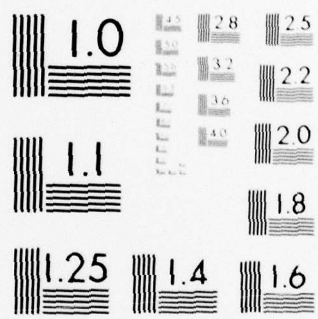
AD-A071 066 COLD REGIONS RESEARCH AND ENGINEERING LAB HANOVER NH F/G 13/2
ROOF MOISTURE SURVEY - U. S. MILITARY ACADEMY. (U)
MAY 79 C KORHONEN, W TOBIASSON
UNCLASSIFIED CRREL-79-16 NL

| OF |
AD
A071066

END
DATE
FILMED
8-79
DDC


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

Special Report 79-16
May 1979

ROOF MOISTURE SURVEY— U.S. MILITARY ACADEMY

Charles Korhonen and Wayne Tobiasson

Prepared for
U.S. MILITARY ACADEMY
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 79-16
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER
   (9) Special rept.
4. TITLE (*and Subtitle*)
   (6) ROOF MOISTURE SURVEY-U.S. MILITARY ACADEMY
5. TYPE OF REPORT & PERIOD COVERED
6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s)
   (10) Charles Korhonen [redacted] Wayne Tobiasson
8. CONTRACT OR GRANT NUMBER(s)
   U.S. Military Academy
   Interagency Order
   MAEN 9-78
9. PERFORMING ORGANIZATION NAME AND ADDRESS
   U.S. Army Cold Regions Research and Engineering Laboratory
   Hanover, New Hampshire
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
   (16) DA Project 4A76 2730AT42
   Task C, Work Unit 003
11. CONTROLLING OFFICE NAME AND ADDRESS
   U.S. Military Academy
   West Point, New York
   (12) 11p.
12. REPORT DATE
   (11) May [redacted]79
13. NUMBER OF PAGES
   10
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.
   (14) CRREL-79-16
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 equipment
   Infrared scanning
   Insulation
   Moisture
   Thermograms

   037 100 Gw

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

The roofs and upper story walls of buildings 745E, 752, and 756 at the U.S. Military Academy, West Point, New York, were surveyed with a hand-held infrared camera to locate sources of reported wall leaks. An electrical resistance probe was used to determine the relative level of moisture in wall components. Several 3-in.-diam core samples of each roof were obtained to verify suspected moisture conditions and to examine the roof membrane in cross section. Wet areas on each roof were outlined with white spray paint. Wall leaks are believed to be caused by wind-driven rain entering the parapet walls in locations where the decorative glaze-coat has spalled off. Recommendations for maintenance of these buildings are based on information derived from the infrared survey, electric resistance readings, core samples and visual examinations.

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, of the Civil Engineering Research Branch, Experimental Engineering Division, U.S. Army Cold Regions Research and Engineering Laboratory.

This study was conducted under U.S. Military Academy Interagency Order no. MAEN 9-78, ***Infrared Survey of Roof and Upper Story Wall of Barracks and Science Building***, and under DA Project 4A762730AT42, *Design, Construction and Operations Technology for Cold Regions*, Task Area C, *Cold Regions Maintenance and Operations of Facilities*, Work Unit 003, *Moisture Detection in Roofs*.

This report was technically reviewed by T. Johnson, E. Lobacz and B. Coutermarsh of CRREL.

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.

ROOF MOISTURE SURVEY—U.S. MILITARY ACADEMY

Charles Korhonen and Wayne Tobiasson

INTRODUCTION

The roofs and upper story walls of buildings 745E, 752 and 756 at the U.S. Military Academy in West Point, New York, were surveyed for entrapped moisture with an AGA Thermovision 750 infrared camera on the nights of 17 and 18 April 1978. These multistoried stone and masonry buildings are used for barracks and classrooms.

On the viewing screen of the AGA infrared camera, building components suspected of containing entrapped moisture appear bright, as opposed to dark for dry areas. Thermograms (photographs of the thermal image on the infrared camera's viewing screen) and daytime photographs are taken of these areas. In this survey, all suspected wet areas on the roofs were outlined with white spray paint. Several 3-in.-diam core samples were obtained of the roof membrane and the insulation to examine the membrane and insulation and to verify the suspected moisture conditions. The water content of each core, determined by weighing a sample before and after oven drying at 110°F, was expressed in a percentage as the weight ratio of water to dry insulation. A Delmhorst model BD-7 moisture probe, which detects changes in electrical resistance of materials, was used to determine the general level of moisture in wall components.

BUILDING 745E

Interior building leaks commenced at building 745E five years ago, two years after construction of this gravel-covered built-up roof. Water enters upper story rooms at several locations around the perimeter of this building. A thorough visual examination of perimeter roof flashing did not reveal any significant defects. However, the decorative glaze-coat on brick work on the interior of the perimeter parapet had spalled off in many locations (Fig. 1); freeze-thaw action was probably responsible. Interior leaks generally coincided with these areas of spalled brick. It was understood that leaks are particularly severe during and after wind-driven rain. A few years ago repairs were made to the mortar joints on the parapet wall in the northeast portion of this roof. Leaks were reported there prior to the patching but no leaks have been reported since.

During this inspection an infrared survey was made at night of the upper story walls of this building. No thermal evidence of residual entrapped moisture was detected in these exterior walls.

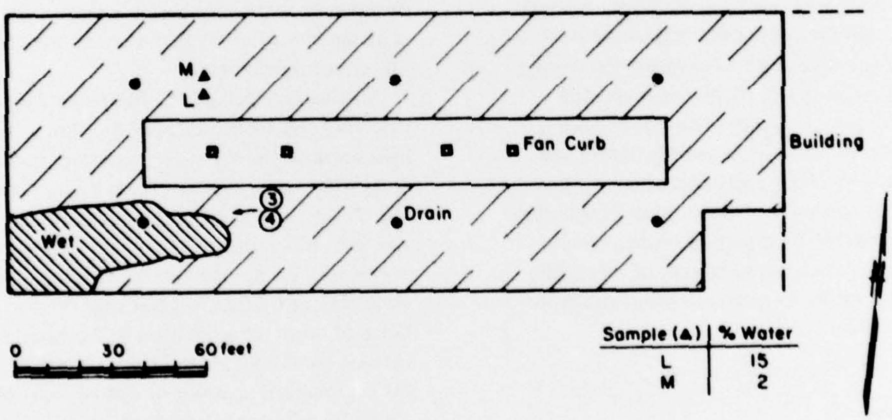
The roof of this building was examined in detail. From top to bottom, this roof consists of a gravel-covered built-up membrane, 1/2 in.-thick urethane insulation, an asphaltic base sheet and a structural concrete deck. When viewed with the infrared camera at night, most of this roof was subtly mottled (i.e. numerous small light and dark areas blended into one another). Such mottling can be caused by differences in the moisture content of the insulation or it can be caused by variations in the color and/or texture of the surface.

Core samples taken the following day in light and dark mottled areas indicated that the insulation in the light areas contained more moisture than that in dark areas. The water content from a light area (sample L, Fig. 2) was 15% and that from a dark area (sample M) was 2%. It is estimated that over half of the insulation in this roof contained about 15% moisture. Tests underway at CRREL suggest that the thermal resistance of urethane insulation is decreased by 5 to 10% when it contains 15% moisture by weight. Therefore, the thermal implications of this amount of moisture are minor. Removing such insulation cannot be justified by energy conservation alone.

Only one well-defined bright thermal anomaly was detected with the infrared camera. This anomaly is shown by the tight hatching in Figure 2. Figures 3 and 4 are, respectively, a thermogram and a daytime photograph of this area. This thermal anomaly was much more intense than the light mottled areas over most of the roof and thus a stronger indication of moisture. No samples were obtained from this area but it is felt that the insulation therein contains substantially more than 15% moisture by weight.

A visual examination of the membrane and flashings revealed that the membrane contained numerous small blisters. Except for the blisters, the

Figure 1. Spalled glazed surfacing on the inboard side of the parapet on building 745E. Similar conditions existed on 752 and 756.



Sample (▲)	% Water
L	15
M	2

Figure 2. Plan view of Building 745E. The tight hatching indicates an area of entrapped moisture. The open hatching indicates that small amounts of moisture are randomly dispersed throughout the roof. The arrow and circled numbers indicate the viewing direction of Figures 3 and 4.

membrane appeared to be in very good condition. However, because of the blisters, it is unlikely that the membrane will be able to function for its intended life of 20 years or more.

The immediate problem of building leaks appears to stem from porous bricks exposed on the inside of the perimeter parapet. It is quite possible that moisture within the roof insulation also entered the roof at the parapets. To prevent leaks and wetting of building components, the spalled masonry should be waterproofed.

Figure 3. Thermogram of wet area in the southwest corner of building 745E. The dashed line approximates a portion of the boundary of the wet area painted on the roof.

Figure 4. Photograph showing the spray painted boundary of the wet area in Figure 3.

Once the source of moisture has been eliminated, it may be possible for moisture in the urethane insulation to dissipate by edge venting at the perimeter of the roof. Although little information or experience is available on the drying ability of urethane insulation, it is doubted that the single very wet area (tight hatching in Fig. 2) will dry in this fashion.

Normally it would be recommended that the membrane and insulation in the very wet area be removed and replaced with dry insulation and a new membrane. However, the entire membrane on this roof is blistered and probably will require replacement in a few years. Therefore, it is suggested that the wet urethane insulation remain in place until it becomes necessary to remove and replace the membrane and insulation over the entire roof.

To maximize the remaining useful life in the blistered membrane, foot traffic should be kept to a minimum and all flashings and penetrations, especially those within the wet area, should be periodically examined and, where necessary, patched to assure that no additional moisture enters the roof.

BUILDING 756

Like 745E, building 756 has been plagued with leaks emanating from the upper story walls. In cross section, these walls consist of a granite block exterior backed by brick, a 3-in.-wide cavity and a concrete masonry unit interior. Just prior to this survey, water was reported to be running out onto the floor from the base of the exterior walls in room 579. At that time, three wall holes were created from within the room in an effort to ascertain the source of water (Fig. 5). Although the source of the leaks was not determined from the holes, it was noted that the through-wall flashing was installed incorrectly which permitted any water that did enter the 3-in.-wall cavity from above to collect and run out onto the floor instead of into exterior weep holes.

A daytime visual examination did not reveal any defects in the roof membrane or its flashings. But the decorative glaze-coat on the inboard side of the parapet walls had spalled off in numerous locations (Fig. 1). Further investigation revealed that interior leaks generally coincided with the spalled areas.

Scanning the external walls of this building from ground level and the internal walls of room 579 with the infrared camera did not reveal any signs of entrapped moisture. The lack of insulation in these walls diminished the chance to detect moisture-caused thermal anomalies. The Delmhorst moisture probe showed that the interior of the wall at the three holes in room 579 was relatively dry with the exception of a slight indication of moisture in the mortar joints.

The roof of this building was identical in cross section to the roof of building 745E. It also exhibited similar thermal mottling when viewed with

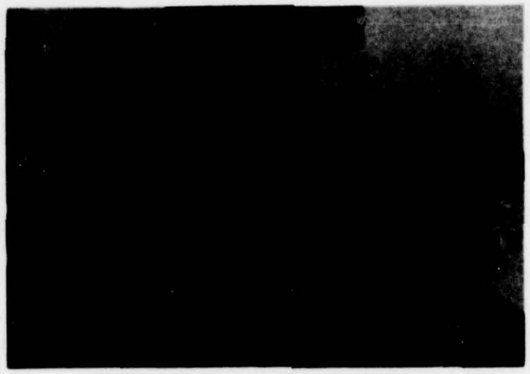


Figure 5. Two of the three holes that were made in the walls of room 579, building 756. Note the water stains on the floor and walls.

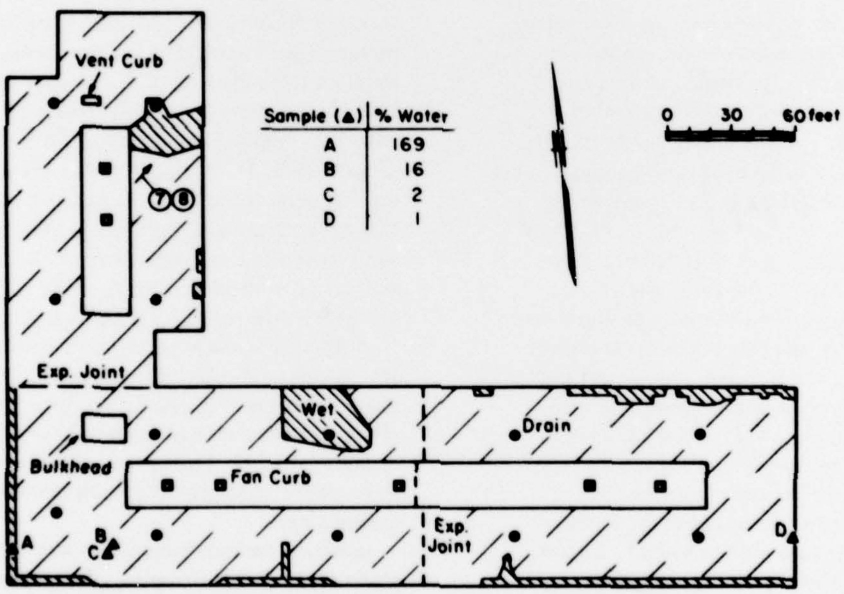


Figure 6. Plan view of building 756.

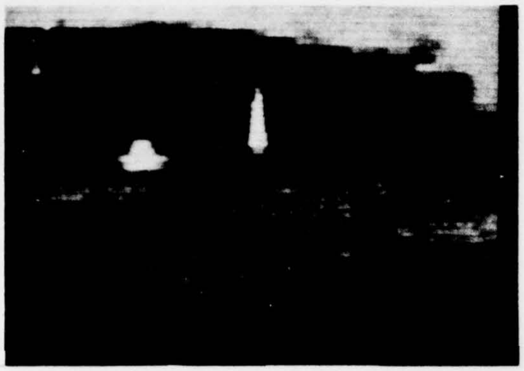


Figure 7. Thermogram of a wet area on Building 756.

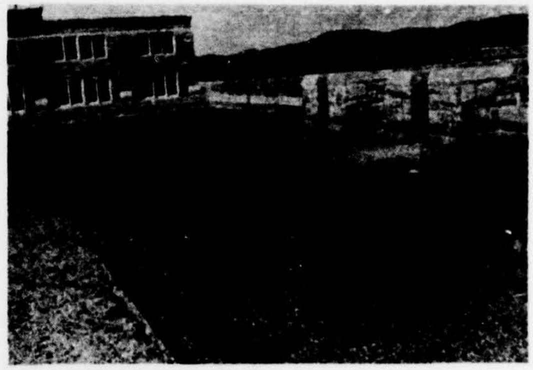


Figure 8. Photograph of the wet area shown in Figure 7.

Figure 9. Windows of building 752 that protrude from the wall creating a flat, horizontal surface at the top of each window. Driving rain may enter there.

the infrared camera at night. From the water contents of core samples B and C (16% and 2% respectively) which were taken from light and dark mottled areas, respectively, and from the thermograms of this roof, it is estimated that over half of the urethane insulation on this roof had a water content of about 16%. The open hatching in Figure 6 is used to indicate that this moisture is located throughout the roof. Although 16% is considered more than normal for a roof of this type, the thermal implications of this amount of moisture are minor, as stated for 745E.

Figure 6 indicates that several well-defined wet areas were located all along the perimeter of this roof. Sample A, which had a water content of 169%, was taken from one typical wet area. Figures 7 and 8 are a thermogram and a photograph of another wet area.

The membrane on this roof is in similar condition to that found on building 745E. Numerous blisters indicate that the membrane is deteriorating.

It appears that building leaks are largely a result of rain entering the walls via spalled parapet bricks. The spalled bricks should be repaired and the entire inboard side of the parapet waterproofed to prevent further wetting of building components.

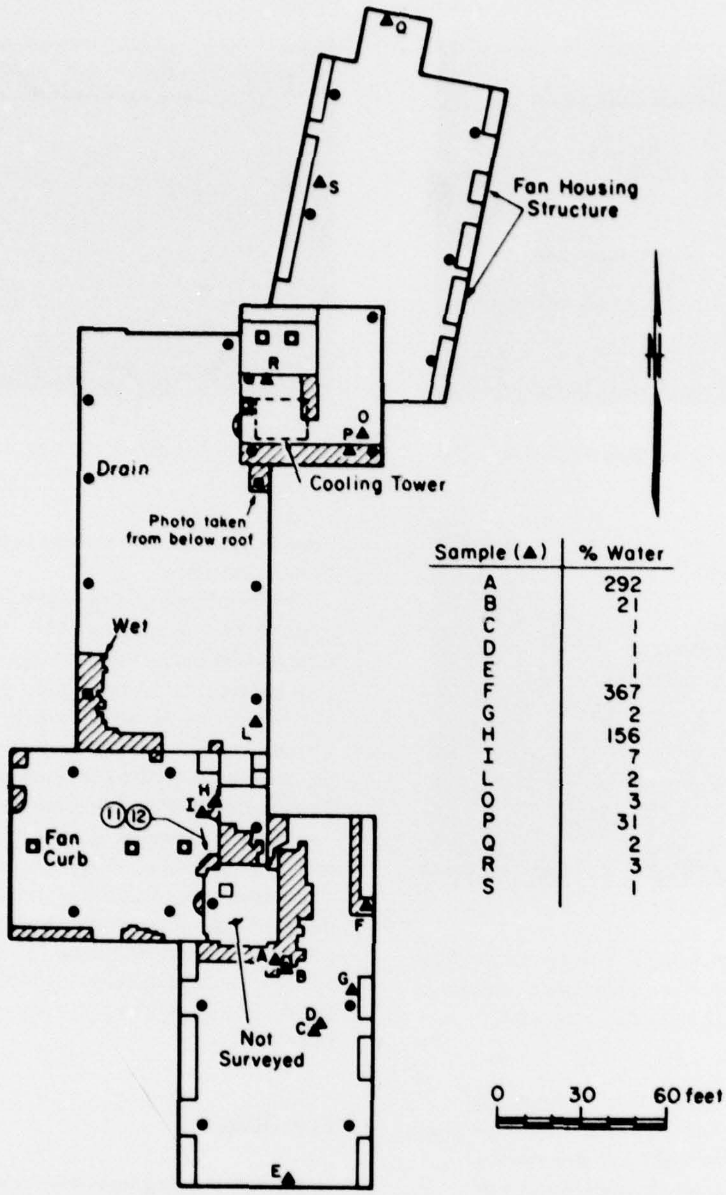
Since it is expected that the membrane on this roof will have to be replaced in a few years, it is recommended that all the wet insulation remain in place until a new membrane is necessary. In the interim, all foot traffic should be minimized and periodic visual examinations should be conducted on this roof to locate and patch any moisture entry points.

BUILDING 752

Interior building leaks have reportedly occurred along nearly all the exterior walls on the upper story of building 752. Leaks have been particularly severe near the windows, especially during a driving rain.

Like buildings 745E and 756, the inboard side of the parapets is finished with glazed brick which has spalled off in many locations (Fig. 1). The resulting surface is highly moisture absorbent. Rain hitting this surface is likely to be wicked into the interior of the wall and eventually finds its way into the building.

The window panels on this building protrude from the surface of the wall (Fig. 9). This creates a flat



Sample (▲)	% Water
A	292
B	21
C	1
D	1
E	1
F	367
G	2
H	156
I	7
L	2
O	3
P	31
Q	2
R	3
S	1

Figure 10. Plan view of building 752.

Figure 11. Thermogram of a wet area on building 752.

Figure 12. Photograph of the wet area shown in Figure 11.

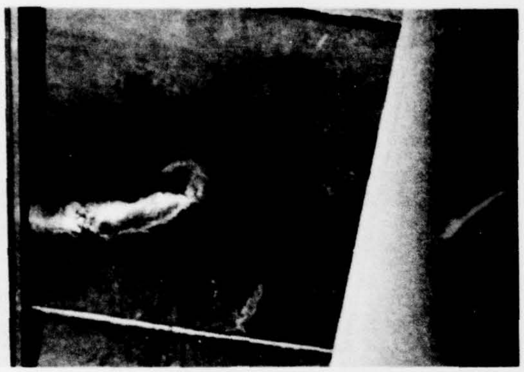


Figure 13. Poorly sealed roof drain. Water from around this roof drain stained the carpet below. Note the water marks on the underside of the deck adjacent to the drain pipe.

horizontal surface at the top of the panel where rain water could temporarily collect and run into the building through voids in the panel-to-wall caulking joint. However, it is also possible that these leaks are caused by water which enters the spalled parapets, runs down the 3-in.-wide wall cavity onto the top of the windows and then into the building.

Neither the Delmhorst moisture probe nor the infrared camera showed any signs of residual moisture within the walls of this building.

The roof of this building from top to bottom consists of a gravel-covered built-up membrane, 1-1/2-in.-thick perlite insulation, a 2-ply vapor barrier and a structural concrete deck. The infrared camera was able to locate several areas suspected of containing wet insulation. Their boundaries were marked with white spray paint. Fifteen core samples were taken to verify the suspected moisture conditions. Their locations and water contents are shown in Figure 10. Samples E, G, L, and R revealed that the detected thermal anomalies surrounding these samples were not moisture-related but were caused by heat radiating from adjacent walls or heat from nearby exhaust fans. Consequently, the spray painted boundaries associated with samples E, G, L, and R are not shown in Figure 10. Of the remaining samples, those indicated as wet by the thermograms were confirmed to be wet and those indicated as dry were confirmed to be dry. Figures 11 and 12 show a typical thermogram and a photograph of a detected wet area.

As noted in Figure 10, a wet rectangular area surrounds a drain on the central roof of this building. During the daytime walk-through inspection it was pointed out that a portion of the carpet directly below this drain had been water stained. Water stains on the underside of the deck surrounding this drain pipe are shown in Figure 13. They suggest that water enters the building here through a defect in the roof membrane-to-drain seal.

The moisture associated with the reported leaks appears to be entering through

1. the spalled brick on the inboard side of the parapets
2. a defect in the membrane-to-drain seal around one drain on the central roof
3. joints between the wall and window panels.

As a first step to solving the wall leaks, it is suggested that the parapet walls be repaired and waterproofed. This may trap some moisture within the parapet and cause additional spalling of the glaze coating.

If leaks still persist at the windows after waterproofing the parapets, all window panel-to-wall joints should be examined and, if necessary, recaulked. If this fails to solve the problem, thought should be given to adding slope to the top of each window to direct rain water away from these areas.

The roof membrane appears to be in excellent condition. It is not blistered. However, entrapped moisture can cause a roof system to deteriorate rapidly. To achieve maximum life from this roof it is suggested that all wet insulation in the hatched areas in Figure 10 be cut out and replaced with dry insulation and built-up roofing. Care should be taken to assure that the membrane-to-drain seal for the problem drain shown in Figure 13 is made watertight.

SUMMARY AND CONCLUSIONS

The upper-story walls of building 745E, 752 and 756 experience leaks during driving rains. The window areas of building 752 also leak during rains.

Since leaks are believed to occur only in the upper portions of these buildings, it does not seem likely that joints in the stone facade are the cause of the leaks. It appears that most of the reported leaks originate from the parapets. The inboard glazed surfacing of the bricks is spalled in many locations. In most cases the spalled areas are directly above reported leaks.

To correct wall leaks, the inboard surface of the parapet walls for buildings 745E, 752 and 756 should be repaired and waterproofed, keeping in mind that any entrapped moisture may cause additional spalling upon freezing. It is suspected that the source of moisture for the window leaks in building 752 is also leakage through the parapets. However, if leaks continue to occur at the windows after the parapets have been waterproofed, all joints between the wall and window panels should be examined and, if necessary, recaulked. A sloped drip-cap might also be added to the top of each window unit to direct water away from that area.

Wet insulation was found on all three roofs. Except for blisters on 745E and 756, the roof membranes appeared to be in good condition, which indicates the possibility of several more years of serviceable life. Because of the blisters, it is considered likely that the membranes on 745E and 756 will significantly deteriorate over the next 5 years. For this reason it is not felt wise to devote effort now to removal and replacement of wet insulation on these two roofs. Rather, it is recommended that the wet urethane insulation remain in place until it becomes necessary to remove and replace the built-up membrane and the 1-1/2-in.-thick urethane insulation over the entire roof. To maximize the remaining life in these blistered membranes, foot traffic should be kept to a minimum and all flashings and penetrations should be examined and, if necessary, patched to prevent further wetting.

The built-up membrane on building 752 is essentially free of blisters. Since entrapped moisture can shorten the useful life of a roof system, it is recommended that all wet areas shown in Figure 10 be cut out and replaced with dry insulation and a built-up membrane. If periodic visual inspections are conducted and any defects patched, many years of useful life should be obtained from this roof.

☆U.S. GOVERNMENT PRINTING OFFICE: 1979—601-496/83