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DIVISION OF BUILDING RESEARCH

ST. LAWRENCE BURNS
RADIOMETER MEASUREMENTS

by

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PREFACE

The circumstances that led to the carrying out of fire tests on eight buildings in the project known as the St. Lawrence Burns, and the objectives and the ways in which these were achieved are fully described in a general report. It constitutes the complete record of the planning and execution of the experiments, together with all general information. The details on each kind of measurement made, including the results obtained, are contained in separate companion reports of which this is one. All the results are combined and are discussed and final conclusions drawn in a summary report.

Duplication has been avoided as far as possible and it will be necessary to refer to the general report in reading any of the other reports including this one for any information which is pertinent to more than one of them. A listing of all reports on the project follows this preface.

The participation of the British Joint Fire Research Organization in the experiment, the interest and support of the Federal Civil Defence authorities, the assistance of the Ontario Fire Marshal and his staff, and finally the complete co-operation and very considerable assistance extended by the Hydro-Electric Power Commission of Ontario are all gratefully acknowledged. It is a pleasure also to be able to record the special contribution made by members of the staff of the Fire Section who worked long hours, often under trying field conditions and at great personal inconvenience, to meet the many deadlines and to complete the project in a most satisfactory manner.

The author of this report is Mr. J. H. McGuire, now research officer with the Fire Section of this Division, who as a member of the staff of the British Joint Fire Research Organization planned and supervised the measurements made with the radiometers, anemometers and resistance thermometers.

Ottawa
December 1959

N. B. Hutcheon
Assistant Director

REPORTS ON THE ST. LAWRENCE BURNS

No.	Sub-Title	Author
150	General Report	G.W. Shorter
151	Smoke and Sound Measurements	G. Williams-Leir
152	Temperature Measurements	G. Williams-Leir
153	Radiometer Measurements	J.H. McGuire
154	Ventilation Rate Measurements	J.H. McGuire
155	Resistance Thermometer Measurements	J.H. McGuire
156	Radiant Temperature of Openings	D.G. Stephenson
157	Gas Analysis	J.R. Jutras
158	Summary Report	G.W. Shorter and J.H. McGuire

ST. LAWRENCE BURNS
RADIOMETER MEASUREMENTS

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Early in 1958 a number of controlled burning experiments were carried out at Aultsville, Ontario, by the Fire Section of the Division of Building Research, National Research Council. The general details of these experiments, which involved the burning of six dwellings and two larger buildings, are described in the first of a series of reports on the St. Lawrence Burns (1).

One of the objects of the tests was to provide information on the spatial separations which should be established between buildings in order to reduce the likelihood of spread of fire by radiative heat transfer. This report describes the instrumentation of the experiments from this aspect and lists the results obtained.

INSTRUMENTS

The type of radiometer used is illustrated in Fig. 9. The sensing element consists of a thin blackened gold disc with a 40 swg chromel-constantan thermocouple attached. It is mounted behind a thin mica window in the body of the radiometer, which is heavy brass to ensure that the rate of temperature rise of the body is small compared with the initial rate of temperature rise of the disc. A second disc and thermocouple are mounted within the enclosure to constitute a cold junction. A typical calibration is illustrated in Fig. 10. This calibration has been found to be almost independent of ambient temperature. As the instruments were specially made for use during the St. Lawrence burns no time was available to determine accurately the effect of draughts. This work is now in hand, however, and will be described in a later report, although a provisional estimate of the effect is that it is small - less than 10 per cent for the winds experienced during the fire tests.

The radiometers were connected by copper-cored cables to a 0- to 5-millivolt, 16-channel recorder printing at a rate of once every four seconds. Fixed carbon resistance potentiometers were included, mounted near the recorder, to introduce suitable scale factors. The nominal value of the resistor connected across the recorder was always 100 ohms and the resistor in series with the radiometer ranged between 100 ohms (nominal) and 330 ohms (nominal). Since the recorder was of the servo-potentiometric type and the resistance between the terminals of the radiometers was less than two ohms, the scale factor introduced by the resistance potentiometers was purely a function of the values of the resistances involved.

FIELD DETAILS

Locations of the radiometers are shown in Figs. 1 to 8. For the first burn three were placed at different distances from the same side of Building No. 1 with the object of deriving the form of the relation between radiation level and distance from the side of the building. To a close approximation interpolation would give the radiation level at an intermediate point between radiometers. During the course of the fire, it was noticed that the wind direction greatly affected radiation levels; those on the leeward side were far greater than those on the windward side because of the greater volume of flame issuing from the windows on the leeward side. It was therefore decided that measurements should be taken on both sides of the buildings, and for subsequent experiments one radiometer was located on the windward side and two at different distances from the leeward side.

It was also observed during the course of the first burn that while the radiation incident on the nearest radiometer originated almost entirely from the fire in the main building, the more distant radiometers were also irradiated by a shed which ignited earlier than was expected. In subsequent tests, ignition of sheds was suppressed and the buildings were stripped of porches, verandahs, etc., which would have substantially influenced radiation measurements.

The radiometers adjacent to the houses were always mounted at a height of 15 ft, at which it was estimated the radiation level would be a maximum. In the case of the larger buildings the nearer radiometers were mounted at a height of 20 ft, the maximum possible with the mounting systems used, although it was estimated that the intensity of radiation might have been slightly greater at a level some 5 ft higher.

In the case of the most distant radiometer the mounting height was only 10 ft, as at this range no great variation of intensity with height, up to about 30 ft, would be expected.

RESULTS AND DISCUSSION

The results are given in Figs. 11 to 18. To allow comparison of the various results the configuration factors of the window and other unprotected openings have been calculated for every point at which a radiometer was located. Dividing the results by the appropriate configuration factors gives hypothetical values of the radiation levels at the openings. These values should not be taken as the black-body emissions of the openings since there was considerable volume of flame above the windows, particularly on the leeward side, which made substantial contribution to the measured levels of radiation remote from the buildings. To determine the effectiveness of this approach as a means of comparing results, Figs. 19 to 25 have been plotted, each figure relating to the two radiometers located on the same side of a building. This concept appears to be useful, for there is a fair measure of agreement between the two curves in each figure. Agreement in the cases of burns No. 4, 5, and 6 (Figs. 21, 22 and 23) is good, and for burns No. 2 and 3 (Figs. 19 and 20) it is acceptable. In the case of the school burn (No. 8, Fig. 25) the agreement is poor. This results largely from the fact that the windows of the school annex made a substantial contribution to the configuration factor at the more distant radiometer, but not at the nearer one. At the time when the radiation from the main body of the building was a maximum the fire in the annex was not fully developed. Values of the hypothetical radiation level at the windows, derived from the results given by the more distant radiometer, are thus much lower than those relating to the nearer one. Agreement for burn No. 7 (Fig. 24) is also marred, to a lesser extent, by a similar effect.

No curves are given for the first burn, because as stated in the previous section the more distant radiometers were also irradiated by a shed which ignited earlier than was expected.

Most combustible materials will ignite within a minute when exposed to a threshold level of radiation, and the maximum values of radiation measured are thus of considerable interest. These are given in Table I. Confining discussion to the hypothetical radiation levels at window openings and using the term radiation level only in this context, the maximum values for the fourth and seventh burns are about the same, as are those for the third and fifth burns. It would, therefore, seem that the use of clapboard exterior cladding does not appreciably increase the maximum levels of radiation from a dwelling. Where the dwellings were lined throughout with highly combustible material, as in buildings No. 3 and 5, values of up to

40 cal/cm^2/sec were obtained. Where the linings were noncombustible, as in buildings No. 4 and 7, the maximum levels of radiation were only about half this value. Building No. 2 gave a maximum value of only 11 cal/cm^2/sec, although it included fibreboard and plywood linings downstairs. It is thought that this was due partly to the absence of combustible linings upstairs and partly to the low speed of the prevailing wind. The ventilation rate measurements and some theoretical considerations (2) indicate that the inlet air speeds involved in a house fire do not usually exceed 7 mph as long as the roof remains intact. Ambient wind speeds of as much as 10 to 14 mph, as prevailed in the tests on the last four houses, could have had a substantial effect on the rate of burning.

Examination of Table I also indicates that radiation levels on the leeward side of a building were often much higher than those on the windward side, but a quantitative analysis of the effect would require further investigation. From physical considerations it seems likely that nonlinearities would be involved. For example, when a wind speed attains a critical value it would be expected that no flames would emanate from windows on the windward side of a building. During certain stages of several of the fires this effect was apparent.

It is of interest to compare the maximum value of the hypothetical radiation level at window openings, given above (40 cal/cm^2/sec), with the black-body temperature measurements given elsewhere (3). At no time was a black-body temperature higher than 1000°C recorded, although it is possible that a slightly higher temperature might have developed in the community hall about 32 minutes after the start of the fire. The radiation level corresponding to a black-body temperature of 1000°C is about 3.6 cal/cm^2/sec so that it follows that the window openings themselves only made a small contribution to the peak levels of radiation recorded by the radiometers.

CONCLUSIONS

The following general conclusions can be drawn from the results given above:

1. The radiation levels from buildings completely lined, internally, with combustible materials may be double those where noncombustible linings are used.

2. If I is the intensity of radiation at a distance from a building and F is the configuration factor for the window openings at the point of measurement,

then I/F is a convenient factor by which the radiation levels from different buildings may be compared. The maximum values of I/F for buildings completely lined with combustible material were of the order of 40 $cal/cm^2/sec$.

3. The contribution of radiation from openings in the exterior walls was, at the periods of peak radiation, substantially less than that from the flames above and surrounding the windows.

4. A period of at least 16 minutes elapsed before maximum radiation levels were attained.

5. Radiation levels were affected by wind conditions, but the results obtained were not adequate to allow a quantitative analysis of the effects.

ACKNOWLEDGEMENT

Acknowledgement is due to Miss M. Law of the British Joint Fire Research Organization for much of the analysis of the results.

REFERENCES

1. Shorter, G.W. St. Lawrence Burns - General Report. N.R.C., DBR Internal Report No. 150, Nov. 1959.

2. McGuire, J.H. St. Lawrence Burns - Ventilation Rate Measurements. N.R.C., DBR Internal Report No. 154, Dec. 1959.

3. Stephenson, D. St. Lawrence Burns - Radiant Temperature of Openings. N.R.C., DBR Internal Report No. 156, Dec. 1959.

TABLE I

MAXIMUM RADIATION INTENSITIES

Burn and Building Number	Exterior Cladding	Interior Lining	Radiometer Numbers	Max. Intensity I ($cal/cm^2/sec$)	Config. factor of openings	I/F ($cal/cm^2/sec$)
1	Brick	Plaster	1 2 4	0.12* 0.15 0.09	₸ ₸ ₸	₸ ₸ ₸
2	Brick	Downstairs - fibre-board and plywood Upstairs - plaster	1 4 2	0.47 0.18 0.08	0.05 0.016 0.04	9 11 2
3	Brick	Fibreboard	1 4 2	1.25 >0.18 0.46	0.034 0.013 0.034	37 >14 14
4	Clapboard	Plaster	1 4 2	0.56 0.17 0.46	0.032 0.011 0.028	18 15 16
5	Clapboard	Pressed paper	1 4 2	1.05 0.32 0.35	0.027 0.008 0.012	37 40 29
6 (Community Hall)	Brick	Plaster; wooden ceiling	1 4 2	0.9 >0.41 0.42	0.075 0.031 0.075	12 >13 6
7	Brick	Plaster	4 3 5	0.9 0.38 0.08	0.058 0.018 0.044	16 21 2
8 (School)	Brick	Plaster; wooden ceiling	4 3 5	0.83 0.17 >0.5	0.049 0.019 0.088	17 9 >6

* Radiometer removed before peak level attained

₸ Not calculated

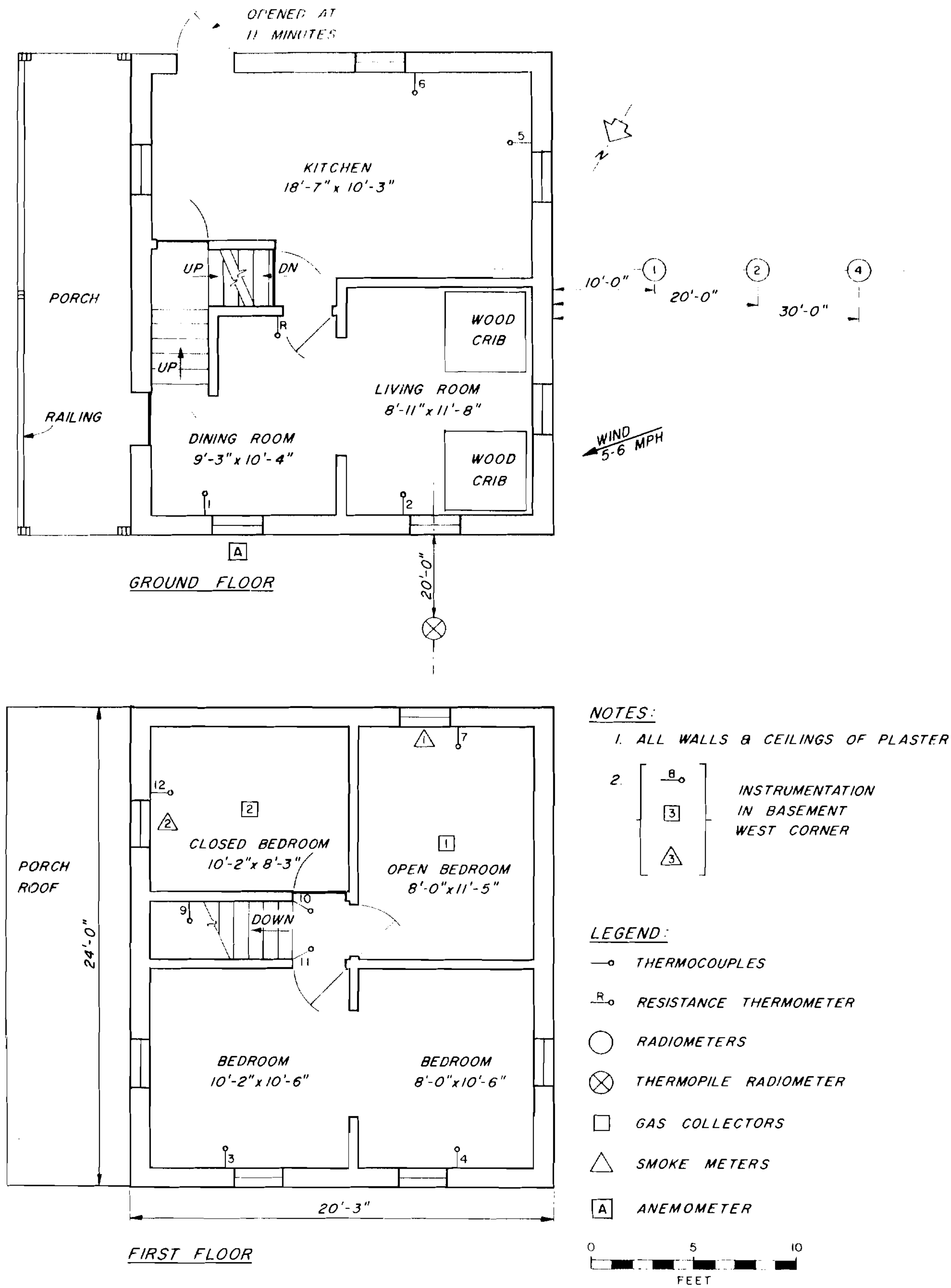


FIGURE 1 - BUILDING No. 1 - TWO-STOREY SOLID BRICK DWELLING

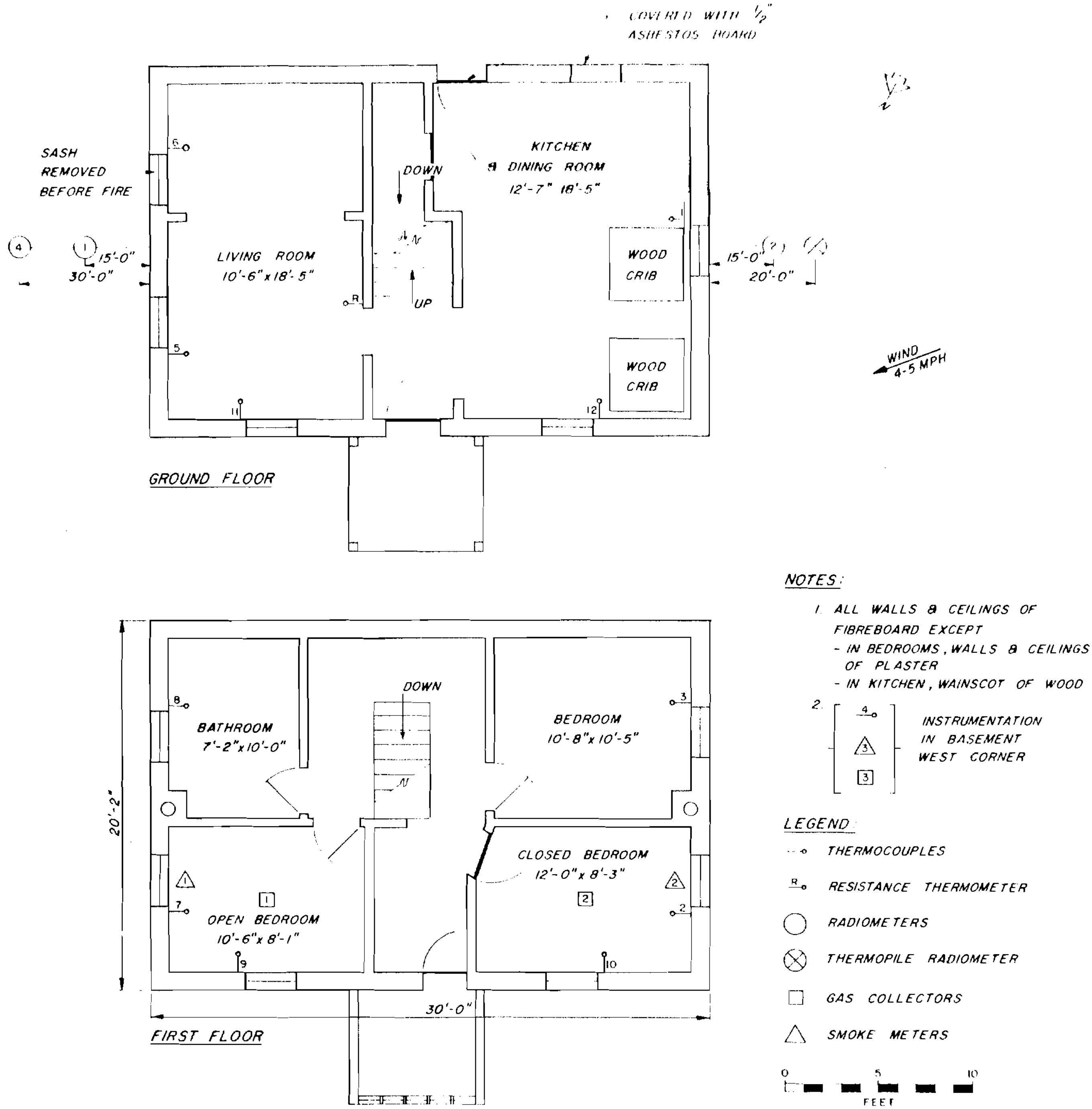
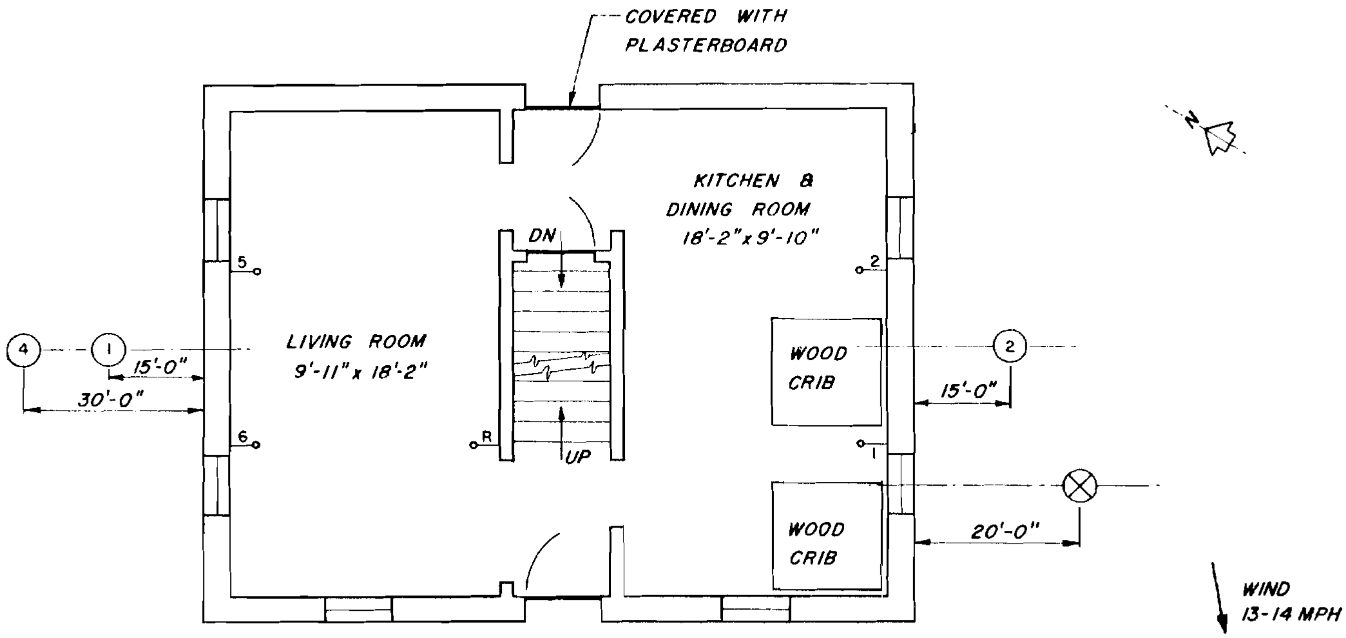
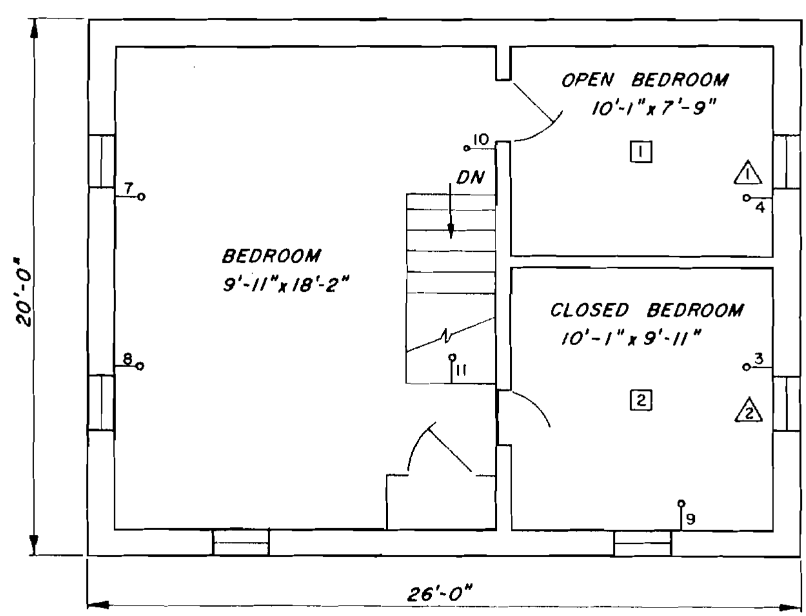


FIGURE 2 - BUILDING No. 2 - TWO-STOREY SOLID BRICK DWELLING



GROUND FLOOR



FIRST FLOOR

NOTES:

1. ALL WALLS & CEILINGS OF FIBREBOARD
2. INSTRUMENTATION IN BASEMENT WEST CORNER

LEGEND:

- THERMOCOUPLES
- RESISTANCE THERMOMETER
- RADIOMETERS
- THERMOPILE RADIOMETER
- GAS COLLECTORS
- SMOKE METERS

0 5 10 FEET

FIGURE 3 - BUILDING No. 3 - TWO - STOREY SOLID BRICK DWELLING

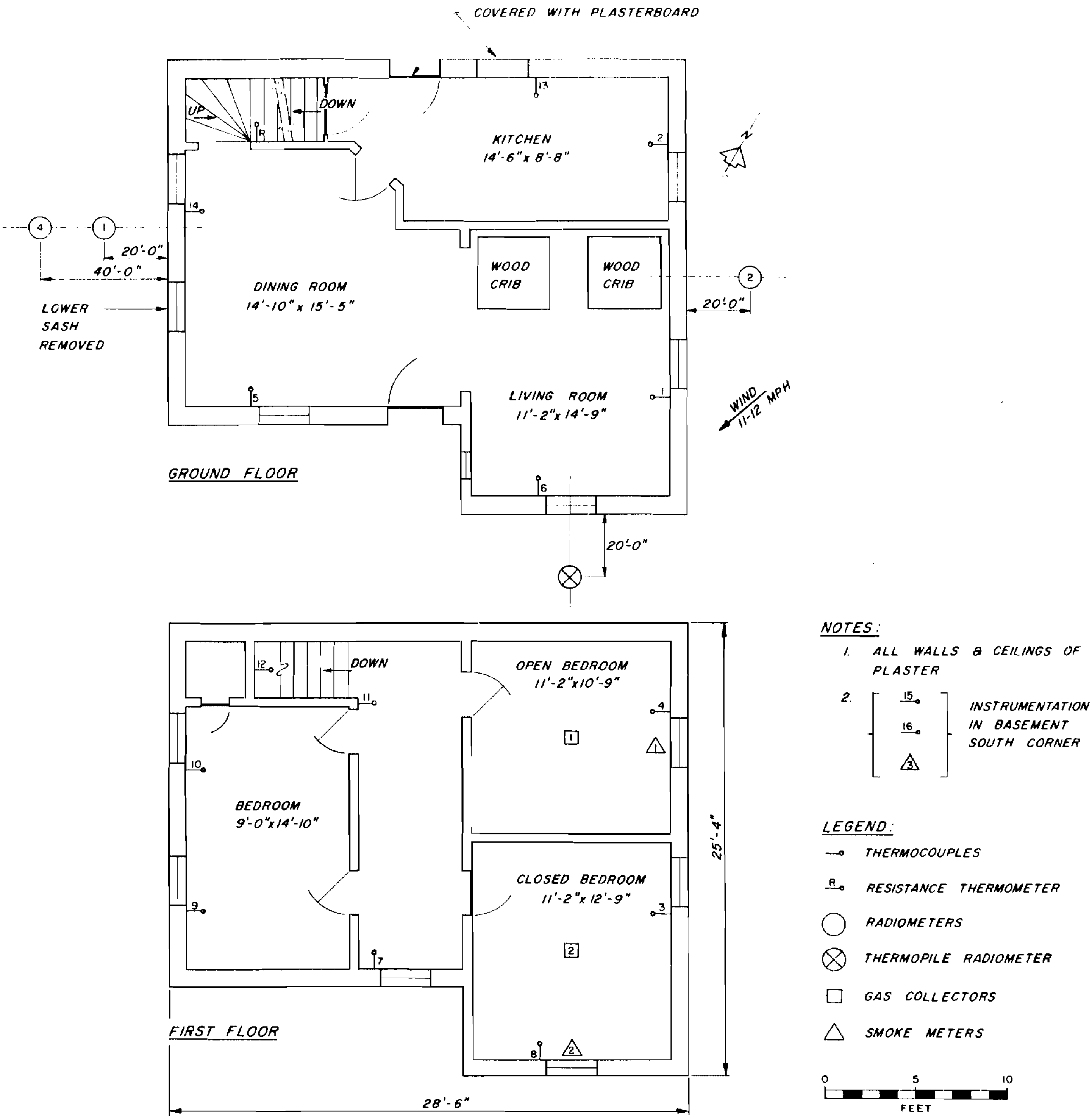


FIGURE 4 - BUILDING No. 4 - TWO - STOREY WOOD FRAME DWELLING WITH CLAPBOARD EXTERIOR AND BRICK INFILLING

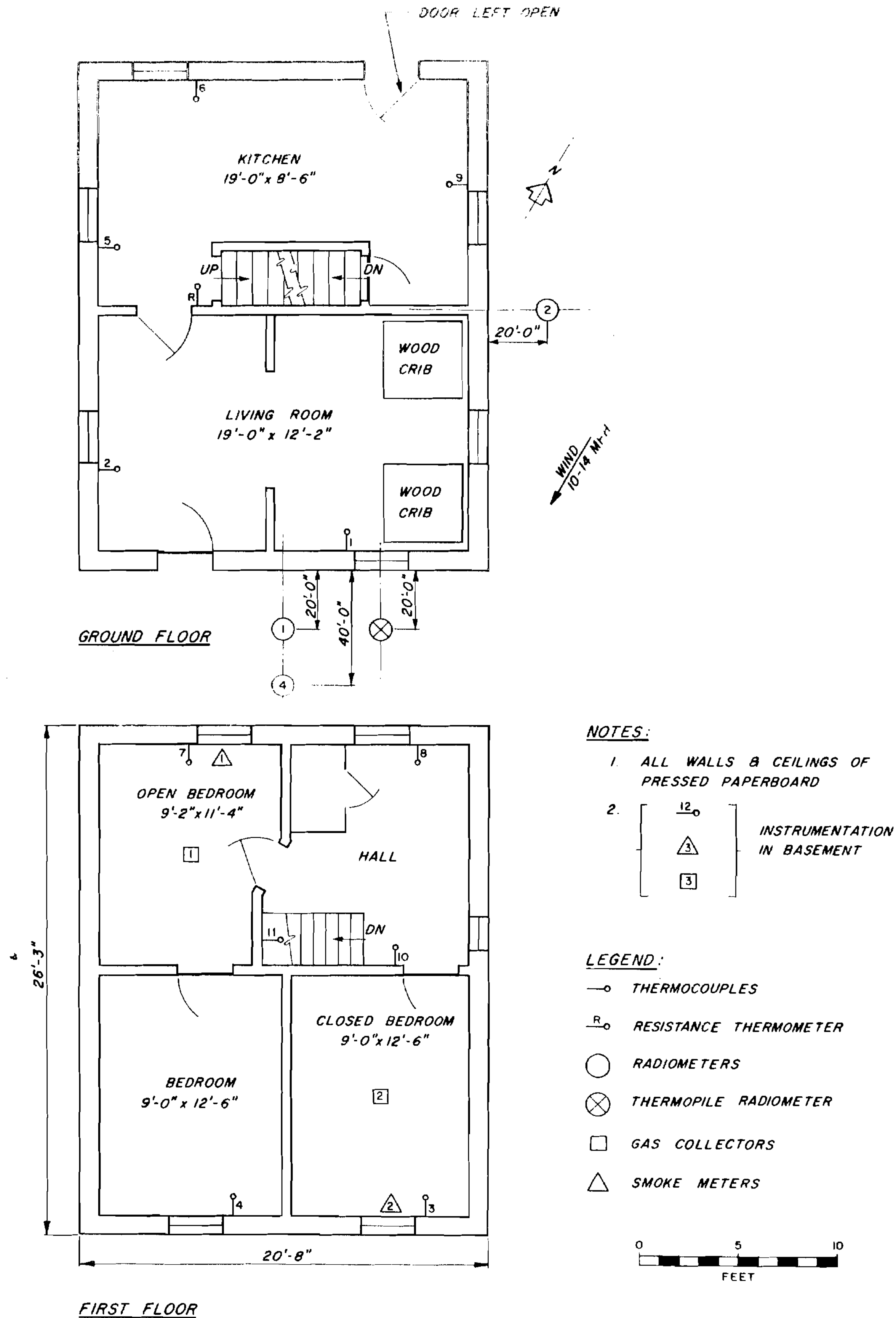


FIGURE 5 - BUILDING No. 5 - TWO - STOREY WOOD FRAME DWELLING WITH CLAPBOARD EXTERIOR

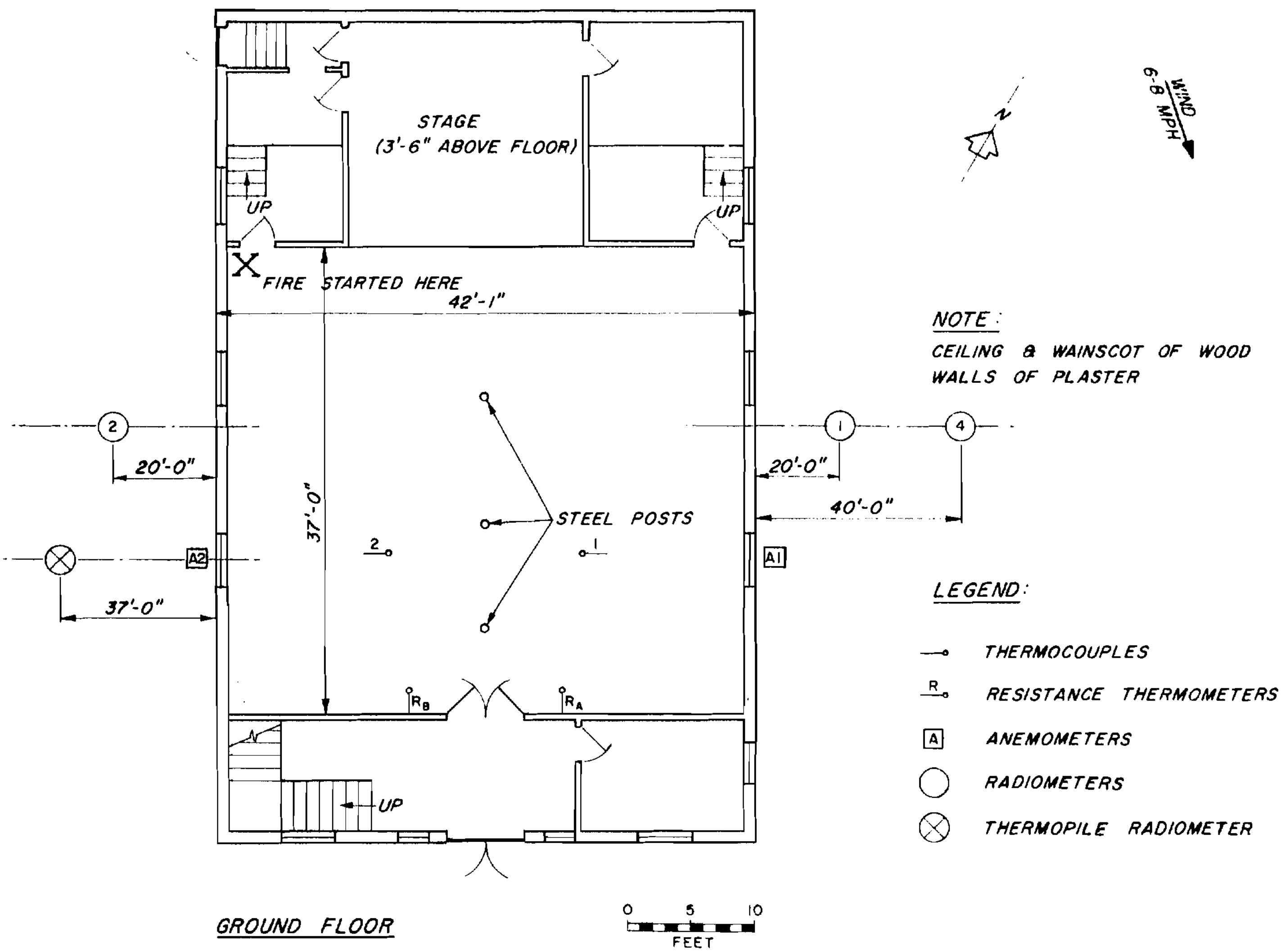


FIGURE 6 - BUILDING No. 6 - TWO - STOREY SOLID BRICK FRATERNITY HALL

FIGURE 6a - ELEVATIONS OF BUILDING No. 6 (FRATERNITY HALL)

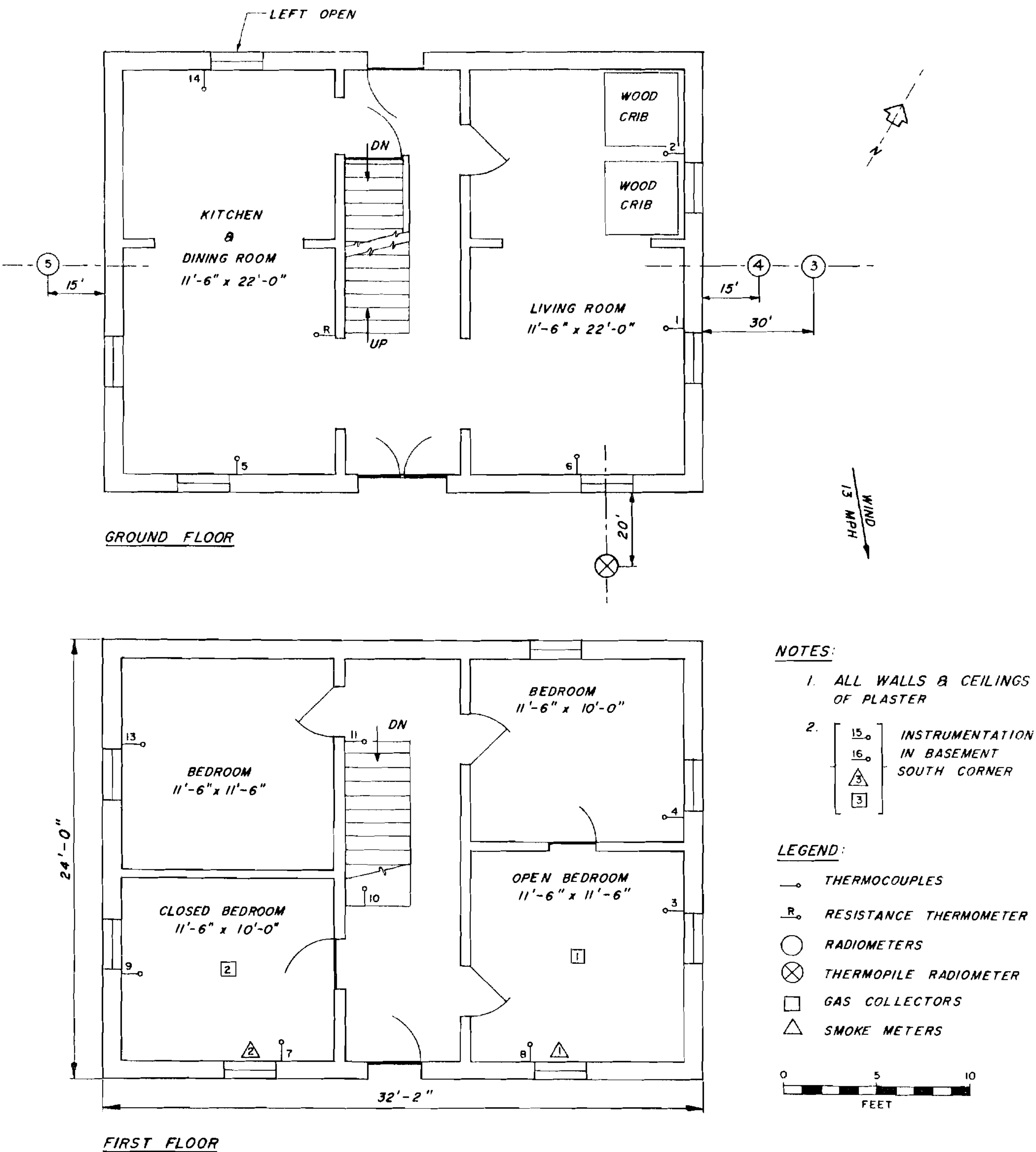


FIGURE 7 - BUILDING No. 7 - TWO - STOREY SOLID BRICK DWELLING

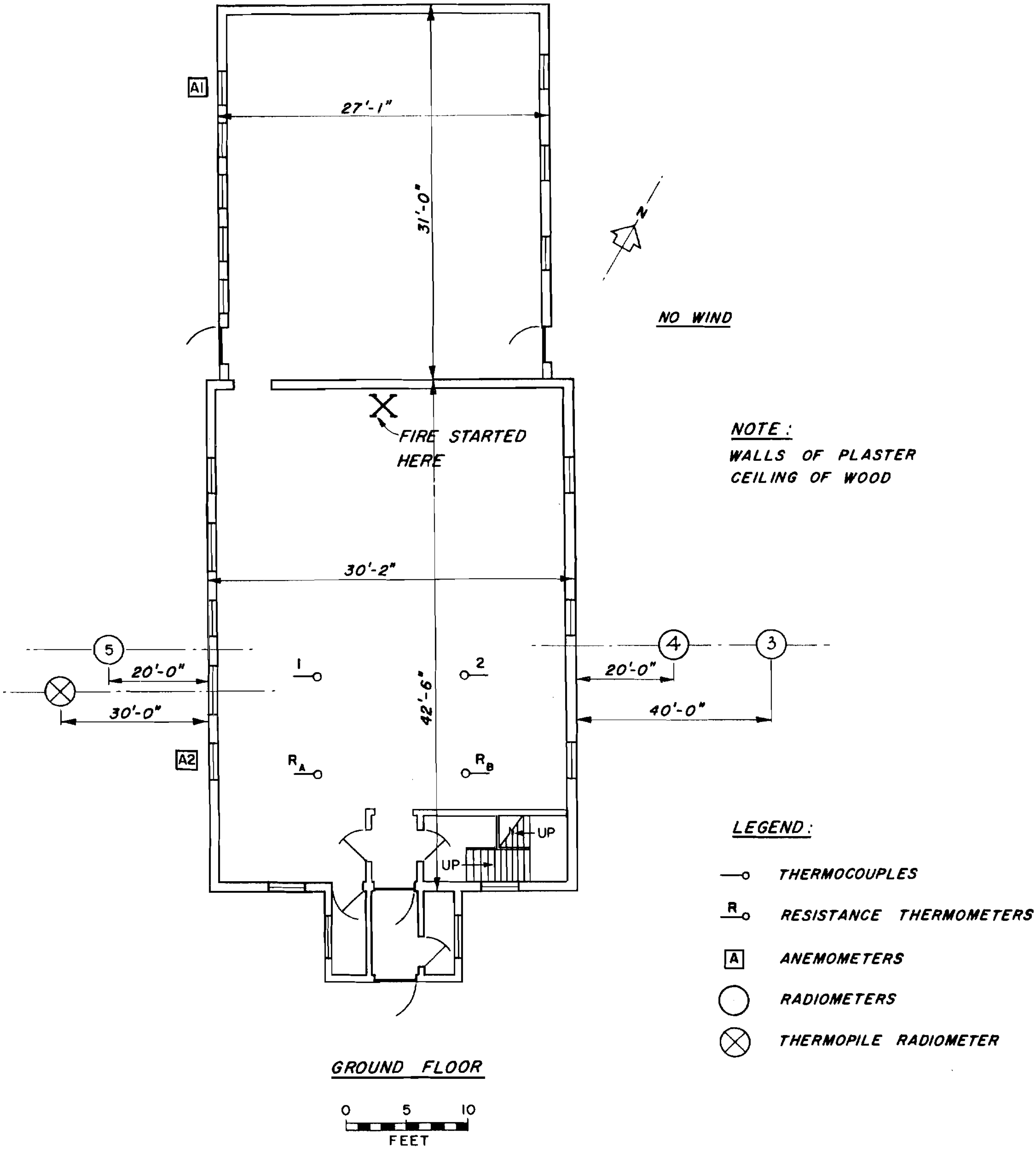


FIGURE 8 - BUILDING No. 8 - TWO - STOREY SOLID BRICK SCHOOL WITH ONE - STOREY EXTENSION AT REAR

FIGURE 8a – ELEVATIONS OF BUILDING No. 8 (SCHOOL)

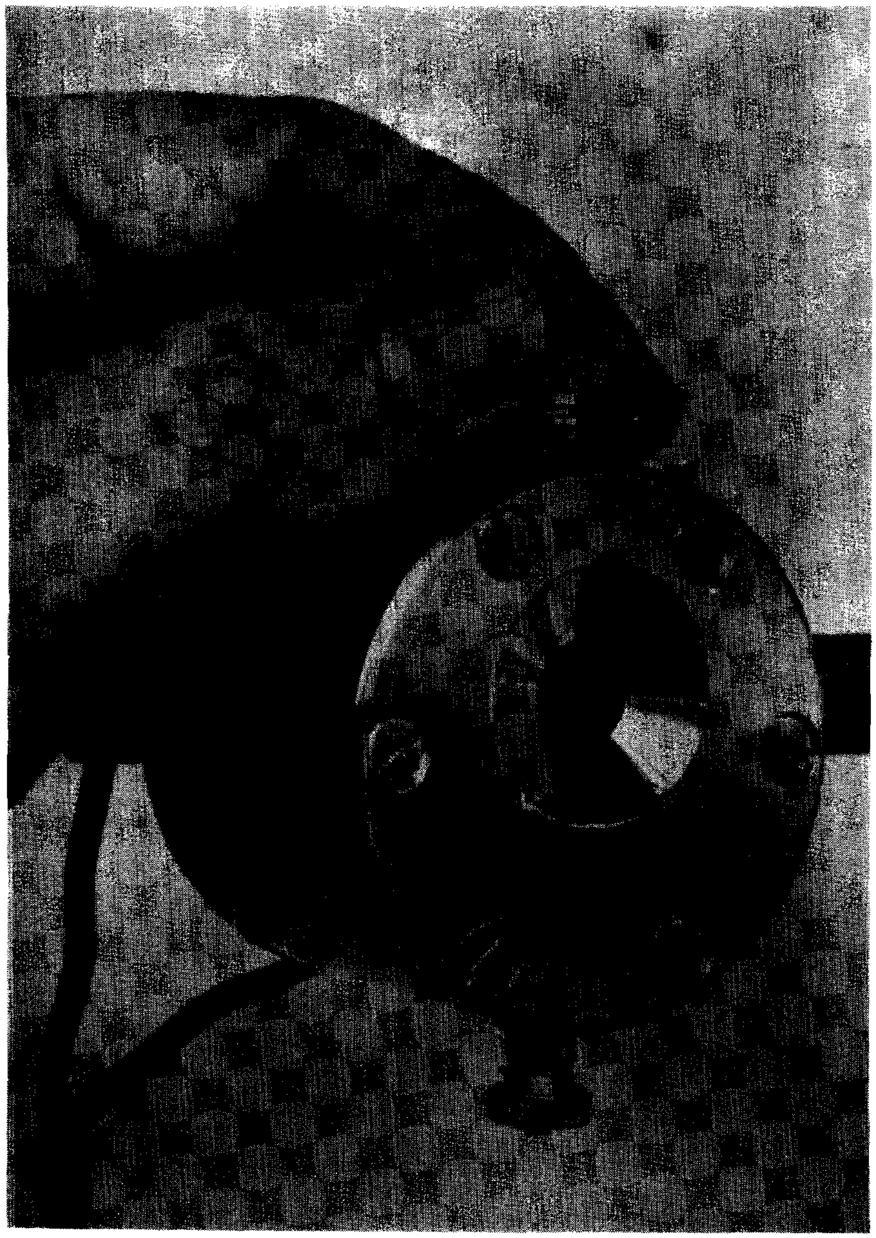


FIGURE 9 RADIOMETER

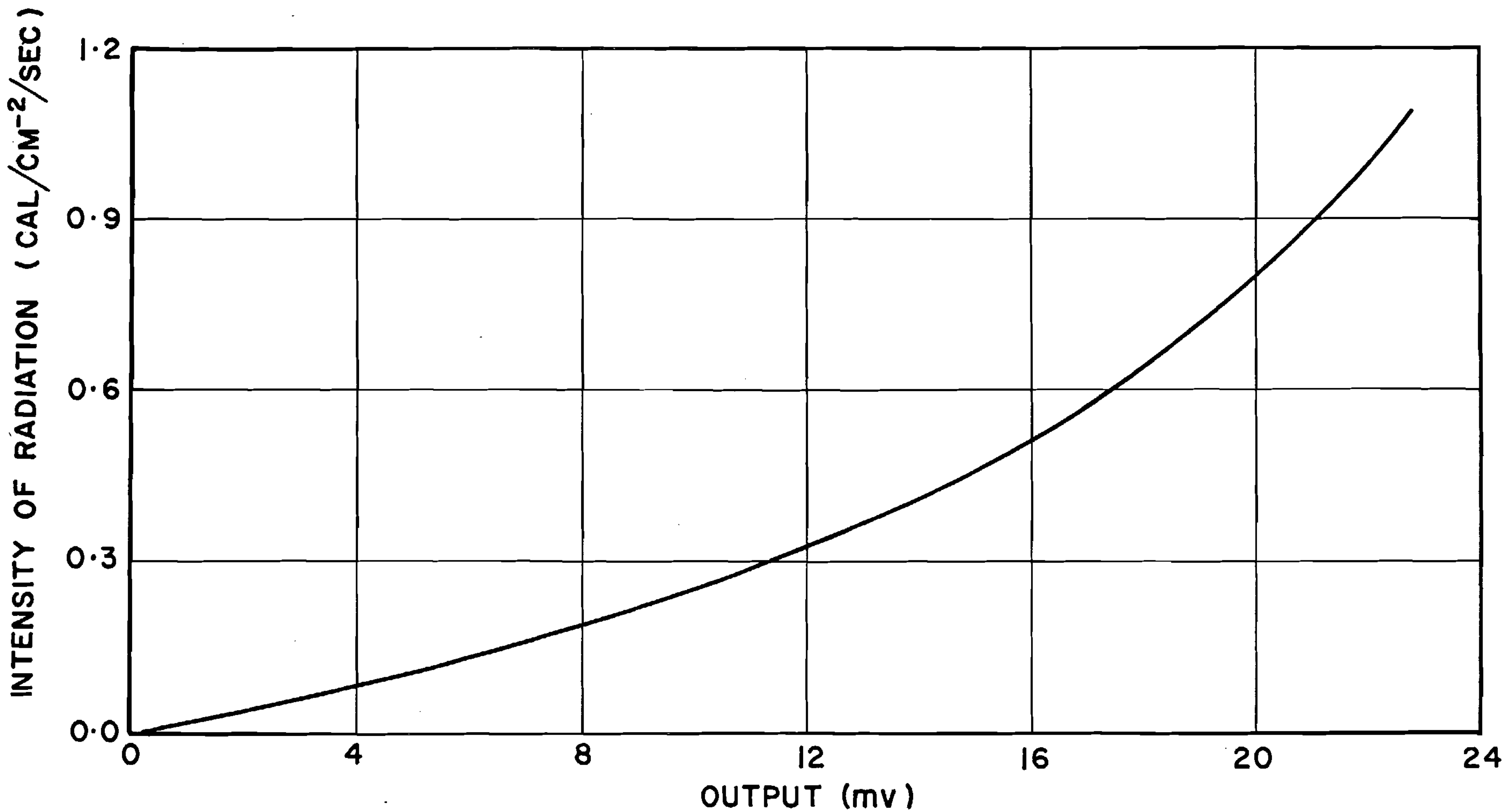


FIGURE 10 CALIBRATION OF RADIOMETER No. 2

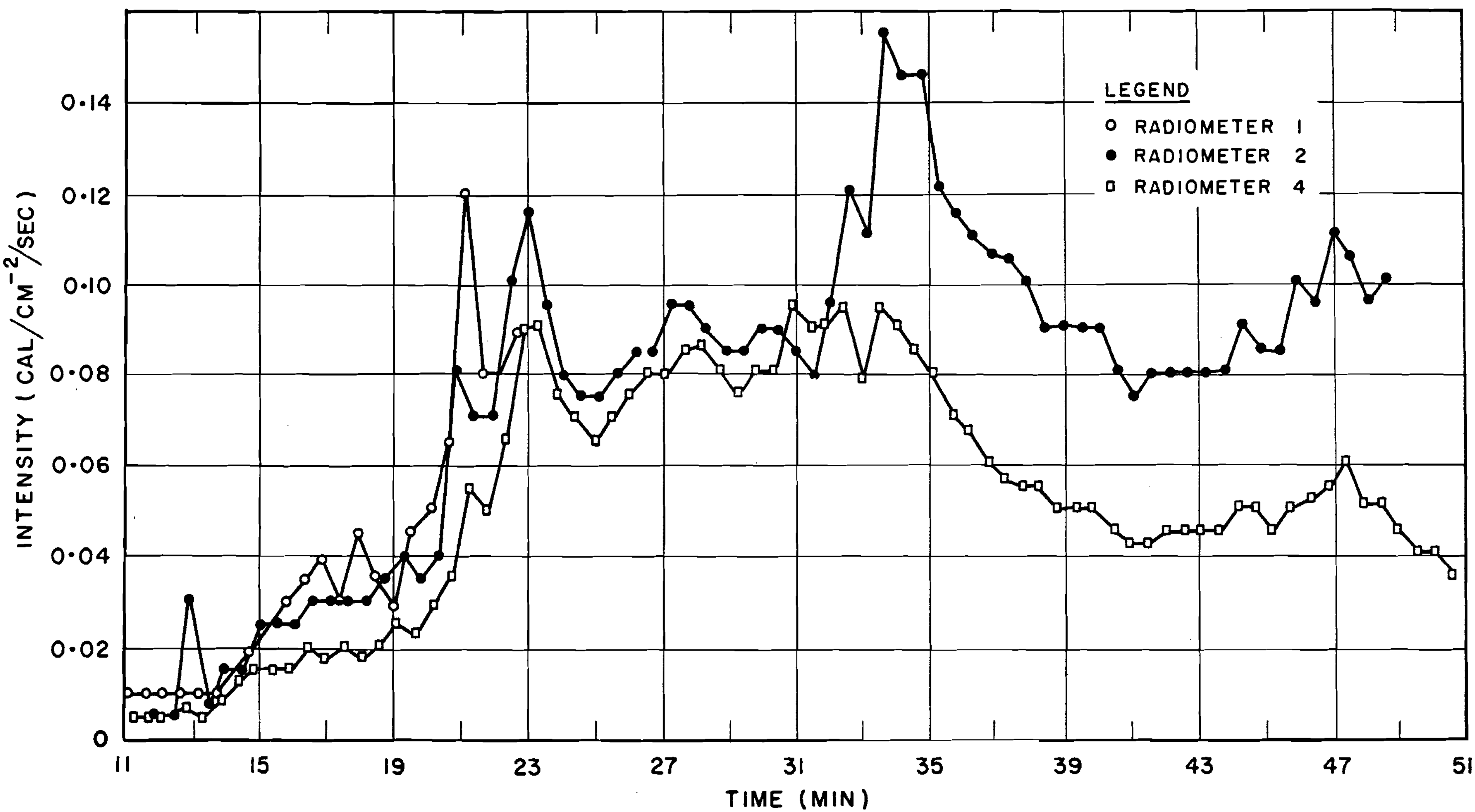


FIGURE 11 RADIATION LEVELS BURN No. 1

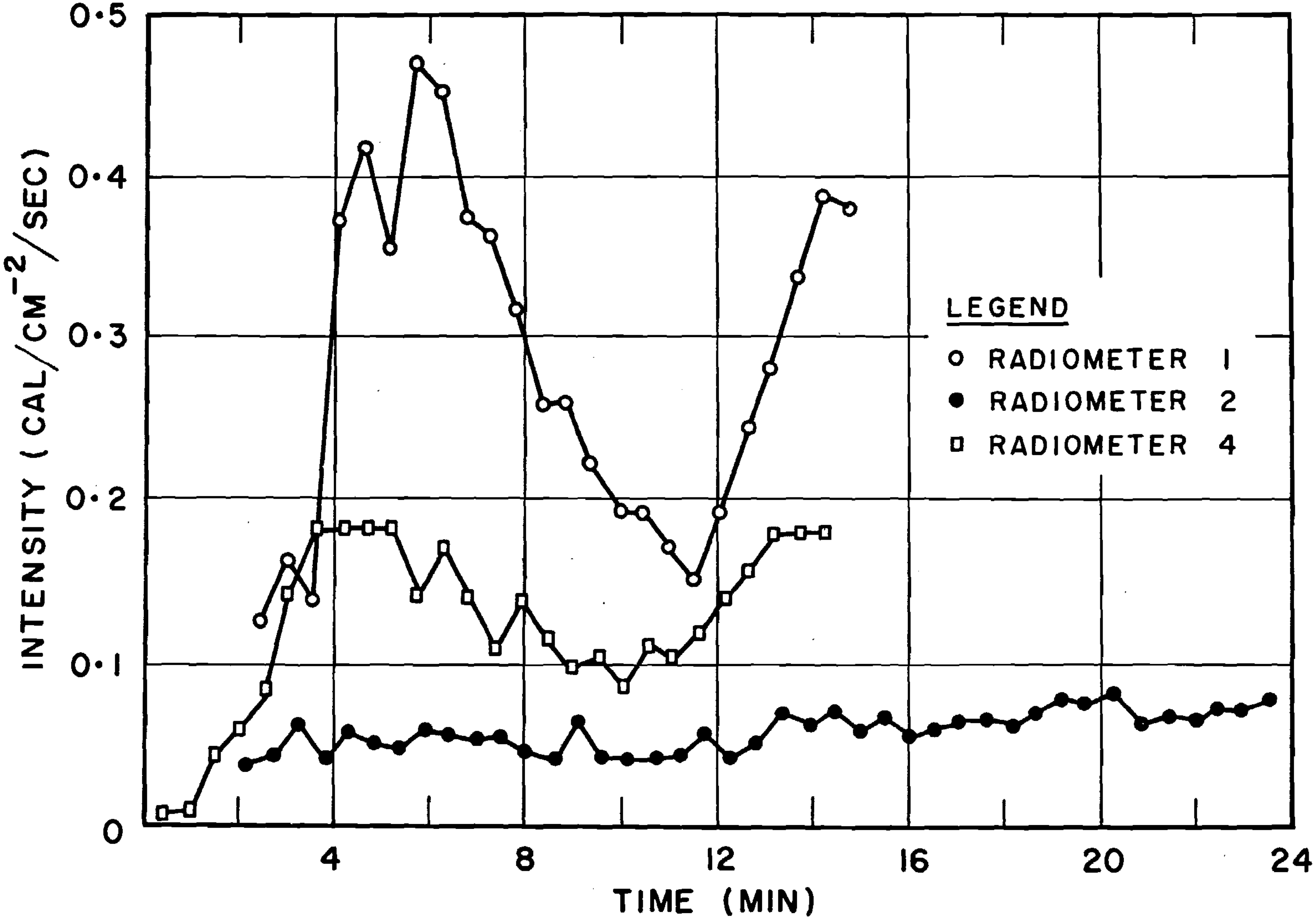


FIGURE 12 RADIATION LEVELS BURN No. 2

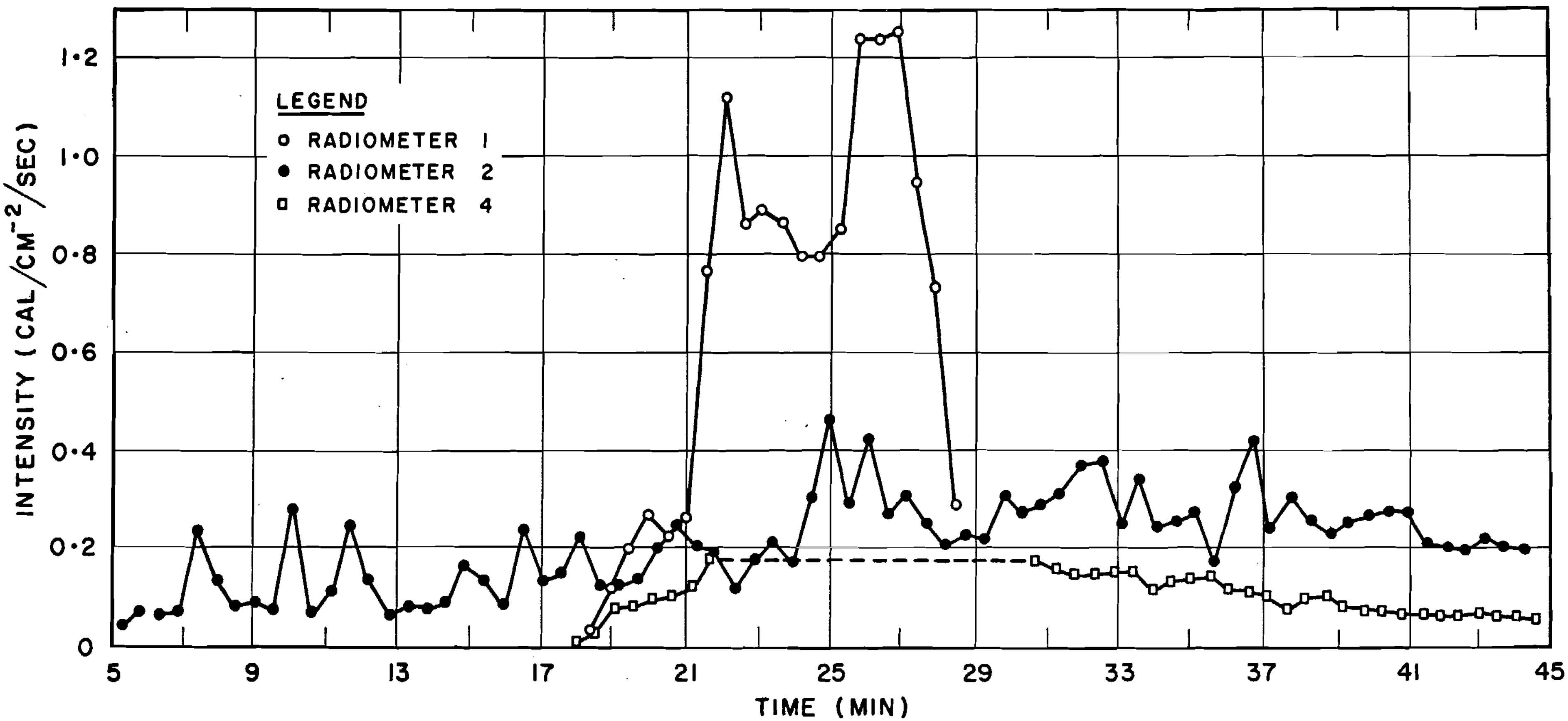


FIGURE 13 RADIATION LEVELS BURN No. 3

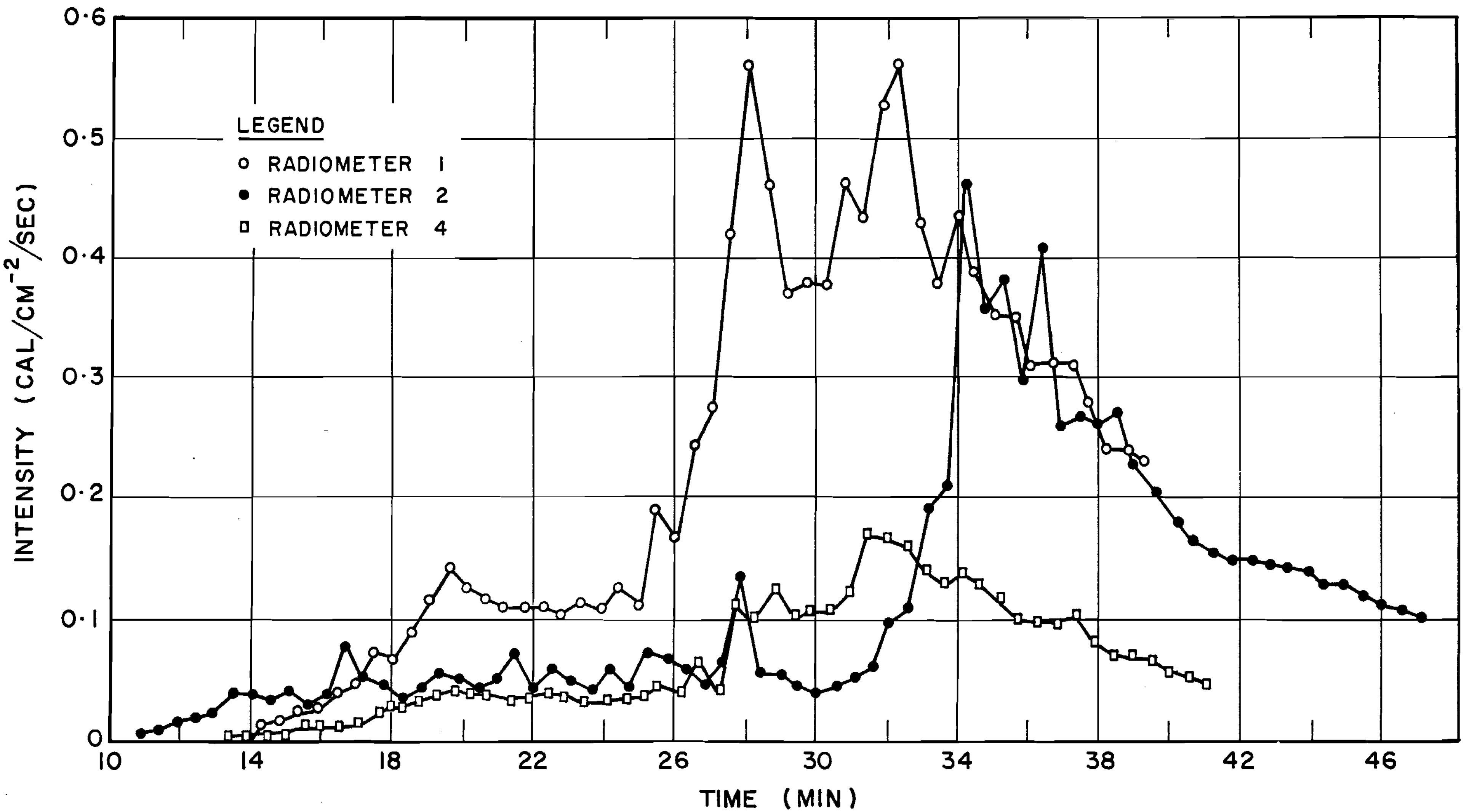


FIGURE 14 RADIATION LEVELS BURN No. 4

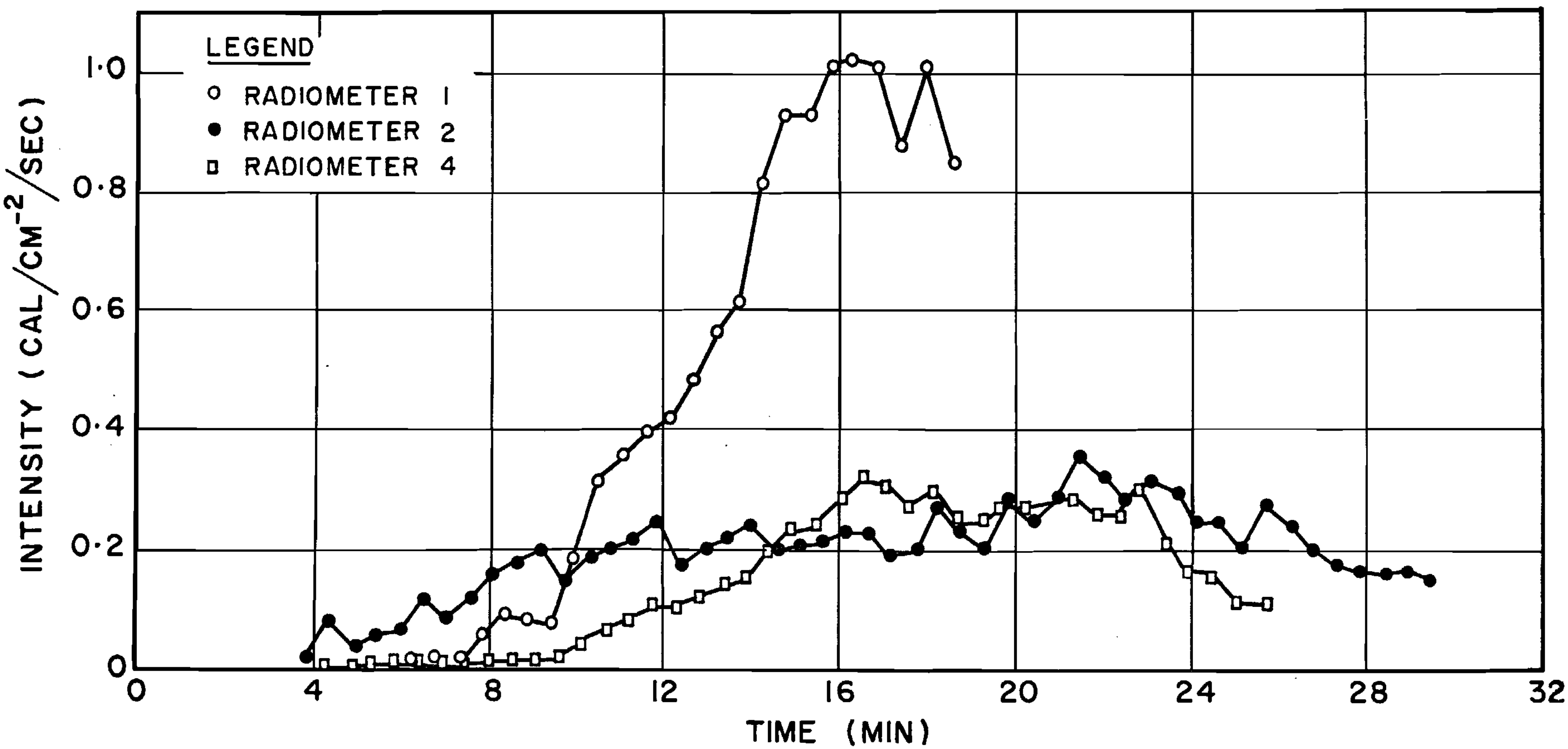


FIGURE 15 RADIATION LEVELS BURN No. 5

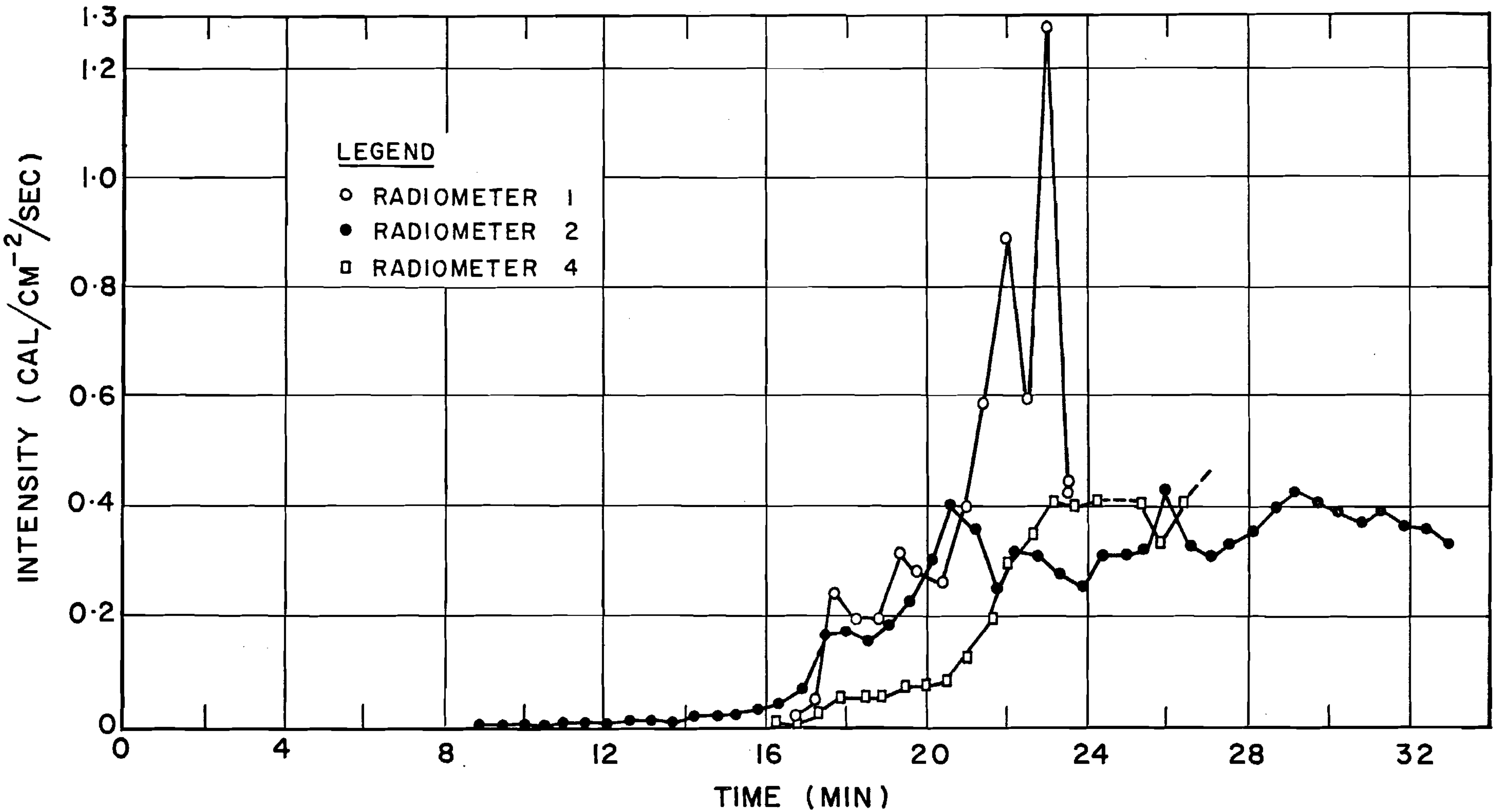


FIGURE 16 RADIATION LEVELS BURN No. 6
(COMMUNITY HALL)

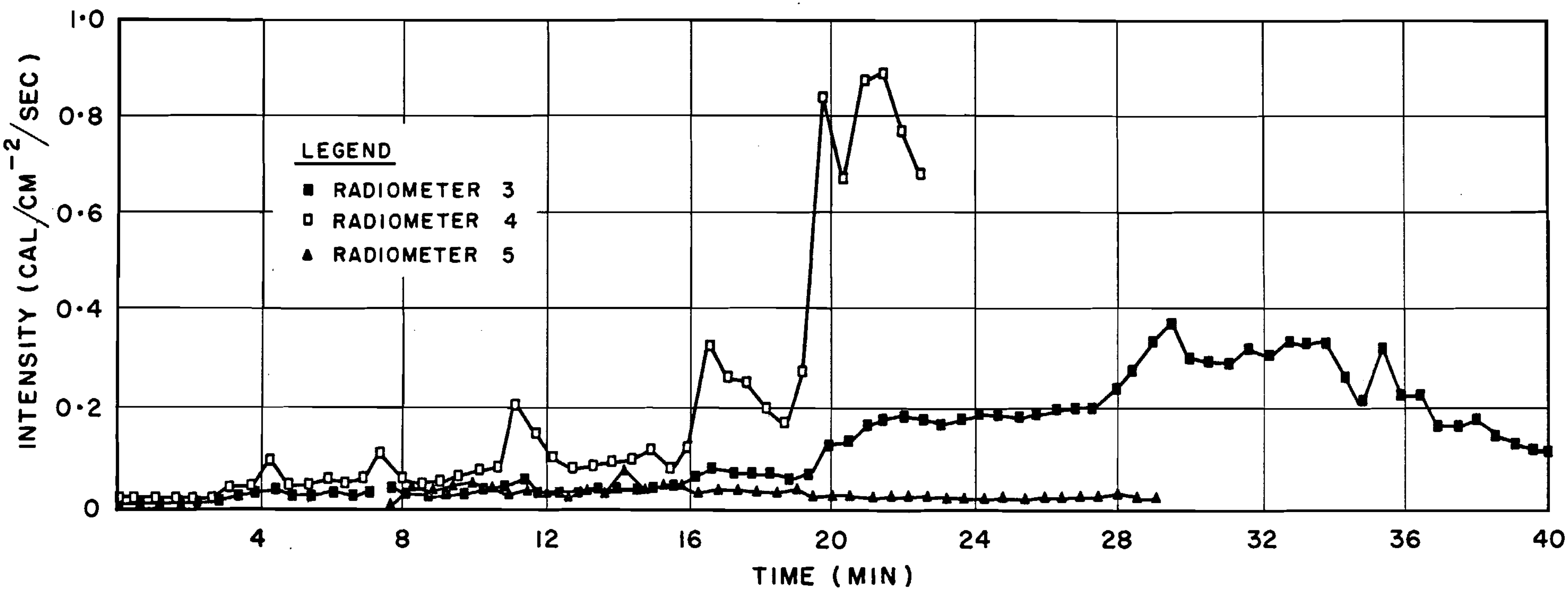


FIGURE 17 RADIATION LEVELS BURN No. 7

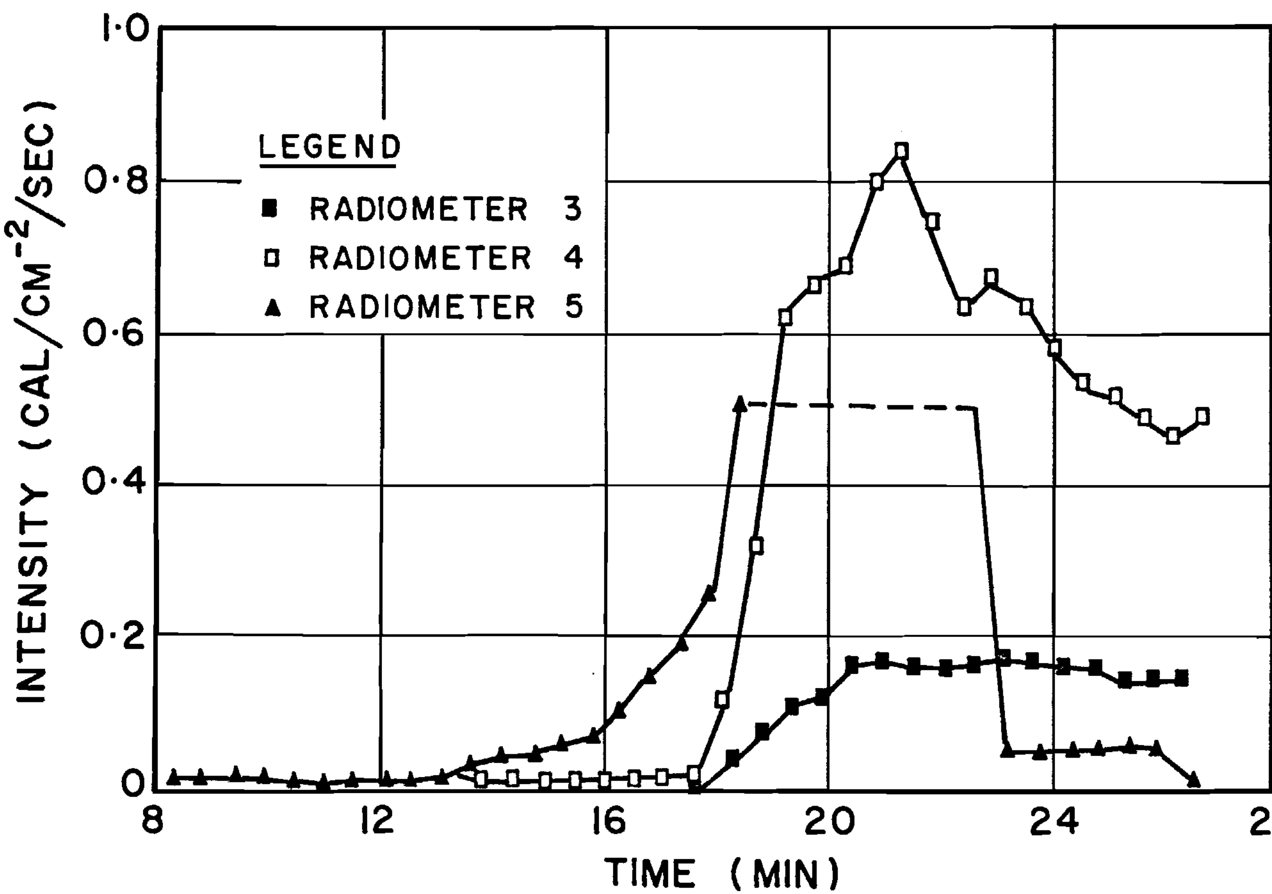


FIGURE 18 RADIATION LEVELS BURN No. 8 (SCHOOL)

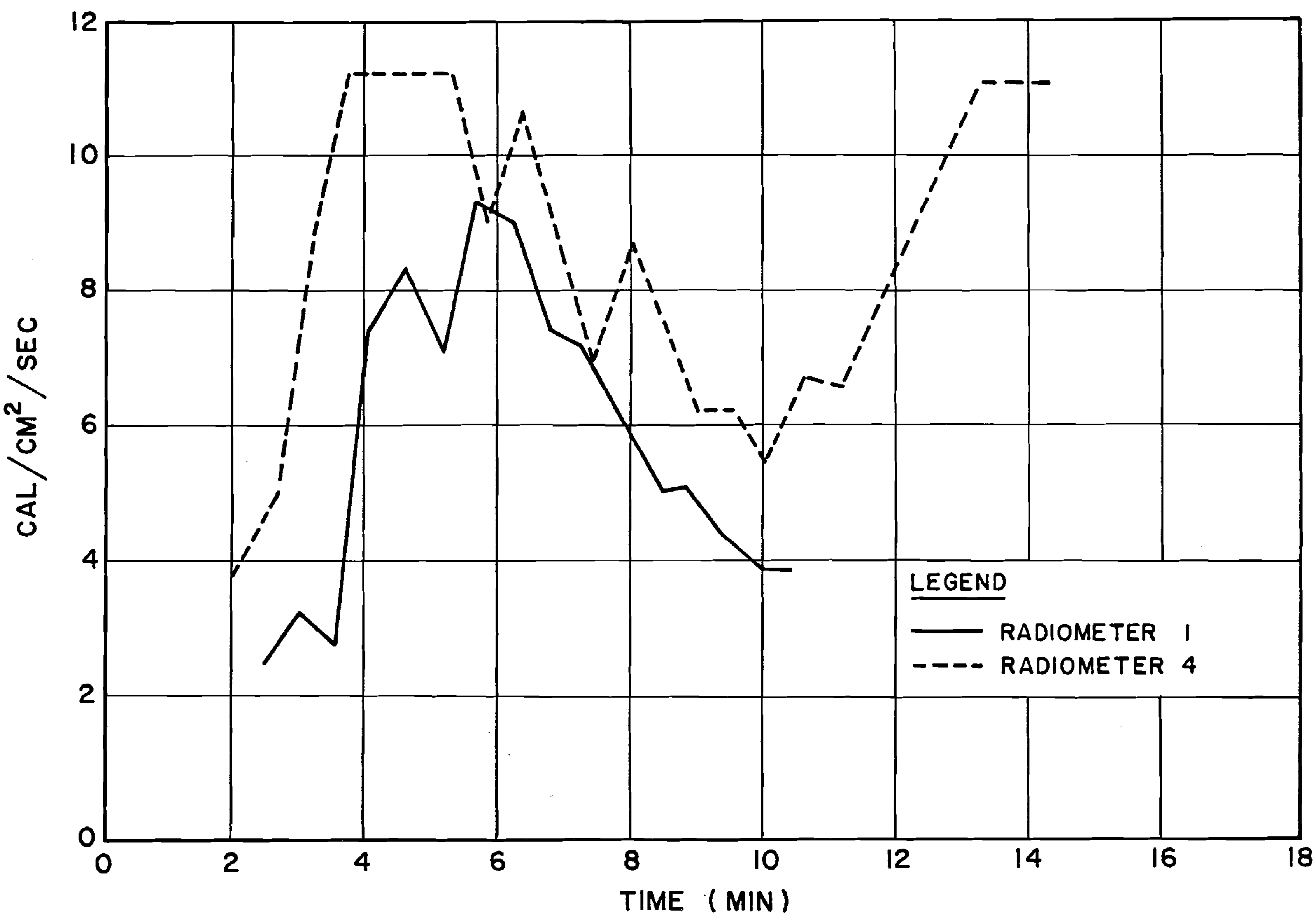


FIGURE 19 HYPOTHETICAL INTENSITIES AT WINDOW OPENINGS
BURN No. 2

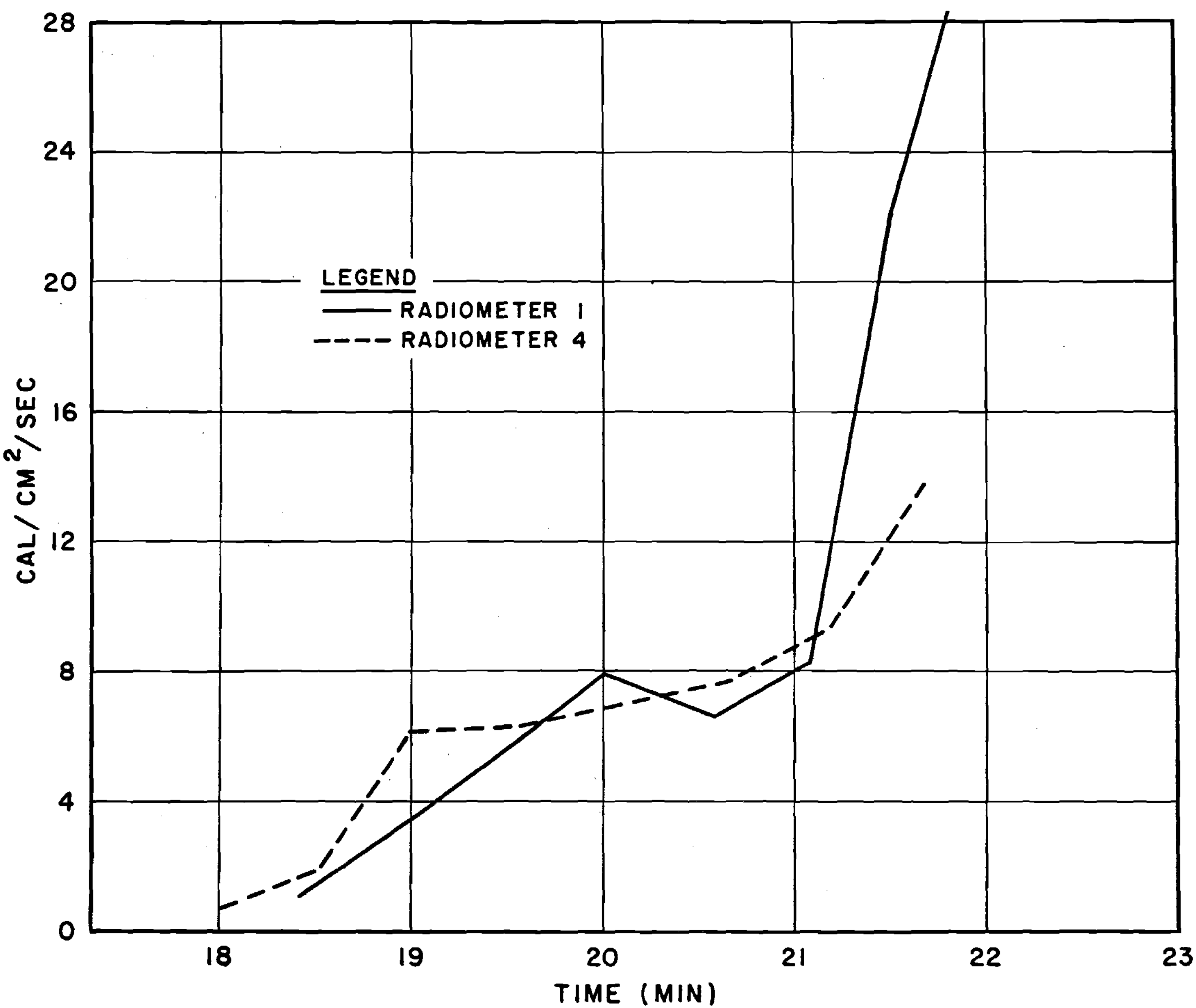


FIGURE 20 HYPOTHETICAL INTENSITIES AT WINDOW OPENINGS
BURN No. 3

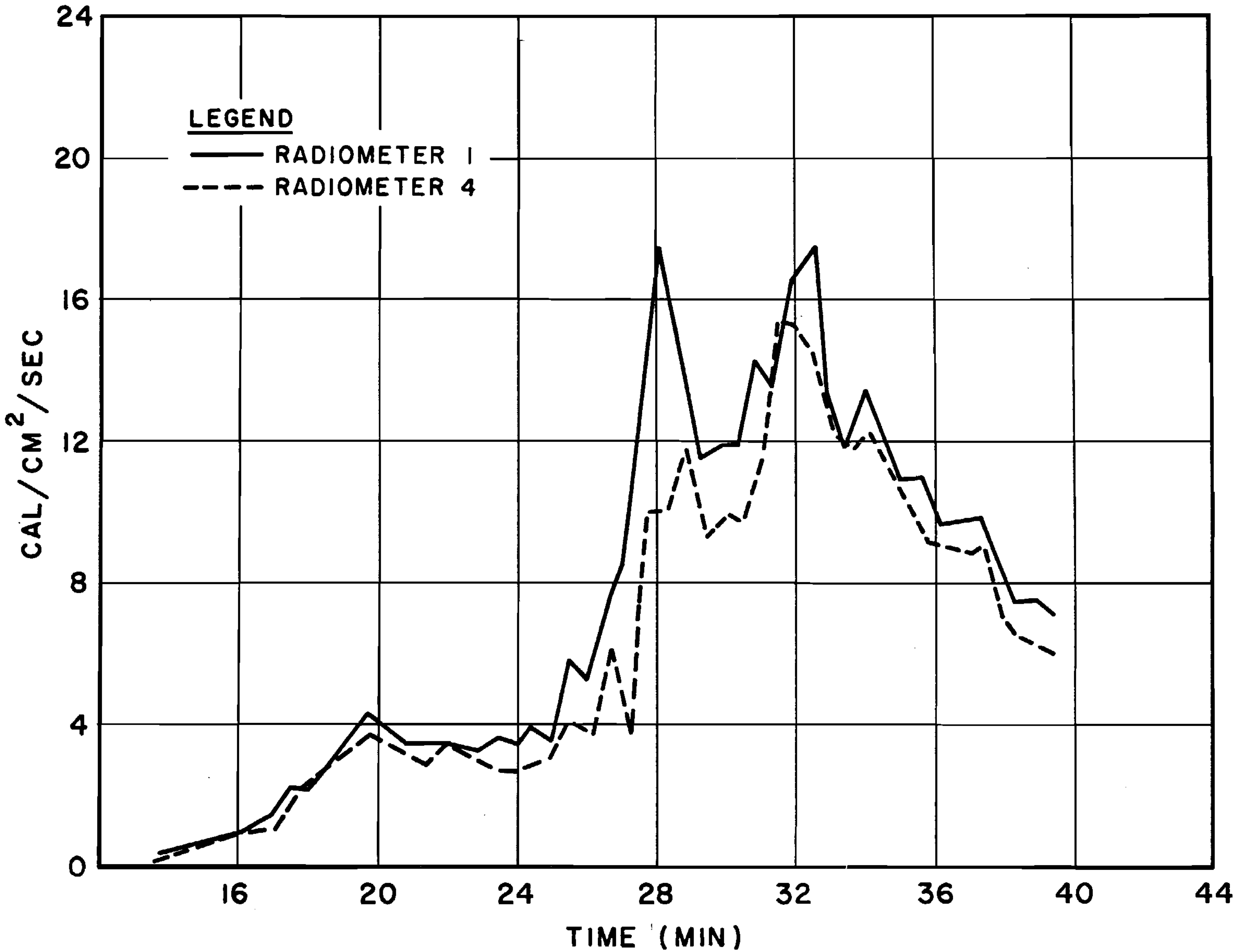


FIGURE 21 HYPOTHETICAL INTENSITIES AT WINDOW OPENINGS BURN No. 4

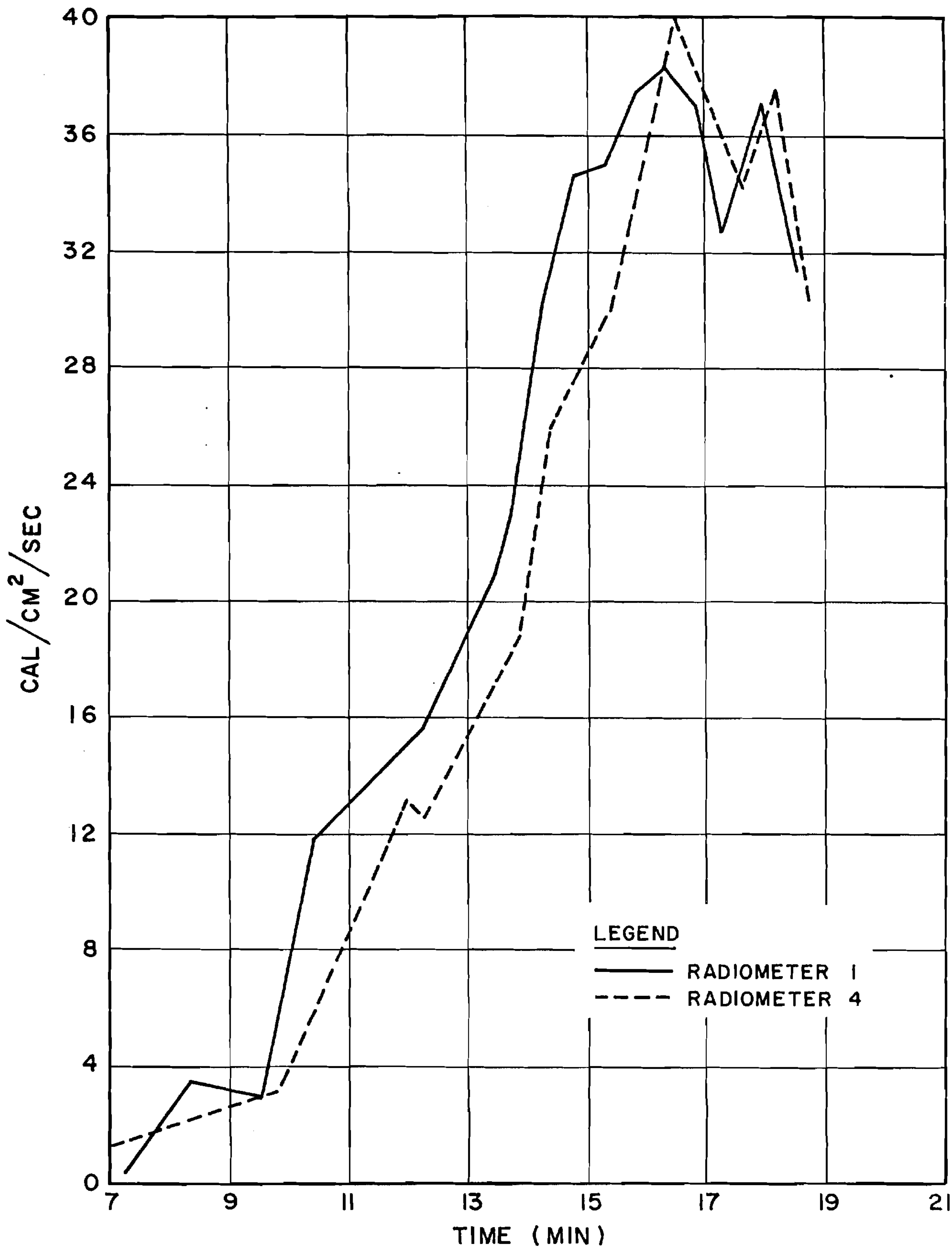


FIGURE 22 HYPOTHETICAL INTENSITIES AT WINDOW OPENINGS BURN No. 5

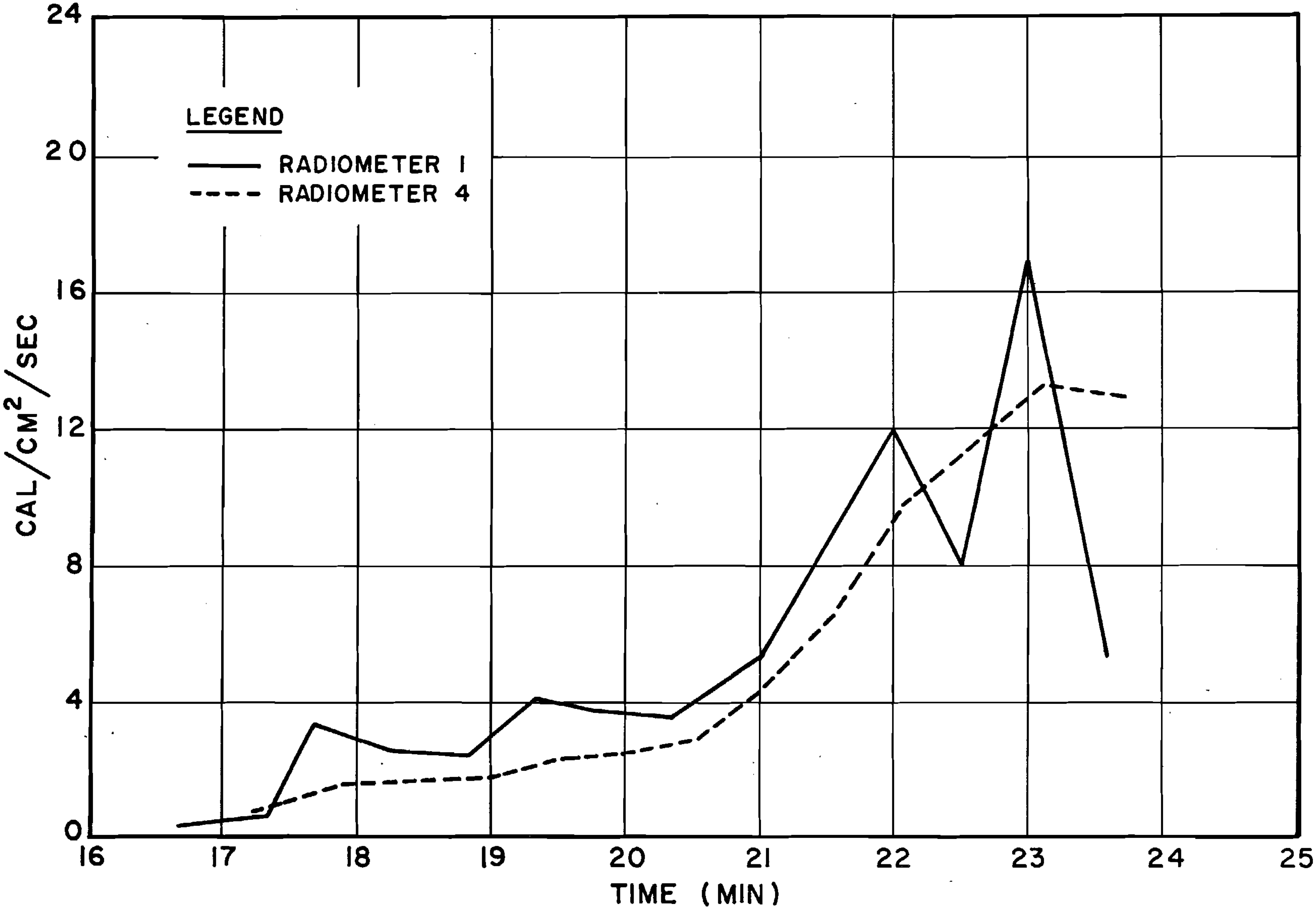


FIGURE 23 HYPOTHETICAL INTENSITIES AT WINDOW OPENINGS
BURN No. 6 (COMMUNITY HALL)

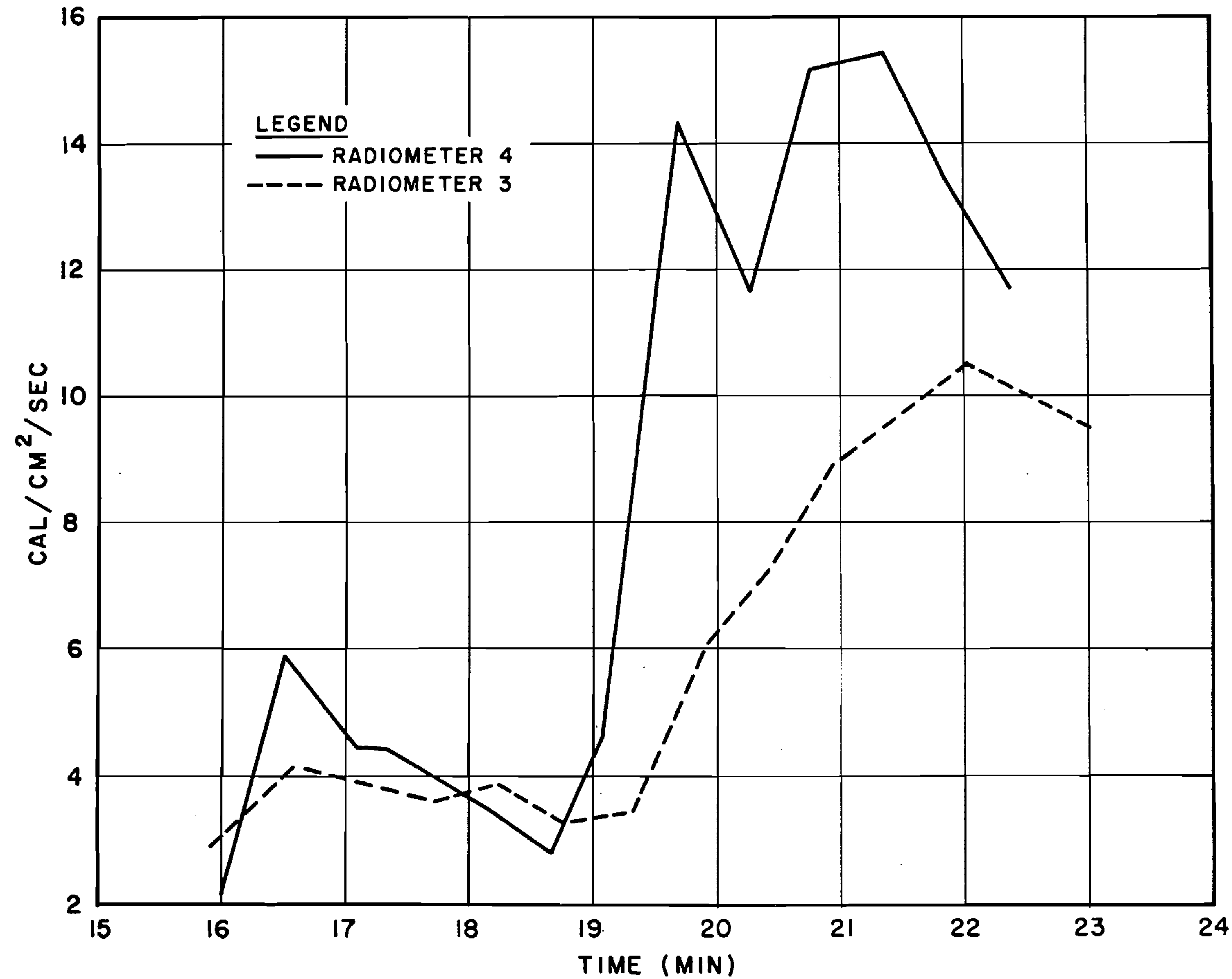


FIGURE 24 HYPOTHETICAL INTENSITIES AT WINDOW OPENINGS
BURN No. 7

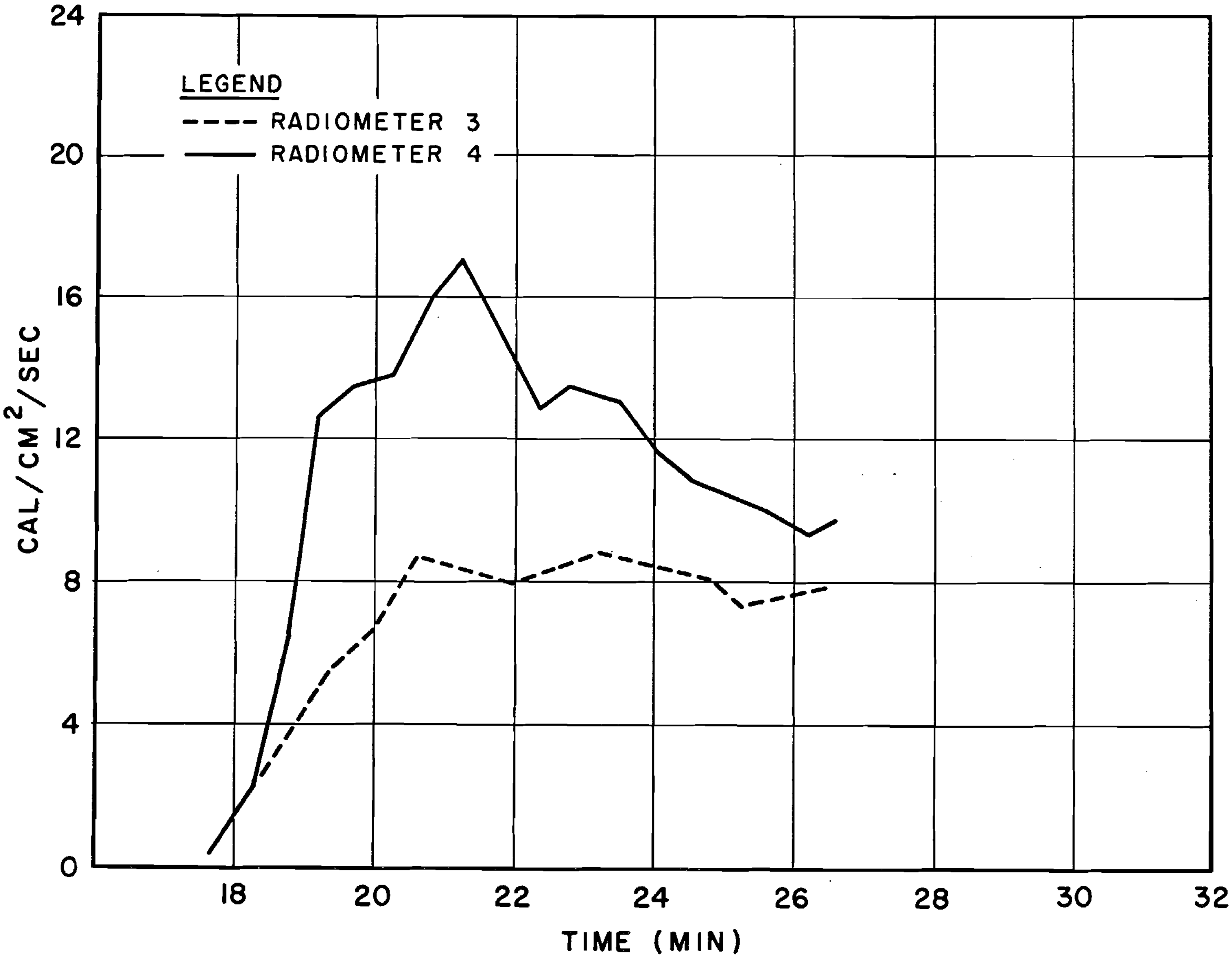


FIGURE 25 HYPOTHETICAL INTENSITIES AT WINDOW OPENINGS BURN No. 8 (SCHOOL)