min.)	Flameout Time (min.)	Length Burned (cm)	
							Top	Bottom
5	1	20	--	1.11	5.0	0:00	36	51
	2	24	--	1.07	5.0	0:11	33	43
	3	19	58	1.09	5.0	0:12	30	37
6	1	22	--	1.06	5.0	0:15	39	55
	2	20	53	1.01	5.0	2:54	44	52
	3	23	53	1.03	5.0	2:15	52	55
7	1	26	--	1.08	5.0	>3	total	total

The MSHA tests showed that belt #5 was more fire-retardant than belt #6, but both products passed, and belt #7 failed. These are exactly the same ranking and pass/fail as was determined here. The flame out times at MSHA were between 14 and 55 s for belt #5 and between 30 and 1153 s for belt #6. Our results were slightly less than those, but it is difficult to say whether the difference is meaningful[1]. The lengths burnt on the top side were 36 cm for belt #5 and 43 cm for belt #6, both in good agreement with the present study.

Belts #8 - 10: Rubber/Steel Cord Types

Three rubber/steel cord belts with the same rubber composition were tested: #8 had 3.8 mm cords and total thickness of 15 mm; #9 had 9.5 mm steel cords and total thickness of 28 mm and #10 had 5.4 mm cords and total thickness of 35 mm. The results are given in Table 2 and Figures 8 - 12.

Belt #8 started producing crackling noises at 30 s and started throwing off hot sparks at 1 minute. After the burner was turned off, the fire remained strong; about 2.5 minutes later, the fire started spreading down the length of the belt. The fire was extinguished about 5 minutes after the removal of the burner. The temperature traces (Fig. 8) show only a gradual and short-lived decline after removal of the burner, then a rapid increase until the fire was extinguished. This trial was a definite "fail".

Belt #9 started crackling at about 40 s, and throwing off hot sparks at about 1.5 minutes. Although a vigorous fire was present by 3.5 minutes, when the burner was removed at 5 minutes, most of the flames disappeared immediately. Qualitatively, there appeared to be more heat produced by this belt than belt #8. The shapes of the temperature traces of the two trials (Fig. 9 and 10) were different, with trial #1 having a sharp rise at about 4 min., and trial #2 having a more-or-less steady increase. The temperatures at 5 minutes were approximately the same, however, and rather high.

[1] In statistical language, the "t-test" applied to the flameout times indicate that the null hypothesis that the two sets are different cannot be rejected at the usual 95% probability level.

Table 2. Results from BELT tests on belts #8 - 10

Belt No.	Trial No.	Temp. (°C)	R.H. (%)	Air Velocity (m/s)	Burner Time (min.)	Flameout Time (min.)	Length Burned (cm)	
							Top	Bottom
8	1	21	--	1.10	5.0	>5	total	total
9	1	24	--	1.08	5.0	1:36	74	48
	2	23	--	1.04	5.0	0:27	102	55
10	1	17	56	1.06	5.0	0:13	50	49
	2	18	45	1.05	5.0	0:52	78	47

Belt #10 had asymmetric thicknesses of covers. Trial #1 was carried out with the thin side down. Glowing particles were thrown off starting at about 1.5 minutes. When the burner was removed at 5 minutes, the flames went out quickly, though considerable glow and smoke persisted. Trial #2 was carried out with the thick side down. Glowing particles were thrown off at 1 minute. The flames appeared to start spreading beyond the flame application zone at about 3 minutes. The flames went out fairly quickly when the burner was removed.

The fact that belt #8 failed and the other two passed, even though they had the same composition, indicates that the thickness of the belt plays an important role. The thickness, of course, is closely related to the heat capacity of the belt. With the high temperatures reached at 5 minutes in the trials on belt #9 (higher than #8), it might be expected that a propagating fire would occur. However, these temperatures are measured near the ceiling; although they provide a reasonably good relative measure of the total heat output of a trial, the temperature of a heavy belt may lag by a considerable amount because of its high heat capacity, and thus not reach its kindling point. At an earlier stage in the program, it was thought that steel cords would improve the fire-retardance because they would be able to conduct the heat away. The fact that belt #9 had much heavier cords than #10 but fared worse indicates that this hypothesis is not valid; rather it is the total heat capacity that is important. (Note that a steel cord belt is intrinsically better than a fabric one, because the latter contains additional flammable material.)

In Part I, rubber/fabric belts with asymmetric thickness covers were tested: in that case, the trials with the thin side down fared worse, in contrast to the present work. In the former case, the difference was attributed to the difference in distortions of the samples when heated. In the case of steel cord belts, there can be little distortion. Because of the nature of the BELT test, the top surface is exposed to more heat than the bottom surface, thus, in the trial with the thin side up, the fire is more likely to penetrate into the layer of rubber next to the steel cord.

Belts #11 & 12

To see the effect of belt thickness (or heat capacity), two PVC/fabric beltings of the same formulation, were tested by the standard method. Belt #11 had a thickness of 7.1 $\pm$ 0.1 mm, and belt #12 had a thickness of 10.1 $\pm$ 0.1 mm. The temperature-time traces are shown in Fig. 13 and 14.

Belt #11 started burning along the edges at about 1 min. At 1.5 minutes, the front edge began curling upwards and started shrinking. At 2.5 minutes, a few burning pieces fell onto the floor (which correlates with a slight dip in the temperature traces). By 4 minutes, there was a vigorous fire with flames spreading down the sample and smoke backing up. After the burner was turned off at 5 minutes, the sample continued to burn well. By 9 minutes, the fire had reached the end of the sample and it was necessary to extinguish it. From the temperature-time trace, the "take-off" point appears to be about 3.5 minutes.

Belt #12 started burning along the edges at about 1.5 minutes. The fire was much less vigorous than belt #11. The flameout time after the burner was removed at 5 minutes was only 33 s. The length burnt was 58 cm on the bottom and 33 cm on the top, which is not excessive. The temperatures appear to be increasing near 5 minutes, indicating possibly that the minimum burner time for belt #12 is not too much greater than 5 minutes.

The substantial difference in flammability between belts #11 and belt #12 can be explained only in terms of the differences in heat capacities.

Belts #13 - 21

Various constructions and formulations of rubber/fabric belts were tested, all but one under standard conditions, to indicate the potential for passing the BELT test (see p. 8).

Although it is clear that belting made of polychloroprene rubber only can easily pass the BELT test, it can be seen that belting made of mixtures of polychloroprene and SBR, or even ones made of SBR alone, can also pass this test. The challenge of formulating belting containing SBR that has adequate fire-retardance is, naturally, much greater than beltings that contain only polychloroprene.

These results show that the thick side down provides a less severe test than the thin side down. In the U.S. proposal, only the thin side down is tested; that does correspond to the more severe case.

MODEL OF SYSTEM

In order to achieve a qualitative understanding of the BELT apparatus, a simple theoretical model was developed. The assumptions are:

1. The walls are perfectly insulating;
2. The burner heats the flame application zone (30 cm in from the front of the chamber) homogeneously and does not directly affect the remaining part of the chamber;
3. The flame application zone part of the chamber is completely homogeneous with respect to temperature; and
4. The specific heat of air, specific volume of air and air velocity are independent of temperature.

Table 3. Results from BELT tests on belts #13 - 21

Belt No.	Rubber	Plies	Covers	Side Down	Temp. (°C)	Air Velocity (m/s)	Burner Time (min.)	Flameout Time (min.)	Length Burned (cm)	
									Top	Bottom
13	chloroprene	3	5 x 1.5	thin	16	1.03	5	0:07	57	57
14	chloroprene	3	2 x 2	--	19	1.09	5	0:23	31	37
15	chloroprene/SBR	1	4 x 2	thick	17	1.00	5	11:05	--	--
				thin	20	1.06	5	17:46	58	60
16	chloroprene/SBR	3	5 x 1.5	thick	18	1.09	5	quenched	--	--
				thin	21	1.11	4	16:59	53	48
17	chloroprene/SBR	3	5 x 1.5	thick	21	1.06	5	0:06	32	43
				thin	26	0.98	5	0:17	33	38
18	chloroprene/SBR	3	2 x 2	--	20	1.07	5	7:08	31	40
19	SBR	1	4 x 2	thick	21	1.09	5	0:54	33	47
				thin	22	1.11	5	8:57	44	53
20	SBR	3	5 x 1.5	thick	21	1.03	5	0:51	30	46
				thin	24	1.05	5	7:37	35	42
21	SBR	3	5 x 1.5	thick	25	1.04	5	15:43	56	54
				thin	27	1.05	5	quenched	--	--

From the specifications of the wall material and experimentally, assumption 1 is a good approximation. Assumption 2 is obviously only a rough approximation. Assumption 3 neglects convection which will make the top part of the chamber hotter than the bottom. The effects of assumption 4 are smaller than those of assumptions 2 and 3.

The rate of flow of methane to the burner is 34 L/min.(1.2 SCFM), which corresponds to 0.56 L/s, or 0.025 mole/s. The heat of combustion of methane is 883 kJ/mole, therefore, the total rate of heat input, assuming perfect combustion, is 22,000 J/s. The volume of the "flame application zone" (cross-section of chamber is 0.46 m square) is 63 L. The volume of air travelling through the chamber (air velocity being 1.02 m/s (200 fpm)) is 210 L/s. The specific heat of air is 0.24 cal/g/°C = 1.3 J/L/°C. Therefore, the rate of heat loss will be 272 J/s/°C $\cdot$ ΔC, where ΔC is the temperature rise.

At some time, the heat loss will equal the heat gained; solving for ΔT, the resultant temperature rise is predicted to be 81°C. Experimentally (Fig.4 of Part I), the maximum temperature at station 2 with the burner only was measured at about 320°C; the temperature in the exhaust rose about 60°C. The latter would be expected to be slightly lower than the mean temperature in the flame application zone because of heat losses through the walls. The temperature at station 2 is high because of convection, thus assumption 2 is not a good approximation. Referring to Fig. 4, it can be seen that station 3 is lower than station 2 and station 4 is even lower; this is probably not due to loss of heat through the walls of the chamber, but to increasingly better homogeneity downstream.

One of the interesting points of Fig. 4 in Part I is the very rapid increase in temperature to a more-or-less stable value, within a few seconds. By taking small time slices (10 ms) and iterating the net heat gain in each slice, the predicted temperature rise can be calculated: it was even faster than the experimental, reaching 95% of the final temperature rise within 1 s. This is an important point, because it shows that, to a very good approximation, the cabinet can be considered to be stabilized with respect to the burner contribution throughout the five minute test.

When a sample is placed on the rack, the situation obviously changes, since the belt will absorb some of the heat. For the purposes of these calculations, the specific heat will be taken as 750 J/kg/°C, a typical value for a solid, and assumed not to vary with temperature. As above, it will be assumed that only the first 30 cm of the sample is affected. In all the calculations following, it will be assumed that there are no chemical reactions in the belt.

If the belt absorbs all the heat, i.e. none is used to heat the air, and it is assumed that the belt is at the same temperature throughout the flame application zone, then its temperature will increase with time linearly as shown in Fig. 15. The numbers on the graph are the mass of belt sample in the flame application zone, and covers the range from the lightest to the heaviest. Note that the rate of temperature rise is inversely proportional to the sample mass.

A second approximation can retain the assumption that the belt initially absorbs all the heat from the burner, but ventilation air flowing across the belt removes some of the heat. If the air is 100% effective at removing the heat, then the temperature rise is 60°C, the same as it is in the absence of the sample. The only difference is that it takes much longer to reach that temperature, especially with heavier samples (see Fig. 16). As the percentage effectiveness of the ventilation air decreases, the calculated temperature rise increases. The minimum ignition temperature of fire-retardant conveyor belting, which should be at least a rough indicator of the temperature that the belting must be heated to before ignition is achieved, is in the region of 500 - 600 °C. (6). This model predicts that the temperature rise does not reach 500°C unless the ventilation air is less than 15% effective. Figure 17 shows the calculated temperature rise, assuming that the ventilation air is only 10% effective. Using a minimum ignition temperature of 620°C[1], the lightest belt would require only about 30 s; the heaviest belt would require almost the full five minutes.

These calculations are not meant to be quantitative, but rather illustrative. The mechanism of ignition of the belting involves the various combustible gases produced during

---

[1] Assuming that the ambient temperature is 20°C, the temperature rise is 600°C.

heating, the exposure of the carcass to the heat source, the heat conductivity of the belting, etc. Nevertheless, the large contribution that the heat capacity of the sample makes to the overall process is quite clear. If products of different thicknesses but otherwise identical are tested, this model predicts substantial differences in the results of the test. These predictions appear to be substantiated by the results of testing belts 11 and 12.

The effect of initial temperature can also be qualitatively evaluated from the model. Referring to Fig. 17, a small decrease in initial temperature would have little effect on the lightest belt, but have progressively larger effects as the belt sample weight increases (because the minimum ignition temperature equals the initial temperature plus the temperature rise). Under some conditions, a small decrease in initial temperature may be enough to change from ignition to non-ignition. Hence, it is important to specify as small a range of allowable ambient temperatures as practical. The proposed MSHA rule specifies 10 - 35 °C.

DISCUSSION

It is clear from both the experimental and theoretical parts of this study that the most important decision to be made on the BELT test is whether or not to vary the time that the burner is applied to the sample as a function of belt thickness (or, strictly, area density). MSHA has chosen not to do so, but has reserved the right to modify the procedure for belt thicknesses greater than 19 mm. The argument for a variable burner time is so that all belts of the same composition will yield the same result. With a constant burner time, there will exist a minimum thickness for most belts below which they fail the test. The argument for a constant burner time is that all belting must withstand a certain stimulus, i.e. a fire of a certain size. To resolve this issue would require a quantitative hazard analysis of all mines in which these beltings can be used, which is far beyond the scope of this study.

Another important aspect to consider is that the BELT test is being evaluated to replace the flame propagation (propane gallery) test specified in the Canadian Standard. This test also has deficiencies. The gallery used is non-insulated, thus much of the heat generated by the combustion is lost. In an actual mine installation, the amount of heat lost will depend on the particular installation: the distance to all the walls (particularly the roof), the nature of the rock (heat conductivity), the rate of air flow, the temperature, etc. The propane gallery also uses an exhaust fan of fixed volumetric capacity, which means that the large quantities of gases produced by the combustion can not be drawn out and "flow reversal" occurs, which can tend to suffocate the combustion process to some degree. The air required for the propane gallery must be drawn from outside, which means that the allowable temperature range for this air must be wider, causing a wider variability in results. Since the volume of air used for the BELT test is much less, laboratory air of an approximately fixed temperature may be used, and the flow reversal does not begin until much later in the combustion process. Hence, the BELT test, despite its deficiencies, would be an improvement in terms of better control over the experimental parameters. Support for this statement is the good agreement between tests conducted here and those conducted by MSHA.

Although generally the BELT test is more severe when belts are placed with their carrying side up, sometimes the reverse is true. Since it is known that mines sometimes reverse their belts in order to obtain the maximum usage of them, it would seem provident for tests to be carried out for both placements.

ACKNOWLEDGEMENTS

The author would like to thank Mr. Harry Verakis of the U.S. Mine Safety and Health Administration, Triadelphia, W. Va., for supplying the drawings and other information on this test, and the manufacturers who supplied samples of conveyor belting.

REFERENCES

1. Mintz, K.J. "Evaluation of the U.S. mid-scale apparatus for measuring the flammability of conveyor belting: Part I", Mining Research Laboratories Divisional Report MRL 91-076(TR); 1992.

2. Lazzara, C.P. and Perzak, F.J. " Conveyor belt flammability tests: comparison of large-scale gallery and laboratory-scale tunnel results", 23rd Int. Conf. Safety in Mines Res. Inst., U.S. Bureau of Mines, Washington; 1987.

3. Verakis, H.C. "Fire hazard evaluation of mine conveyor belts", 3rd Int. Conf. Polymers in Mining, Univ. Lancaster, The Plastics and Rubber Institute; 1989.

4. CAN/CSA-M422-M87 "Fire-performance and antistatic requirements for conveyor belting", Canadian Standards Association, Toronto; 1987.

5. U.S. Department of Labor, "30 CFR Part 14, et al. Requirements for Approval of Flame-Resistant Conveyor Belts; Proposed Rule", Federal Register, vol. 57, no. 248, Dec. 24, 1992.

6. K.J. Mintz and K.V. Inglis "Minimum ignition temperature: an alternative small-scale flammability test for conveyor belting", Mining Research Laboratories Divisional Report 90-138(TR); 1990.

Fig. 1. Belt #5, Trial #1, 5.0 min. Burner Time

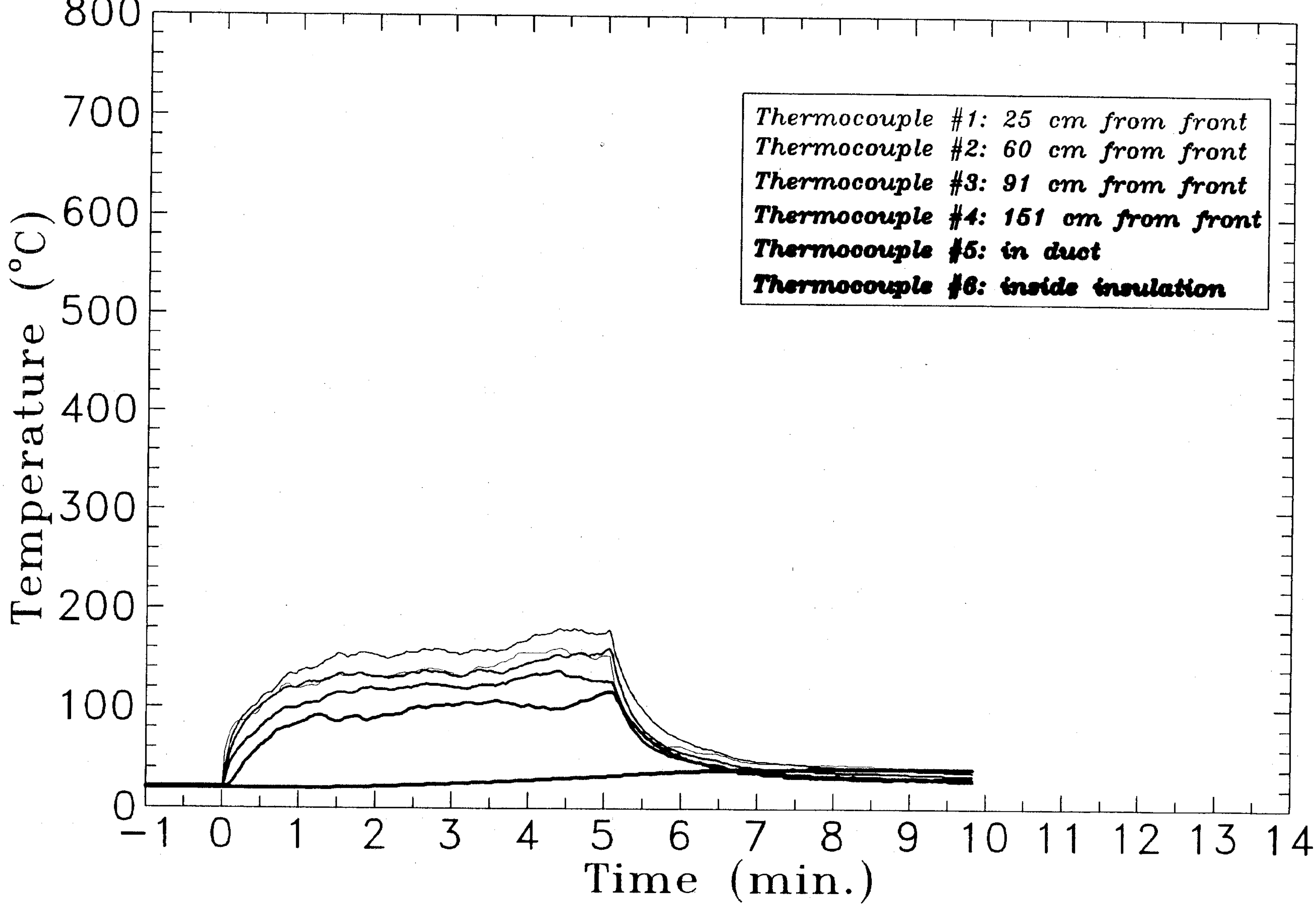


Fig.2. Belt #5: trial #2, 5.0 min. Burner Time

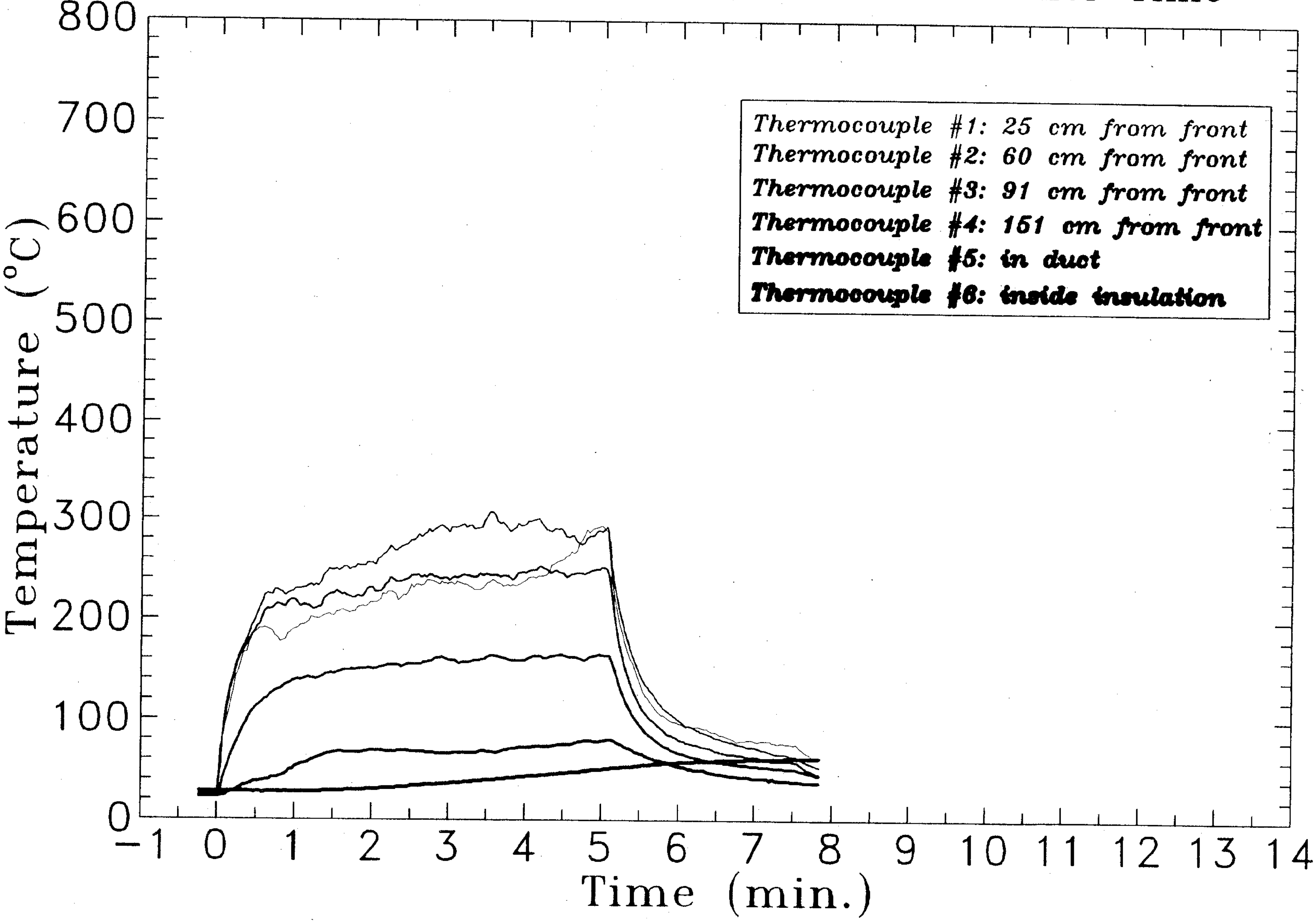


Fig.3. Belt #5: Trial #3, 5.0 min. Burner Time

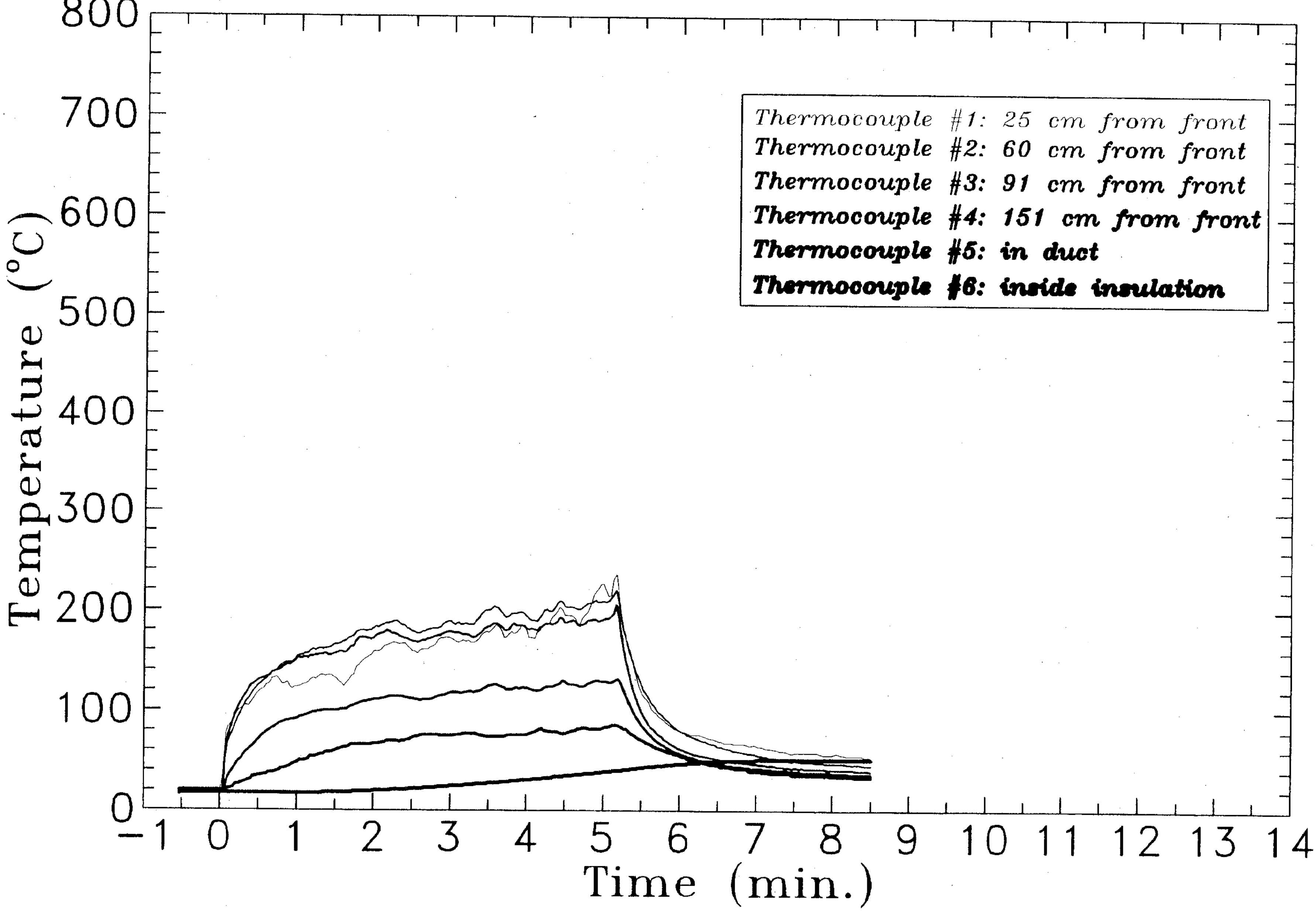


Fig.4. Belt #6: Trial #1, 5.0 min. Burner Time

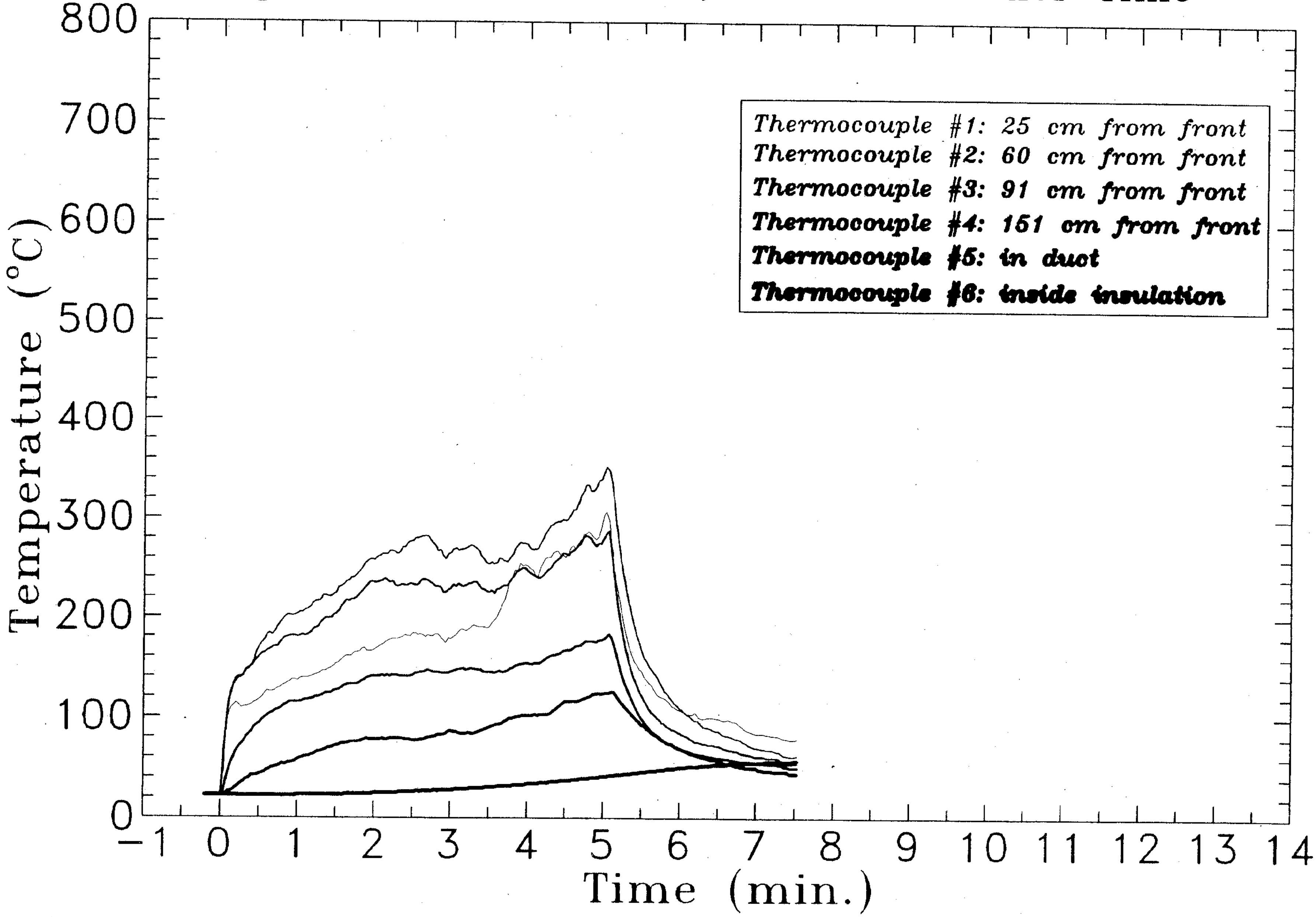


Fig.5. Belt #6: Trial #2, 5.0 min. Burner Time

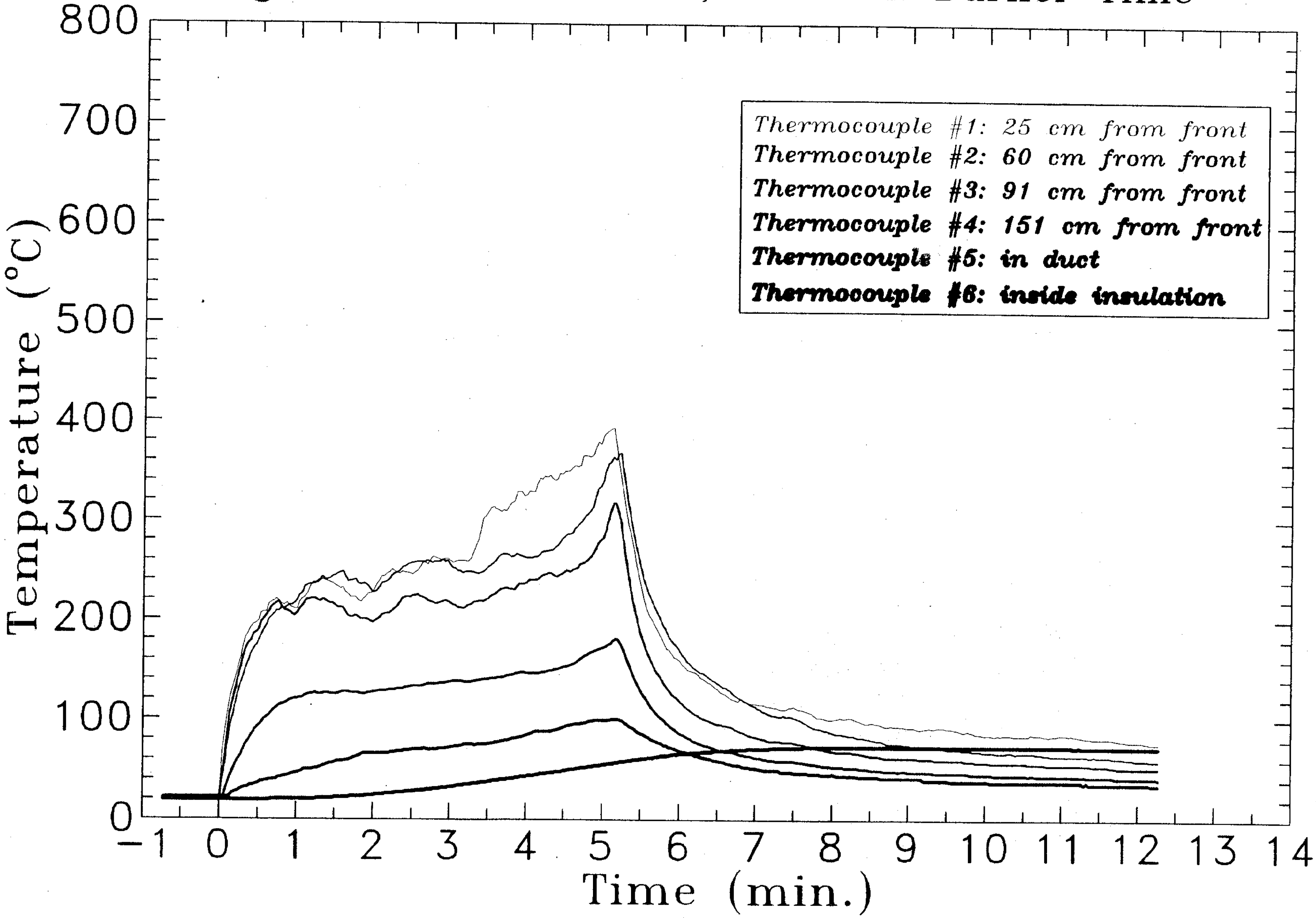


Fig.6. Belt #6: trial #3, 5.0 Min. Burner Time

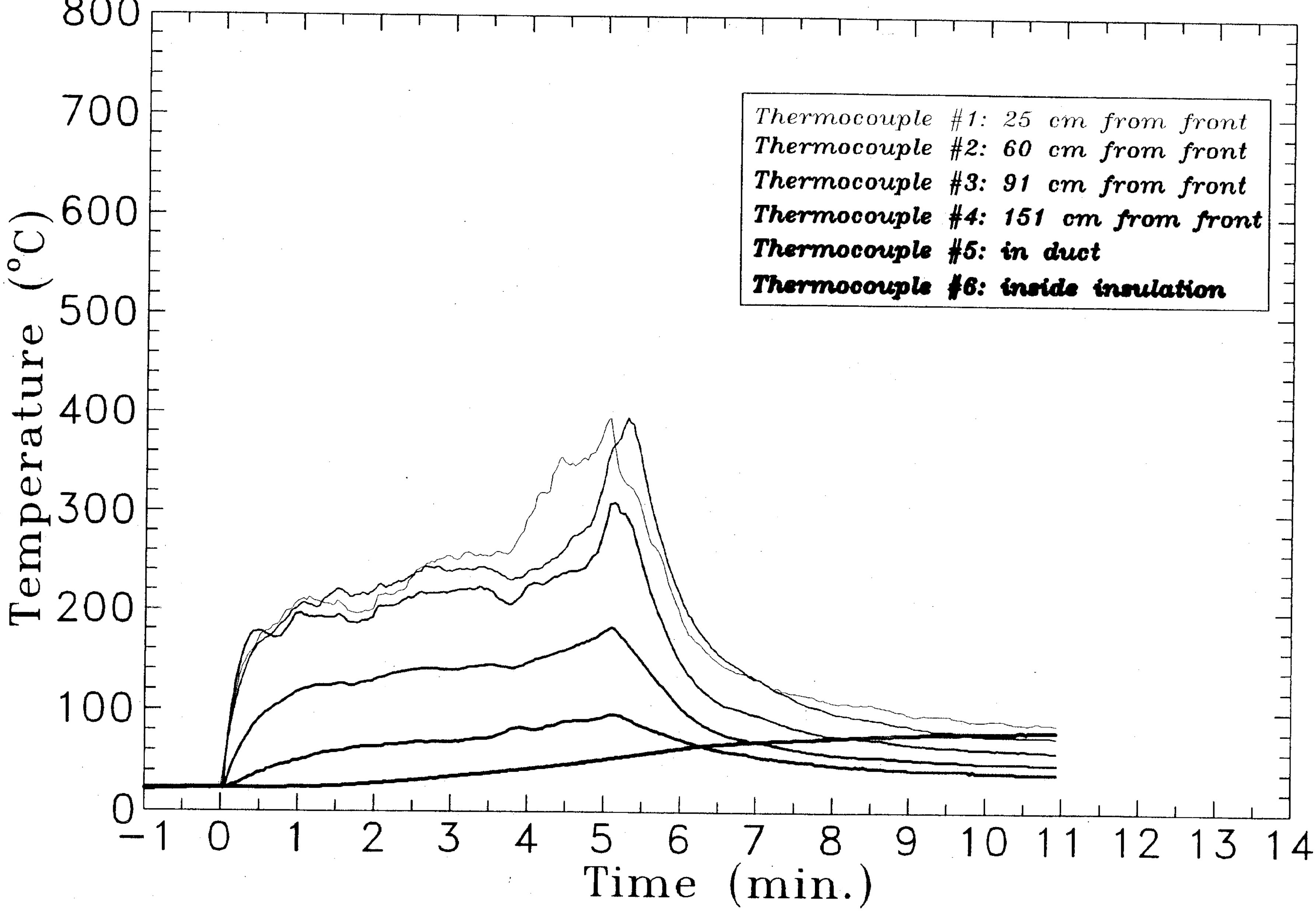


Fig.7. Belt #7: Trial #1, 5.0 min. Burner Time

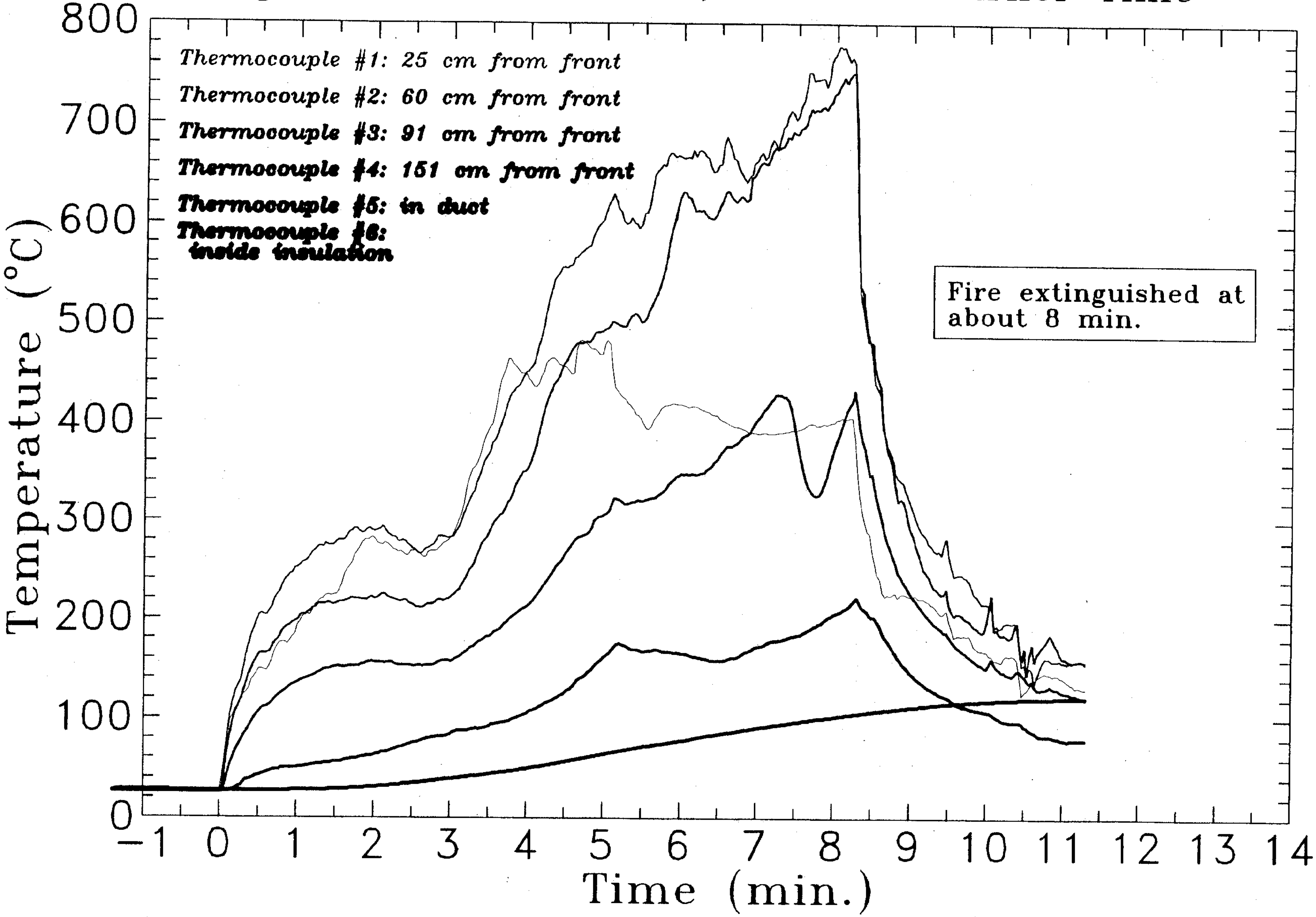


Fig.8. Belt #8: Trial #1, 5.0 min. Burner Time

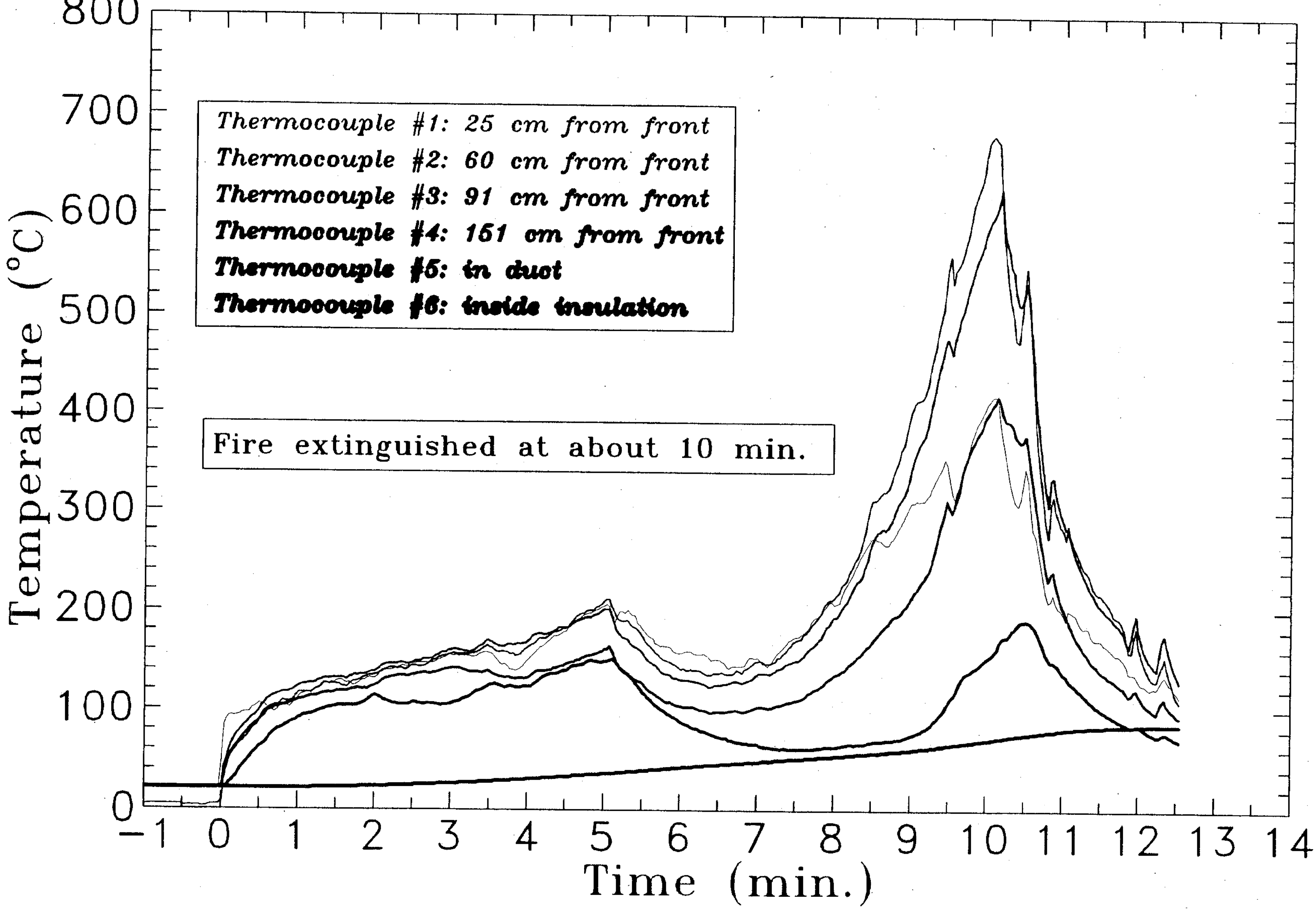


Fig.9. Belt #9: Trial #1, 5.0 min. Burner Time

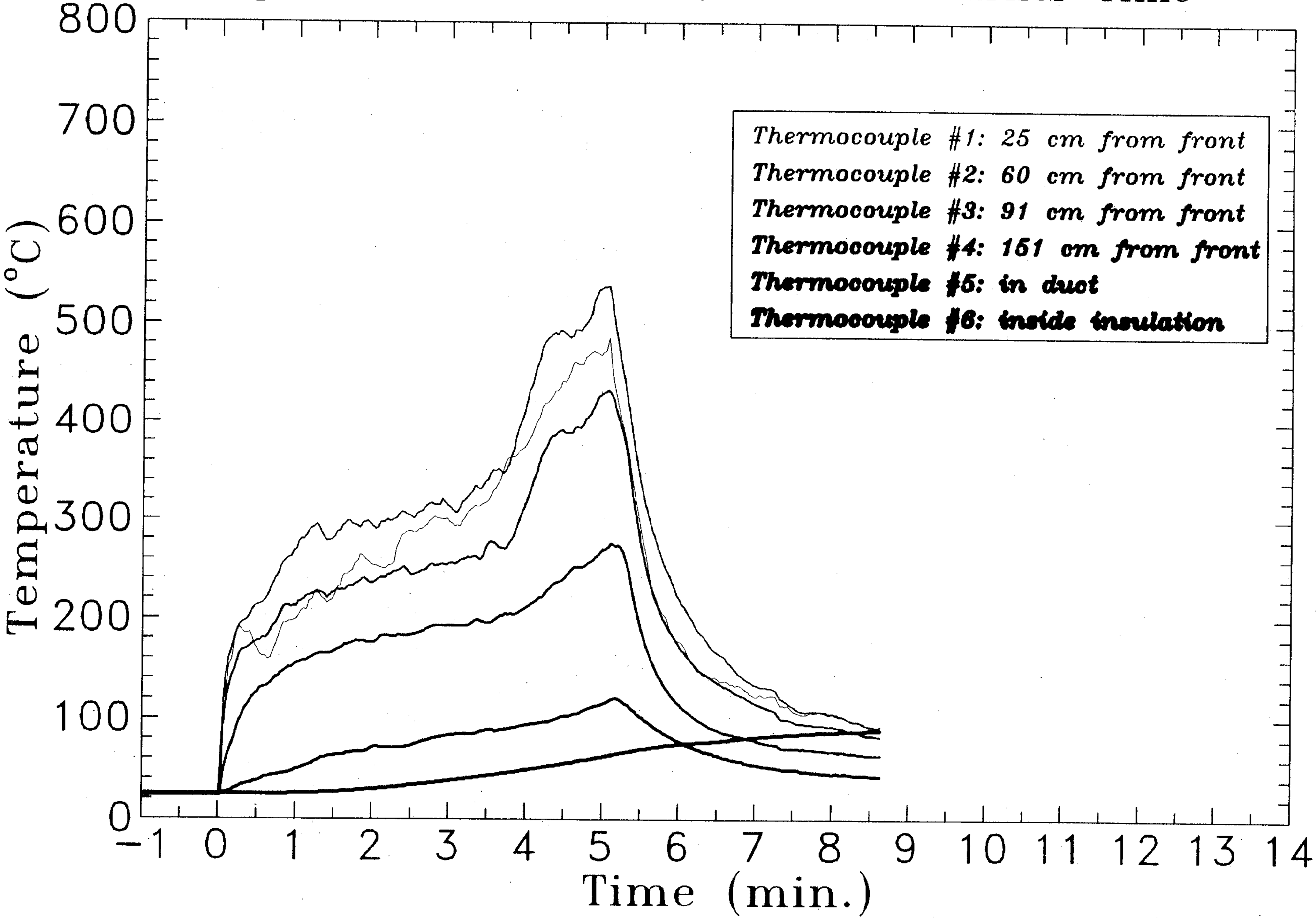
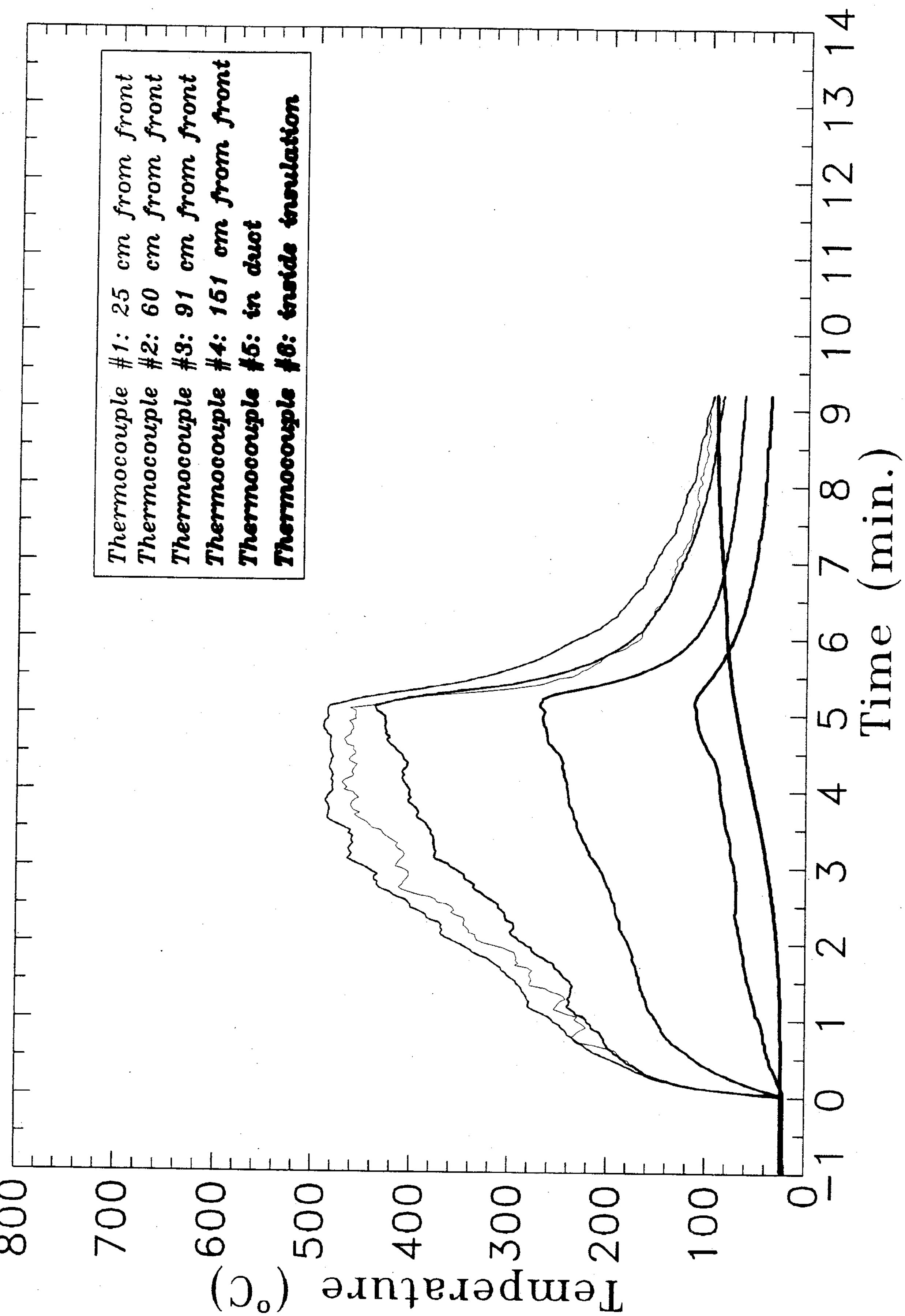


Fig.10. Belt #9: Trial #2, 5.0 min. Burner Time



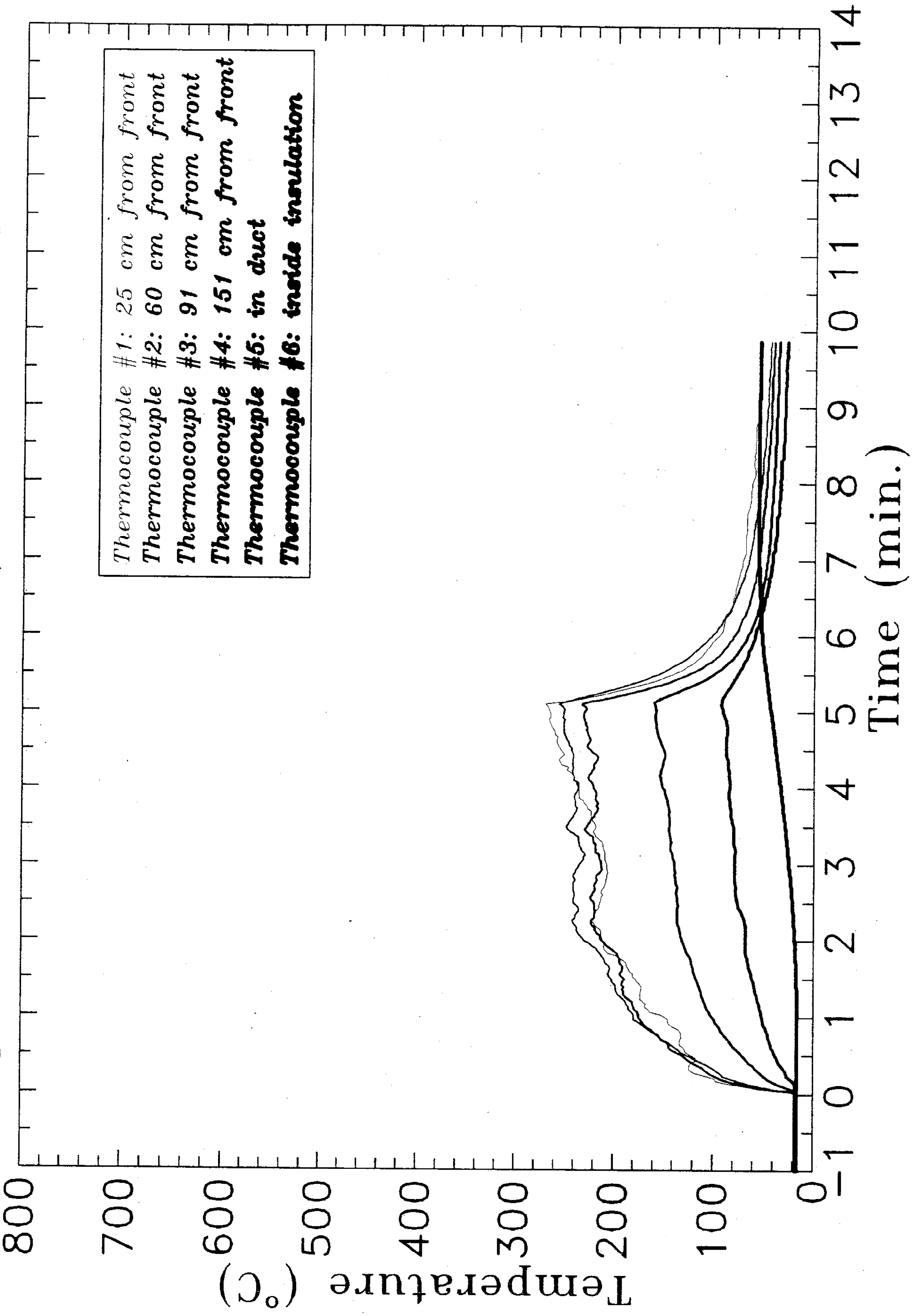


Fig.11. Belt #10: Trial #1, thin side down

Fig.12. Belt #10: Trial #2, thick side down

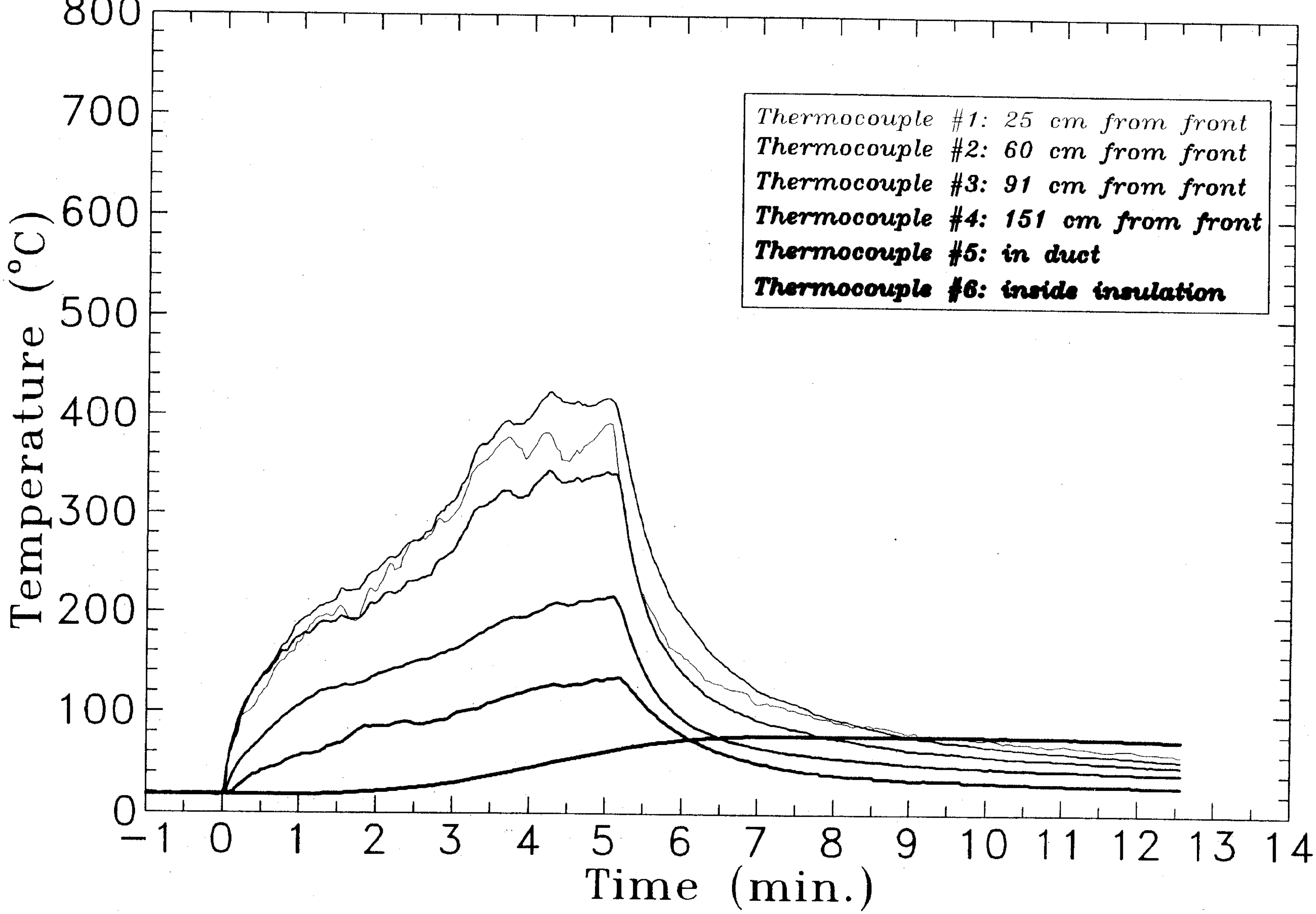


Fig. 13. Temperature/traces for Belt #11 (Thin PVC)

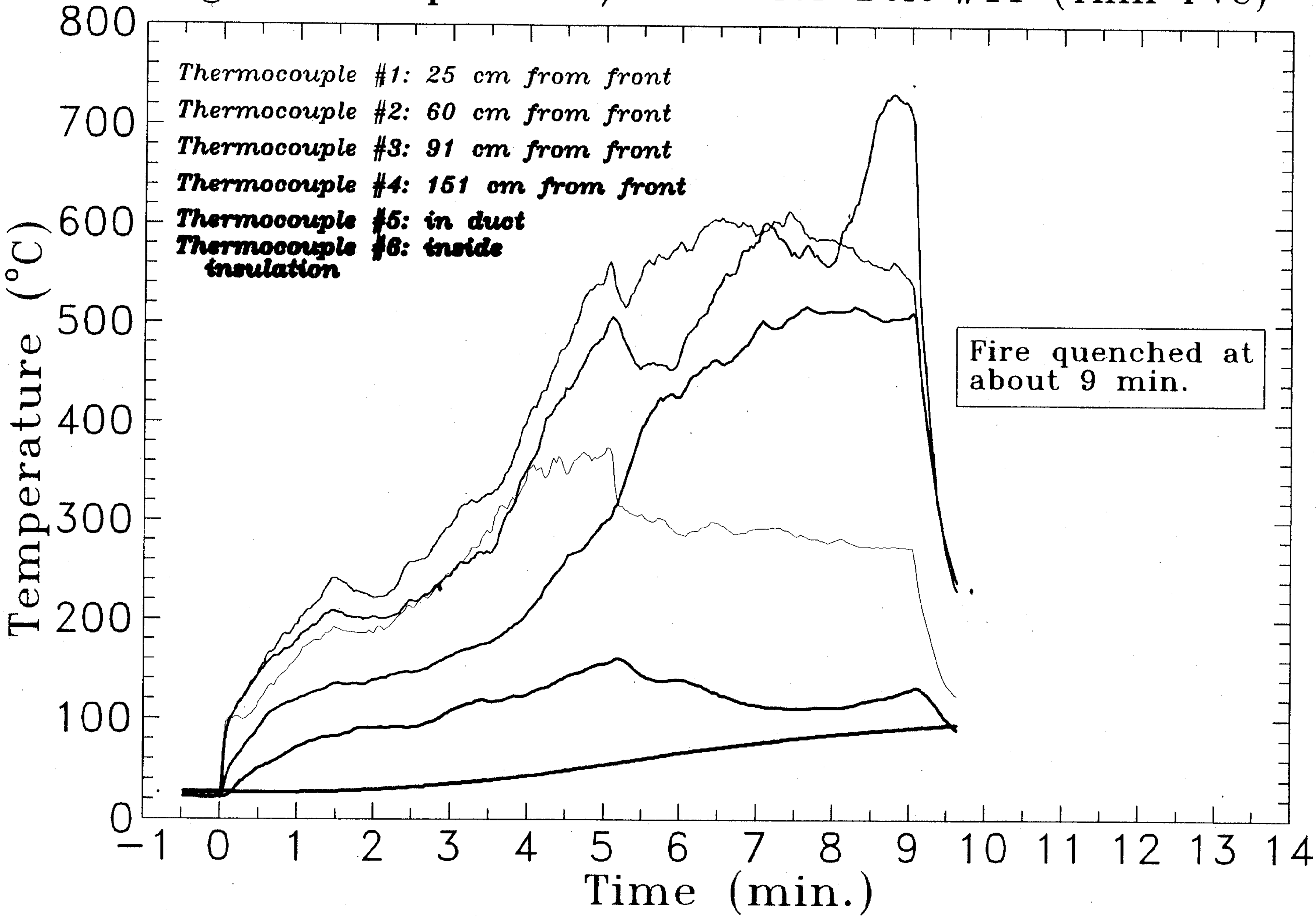


Fig.14. Temperature/traces for Belt #12 (Thick PVC)

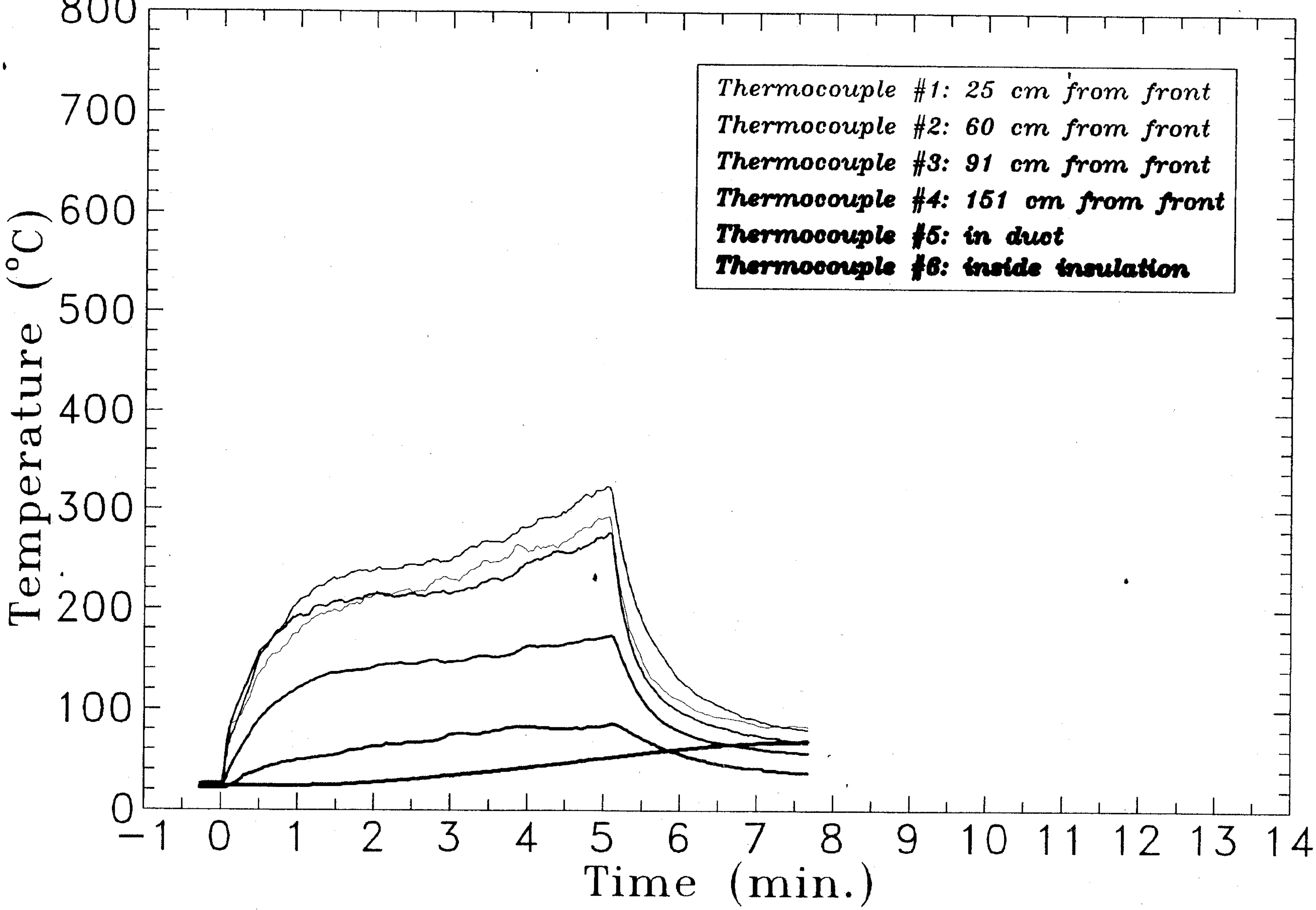


Fig.15. Calculated Temperature Rise, Assuming Belt Absorbs All Heat

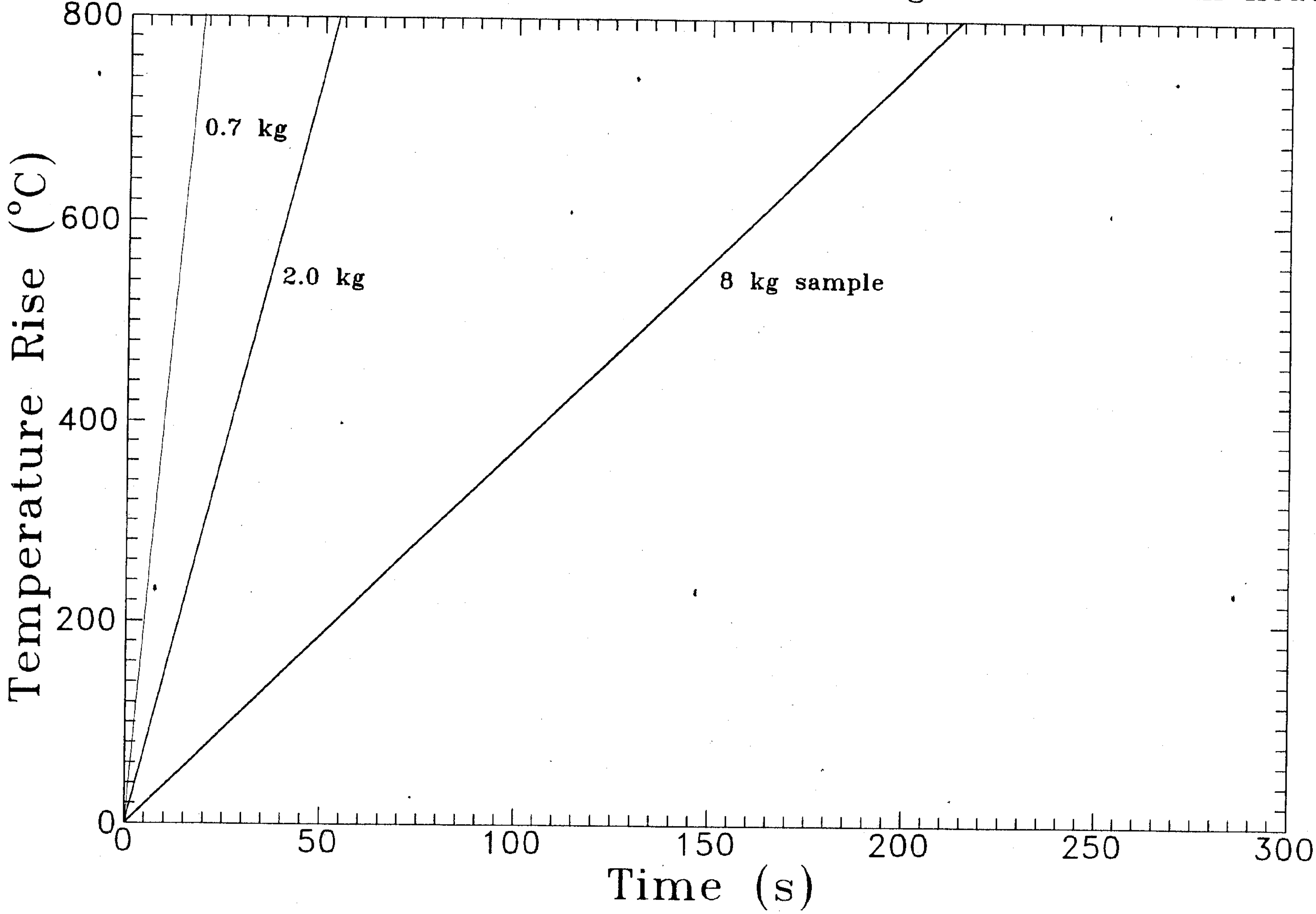


Fig.16. Calculated Temperature Rise, Assuming Ventilation Air is 100% Effective

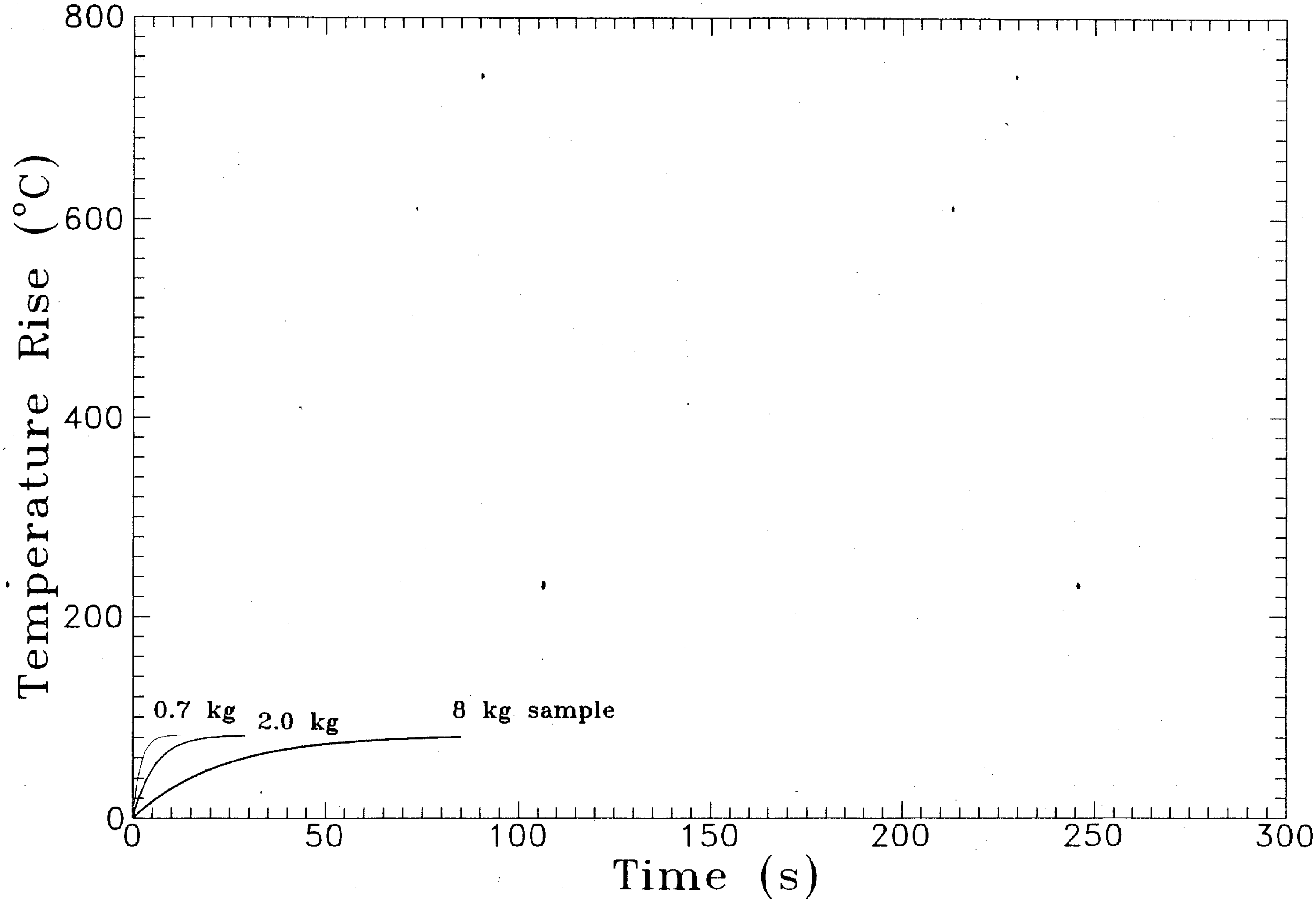


Fig.17. Calculated Temperature Rise, Assuming Ventilation Air is 10% Effective