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ROOFING RESEARCH

by

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1. SUMMARY

Studies of the engineering properties of built-up roofing have been underway in the Building Research Laboratories of NBS. Utilization of these properties will be discussed in relation to the reduction of potential failures of roofing membranes in service.

Descriptions of the newly-developed fluid roofing systems and the one-ply sheet systems which have both been brought into play by the increasing use of irregular-shaped thin-shell concrete decks, increased cost of labor, and the demand for more factory-finished products that leave little room for application errors, will also be given.

References to research by others particularly significant to improved roofing systems will be cited.

2. INTRODUCTION

Considerable progress has been made in the development and design of different types of roofing systems. I would like to present to you three facets of roofing research and developments:

<u>FIRST</u> some highlights of roofing research in the Building Research Division at the National Bureau of Standards;

<u>SECOND</u> a brief description of some of the newly-developed roofing systems; and,

<u>THIRD</u> the present status of roofing research.

3. ROOFING RESEARCH AT NBS

A major percentage of flat roof construction in the United States consists of built-up roof systems. The term "Built-Up Roofing" is used to describe roofs which are installed in layers directly upon the roof decks of buildings. There are many different materials and, they are placed over many different types of insulated or non-insulated roof decks. In recent years serious splitting and wrinkle-cracking failures have occurred in built-up roof membranes. These failures appeared most frequently on membranes applied over insulation and after periods of cold weather.

A part of the roofing research at the National Bureau of Standards has been to measure the natural solar heating and radiative cooling of exposed built-up roof systems and to obtain data on the thermal expansion and contraction characteristics of the composite built-up membrane in order to better understand causes of the splitting failures.

Ten built-up roofs on wood and concrete decks, both insulated and non-insulated were constructed and placed on top of a roof in Washington, D. C. Each construction contained copper-constantan thermocuples at selected locations for recording temperature continously 24 hours a day. Figure 1 is a schematic diagram of a typical specimen. Five surfaces representing those commonly used on built-up roofs were used in the experimental work. Figure 2 shows a general view of the outdoor exposures.

The results illustrated in Figure 3 show the extent of temperature changes for a smooth black surface built-up membrane on insulated and uninsulated concrete decks on a summer day in August. Figure 4 illustrates the effect of the protective surface on the temperature and the rate of temperature change of membranes placed over insulation. From this series of experiments sub-cooling temperature less than ambient were also measured[1][1/].

These temperature variations expose the roofing to extreme thermal stresses particularly in the range from 30°F to -30°F. Both the data obtained and observations of splitting and shrinkage suggest that thermal movement of the built-up roofing may be involved. Figure 5 illustrates the method used to measure the membrane movements with a Whittemore Strain Guage. The results shown in Tables 1 and 2 indicate built-up roof membranes undergo greater thermal expansive and contractive movements than most other components of a roof system at low temperatures.

From these investigations [2] the following suggestions have been made, and accepted by some roofing contractors and manufacturers to help prevent premature roofing failure:

1. Tape insulation joints
2. Place long dimension of insulation parallel to short dimension of roof.
3. Place long dimension of roofing felt parallel to long dimension of roof.

1/ Figures in brackets indicate literature references at the end of this paper.

TABLE 1. APPARENT LINEAR THERMAL EXPANSION COEFFICIENT OF ROOFING FELTS

(TEMPERATURE RANGE 30°F to -30°F)

Description	Expansion Coefficient per °F	
	"With Machine"	"Across Machine"
Felt, Organic, Asphalt-Saturated	6.3×10^{-6}	13.3×10^{-6}
Felt, Asbestos, Asphalt-Saturated	6.3×10^{-6}	13.0×10^{-6}
Felt, Glass fiber, Asphalt-Saturated	14.5×10^{-6}	18.2×10^{-6}
Felt, Organic, Coal-tar Saturated	6.5×10^{-6}	15.2×10^{-6}

TABLE 2. APPARENT LINEAR THERMAL EXPANSION COEFFICIENT OF BUILT-UP MEMBRANES (TEMPERATURE RANGE 30°F to -30°F)

Description	Expansion Coefficient per °F	
	"With Machine"	"Across Machine"
Asphalt - Asphalt-Sat. Organic Felt	10.9×10^{-6}	20.8×10^{-6}
Asphalt - Asphalt-Sat. Asbestos Felt	8.3×10^{-6}	20.3×10^{-6}
Asphalt - Asphalt-Sat. Glass Felt	18.1×10^{-6}	26.1×10^{-6}
Coal-Tar Pitch-Coal-Tar-Sat. Organic Felt	10.4×10^{-6}	29.4×10^{-6}

4. Have positive adhesion of insulation to deck.

5. Have optimum strength adhesive of roof membrant to insulation.

6. Use of expansion joints.

7. In areas of the country were extreme cold weather prevails use roofing membranes with high thermal-shock resistance.

4. NEW ROOFING SYSTEMS

A number of new roofing materials and roof systems have appeared on the market in the last 5 years. Some of these systems have been introduced as substitutes for current types of roofing for both flat and steep roofs, whereas, others have been promoted to serve a particular function which conventional roofings can accomplish only with difficulty; for example, the protection of roofs of unusual contours as the curved shells, the dome, the folded plate, or the hyperbolic paraboloid as shown in Figures 6 and 7. In some cases, the new systems were designed to fulfill both needs. A few of the newer systems allow more utilization of the roof as a work or recreation area.

Studies of the outdoor exposure effects and simulated exposure effects are being made on the roofs. The two types being evaluated are prefabricated sheets and liquid-applied coatings. The sheet materials have an exposed top surface of chloroprene (Neoprene) rubber, chlorosulfonated polyethylene (Hypalon) rubber, butyl-rubber or polyvinyl-fluoride (Tedlar) polymer. The back layer of some of the sheets are asbestos felts. The sheets are applied with an organic solvent-based adhesive with the overlapped joints tapped..

The liquid-applied coatings are brushed, rolled, or sprayed in multi layers. In one recommended commercial system six coatings, 1-primer, 3-base and 2-top coatings, are applied to yield a total dry film thickness of over 20 mils. The liquid-applied coatings under study for their durability are noprene-Hypalon, butyl-rubber emulsion without top coating and with a top coating of Hypalon or polyvinyl chloride acetate, silicone rubber and polyurethane foam. Fiber reinforcement of glass fiber cloth, glass fiber random nat, or chopped glass fibers are used.

Surface preparation plays a very important part in the success or failure of these new systems. The surfaces for the most part must be clean, dry, and primed because of the need for mechanical and chemical bond to the deck being waterproofed or roofed.

5. ROOFING RESEARCH BY OTHERS

With the introduction of rubbers and plastics into this area of building construction large chemical companies have joined the roofing products manufacturers in studying the properties of roofing.

Studies on wind resistance, nailing and hail damage have been undertaken by the Underwriters' Laboratories and many roofing manufacturers.

Moisture effects are being studied at the Pennyslvania State University.

Load-strain properties and their relation to splitting are being measured by the Governmental Building Research organizations in Canada and in Australia.

Development of a thermal-shock resistance factor for bituminous built-up roofing membrane made in the laboratory as well as obtain in the field is being undertaken at NBS.

6. REFERENCES

[1] W. C. Cullen, "Solar Heating, Radiative Cooling and Thermal Movement - Their Effects on Built-Up Roofing", NBS Technical Note No. 231 (Dec. 1963).

[2] W. C. Cullen,"Effects of Thermal Shrinkage on Built-Up Roofing", NBS Monograph 89 (1965).

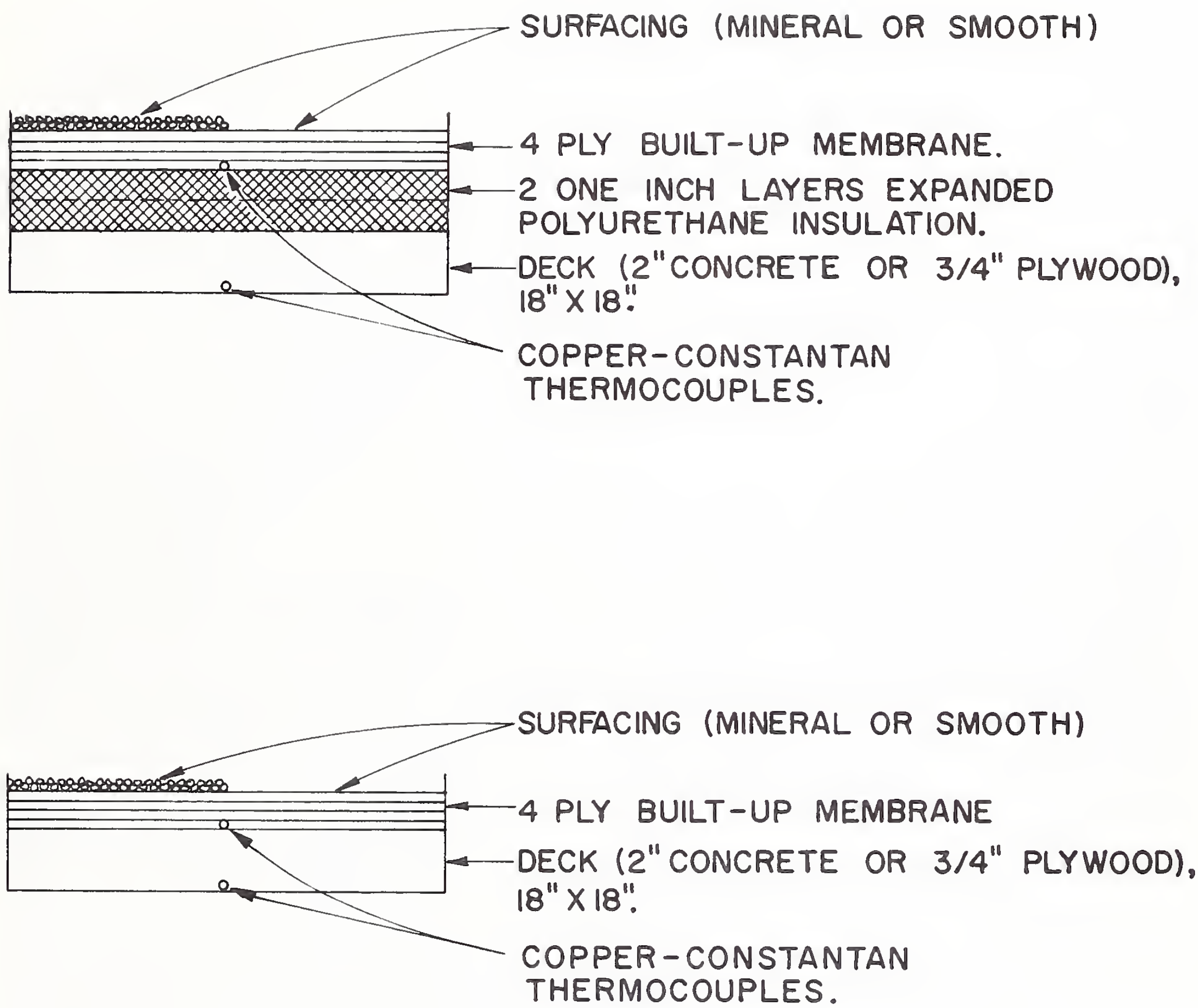


Figure 1. Schematic diagram of typical built-up roof specimens exposed outdoors.

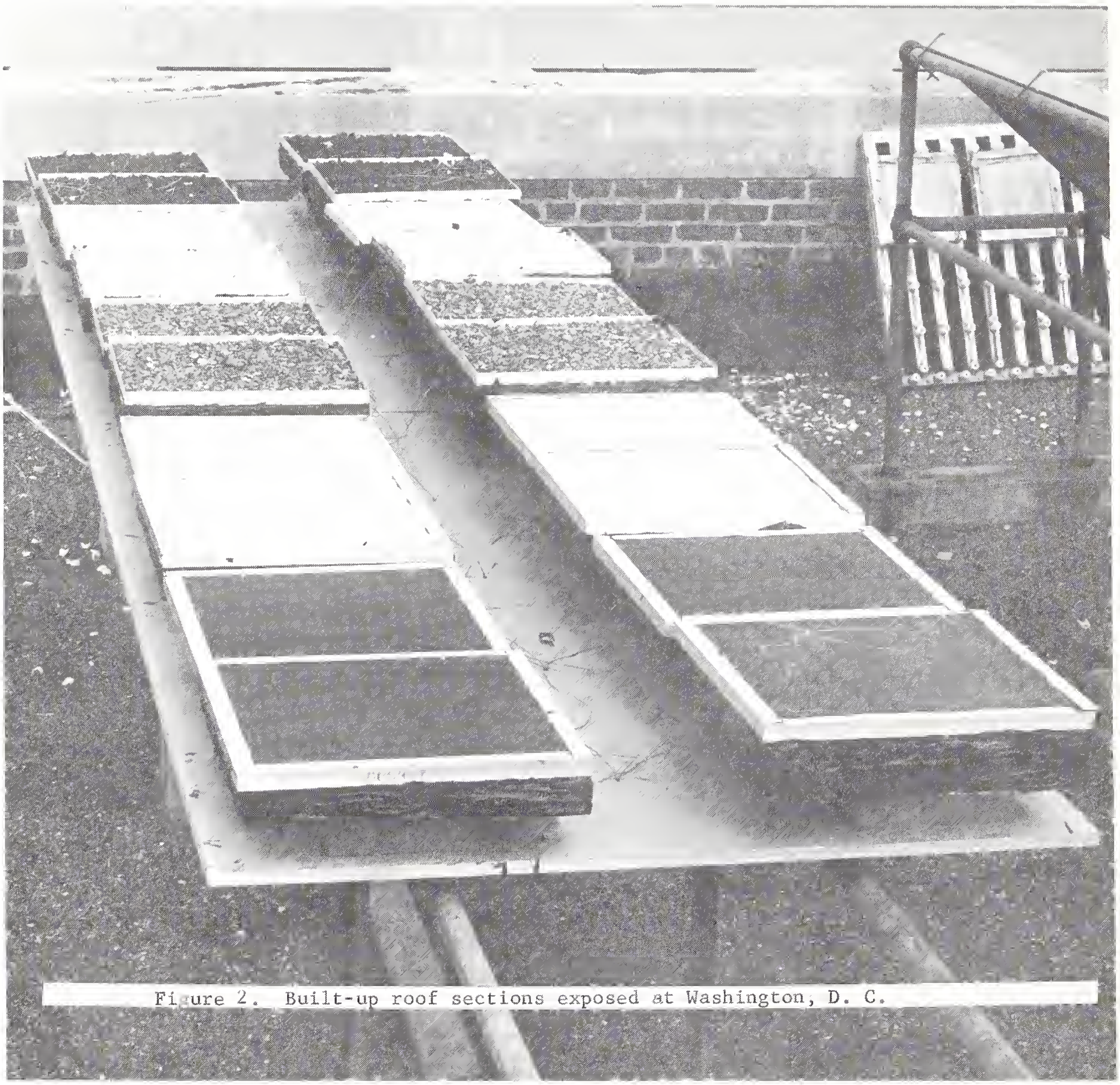


Figure 2. Built-up roof sections exposed at Washington, D. C.

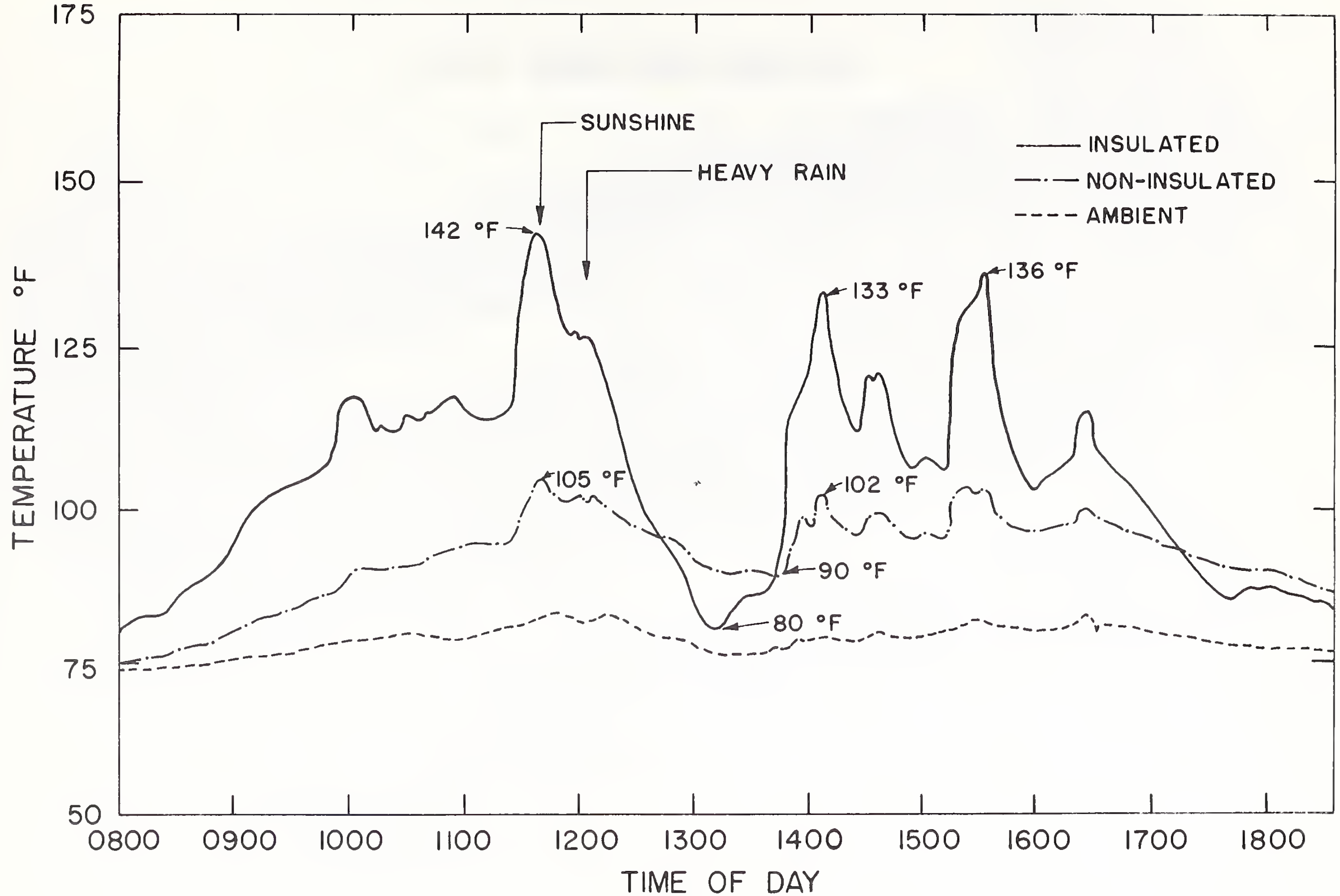


Figure 3. Time-temperature curves for built-up membranes on insulated and non-insulated concrete decks.

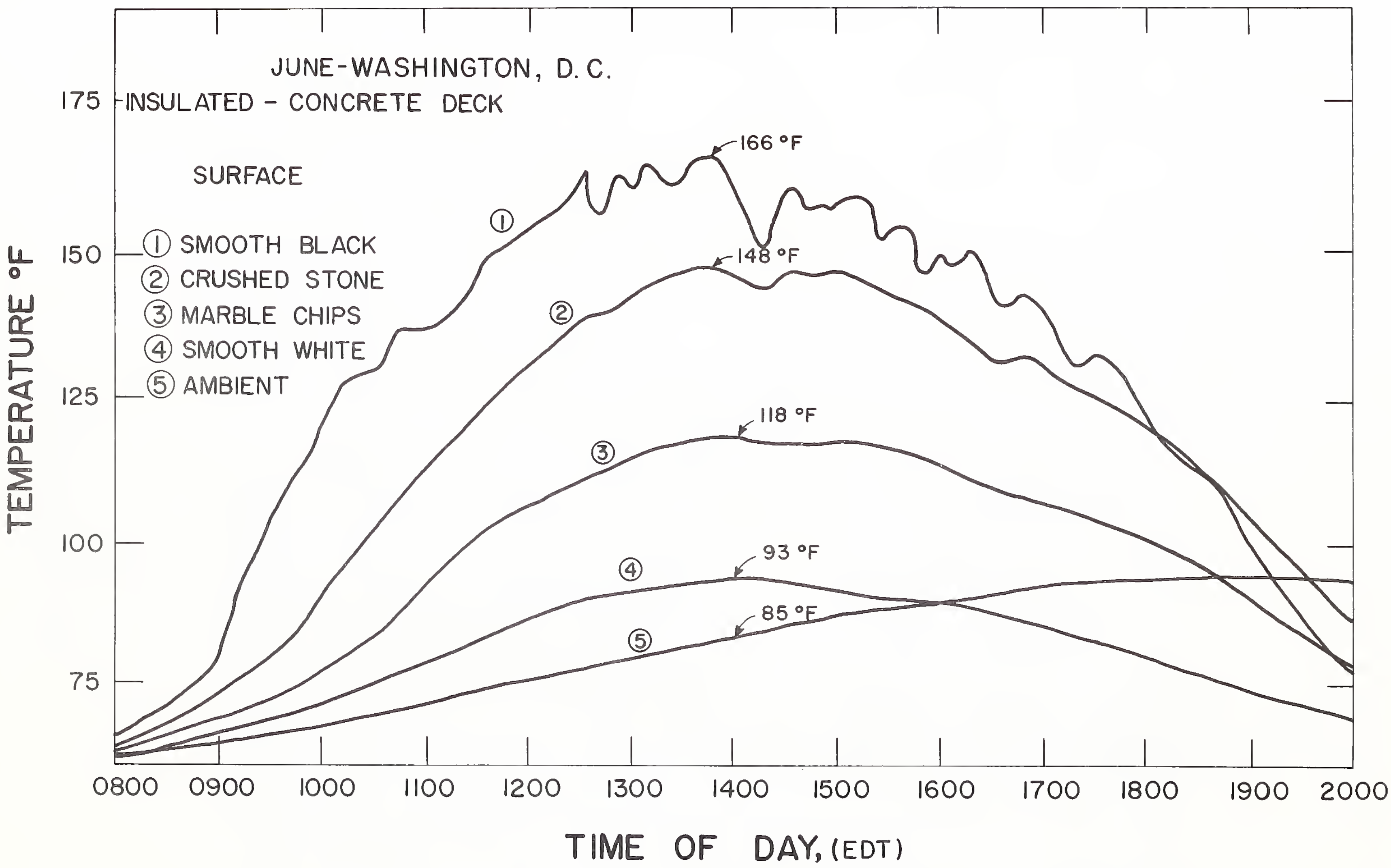


Figure 4. Effect of surface treatment on the solar heating of built-up membranes during summer exposure.

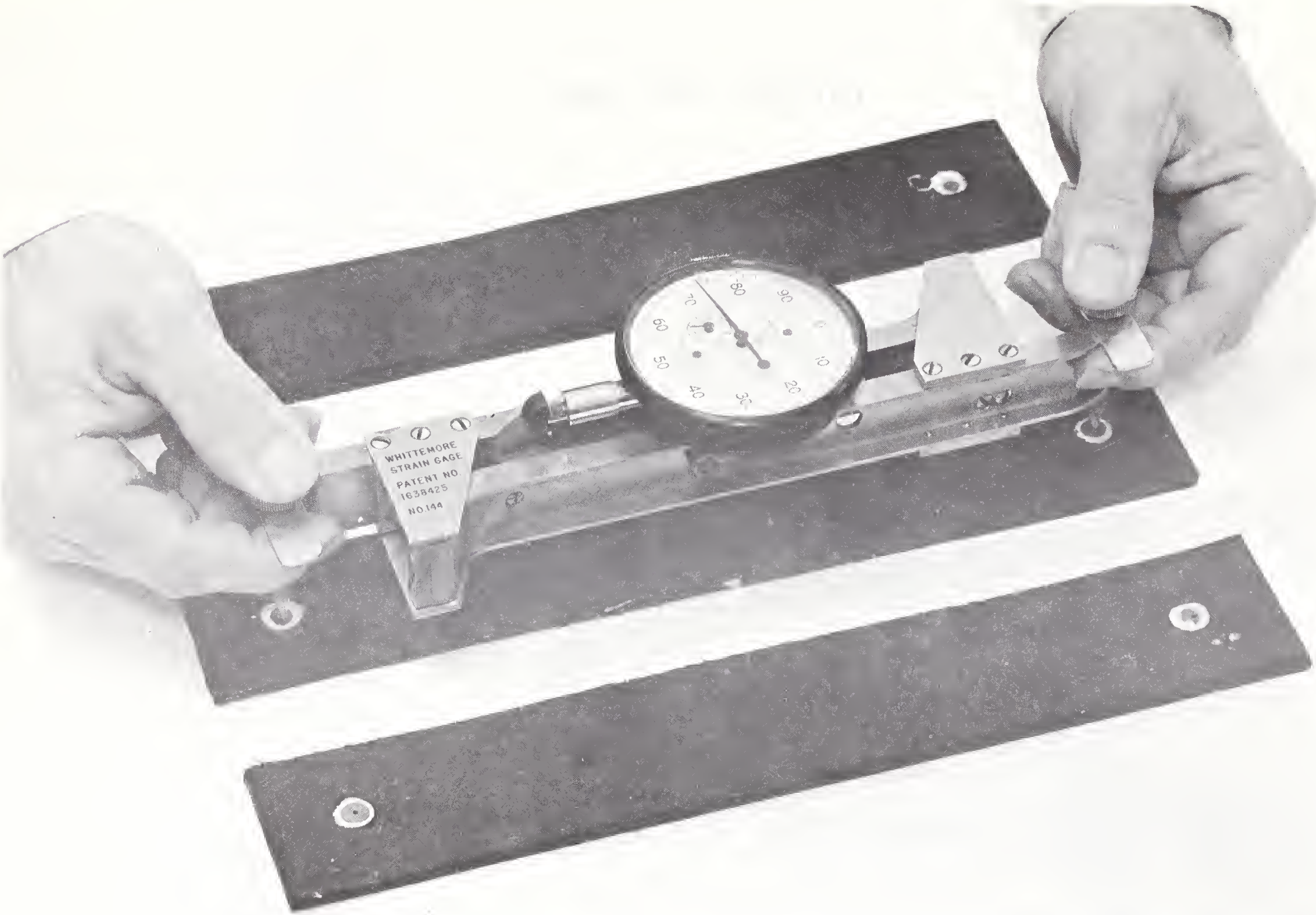


FIGURE 5. THERMAL MOVEMENT MEASUREMENT TECHNIQUE.

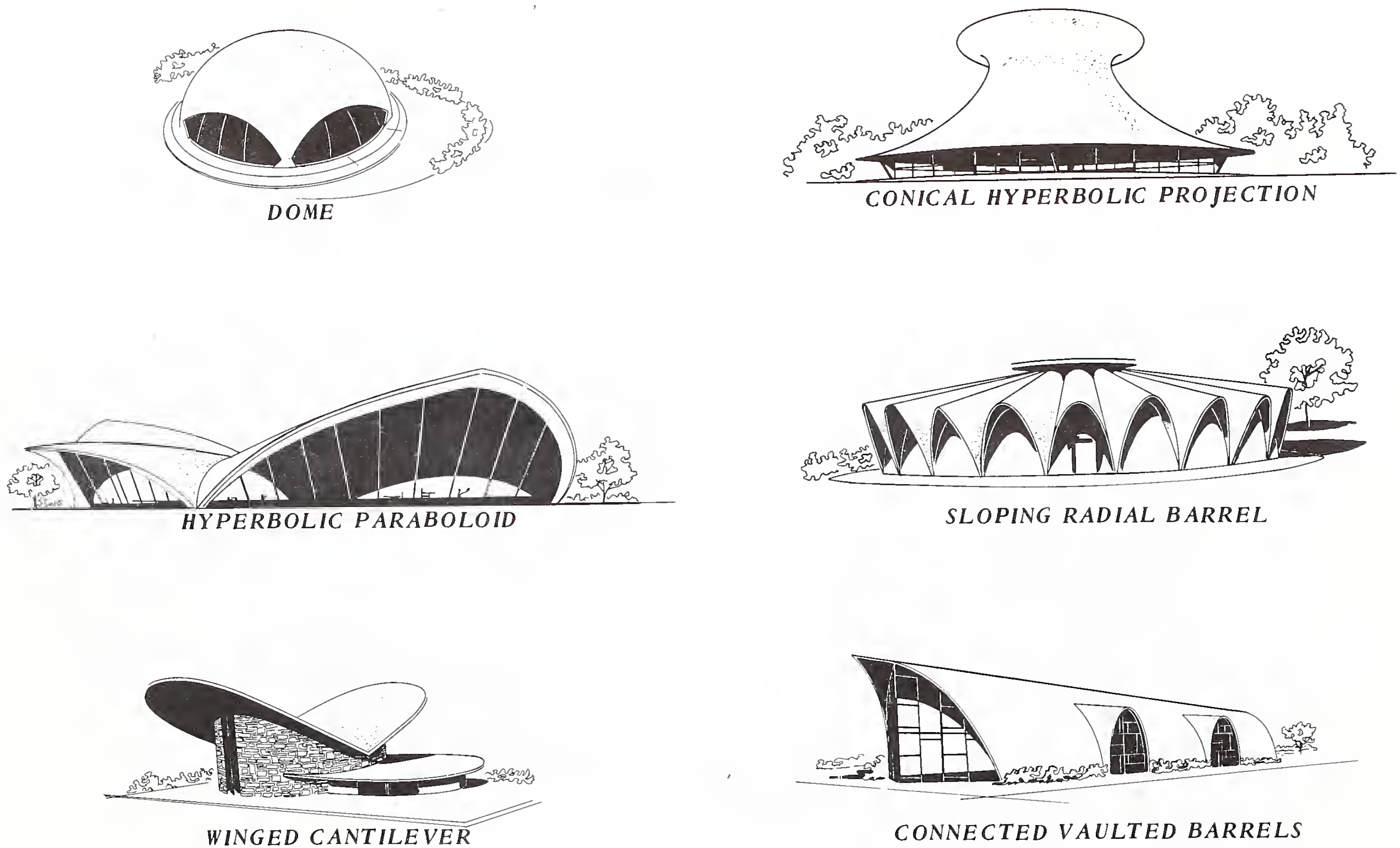
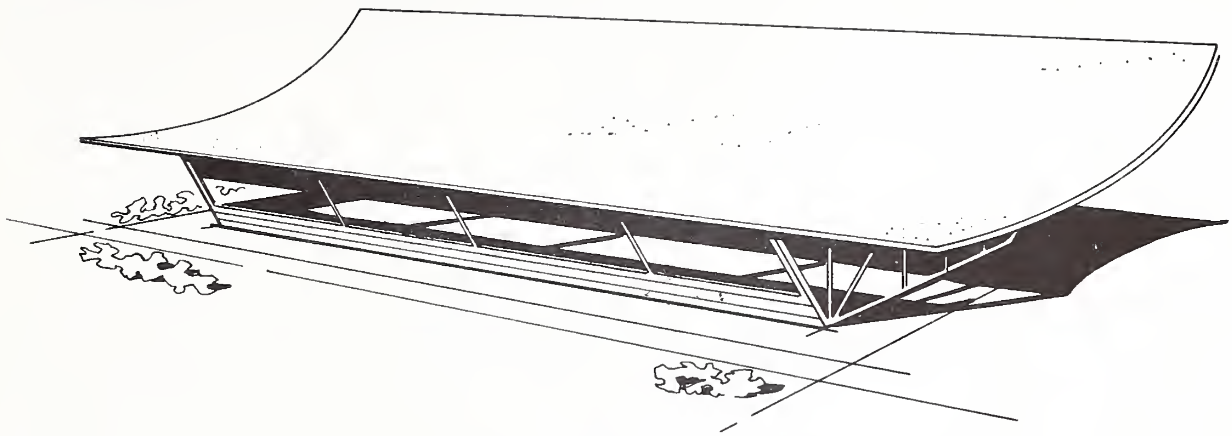
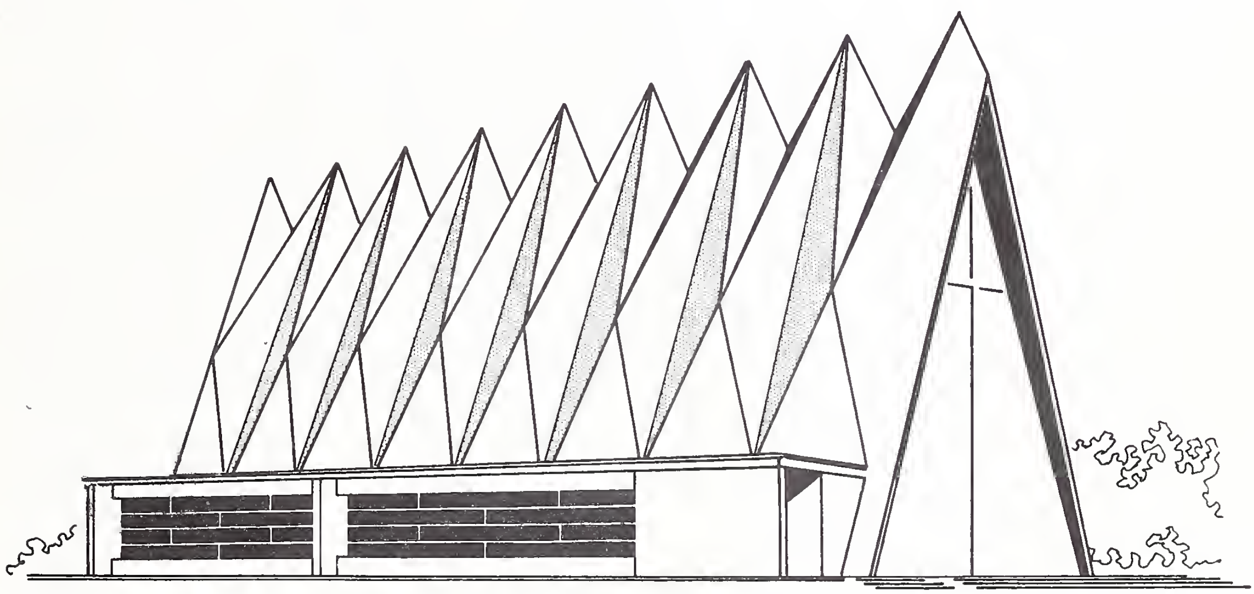


Figure 6. Illustrations of irregular-shaped roofs.



CONCAVE HAMMOCK



TETRAHEDRAL

Figure 7. Illustrations of irregular-shaped roofs.