NATIONAL RESEARCH COUNCIL

CANADA

DIVISION OF BUILDING RESEARCH

ST. LAWRENCE BURNS
RESISTANCE THERMOMETER MEASUREMENTS

by

J.H. McGuire

Report No. 155

of the

Division of Building Research

OTTAWA

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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 supvervised 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

RESISTANCE THERMOMETER MEASUREMENTS

by

J.H. McGuire

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, 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).

This report is concerned with resistance wire thermometer measurements made by the British Joint Fire Research Organization to provide information on the growth of the heat content of the gases in a burning enclosure. Measurement of the resistance of a wire gives its mean temperature, to a close approximation, and if the wire is thin is a measure of the mean temperature of the gases surrounding the length of the wire. The heat content of the gases can then be estimated by postulating the form of the temperature distribution along the length of the wire.

INSTRUMENTATION

The sensing element of the resistance thermometer was required to have a length of about 6 ft for the measurements in the houses and between 20 and 30 ft for the measurements in the larger buildings. A time constant of less than a minute was also essential. Copper wire meets these requirements, and a resistance measuring bridge (Fig. 9) was constructed for an element resistance of 3 ohms at ambient temperature. Such a value of resistance is given by approximately 6 ft of 40 swg copper wire or 25 ft of 34 swg copper wire.

The circuit of the resistance bridge is shown in Fig. 10. The Wheatstone bridge is duplicated to allow the use of two resistance wire elements, if necessary, and controls and milliameters are incorporated to allow standardization of the potential differences across the bridge and to balance it at ambient temperature when an element with a resistance a few per cent different from 3 ohms is used. Calibration of the bridge unit is given in Fig. 11. Bridge outputs were connected to servo-potentiometric pen recorders.

LOCATION OF RESISTANCE ELEMENTS

In each of the houses 40 swg resistance wire was mounted near the staircase as indicated in Figs. 1 to 5,7; it stretched from a point 1 ft above the floor to a point approximately 1 ft 6 in. below the ground floor ceiling level. In the larger buildings two elements of 34 swg copper wire were installed at the sites shown in Figs. 6 and 8. The length of the wire was approximately 21 ft with its lower end at ground floor level.

RESULTS

Results are given in Figs. 12 to 17 and have been corrected for the effect introduced by connecting-lead resistance.

No direct significance may be given to the results for the second resistance element used in the larger buildings; after the experiments had been completed it was found that the recorder which was fed from bridge A was faulty. It will be noticed, however, that the time waveform of the relevant outputs is similar in the case of each of the large buildings. It is likely that the error in the reading is a constant factor. Assuming this to be true, it can be said that the gases in the buildings were stratified right up to the time of flashover, when flames enveloped the resistance wires and they were destroyed.

HEAT CONTENT OF THE GASES

If it is desired, from the results given, to determine the heat content of the gases at any time, then it must be assumed that temperature is a function of height only and that the form of the function is known. The requirement that the function be known arises from the fact that density is a function of temperature and hence the expression for the heat content is:

$$Q = A\rho_o T_o s \int_o^H \frac{\theta}{T_o+\theta}\, dh$$

where A = floor area of building

H = height

ρ_o = density at ambient temperature T_o

s = specific heat

and θ = temperature rise above ambient temperature T_o

The calibration of the resistance bridge gives a measure of

$$\frac{1}{H}\int_0^H \theta \, dh$$

which differs in form from the integral in the previous expression. Some assumption must therefore be made about the variation of temperature with height. The heat content of the gases in the school, up to a height of 21 ft (the height of the resistance wire) and for a time of 14 minutes after ignition, has been calculated for four different assumed temperature-height functions; the results are given in Table I.

The last of the four assumed distributions is an extreme one which requires a ceiling temperature higher than would be attained in fires of this kind. It is therefore reasonable to assume 2.5×10^7 as the best estimate of the heat content at 14 minutes.

REFERENCE

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

TABLE I

HEAT CONTENT OF GASES IN SCHOOL AFTER 14 MINUTES

$\frac{1}{H}\int_0^H \theta dh$	Assumed temperature-height function	Heat content
420°C	$\theta = \frac{840h}{H}$	2.84×10^7 calories
420°C	$0<h<\frac{H}{2}$; $\theta = 210°C$ $\frac{H}{2}<h<H$; $\theta = 630°C$	2.98×10^7 calories
420°C	$0<h<\frac{H}{2}$; $\theta = 0$ $\frac{H}{2}<h<H$; $\theta = 840°C$	1.99×10^7 calories
420°C	$0<h<\frac{3H}{4}$; $\theta = 0$ $\frac{3H}{4}<h<H$; $\theta = 1680°C$	1.16×10^7 calories

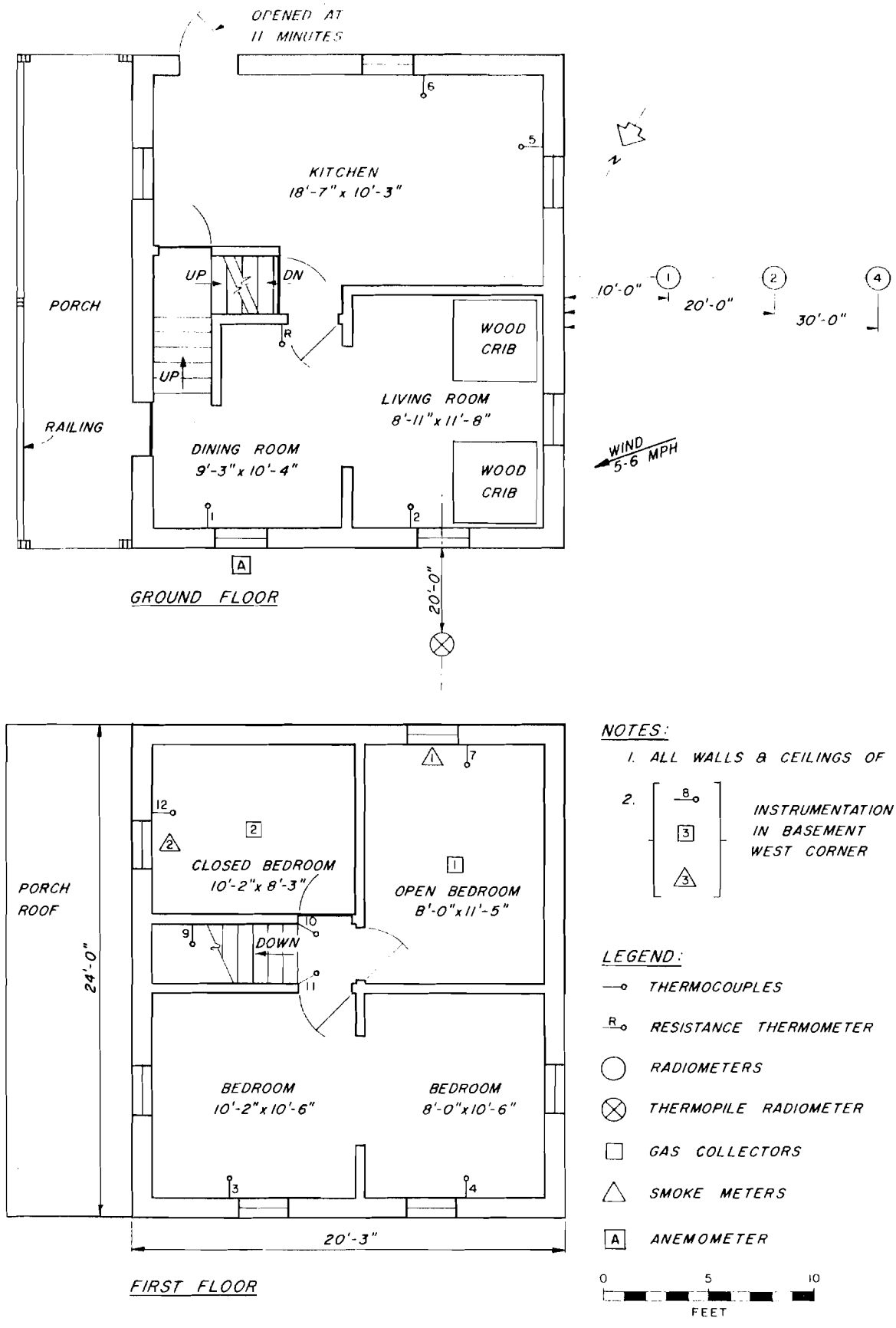


FIGURE 1 - BUILDING No. 1 - TWO-STOREY SOLID BRICK DWELLING

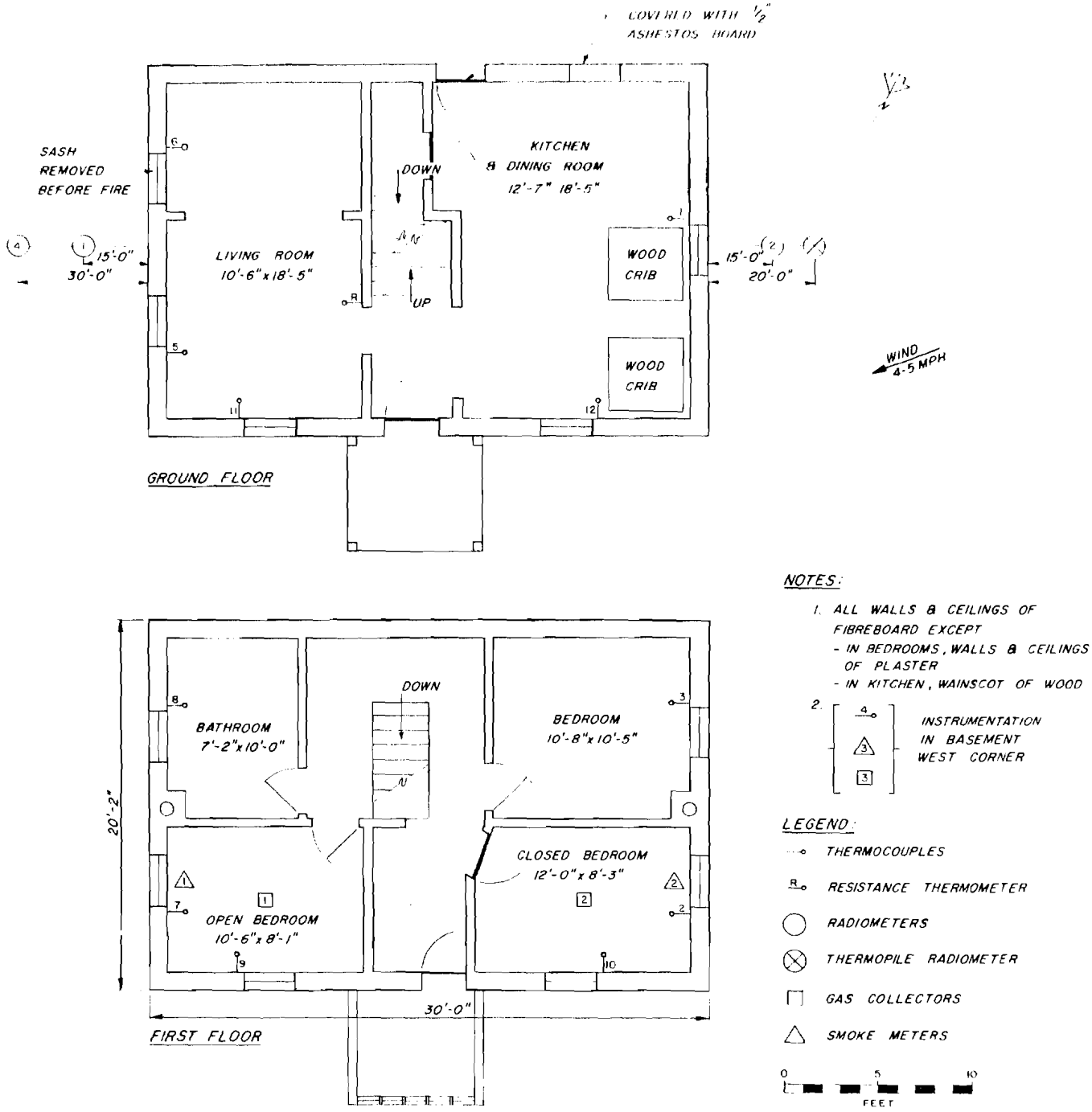
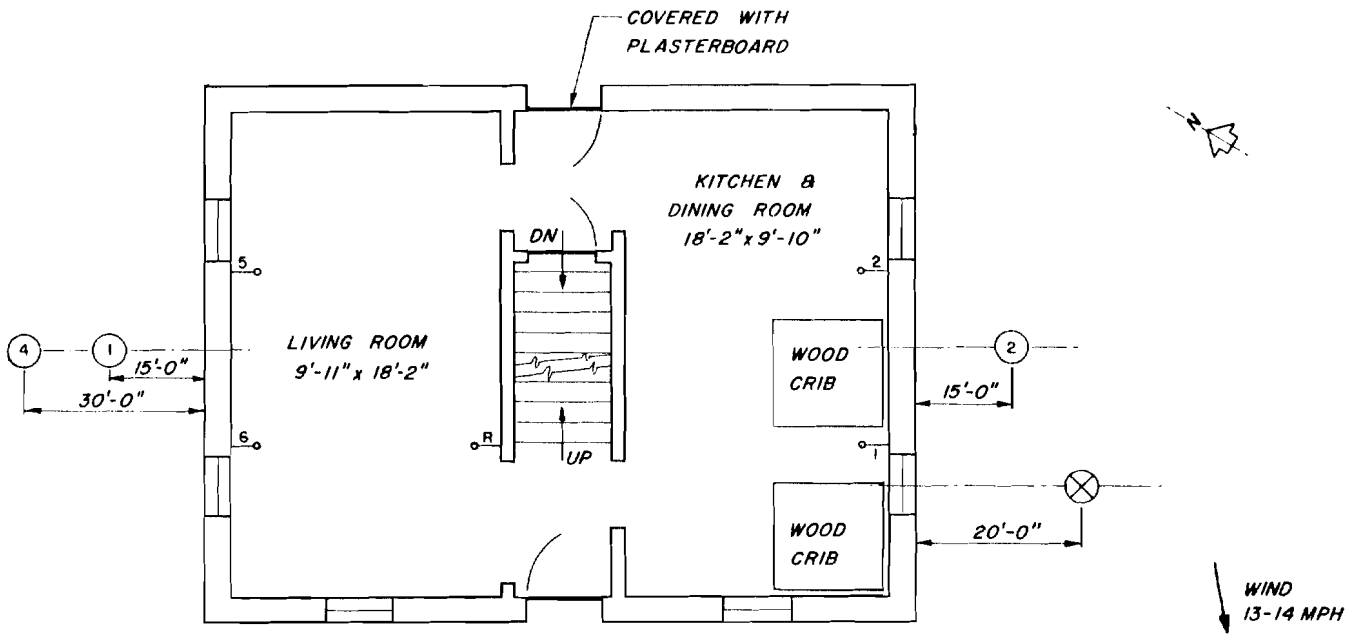
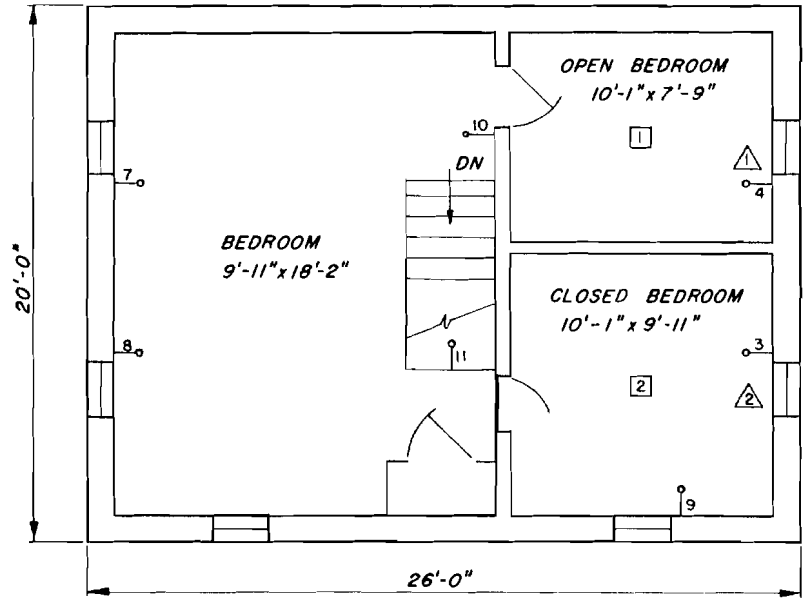


FIGURE 2 - BUILDING No. 2 - TWO-STOREY SOLID BRICK DWELLING





NOTES:

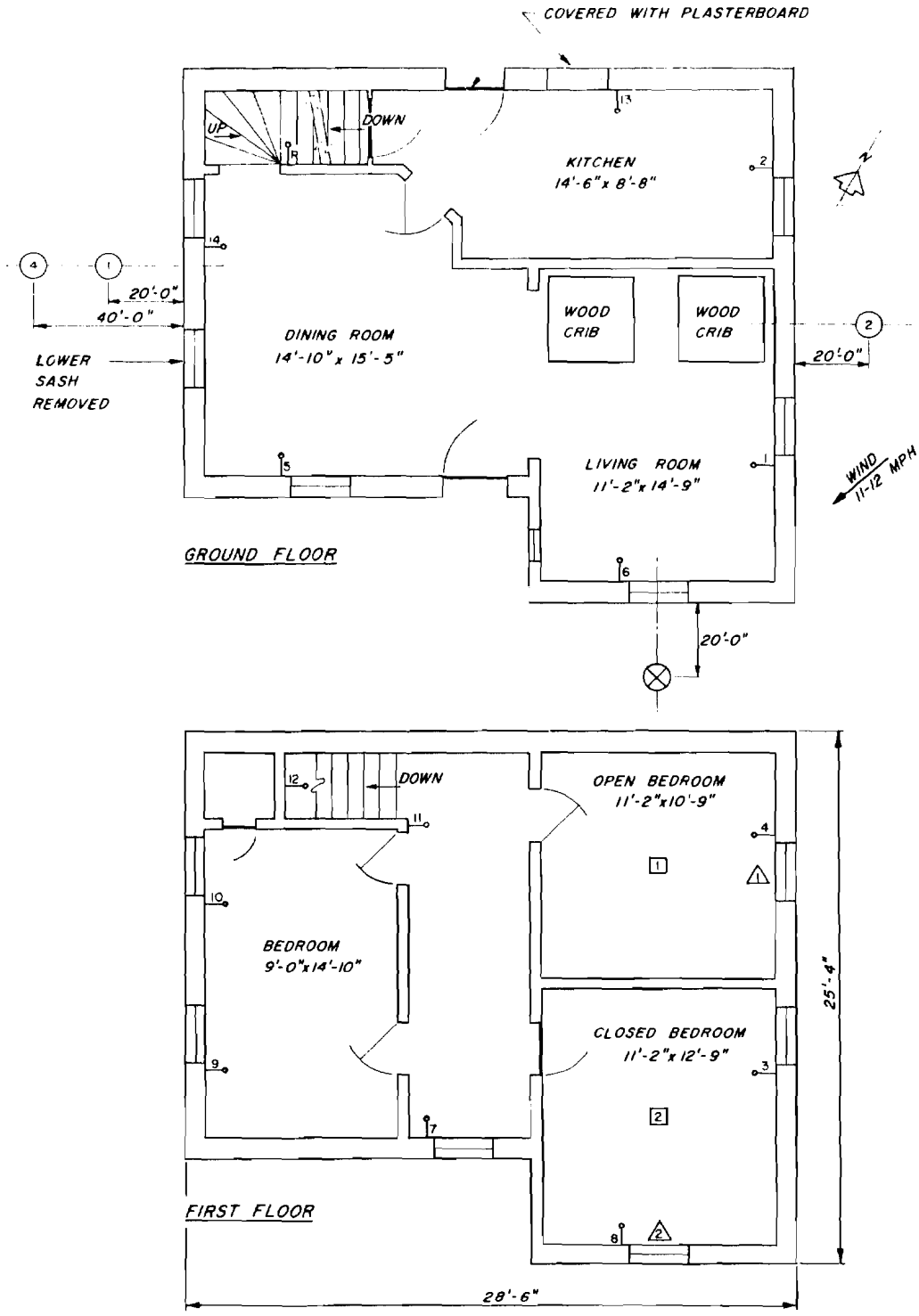
1. ALL WALLS & CEILINGS OF FIBREBOARD
2. INSTRUMENTATION IN BASEMENT WEST CORNER

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



NOTES:

1. ALL WALLS & CEILINGS OF PLASTER
2. 15, 16, 3 — INSTRUMENTATION IN BASEMENT SOUTH CORNER

LEGEND:

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

0 5 10 FEET

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

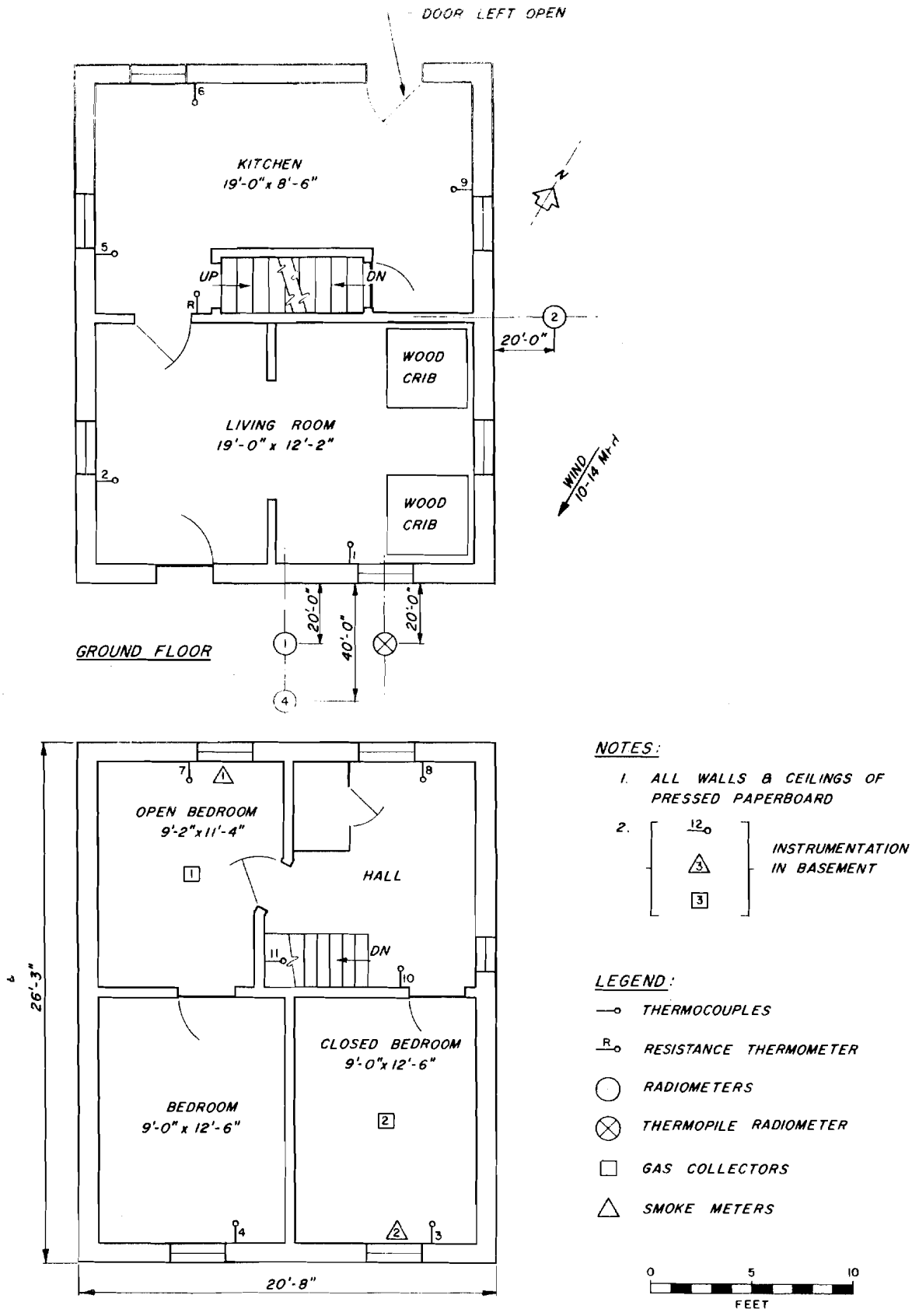


FIGURE 5 - BUILDING No. 5 - TWO - STOREY WOOD FRAME DWELLING WITH CLAPBOARD EXTERIOR

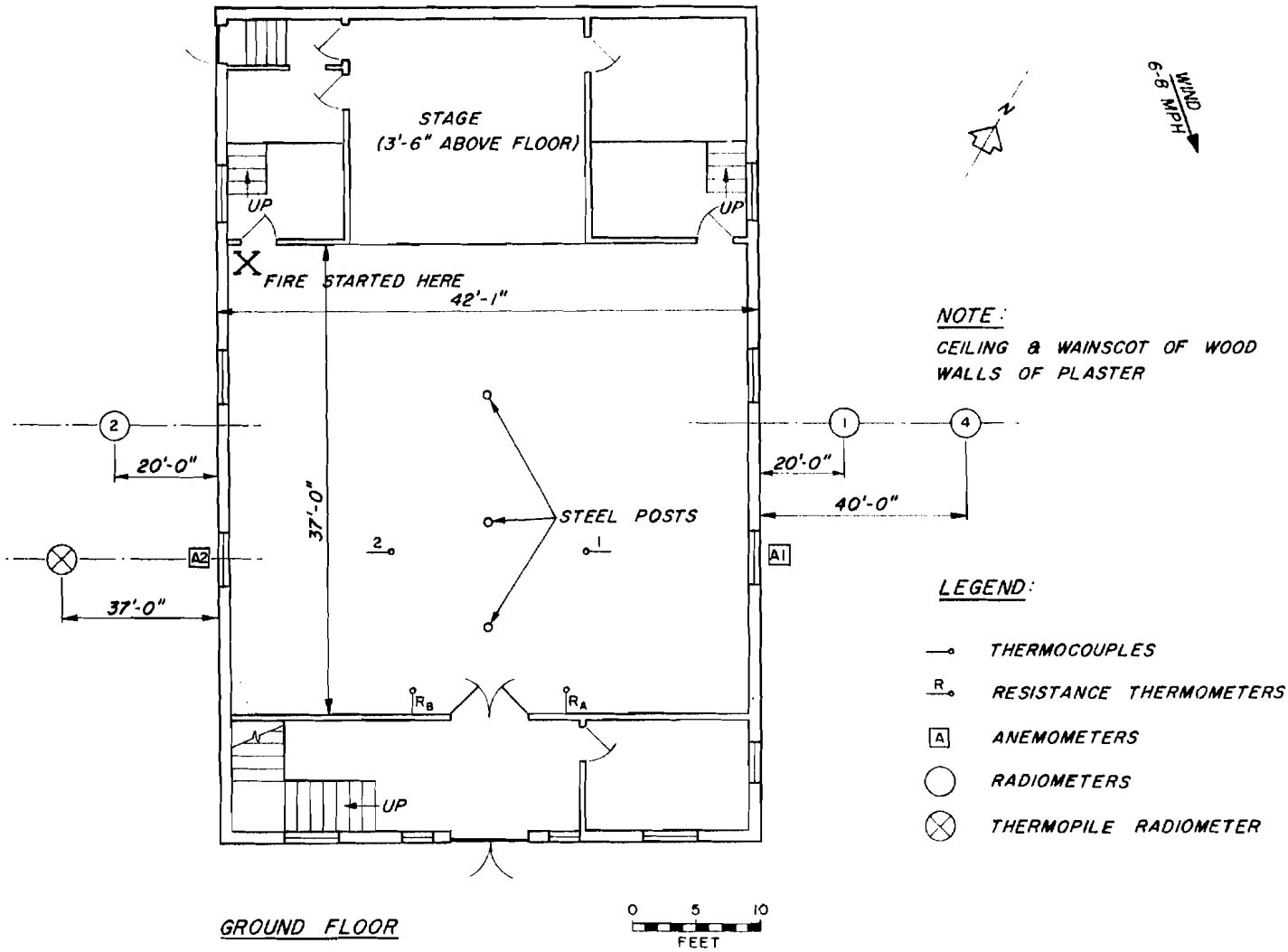
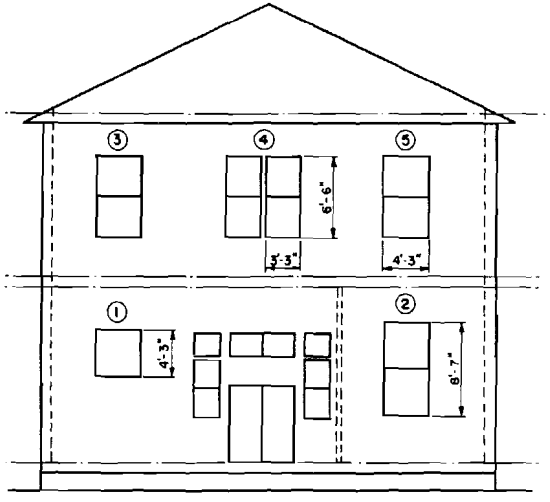
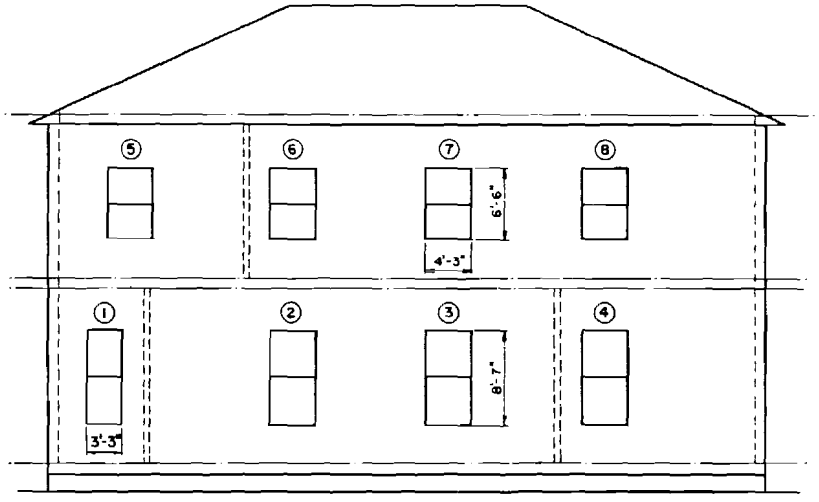


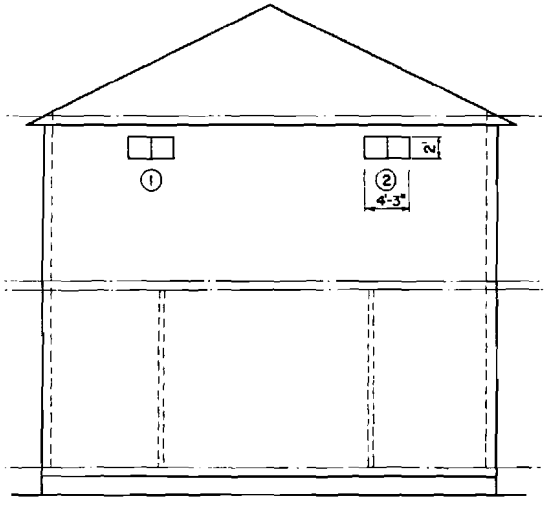
FIGURE 6 - BUILDING No. 6 - TWO - STOREY SOLID BRICK FRATERNITY HALL



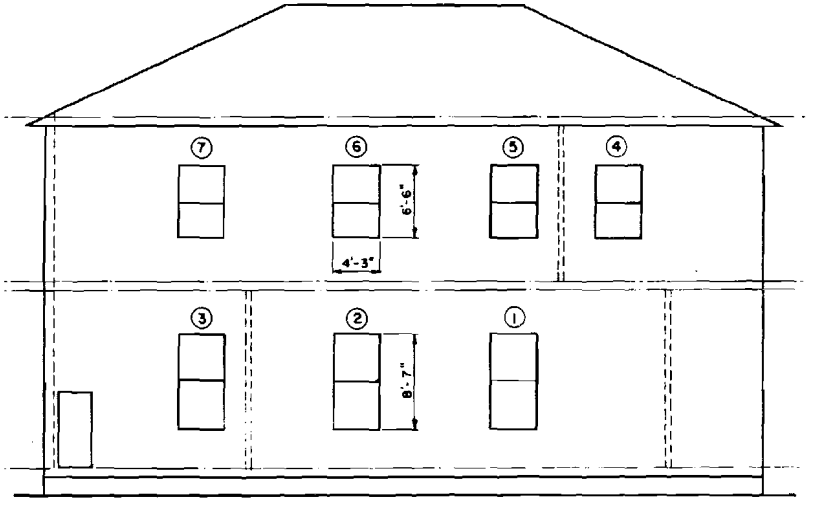
FRONT ELEVATION



EAST ELEVATION



REAR ELEVATION



WEST ELEVATION

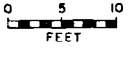


FIGURE 6a - ELEVATIONS OF BUILDING No. 6 (FRATERNITY HALL)

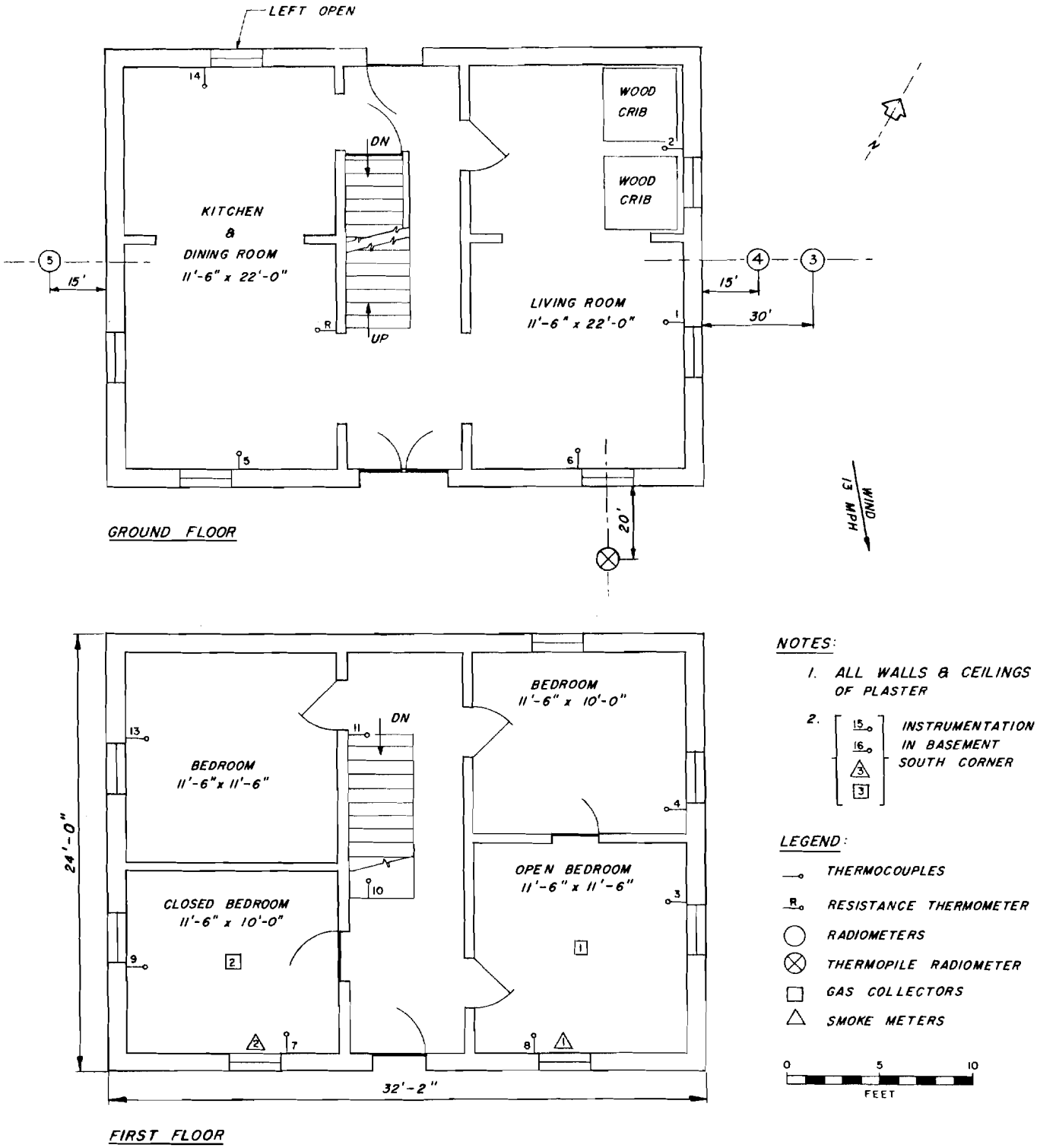


FIGURE 7 - BUILDING No. 7 - TWO - STOREY SOLID BRICK DWELLING

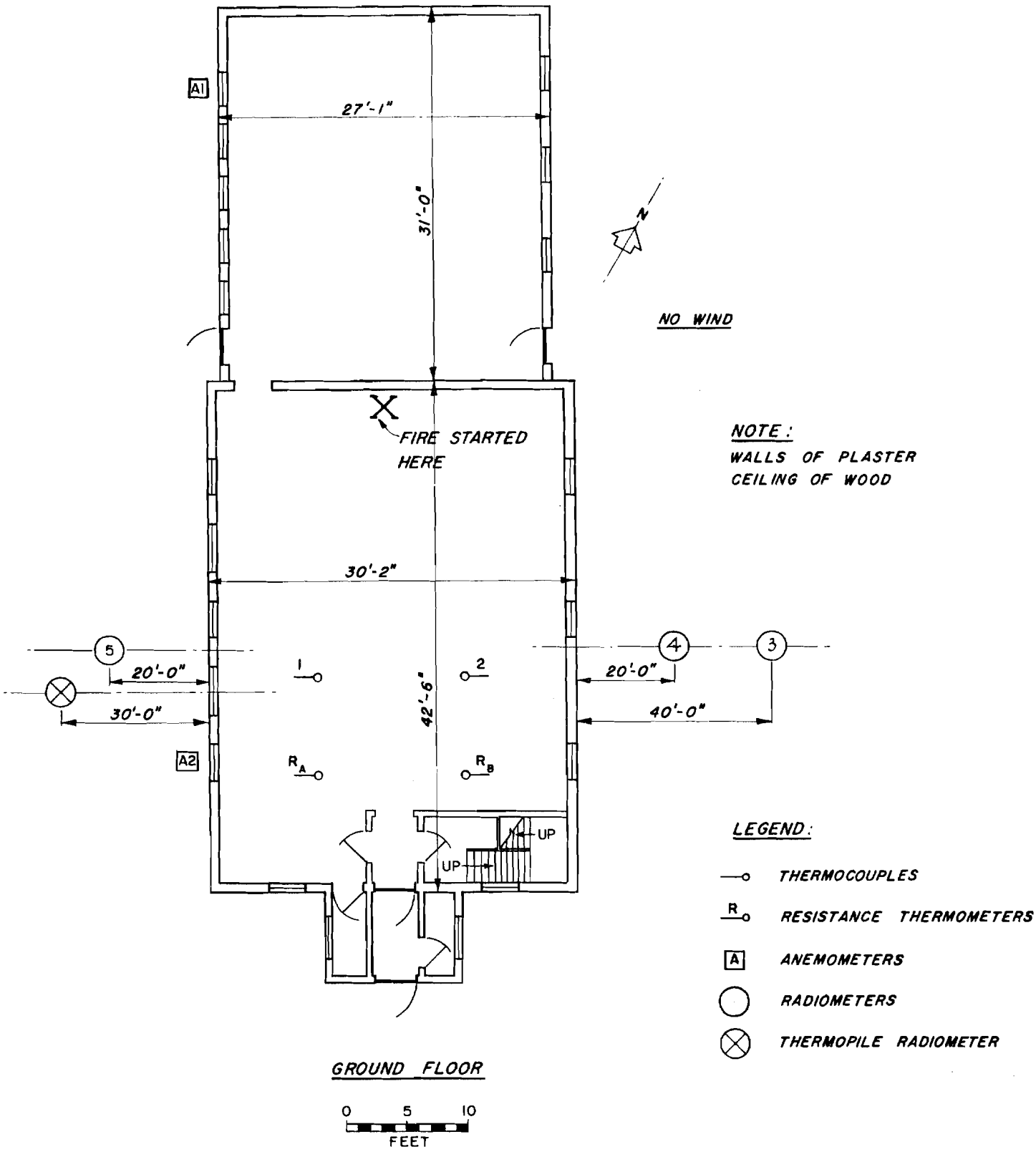
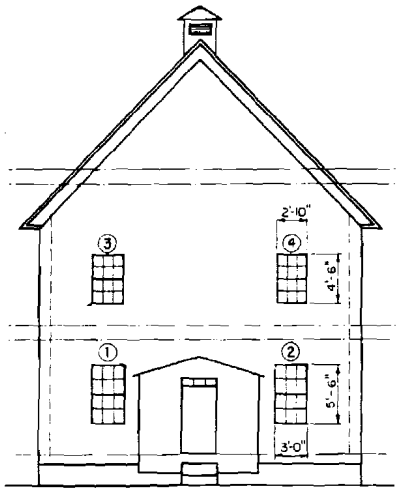
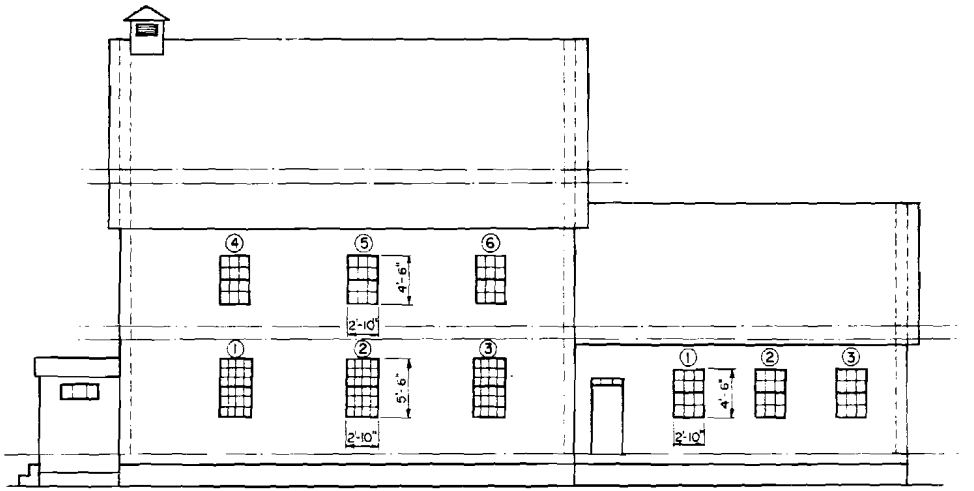


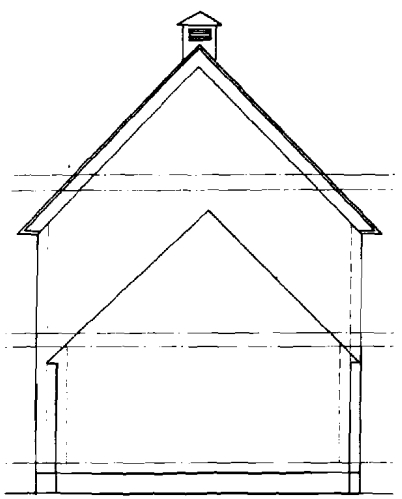
FIGURE 8 - BUILDING No. 8 - TWO - STOREY SOLID BRICK SCHOOL WITH ONE - STOREY EXTENSION AT REAR



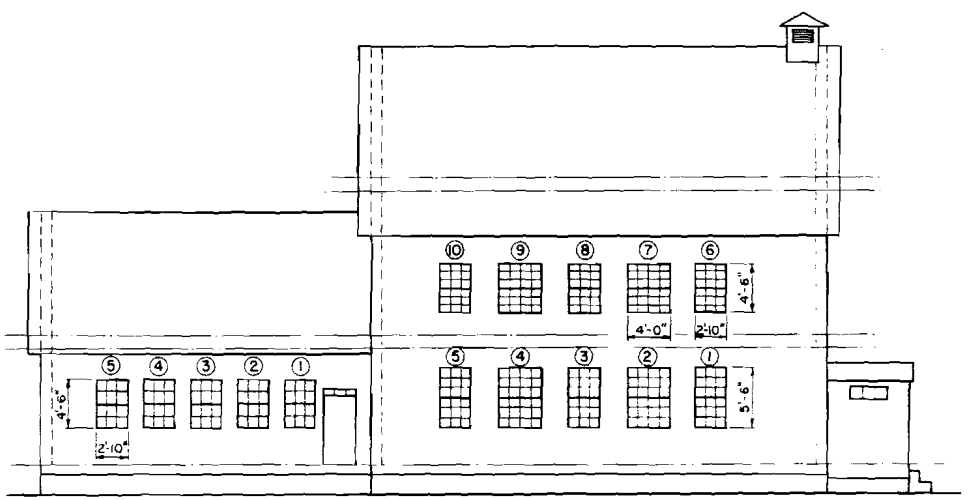
FRONT ELEVATION



EAST ELEVATION



REAR ELEVATION



WEST ELEVATION

0 5 10
FEET

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

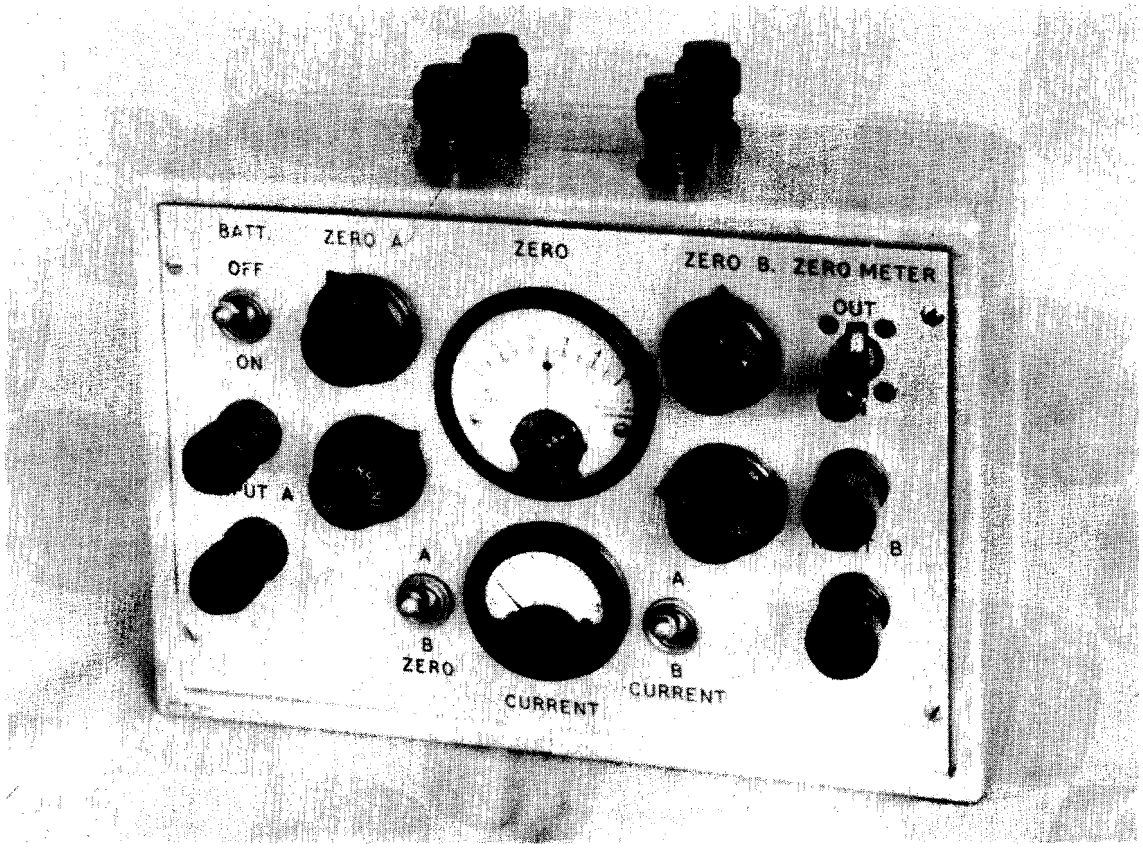


FIGURE 9 MEASURING BRIDGE

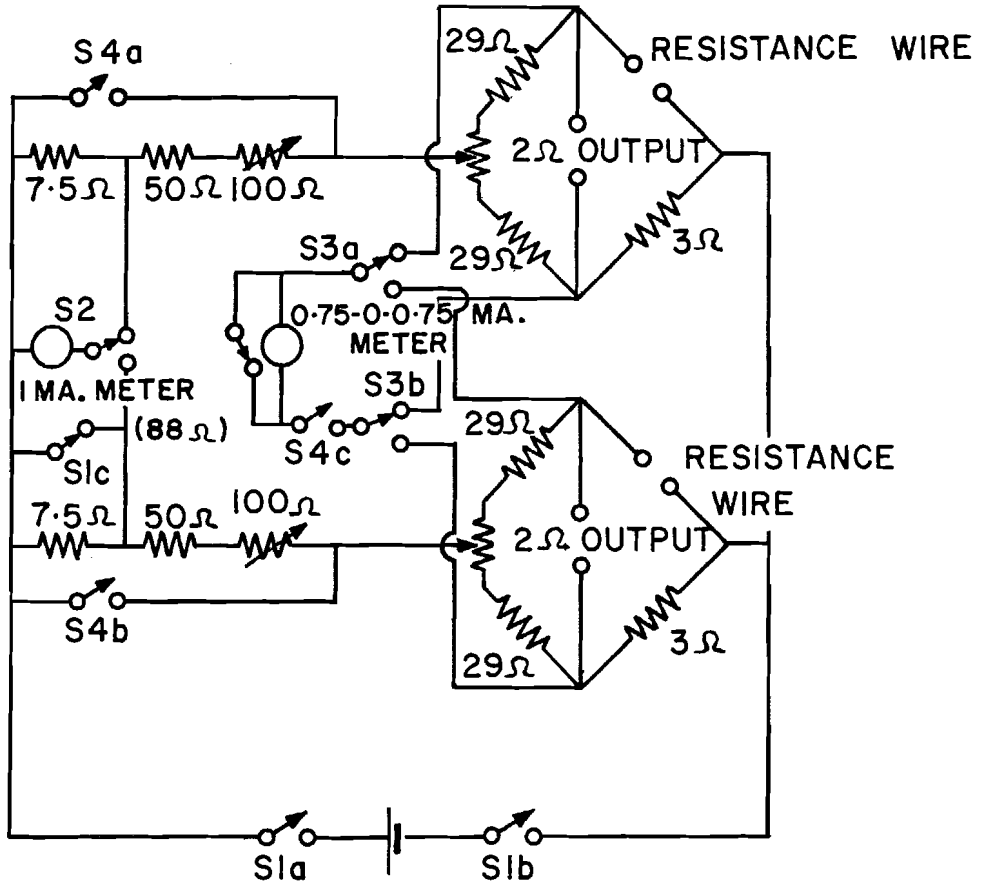


FIGURE 10 CIRCUIT DIAGRAM OF BRIDGE

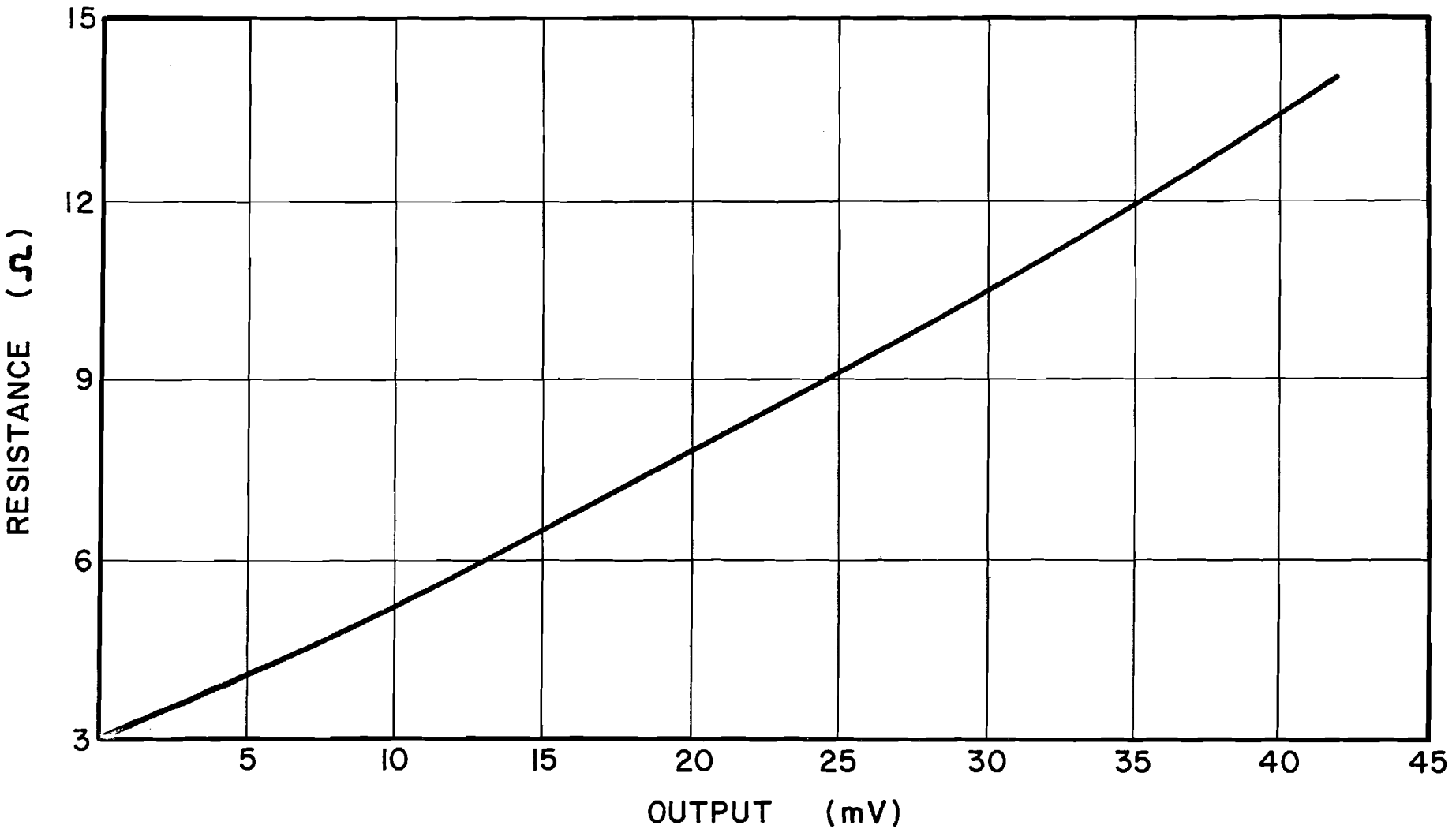


FIGURE 11 CALIBRATION OF BRIDGE UNIT

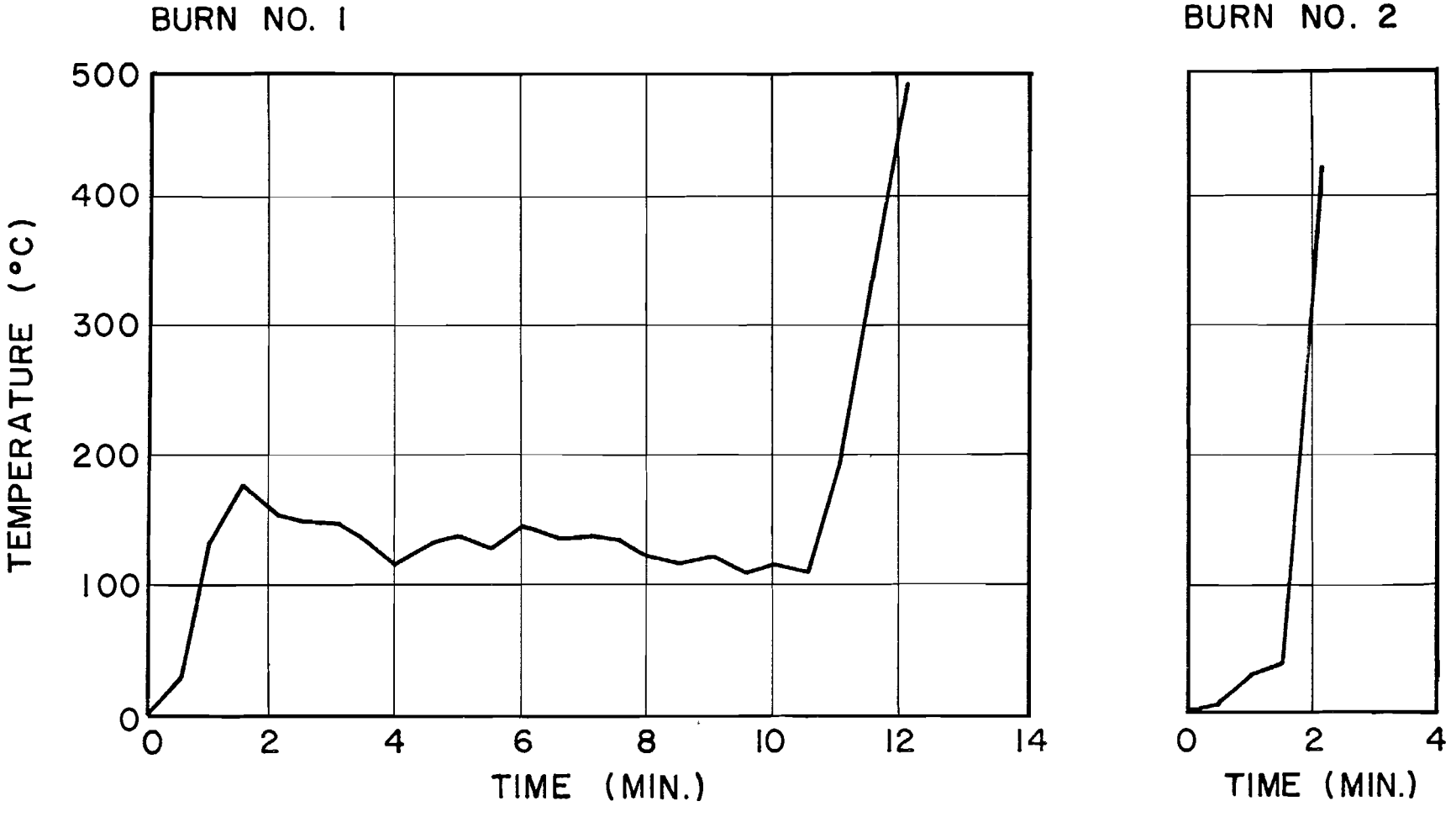


FIGURE 12 TEMPERATURE–TIME CURVES

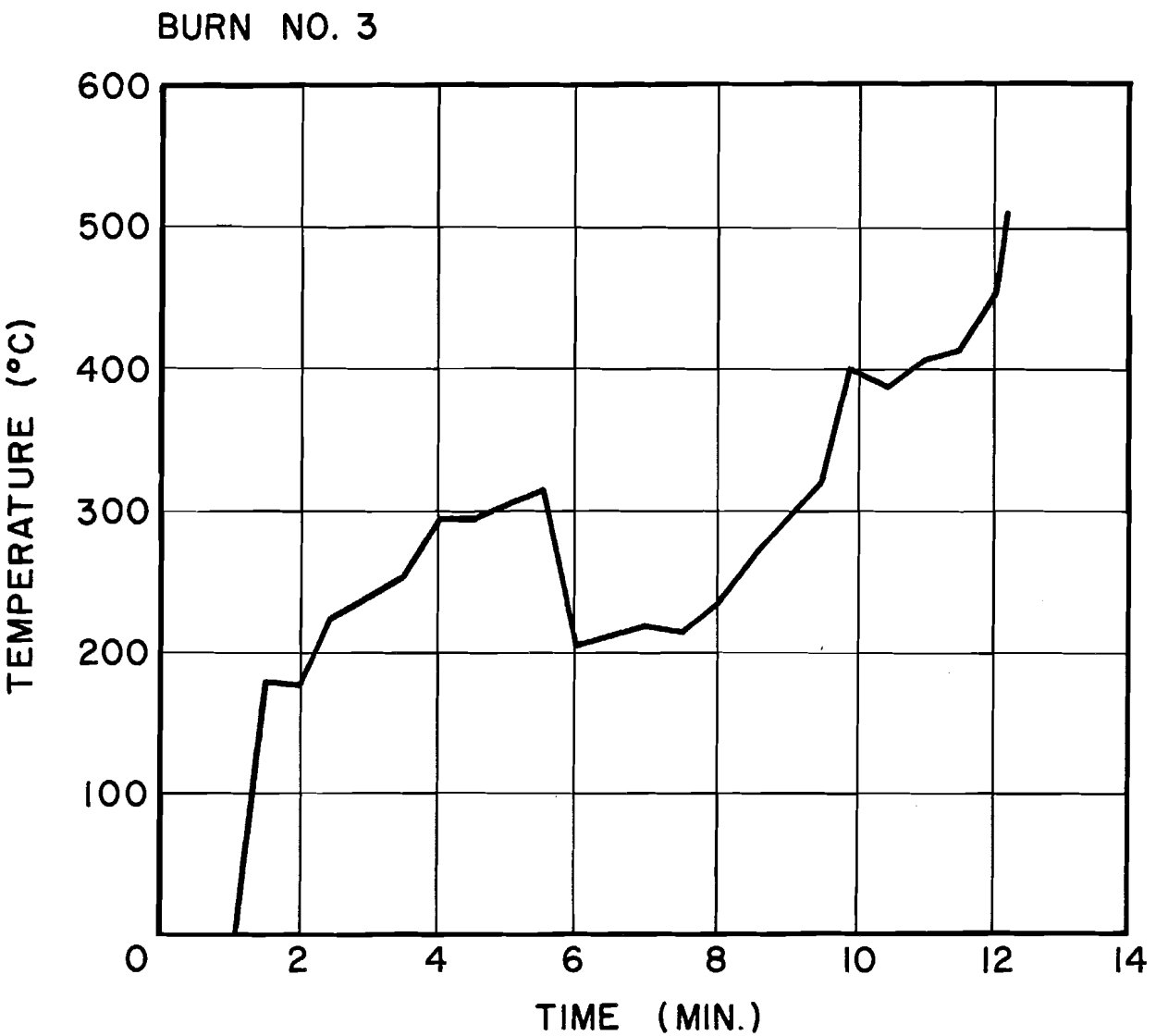


FIGURE 13 TEMPERATURE - TIME CURVE

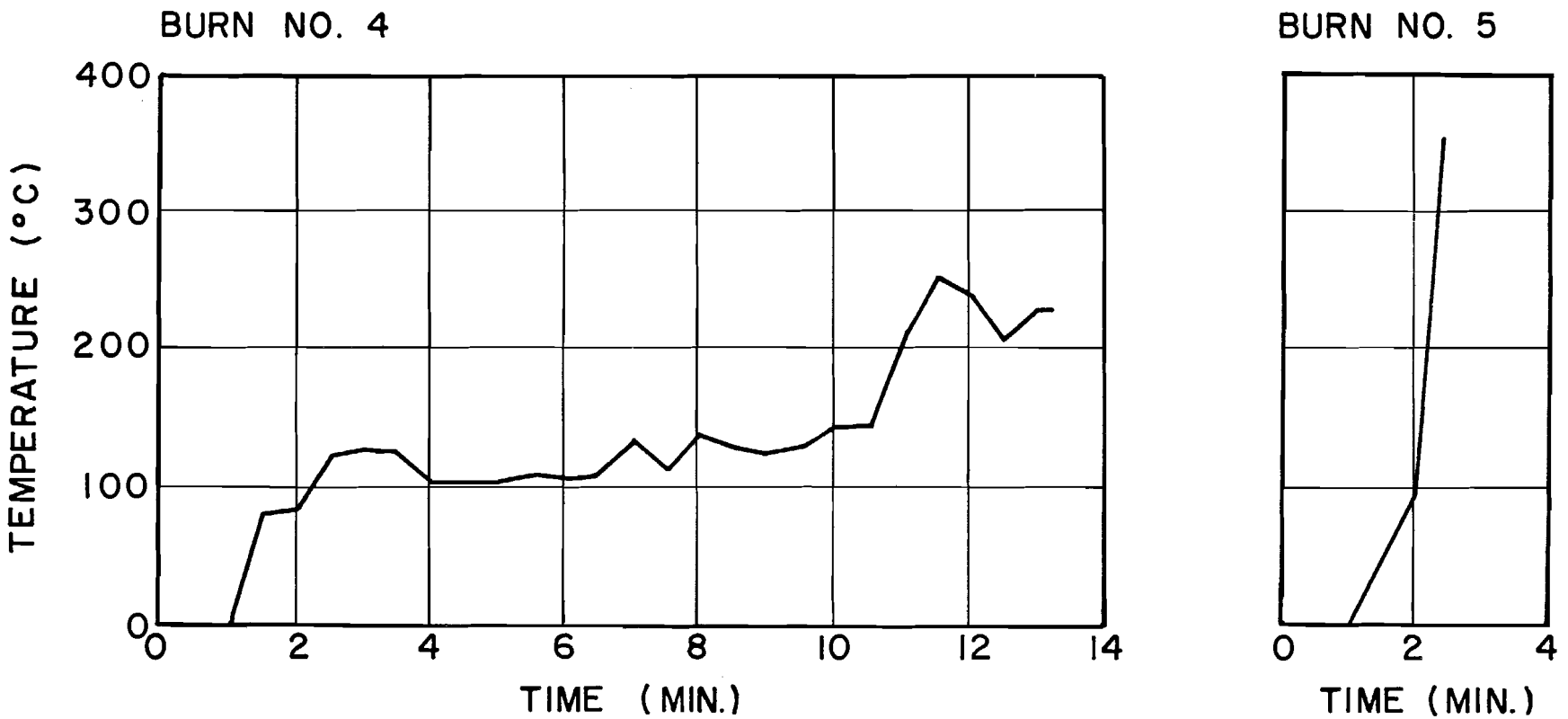


FIGURE 14 TEMPERATURE-TIME CURVES

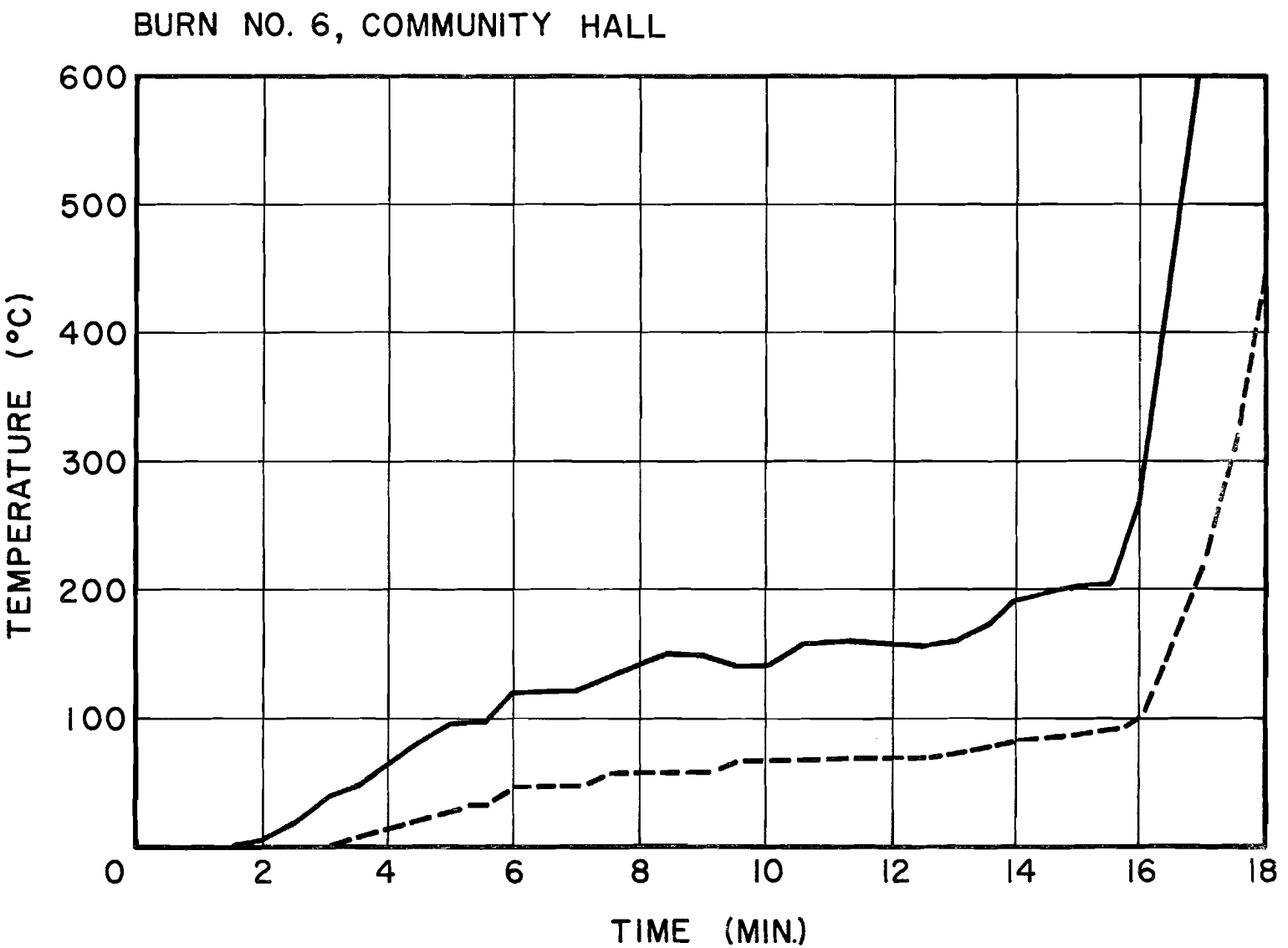


FIGURE 15 TEMPERATURE - TIME CURVES

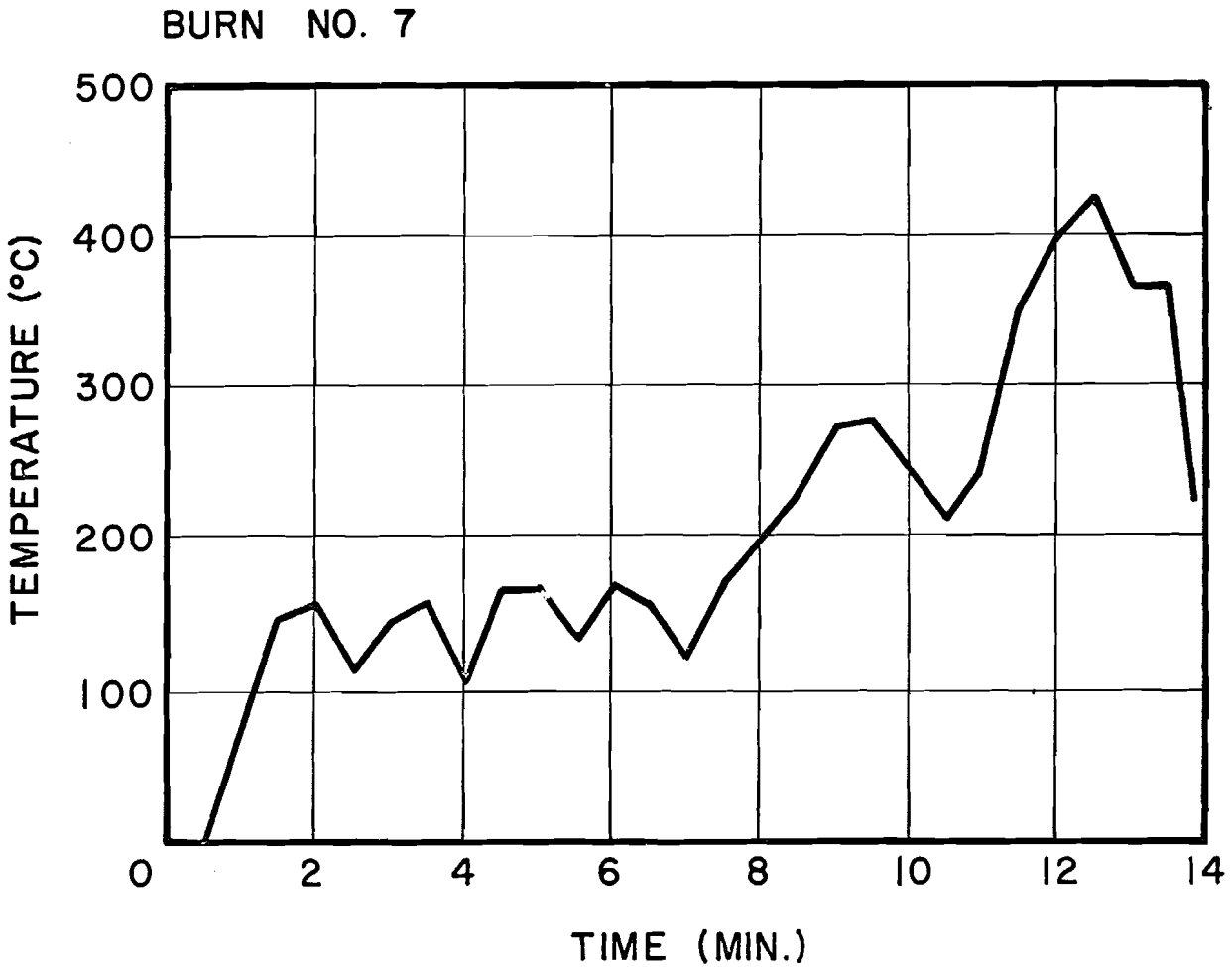


FIGURE 16 TEMPERATURE - TIME CURVE

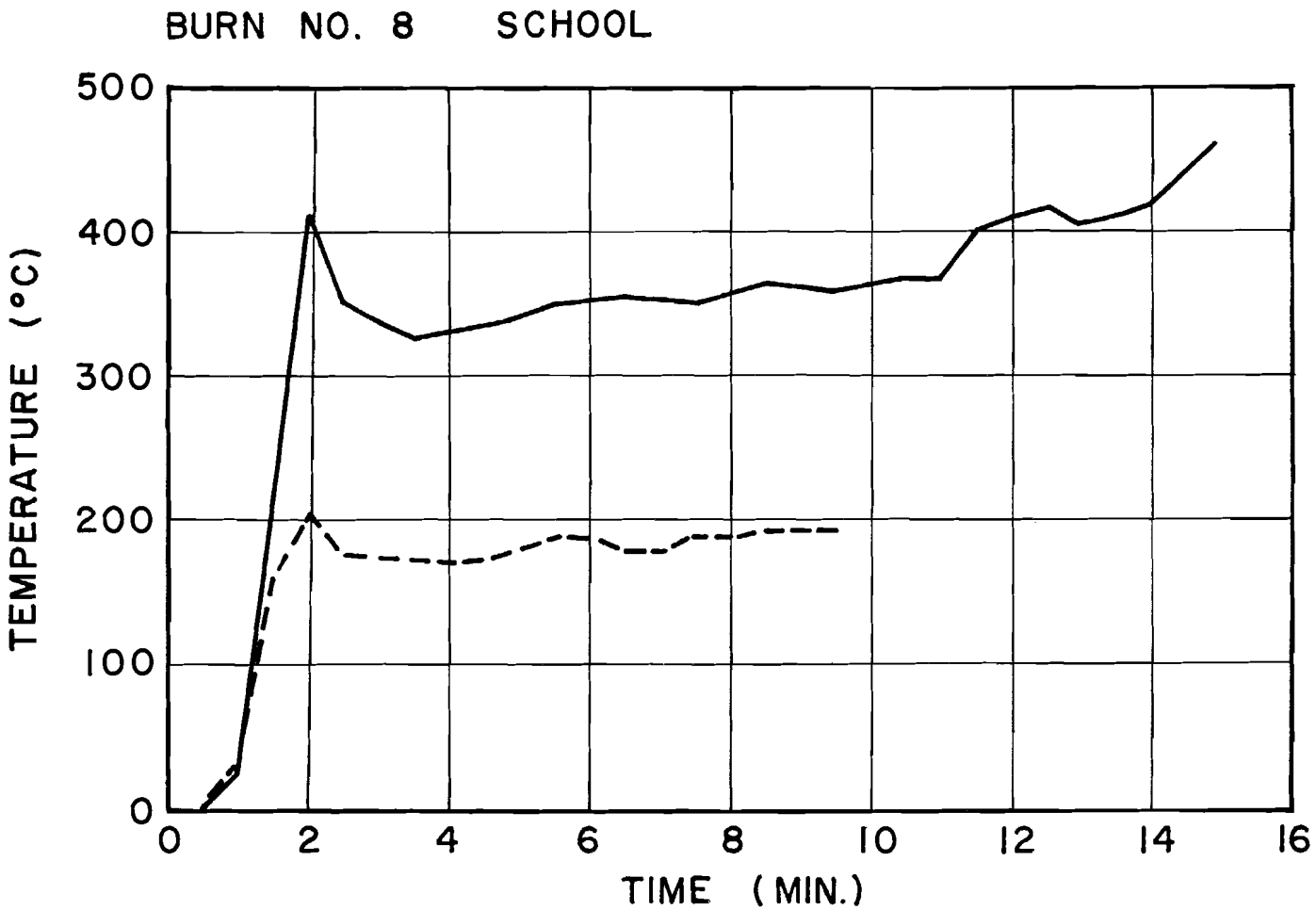


FIGURE 17 TEMPERATURE-TIME CURVES