Special Report 80-14

March 1980

CRREL ROOF MOISTURE SURVEY, PEASE AFB BUILDINGS 35, 63, 93, 112, 113, 120 and 220

Charles Korhonen and Wayne Tobiasson

Prepared for
DIRECTORATE OF MILITARY PROGRAMS
OFFICE, CHIEF OF ENGINEERS
By
UNITED STATES ARMY
CORPS OF ENGINEERS
COLD REGIONS RESEARCH AND ENGINEERING LABORATORY
HANOVER, NEW HAMPSHIRE, U.S.A.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Special Report 80-14	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (*and Subtitle*): CRREL ROOF MOISTURE SURVEY, PEASE AFB BUILDINGS 35, 63, 93, 112, 113, 120 and 220	5. TYPE OF REPORT & PERIOD COVERED
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(*s*): Charles Korhonen and Wayne Tobiasson	8. CONTRACT OR GRANT NUMBER(*s*)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire 03755	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: DA Project 4A762730AT42, Task Area C, Work Unit 3
11. CONTROLLING OFFICE NAME AND ADDRESS: Directorate of Military Programs, Office, Chief of Engineers, Washington, DC 20314	12. REPORT DATE: March 1980
	13. NUMBER OF PAGES: 37
14. MONITORING AGENCY NAME & ADDRESS (*if different from Controlling Office*)	15. SECURITY CLASS. (*of this report*): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (*of this Report*)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (*of the abstract entered in Block 20, if different from Report*)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (*Continue on reverse side if necessary and identify by block number*)

Built-up roofs
Infrared scanning
Insulation
Moisture
Roofs
Thermograms

20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

We surveyed the roofs of seven buildings at Pease AFB with a hand-held infrared scanner to detect wet insulation. We used white spray paint to outline the wet areas and took core samples of the built-up membrane and insulation to verify our findings. Flashing defects around penetrations and bordering walls appear to be the major cause of the wet insulation found on these roofs. Since most problem areas are localized, we directed our repair recommendations toward salvaging as much of each roof as is economically possible.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

PREFACE

This report was prepared by Charles Korhonen and Wayne Tobiasson, Research Civil Engineers, Civil Engineering Research Branch, Experimental Engineering Division, U.S. Army Cold Regions Research and Engineering Laboratory.

This study was conducted under DA 4A762730AT42, Design, Construction and Operations Technology for Cold Regions, Task Area C, Cold Regions Maintenance and Operations of Facilities, Work Unit 3, Moisture Detection in Roofs.

E. Lobacz and B. Coutermarsh of CRREL and N. Turner of the Base Civil Engineer's staff, Pease Air Force Base, technically reviewed this report.

The contents of this report are not to be used for advertising or promotional purposes. Citation of brand names does not constitute an official endorsement or approval of the use of such commercial products.

CONTENTS

ILLUSTRATIONS

INTRODUCTION

The roofs of seven buildings (35, 63, 93, 112, 113, 120, and 220) at Pease AFB, Portsmouth, N.H., were surveyed for wet insulation with a hand-held infrared camera during the evenings of 25 October, 31 October, and 1 November 1977. The AGA Thermovision 750 infrared camera used for these surveys displays a live black and white thermal image of the roof's surface on a cathode-ray-tube (CRT) viewing screen. Areas of a roof containing wet insulation appear as bright thermal anomalies on the viewing screen as opposed to dark gray for areas containing dry insulation. We outlined all wet areas with white spray paint and took Polaroid photographs of the viewing screen to further document the anomalies. Such photographs are termed thermograms.

Several 3-in. (7.6-cm) diameter core samples of the membrane and insulation were taken on these roofs using a CRREL-designed coring device. Samples were sealed in plastic bags and brought to CRREL where they were weighed, dried in an oven for a week at 120°F (49°C), and reweighed. Moisture content of the insulation is defined as the weight of the water in the insulation divided by the weight of the dry insulation, expressed as a percent.

The technique used to find wet roof insulation is discussed in detail by Tobiasson et al. (1977 a,b). Other roofs at Pease AFB surveyed in the past are discussed by Korhonen et al. (1977).

SURVEYS

Building 113

The roof on this building comprises a gravel-covered, built-up membrane underlain by 2 1/4 in. (5.7 cm) of wood fiber insulation. We identified several areas suspected of containing wet insulation (shown by the hatched areas in Fig. 1).

Samples of the insulation from within these hatched areas were wet. Building occupants indicated that the roof leaked.

Thermograms and photographs of three large wet areas are shown in Figures 2 - 4. We suspect that flashing defects and punctures in the built-up membrane are the cause of these wet areas even though we did not observe any during this survey.

Several additional wet areas were also marked on this roof. Most of these were relatively small and should be patched before they get larger.

Several small blisters were noted in the northern portion of this roof (left of the dashed line in Fig. 1). Brief visual examinations of this roof were made in September and November 1978. At those times blisters were present over the entire roof, suggesting progressive membrane deterioration.

Since only a small percentage of this roof contains wet insulation but the entire membrane appears to be rapidly deteriorating, we suggest that all the gravel be removed and the tops of all blisters cut away. All wet insulation should then be cut out and replaced with dry insulation. Additional insulation should be added over the entire roof to improve its thermal resistance. It may be possible to affix the new insulation to the existing membrane with hot bitumen, but it may be necessary to use mechanical fasteners.

The insulation should then be covered by a gravel-covered built-up membrane. We estimate that this procedure will increase the roof's dead load by approximately 5 lb/ft^2 (24 kg/m^2).

No wet insulation was found on the penthouse roof, but the built-up membrane there was very brittle. This roof should not be expected to remain watertight much longer and should be repaired in the same summer as the lower roof.

Building 120 (Aircraft Maintenance Shop)

This gravel-covered roof was comprehensively surveyed for wet insulation in September 1975 and again during this survey (October 1977). The insulation between the gypsum deck and the built-up membrane is 1 1/2-in.(3.8-cm)-thick glass fiber, some of which is wet. There is no visual evidence of interior building leaks. Apparently the vapor barrier below the insulation has prevented roof moisture from entering the gypsum deck.

Figure 5 presents the results of the 1975 and 1977 surveys. The number and size of wet areas have greatly increased, indicating that moisture is entering the roof. One contradiction exists: the wet area surrounding sample E (Fig. 5) decreased in size and water content. This area may have lost moisture through the edge of the roof.

We consider membrane punctures created by guy wire anchor bolts responsible for the wet insulation found at each end of this roof. Figure 6 is a 1975 thermogram of a bright area surrounding the anchor bolt in the southeast corner and a photograph of the same area. From a comparison of the water content of the 1975 Samples C and A (C = 355% and A = 105%) it is evident that the insulation was much wetter near the bolt than at a distance from it, strongly suggesting that moisture enters the roof near the anchor bolt. The thermogram in Figure 7 shows the extent of wetting in 1975; the photograph shows the boundaries painted in 1977.

A 1975 thermogram (Fig. 8) shows that the thermal anomaly in the northeast corner is somewhat mottled, suggesting that this area of the roof was not uniformly wet. Since the infrared camera was not used to select a sample location from this mottled area, we believe that sample R was inadvertently selected from a dry (dark) portion of the mottled area. This explains its low water content even though it is located within a "wet" area. In 1977 this area was again mottled. However this time the infrared camera was used to select two sample sites. Samples F' and G' were both wet as expected. The photograph in Figure 8 shows the boundaries of this wet area.

The area of wet insulation shown in Figure 9 was first detected during the 1977 survey. Although no membrane defects were noted, the shape and location of the anomaly seem to indicate that moisture enters this area from the base of the vent stack.

The top photograph in Figure 10, taken in 1975, shows an antenna mounted on the surface of the roof. In the foreground, a wet area is outlined with spray paint. In 1977 this same antenna was tipped over and the wet area had increased in size. This sequence strongly suggests that water enters this area of the roof through membrane defects associated with the antenna.

Low blisters were noted over much of this roof and the membrane from each sample was brittle. We expect that a new built-up roof will be required shortly. Rather than wait until severe leaks occur, we suggest that the gravel be removed from this membrane and all areas of wet insulation be cut out and replaced with dry insulation. A new layer of insulation, perhaps mechanically fastened to the deck, should be added over the entire roof and a new gravel-covered built-up roof installed.

Building 35 (Operational Training Building)

This roof is composed of three levels (see Fig. 11). Approximately 2 ft (0.6 m) separates each level, with Level 1 the highest and Level 3 the lowest. Level 1 is gravel-covered while Levels 2 and 3 have a gravel surface that is over-coated with a bituminous seal coat. Overall, Level 1 appeared much brighter than the other two levels when viewed with the infrared camera. Core samples revealed that Level 1 had wood fiber insulation which is only 1/2 in. (1.3 cm) thick, while Levels 2 and 3 had glass fiber insulation 1 1/2 in. (3.8 cm) thick. Thus the thermal image was brighter on Level 1 because that section had less insulation than the other two levels. Because the Level 1 roof was uniformly bright we expected it to be free of wet insulation. Sample A, taken on Level 1 (see Fig. 11), was dry, which verified this expectation. Visually, the built-up membrane on Level 1 appeared to be in excellent condition. No remedial work is necessary there.

Five thermal anomalies were detected with the infrared camera on the Level 2 and 3 roofs. They are shown as hatched areas in Figure 11. Core samples subsequently verified that the insulation in these areas was wet. Figures 12 and 13 show a thermogram and three daytime photographs of these wet areas.

Visually, only one obvious moisture entry point was uncovered. The arrow in Figure 13 points to a deep split in the over-coating. It is likely that moisture entered the roof at this location. Building occupants pointed out two sections of ceiling stained by leaks which occur each winter. One leak is under the split shown in Figure 13; the other leak coincides with the area shown in Figure 12.

Unlike sample A, the membrane of samples B through E was brittle. It delaminated during the sampling process. This lack of interply bonding indicates that the membrane is very aged and probably will not last much longer. Due to the heavy over-coating on levels 2 and 3, we do not feel that the gravel can be removed without damaging the glass fiber insulation. We expect that simply cutting out and patching the wet areas is not an economical repair alternative because the entire membrane is so old and brittle. We recommend that all the membrane and insulation on Levels 2 and 3 be removed and replaced with new, insulated, built-up roofing.

Building 112 (Parachute Shop)

Infrared surveys were conducted on the main roof of this building in October 1975 and in May 1976 in addition to this survey (October 1977). Brief follow-up surveys were also conducted in November 1978 and April 1979. Essentially the wet areas shown in Figure 14 have been detected each time. The main roof consists of a wood deck, 1 1/2 in. (3.8 cm) of glass fiber insulation, and a gravel-covered built-up membrane.

Severe roof leaks plagued the northern end of this building in 1975. An infrared survey at that time revealed that a rectangular area surrounding a drain contained wet insulation. A pond of bitumen poured around that drain stopped those leaks. However, a 1977 thermogram (Fig. 15) indicates that moisture is still entrapped there.

The other wet area detected on this roof is shown in Figure 16. Visually, that area appeared to be in good condition. We suspect that moisture entered through the wall flashing adjacent to this area.

Since the October 1975 survey no additional wet areas have developed, no interior leaks have been reported, and the wet areas initally detected have remained essentially the same size. Currently the membrane is watertight. Perhaps this roof will remain watertight a few more years. Rather than repair it now, we recommend that it be scheduled for repair work in the next 2 to 3 years. In the interim we are conducting insulation drying experiments on the roof. In April 1979 we installed two breather vents in the northern wet area.

Once repair work does become necessary, we recommend that a process similar to that outlined for Buildings 113 and 120 be followed.

Building 63 (Chapel)

We detected subtle thermal anomalies unrelated to entrapped moisture on the flat portion of this roof (Fig. 17). The main roof is steeply sloped and was not surveyed. The anomalies were attributed to variations in surface color caused by differences in the extremely heavy bituminous overlays previously applied to this roof. Sample A showed that there is no insulation above the wood deck so we cannot make recommendations based on entrapped moisture.

Visually, the base flashings appear to be in good condition. Although the overlay is dry and cracked, the membrane of sample A exhibited good interply bonding. Barring any leaks, we feel that a few more years of serviceable life can be expected from this roof. The heavy overlay will hinder any patching attempts. For this reason and because this roof is rather small, we suggest that the existing membrane be replaced by a new built-up membrane and insulation if leaks develop.

When a new membrane is installed, insulation should be added to reduce heat losses and significantly improve the chances of obtaining a long-lasting trouble-free roof. Built-up membranes installed directly on wood decks are often problematic.

Building 93 (Hospital)

This roof consists of a concrete deck sloped toward internal drains, 2 in. (5.1 cm) of glass fiber insulation, and a gravel-covered built-up membrane.

Chronic roof leaks have plagued this building since it was constructed in the early 70's. Findings from the 1975, 1976, and 1977 infrared surveys on this roof generally show that most areas of wet insulation are associated with membrane penetrations, especially roof drains (Fig. 18).

Five areas of wet insulation were uncovered during the 1975 infrared survey (Fig. 18a). Since the roof was still under warranty, the contractor decided to patch all visual defects in flashings and install insulation breather vents in an attempt to dry these areas.

A second infrared survey was conducted in 1976. Comparison with the 1975 survey showed that the five wet areas detected in 1975 were about the same size in 1976. The 1975 and 1976 boundaries of one wet area are shown in Figure 19. Either the vents were ineffective at drying insulation or additional moisture entered the insulation at about the same rate it escaped. We believe the former is the correct explanation.

In 1976 seven new "suspected wet" areas were also detected. They are shown by dashed hatching in Figure 18b. They are termed "suspected wet" since no samples were taken in 1976. These "suspected wet" areas strongly suggest that in 1976, moisture was entering the roof at several membrane penetrations. Three of these areas were located on the fourth floor roof which had not contained any problem areas in 1975. Two are shown in Figure 20. We examined the drains in this area and in one case found that the lead flashing was not well bonded to the membrane. We also noted numerous flashing flaws (Fig. 21).

The 1977 survey (Fig. 18c) revealed even greater wetting of the insulation. Figure 22 shows a larger wet area than that in Figure 19.

The wet area in the northwest corner of the lower roof is shown in Figure 23. Breather vents installed within this wet area have not been able to dry it out. Sample C' (Fig. 18c), which was taken in 1977 close to 1975 sample C (Fig. 18a), showed the moisture content increasing from 132% in 1975 to 190% in 1977. Although this roof is continuing to collect moisture, core samples indicate that the membrane is in fairly good condition. If the leaks can be eliminated, several years of serviceable life can be expected from this membrane. Therefore, we suggest that only the membrane and insulation in wet areas be cut out and replaced with new dry materials. Extra attention should be directed toward effective sealing of flashing and roof penetrations to avoid a repetition of the current problem.

The wet area where sample E' was obtained (Fig. 18c) was not well defined. It is possible that internal moisture from the kitchen caused insulation in this area to accumulate moisture. The same argument can be advanced for the area surrounding sample F'. Wetting of that area might also be explained by entry of driving rain along the east wall of the high portion of the building. If these areas are cut out and replaced, attention should be given to achieving a continuous vapor barrier along this wall and providing effective cap flashing where the wall and roof abut. Because the root cause of moisture for this area is not well defined, it may be wise to replace all roofing and insulation to the northeast of dashed line XYZ in Figure 18c. A tight vapor barrier should be installed and the insulation should be edge-vented to prevent creation of a vapor trap.

The northern valley of the high roof accumulated considerable moisture from 1976 to 1977. Some early signs of moisture entry were also detected in the southern valley of that roof. We recommend that a 15-ft (4.6-m) wide strip of membrane and insulation down both valleys be removed and replaced with dry insulation and a new built-up membrane. The four parallel dashed lines in Figure 18c delineate the two areas requiring replacement.

When replacing the wet insulation on this roof it will not be possible to increase the thickness of new insulation for energy conservation purposes as that would complicate drainage. Consequently, a urethane or urethane-perlite composite insulation should be used since, for a given thickness, it is thermally more efficient than glass fiber insulation.

Building 220

This two-level roof consists of a wood deck, 2 1/4 in. (5.7 cm) of wood fiber insulation, and a gravel-covered built-up membrane. One large area of wet insulation was uncovered on this roof (see Fig. 24). The remainder of the roof is considered dry since no other thermal anomalies were detected and since sample B had a water content of only 11%. Building occupants indicated that leaks occurred below the wet area following a heavy rain or snowfall.

Patches applied in the spring of 1977 appear to have stopped the leaks. Although the immediate problem may be corrected, the problem of entrapped moisture remains (see Fig. 25).

Samples A and B show this membrane to be in good condition. The useful life of this roof can be extended by cutting out the portion containing wet insulation and replacing it with dry insulation and a new membrane. By replacing the wood fiber insulation with a similar thickness of more efficient urethane-perlite composite insulation, the insulating value of the roof can be significantly improved.

Ponded water was noted between the two drains (Fig. 25). When the wet insulation is being replaced, slope should be added to eliminate ponding.

SUMMARY

The aged condition of the built-up membrane and the presence of wet insulation on Buildings 113 and 120 indicates that replacement systems are needed. Although the entire membrane on these roofs is in poor condition, only a small portion of each roof contains wet insulation. Therefore, we recommend that all gravel be removed from these roofs, and that all wet areas be cut out and replaced with dry insulation. A new layer of insulation, possibly mechanically fastened, should then be added over each roof to increase its thermal resistance and to provide a good substrate for a new gravel-covered built-up membrane. These repairs should increase the roof's dead load by about 5 lb/ft^2 (24.5 kg/m^2).

Because of the over-coating and the aged condition of Levels 2 and 3 on Building 35, we recommend that all the insulation and the membranes on these two levels be removed and replaced with new insulated built-up roofing. No work is necessary on Level 1 since the membrane there is in good condition and the insulation is dry.

Since the roof of Building 112 has not developed any leaks over the past 3 1/2 years, we feel that it will probably remain watertight for a few more years. At the present time, no work is needed on this roof, but repairs probably will be needed in 2 to 3 years. At that time the gravel and any wet insulation should be removed and insulation and a new membrane added over the entire roof.

Once additional leaks develop on Building 63, we suggest that the existing built-up membrane be removed and replaced. Currently no insulation exists over the wood deck. Before a new membrane is installed, insulation should be added, not only to increase the roof's efficiency, but also to provide a stable substrate for the new membrane.

The built-up membrane on Buildings 93 and 220 appears to be in good condition, possibly capable of yielding several more years of service if localized moisture problems can be solved. The membrane and insulation in wet areas should be removed and replaced with dry insulation and a new membrane. Slope should be added to drain the ponded water on the roof of Building 220.

In conjunction with the above, a comprehensive visual inspection of all roofs except that of Building 112 should be made with particular attention paid to locating and eliminating flaws at flashings and penetrations.

LITERATURE CITED

1. Korhonen, C., W. Tobiasson and T. Dudley. (1977) CRREL roof moisture survey, Pease AFB Buildings 33, 116, 122, and 205. U.S. Army Cold Regions Research and Engineering Laboratory Special Report 77-2 (also ASHRAE Journal, Sept. 1977, 41-44).

2. Tobiasson, W., C. Korhonen and T. Dudley (1977a) A roof moisture survey, ten State of New Hampshire buildings. CRREL Report 77-31.

3. Tobiasson, W., C. Korhonen and A. Van den Berg (1977b) Hand-Held infrared systems for detecting roof moisture, In Symposium on Roofing Technology, 21-23 Sept 1977, National Bureau of Standards (proceedings published by National Roofing Contractors Association).

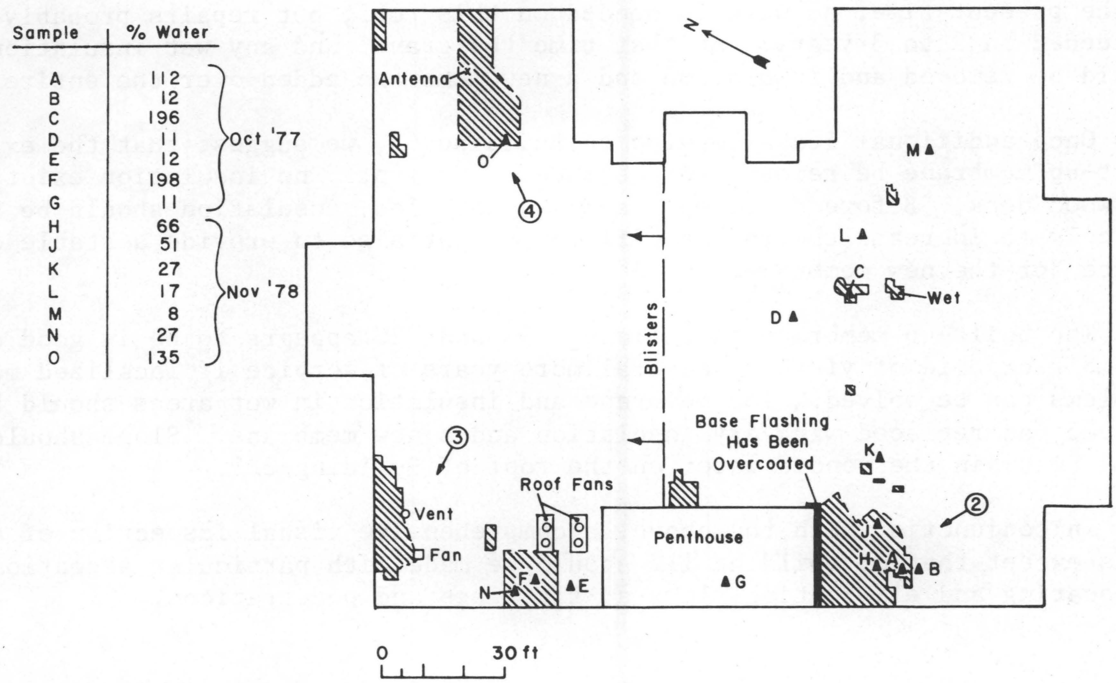


Figure 1. Plan view of Building 113. On all roof plans, circled numbers indicate the location and viewing direction of thermograms or photographs, dotted lines are general boundaries, and solid lines are exact boundaries of wet areas, which are depicted by hatching.

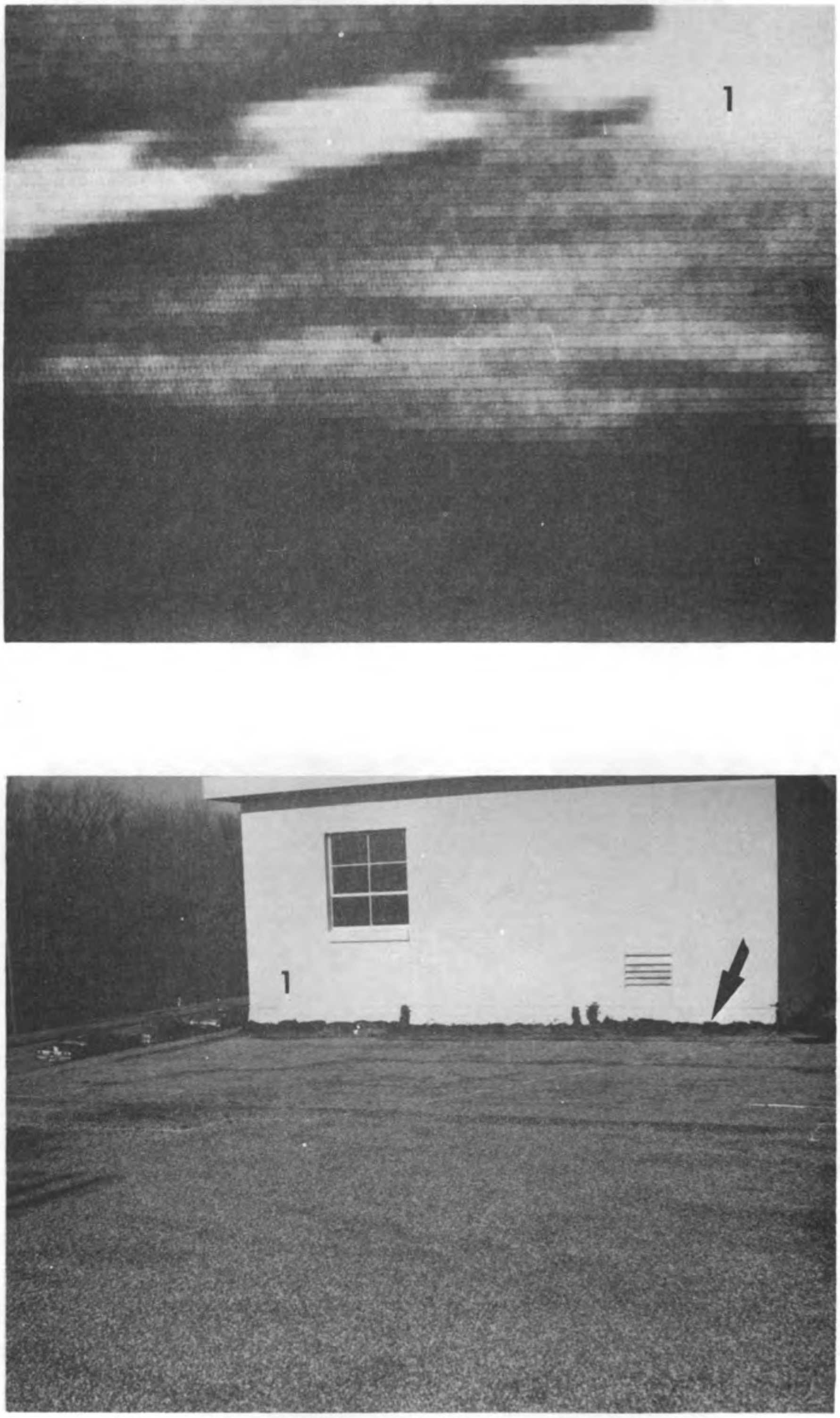


Figure 2. Thermogram and photograph of wet area abutting the penthouse on Building 113 (arrow points to patched flashing).

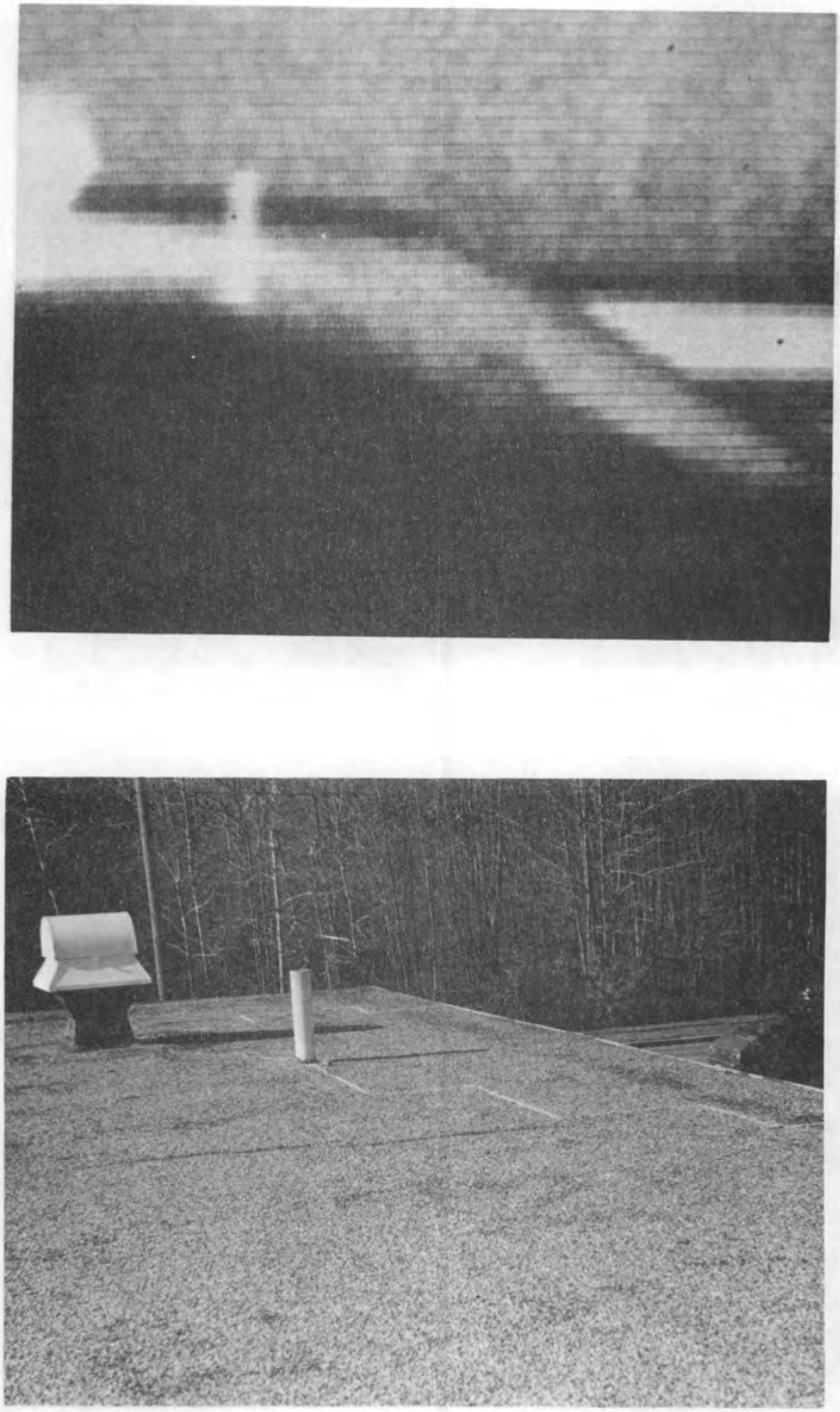


Figure 3. Thermogram and photograph of wet area that appears to be emanating from the base of a roof fan, Building 113.

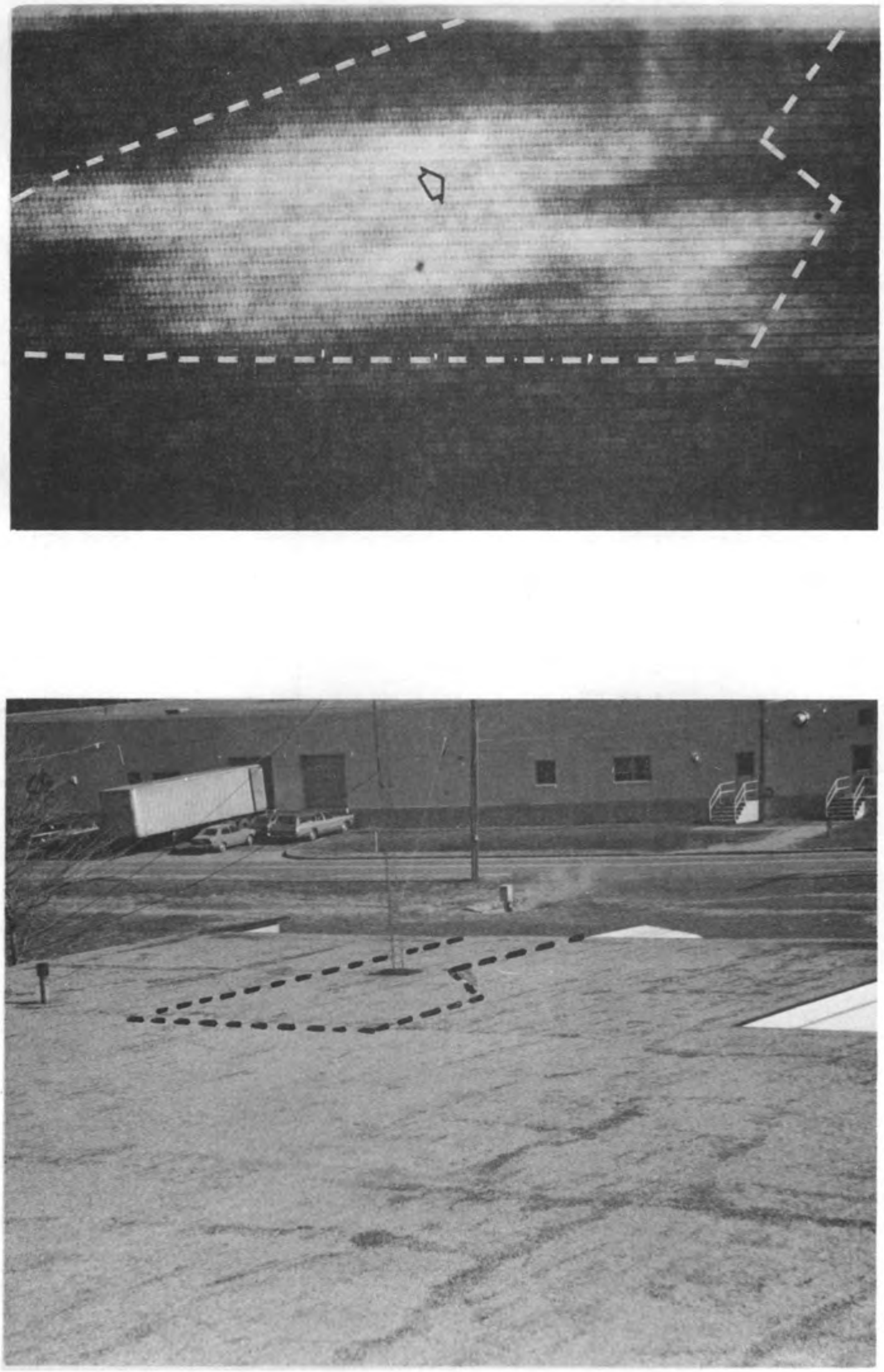
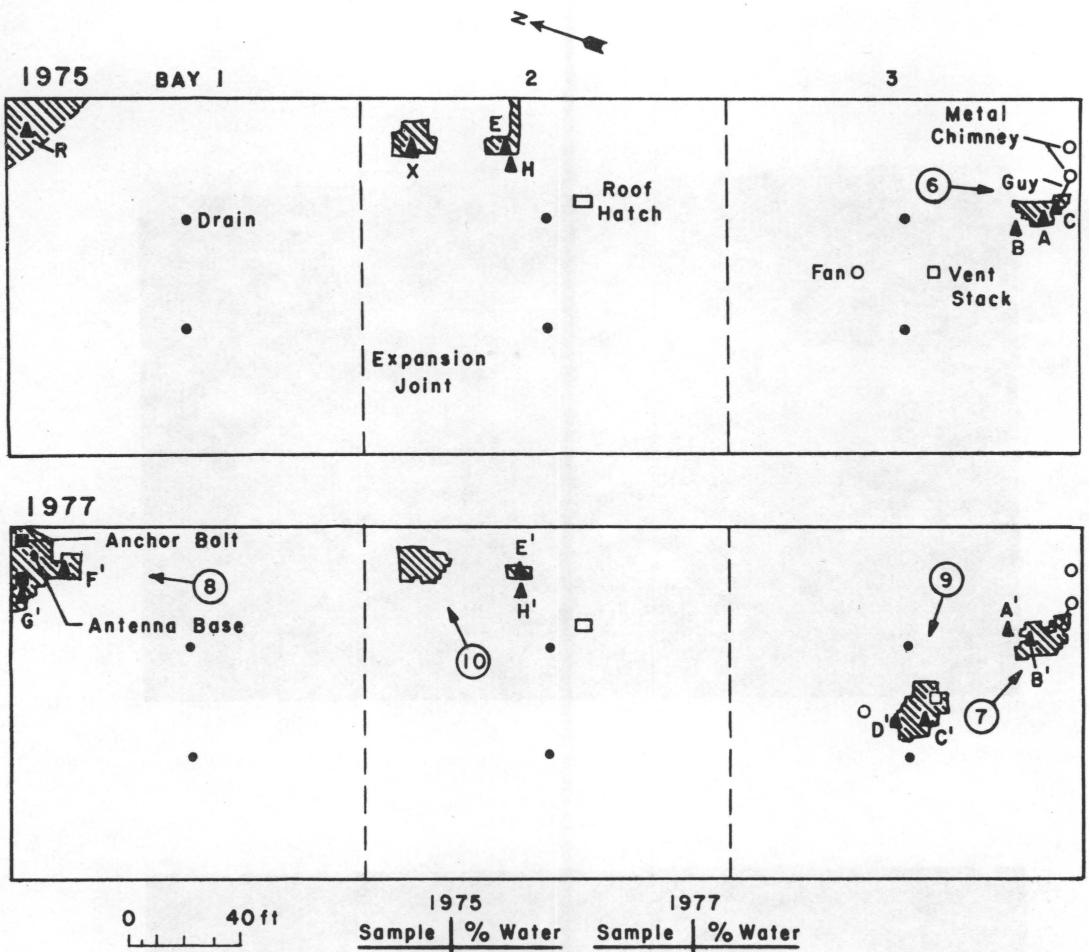


Figure 4. Thermogram and photograph of wet area surrounding antenna, Building 113 (arrow points to antenna).



1975	
Sample	% Water
A	105
B	1
C	355
*E	171
*H	0
R	1
X	269

1977	
Sample	% Water
A'	0
B'	140
C'	197
D'	0
*E'	41
F'	21
G'	92
*H'	0

* identical sample location for '75 + '77

Figure 5. Plan views of the 1975 and 1977 survey results for Building 120.

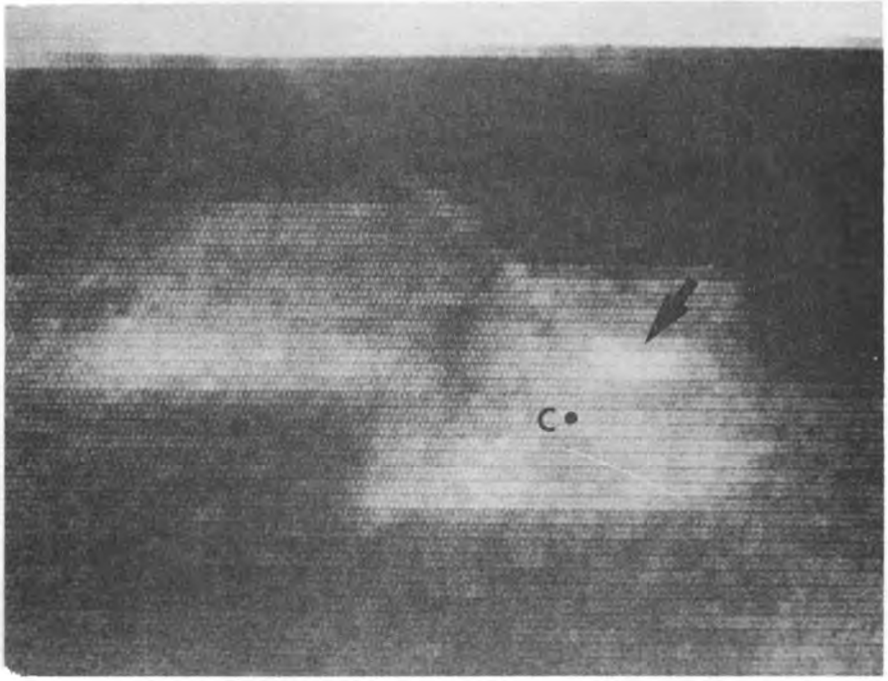


Figure 6. 1975 thermogram and 1975 photograph of wet area surrounding bolt, Building 120 (arrow points to bolt).

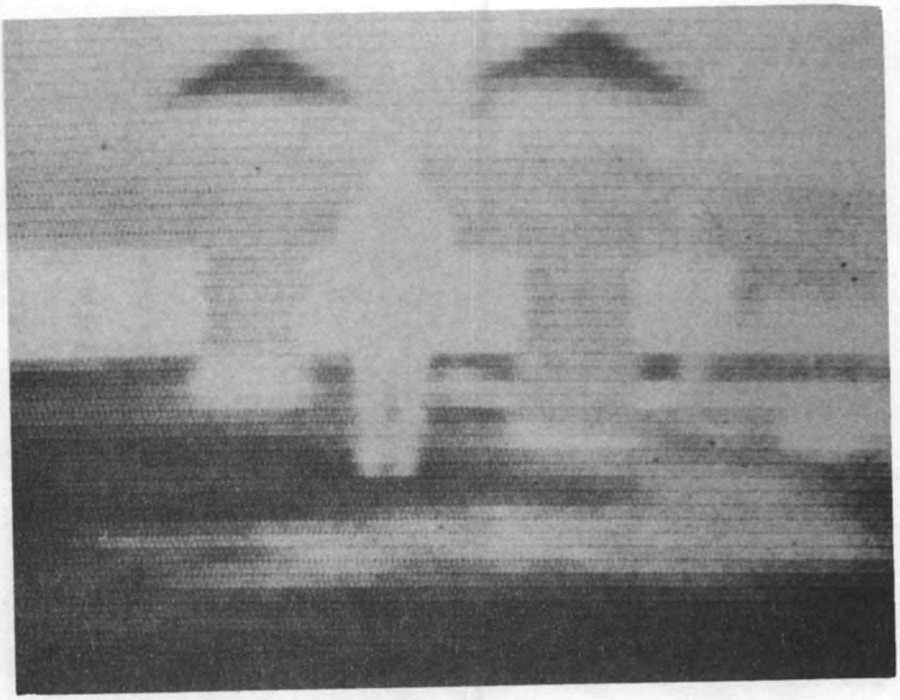


Figure 7. 1975 thermogram and 1977 photograph showing extent of wet area surrounding bolt, Building 120.

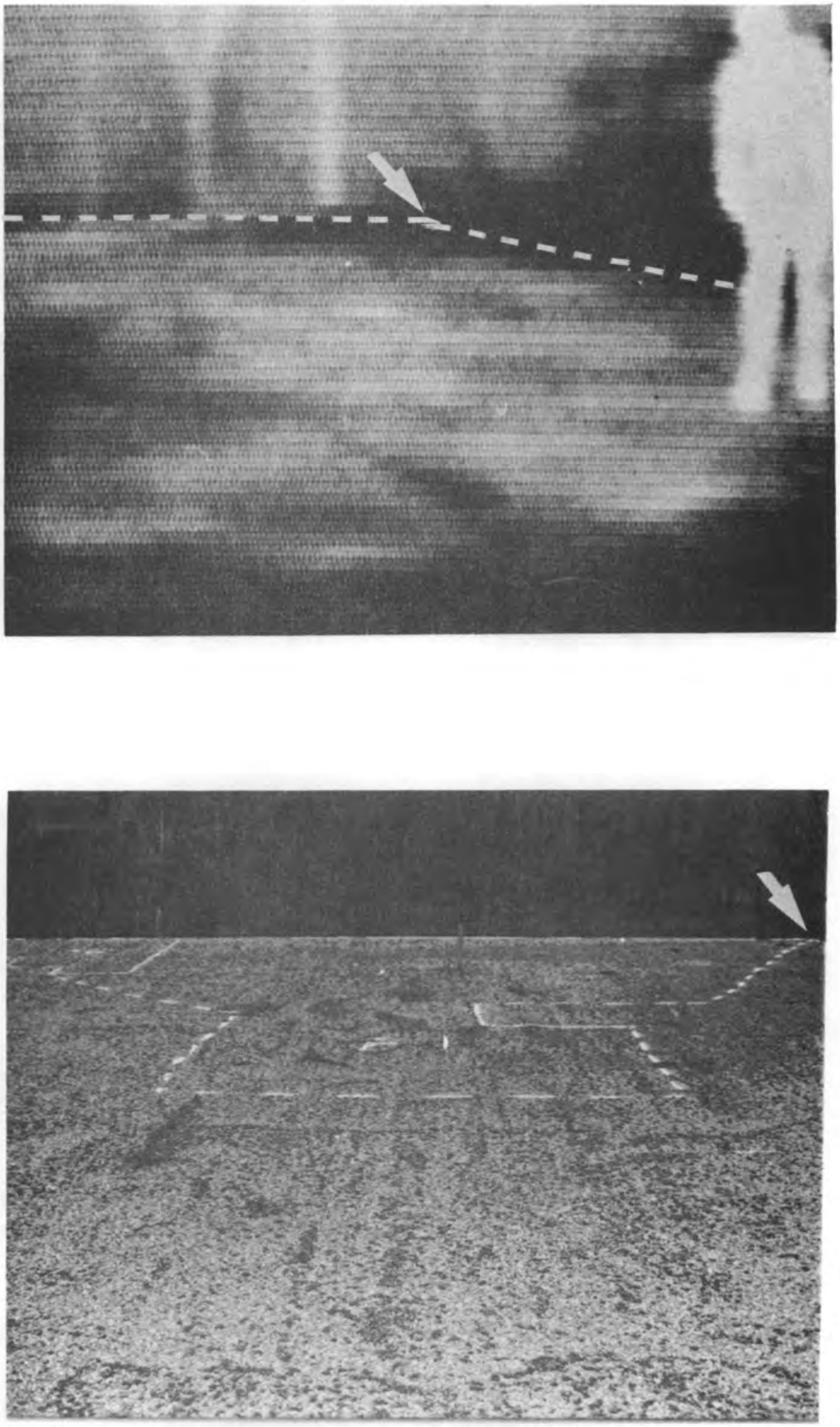


Figure 8. 1975 thermogram and 1977 photograph of wet area in northeast corner of roof, Building 120 (arrow points to the corner of roof).

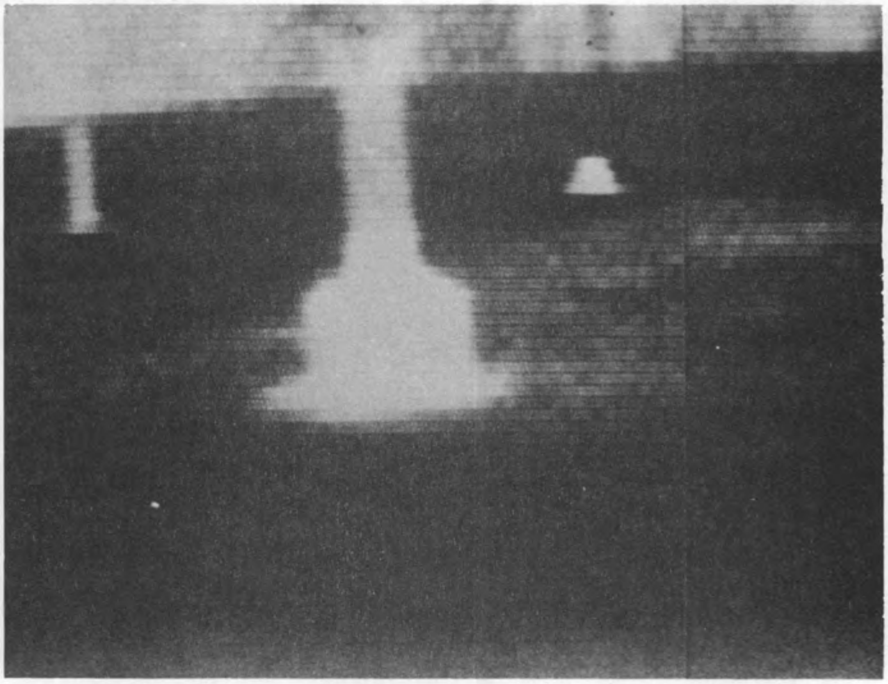


Figure 9. 1977 thermogram and 1977 photograph of wet area, Building 120.

Figure 10. 1975 (top) and 1977 photographs of wet area in bay 2, Building 120. Notice increase in extent of outlined area.

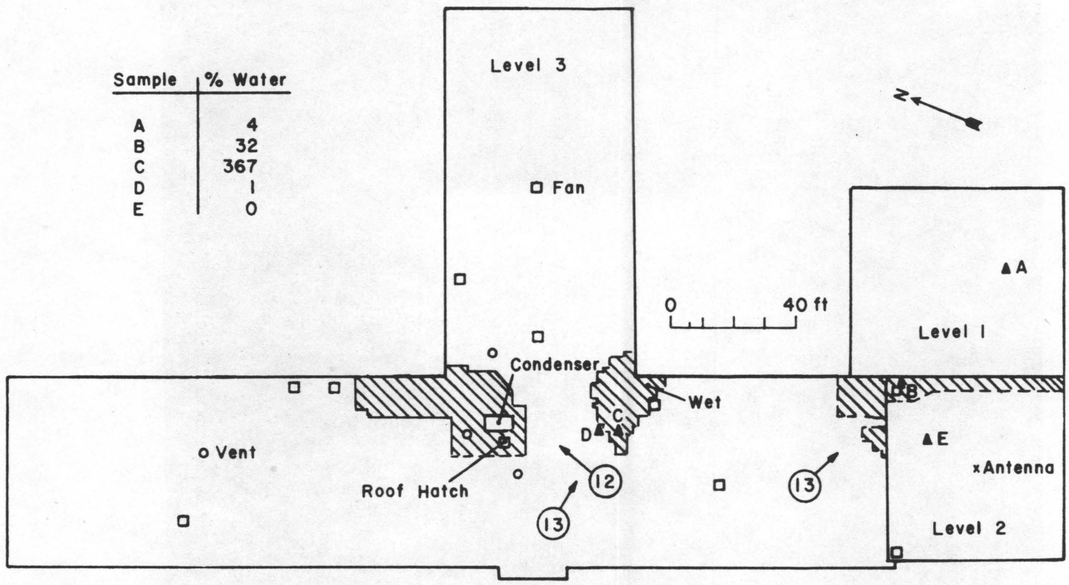
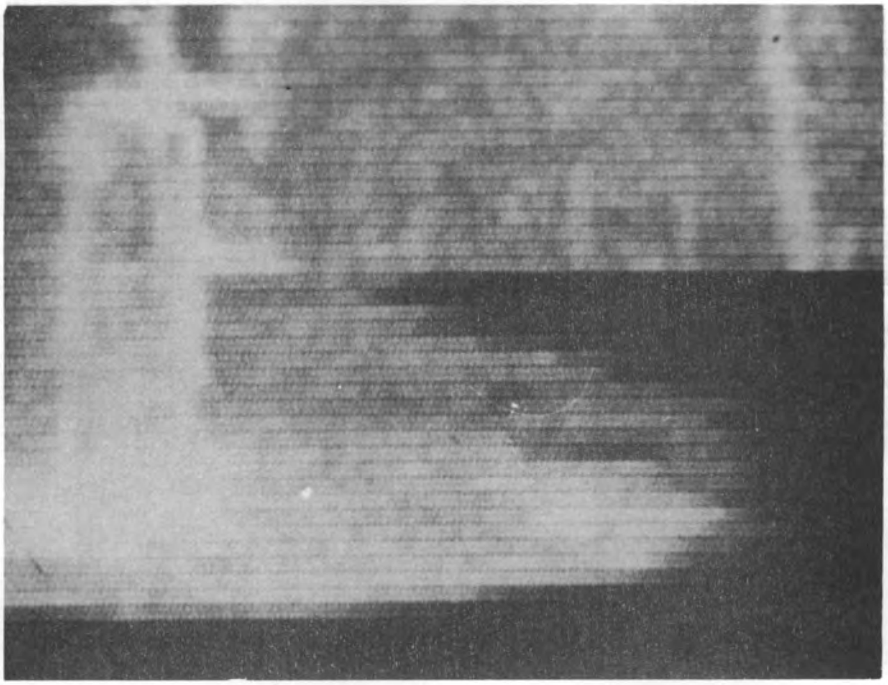


Figure 11. Plan view of Building 35.



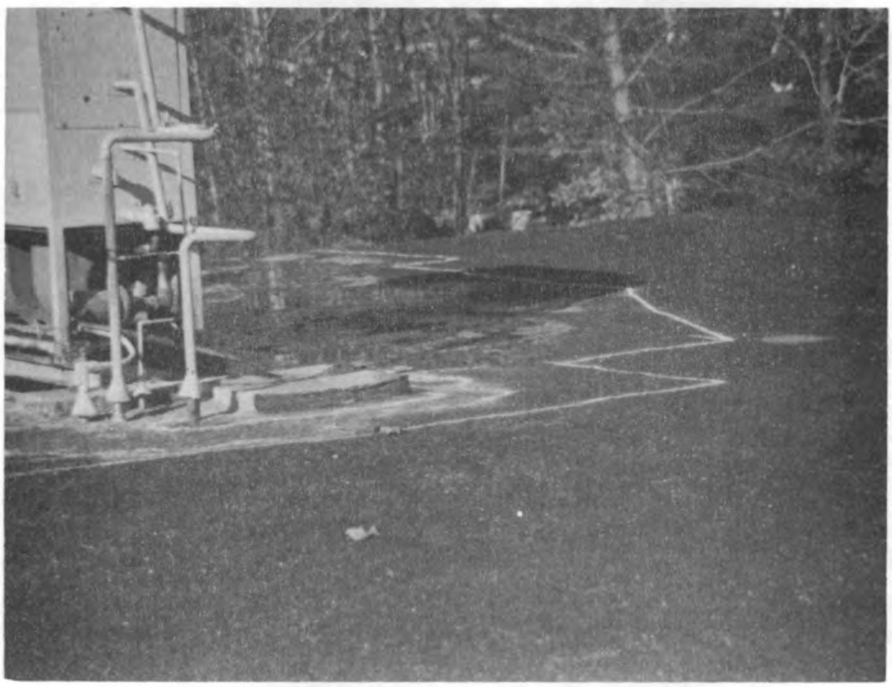


Figure 12. Thermogram and photograph of a wet area on Building 35.

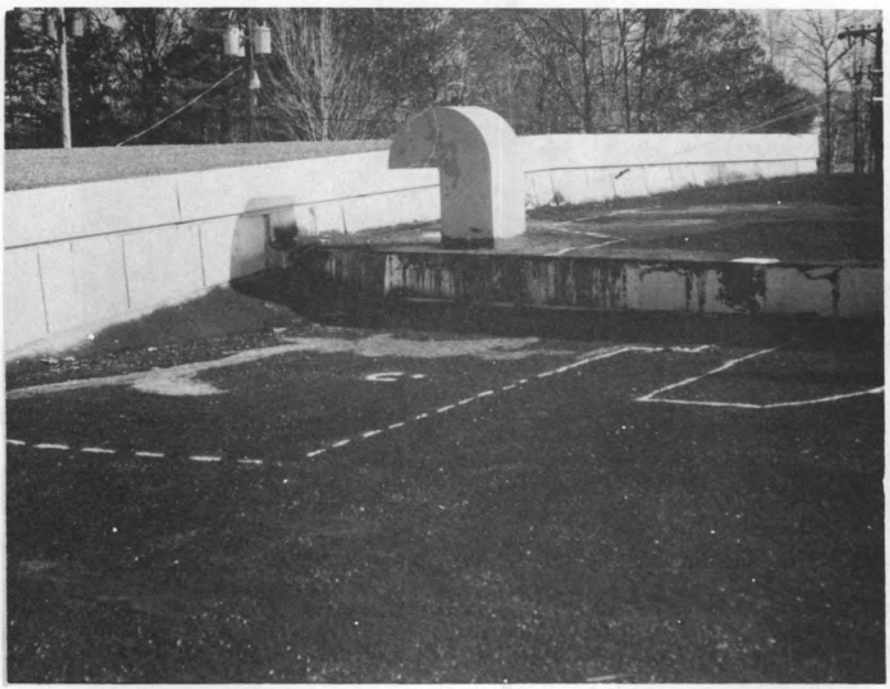


Figure 13. Wet areas on roof of Building 35 (arrow points to a split in the roof membrane).

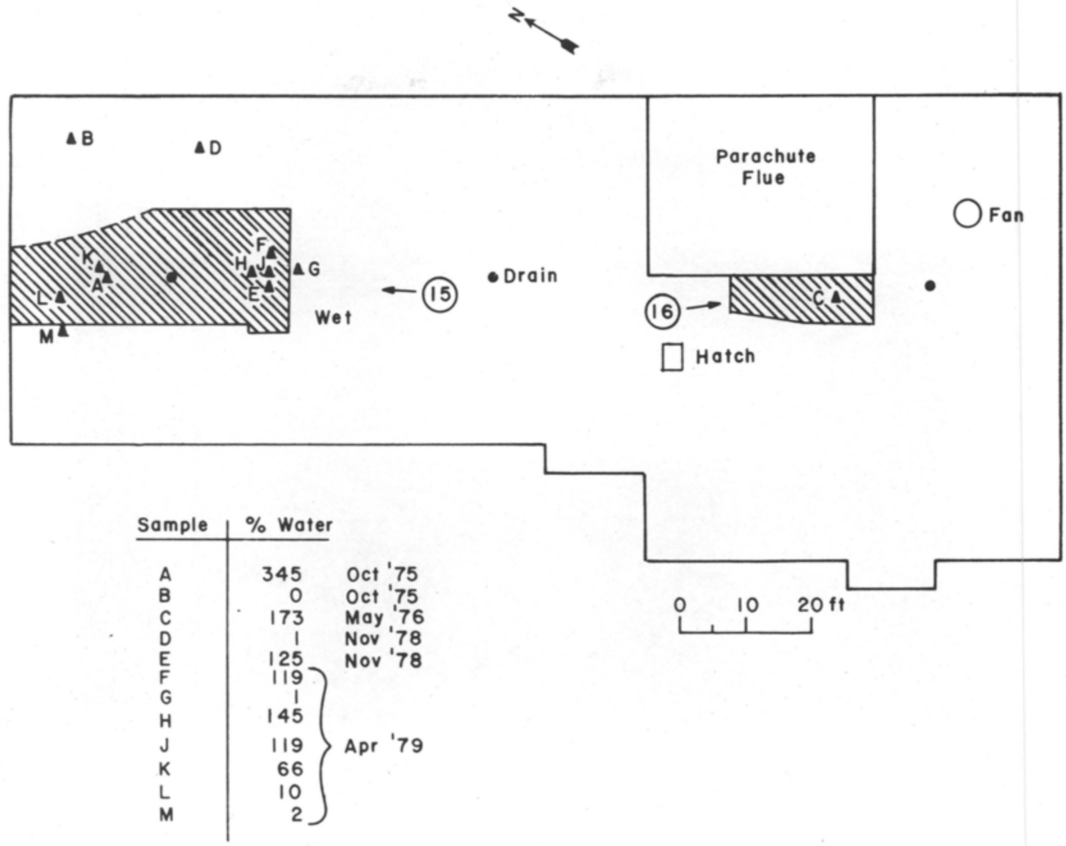


Figure 14. Plan view of Building 112.

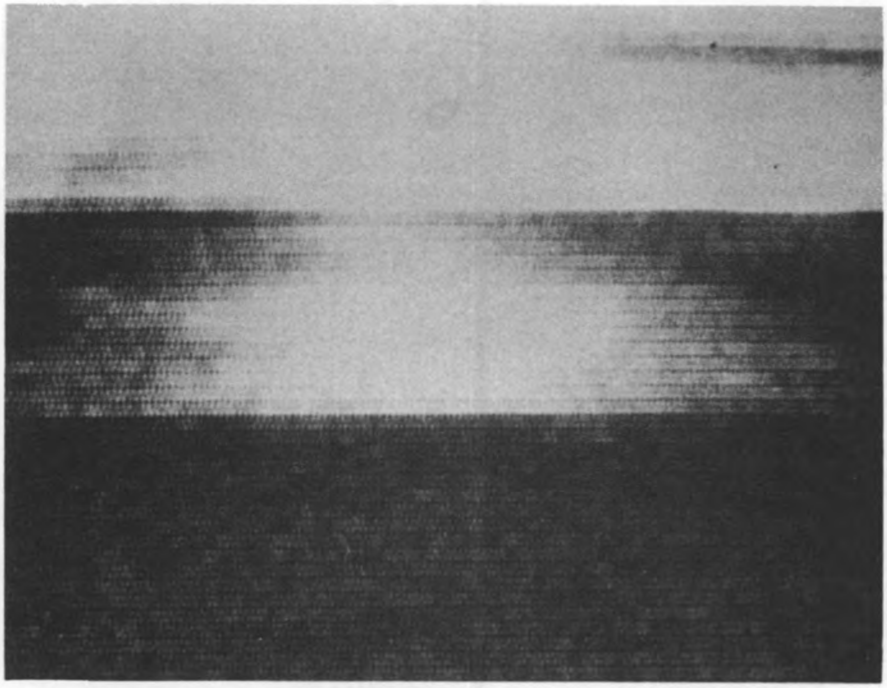
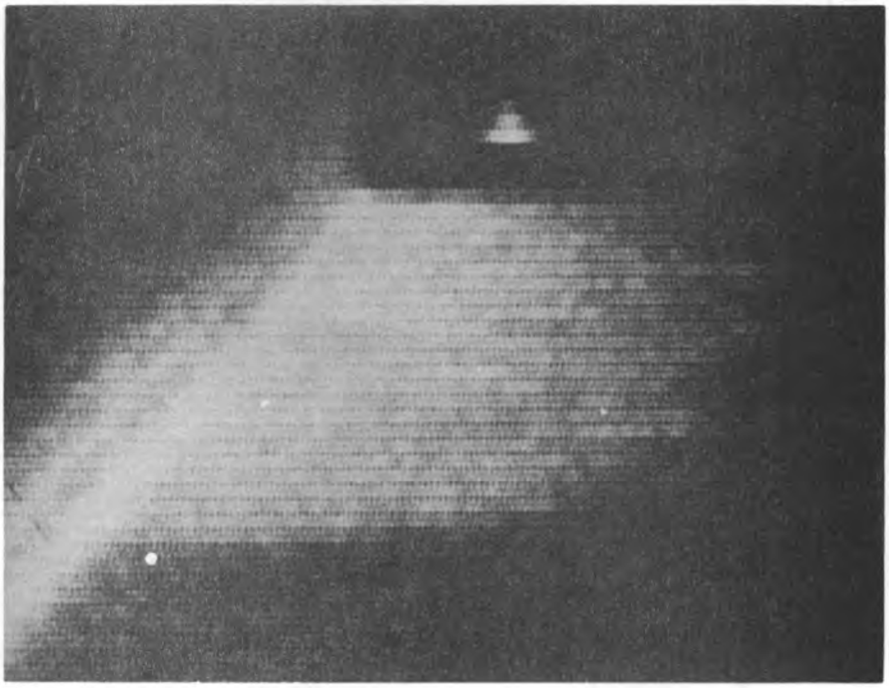


Figure 15. 1977 thermogram and photograph of wet area, Building 112.



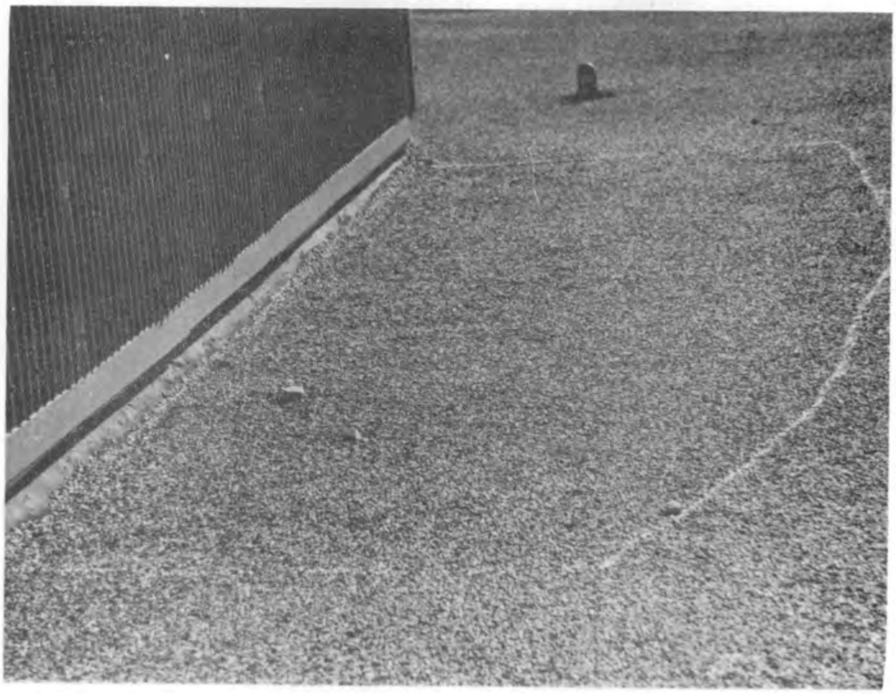


Figure 16. 1977 thermogram and photograph of wet area abutting parachute flue, Building 112.

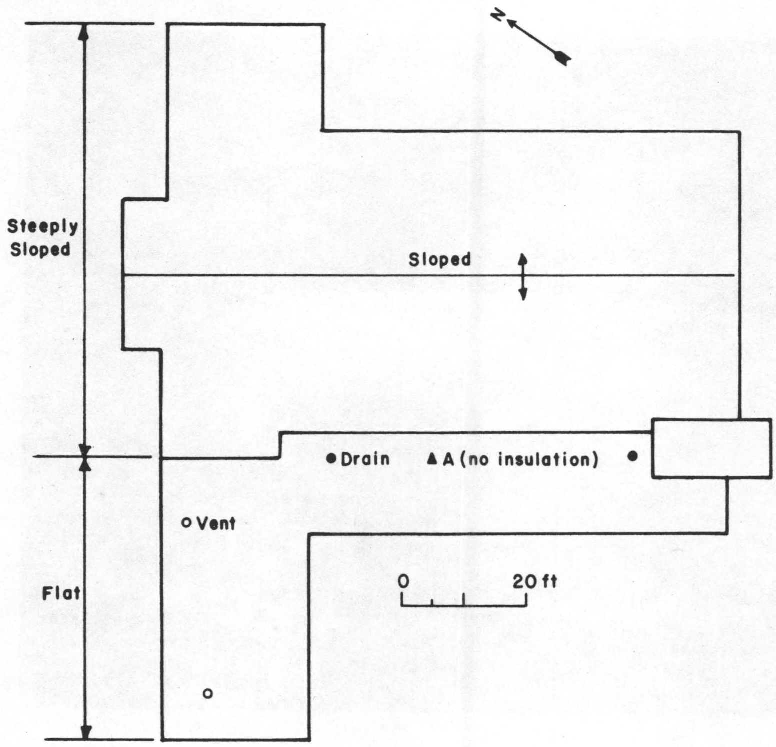
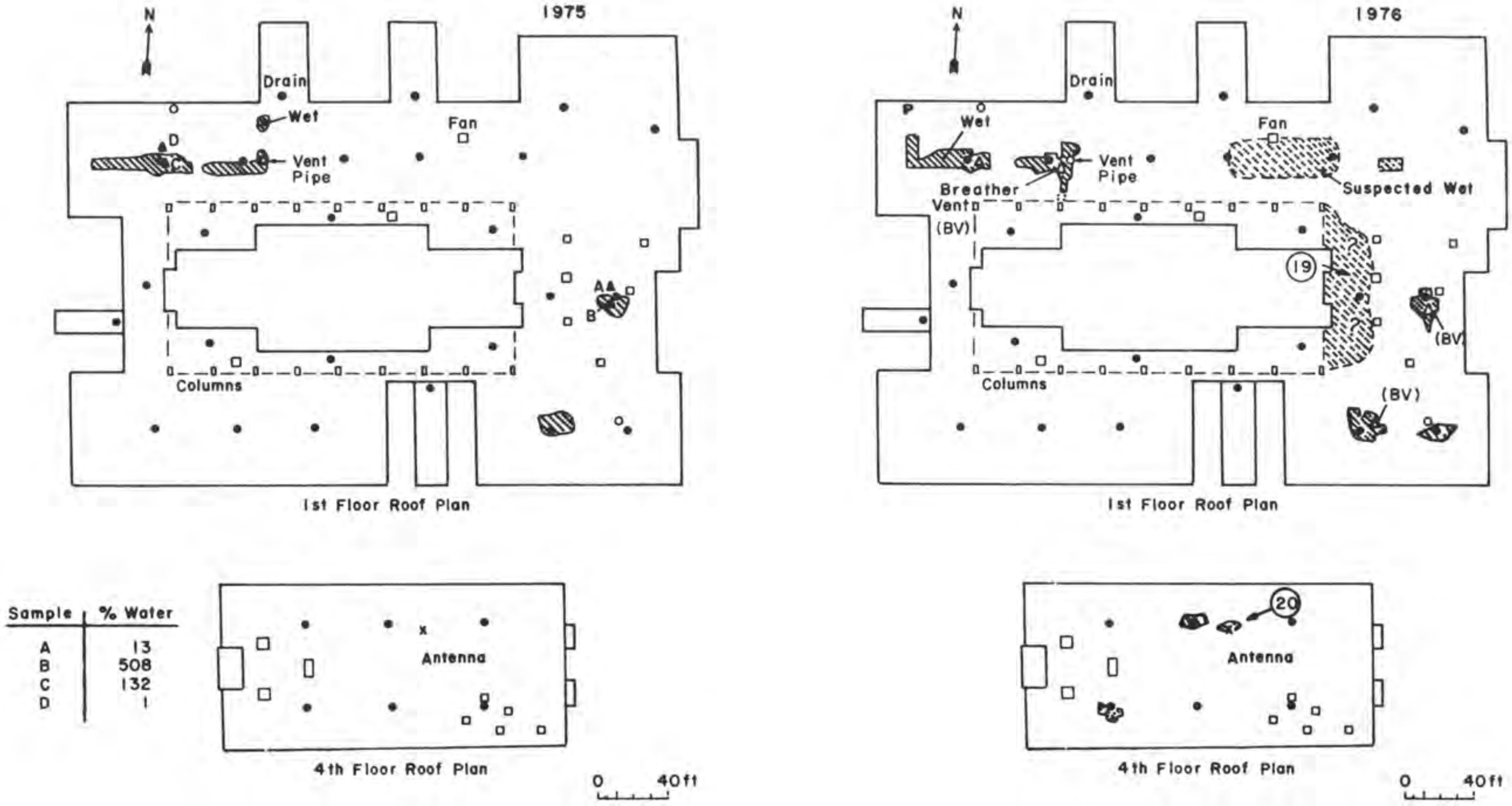


Figure 17. Plan view of Building 63. The sloped portion was not surveyed. The flat area contained subtle thermal anomalies when viewed with the infrared camera.

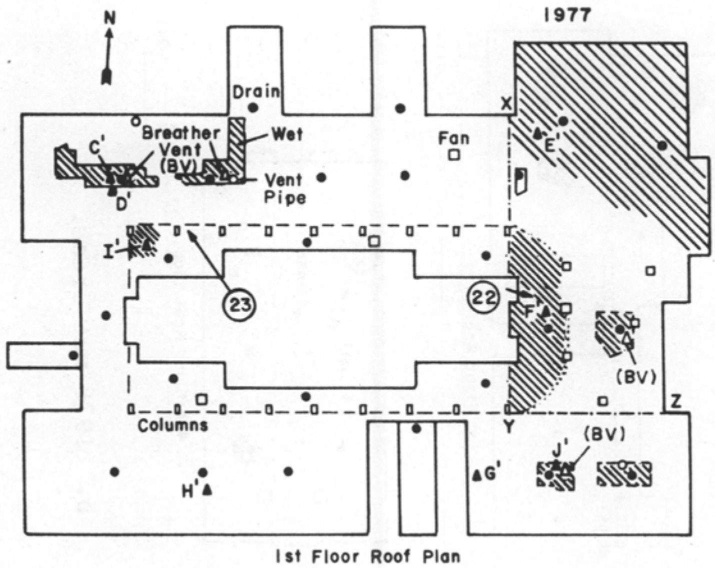


Sample	% Water
A	13
B	508
C	132
D	1

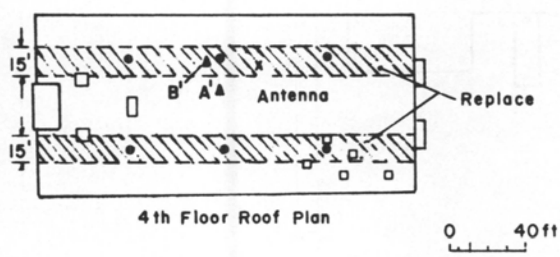
a. 1975 wet areas.

b. 1976 wet areas.

Figure 18. Plan view of Building 93. Because no samples were taken in 1976, dashed hatching is used to indicate suspected wet areas which were not wet in 1975.



Sample	% Water
A'	1
B'	60
C'	190
D'	1
E'	106
F'	177
G'	1
H'	1
I'	63
J'	357



c. 1977 wet areas.

Figure 18. (cont'd) Plan view of Building 93.

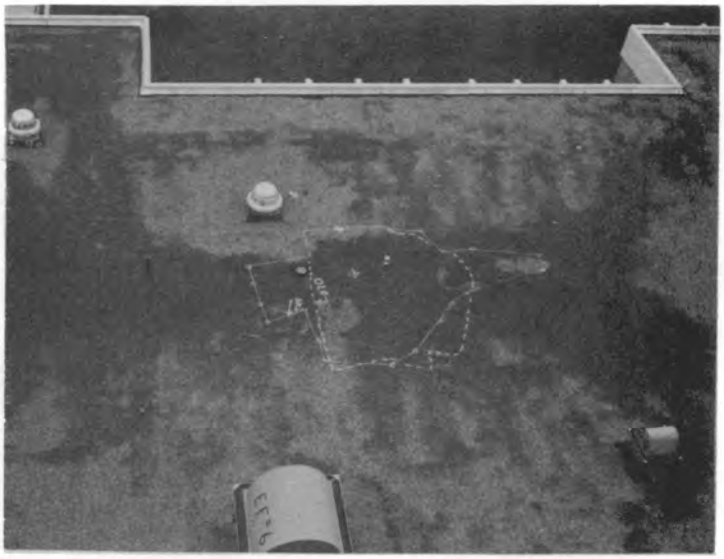


Figure 19. 1976 view from upper roof showing 1975 boundary (dashed) and 1976 boundary (solid) of the thermal anomaly on the eastern end of the lower roof.

Figure 20. Painted boundaries of two 1976 thermal anomalies on the upper roof. Both anomalies are associated with roof penetrations (i.e., an antenna and a drain).

Figure 21. A typical flashing defect. Over 30 defects were noted in 1976. Note that a pen has been inserted into the split.

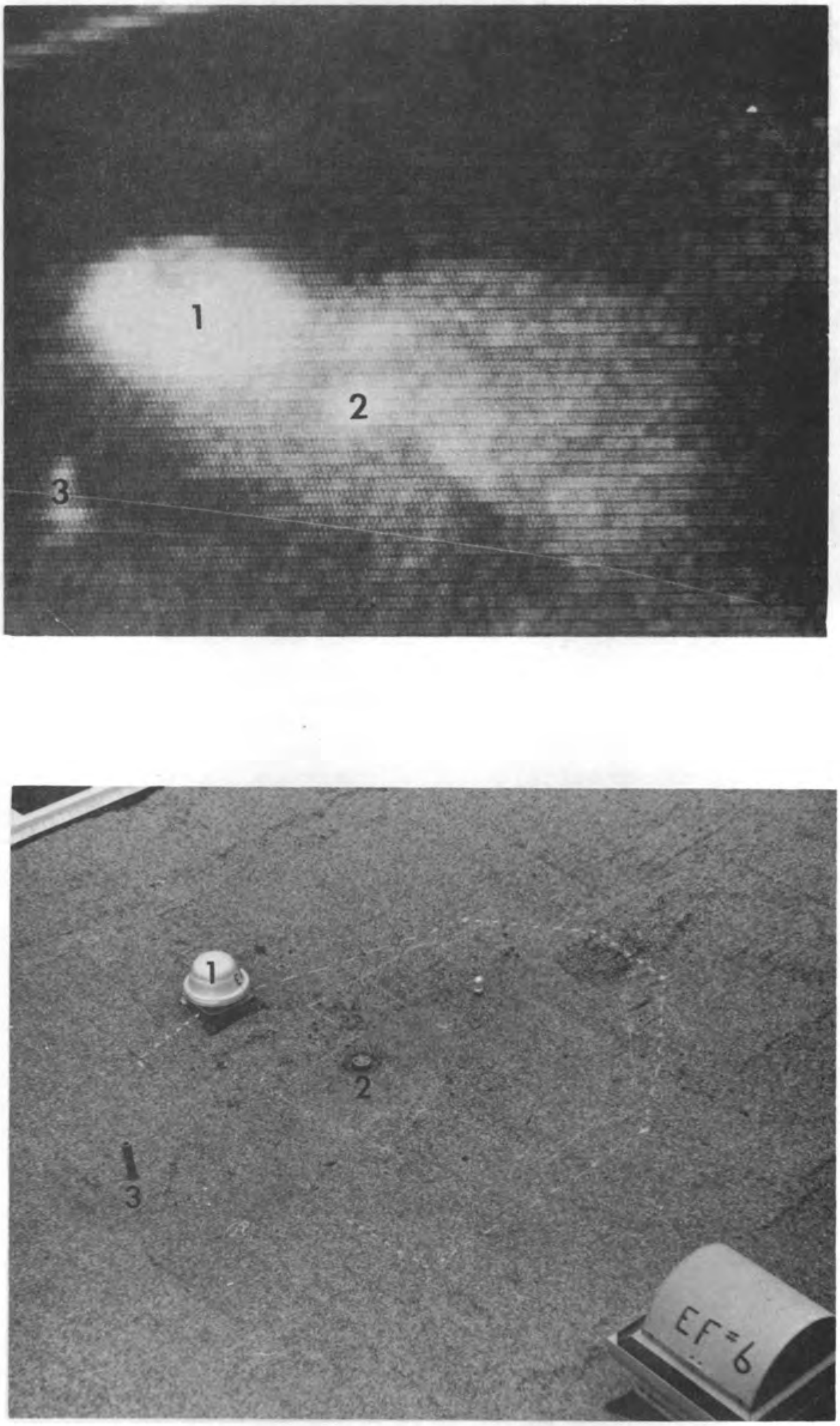


Figure 22. 1977 thermogram and photograph of wet area in Figure 19.

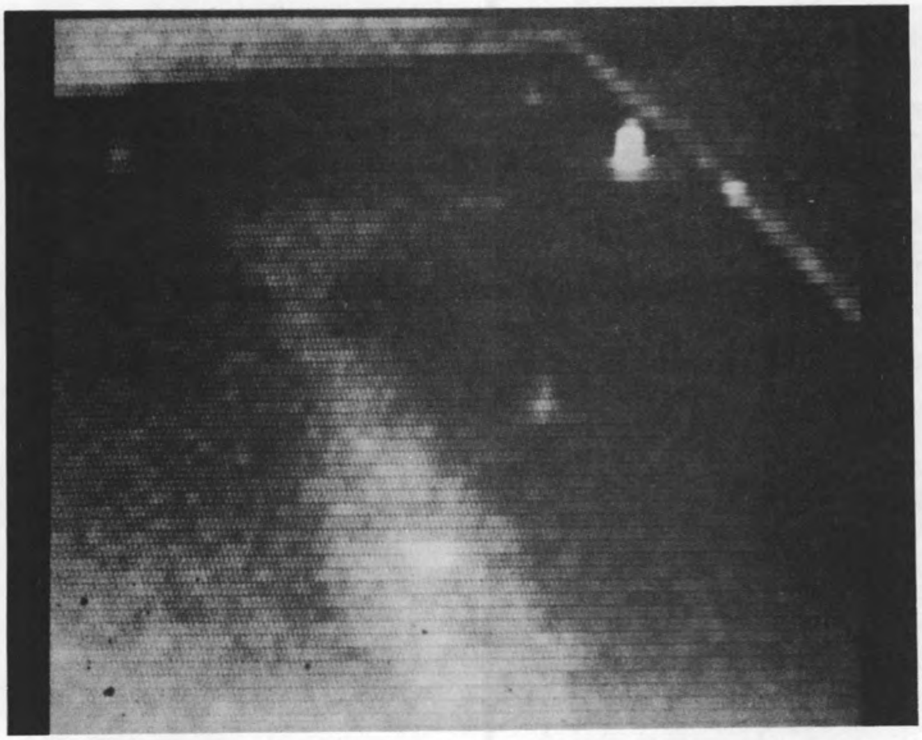


Figure 23. Thermogram and photograph of wet area on Building 93 (solid line shows extent of wet area in 1976, dotted line shows extent of wet area in 1977).

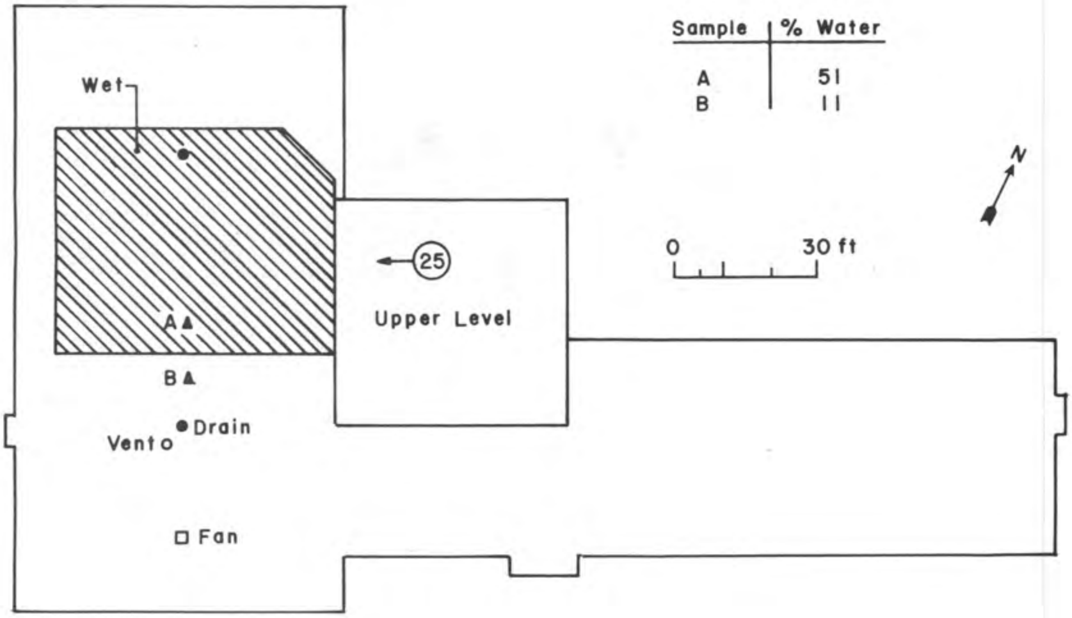


Figure 24. Plan view of Building 220.

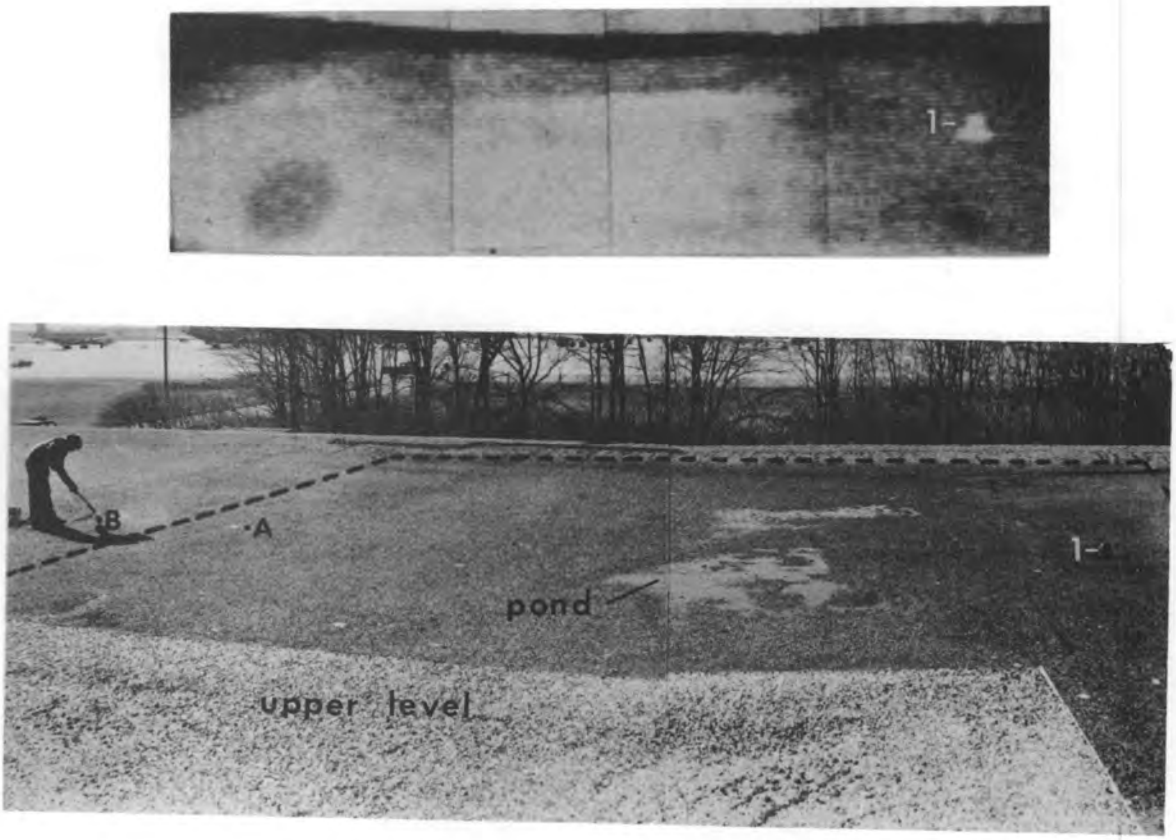


Figure 25. Thermogram mosaic and photograph of wet area on Building 220 (1 - drain).