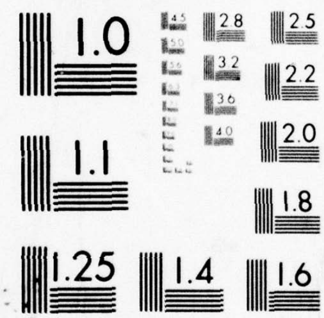
AD-A036 090 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 13/13
ROOF MOISTURE SURVEYS AT PEASE AFB, NEW HAMPSHIRE, AND OFFUTT A--ETC(U)
JAN 77 L E LINK

UNCLASSIFIED WES-MP-M-77-2 NL

1 OF 1
AD
A036090

END
DATE
FILMED
3-77



MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

MISCELLANEOUS PAPER M-77-2

ROOF MOISTURE SURVEYS AT PEASE AFB, NEW HAMPSHIRE, AND OFFUTT AFB, NEBRASKA

by

Lewis E. Link, Jr.

Mobility and Environmental Systems Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

January 1977
Final Report

Approved For Public Release; Distribution Unlimited

Prepared for U. S. Air Force Strategic Air Command
Offutt Air Force Base, Omaha, Nebraska 68113

M. P. M-77-2 ROOF MOISTURE SURVEYS AT PEASE AFB, NEW HAMPSHIRE, AND OFFUTT AFB, NEBRASKA

Destroy this report when no longer needed. Do not return it to the originator.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Miscellaneous Paper M-77-2	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER (14) WES-MP-M-77-2
4. TITLE (and Subtitle) (6) ROOF MOISTURE SURVEYS AT PEASE AFB, NEW HAMPSHIRE, AND OFFUTT AFB, NEBRASKA.		5. TYPE OF REPORT & PERIOD COVERED (9) Final report. Mar-Jun 76,
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) Lewis E. Link, Jr		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Engineer Waterways Experiment Station Mobility and Environmental Systems Laboratory P. O. Box 631, Vicksburg, Miss. 39180		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (12) 55p.
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Air Force Strategic Air Command Offutt Air Force Base Omaha, Nebr. 68113		12. REPORT DATE (11) Jan [redacted] 77
		13. NUMBER OF PAGES 51
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)

Moisture	Pease Air Force Base, N. H.
Nuclear meters	Roofs
Offutt Air Force Base, Nebr.	Thermal infrared imagery

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

A new technique for surveying roof moisture was applied at Pease AFB, New Hampshire, and Offutt AFB, Nebraska. The technique consists of using airborne thermal infrared (IR) imagery to rapidly examine all built-up roofs on an installation, and a nuclear moisture meter to examine in detail (on the roof) roof areas identified on the IR imagery to have possible entrapped moisture. The results of the surveys at these two Air Force Bases show

(Continued)

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

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

038 100

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

20. ABSTRACT (Continued).

that the survey technique is a very effective means of detecting roof areas with entrapped moisture. Twenty-three of the 238 buildings examined with thermal IR imagery were suspected to have areas with entrapped moisture. Detailed surveys with the nuclear meter showed that 14 of the 23 buildings had entrapped-moisture problems. The presence of elevated roof structures, vents, and standing water caused anomalies initially suspected to be due to entrapped moisture on several buildings. Prior knowledge of the existence of these features would have significantly reduced the number of misinterpretations. It is recommended that an initial draft of a manual for operational application of the thermal IR-nuclear meter roof survey technique be prepared. Questions remaining that concern certain technical aspects of the technique can be answered during the preparation of the manual and as a portion of the initial applications of the technique by Strategic Air Command personnel.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

PREFACE

The work reported herein was conducted from March to June 1976 by the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, and was authorized in MIPR No. ACFM 75-4, dated 24 April 1975, from the U. S. Air Force Strategic Air Command (SAC), Offutt AFB, Nebraska, to the WES.

The study was conducted under the general supervision of Messrs. W. G. Shockley, Chief of the Mobility and Environmental Systems Laboratory, and B. O. Benn, Chief of the Environmental Systems Division, and under the direct supervision of Dr. L. E. Link, Jr., Chief of the Environmental Research Branch (ERB). Mr. C. A. Miller, ERB, was responsible for the field data collection program. Dr. Link prepared the report.

Acknowledgment is made to the personnel of the 155th TAC Reconnaissance Group of the Nebraska Air National Guard, Lincoln, Nebraska, who flew the missions to obtain the imagery of Pease AFB, New Hampshire, and Offutt AFB, Nebraska. In addition, MAJ Richard Wyatt, Messrs. Ed Morgan and Mike Toriello, Facilities Maintenance Division, SAC, Offutt AFB, Nebraska, and LT Mike Suflita, Pease AFB, New Hampshire, provided excellent support during the execution of this study.

Directors of the WES during the conduct of the study and preparation of the report were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

ROOF MOISTURE SURVEYS AT PEASE AFB, NEW HAMPSHIRE, AND OFFUTT AFB, NEBRASKA

PART I: INTRODUCTION

Background

1. The work reported herein is a continuation of that described in U. S. Army Engineer Waterways Experiment Station (WES) Miscellaneous Paper M-76-14.* That report presented background information and the basic concept of a new technique for rapidly surveying built-up roofs for entrapped moisture, documented the application of the technique to roofs at Dyess AFB, Texas, and discussed in detail the procedures used and the results.

2. The new roof survey technique was designed to take advantage of the best properties of both thermal infrared (IR) imaging systems and nuclear moisture meters. The IR imagery is used to quickly survey roofs of all buildings on an installation to identify those with potential entrapped-moisture problems. The nuclear meter provides a direct "on-the-roof" means of validating the anomalies on the IR imagery identified to be areas with entrapped moisture. The basic steps for applying the combined thermal IR-nuclear meter technique are:

- a. Design imagery mission.
- b. Acquire imagery (mission execution).
- c. Interpret imagery to find areas suspected of having entrapped moisture.
- d. Conduct nuclear moisture meter surveys of suspected areas.
- e. Produce roof moisture maps.

Purpose and Scope

3. The investigations reported herein were conducted as part of

* L. E. Link, Jr., "Demonstration of a New Technique for Rapidly Surveying Roof Moisture," Miscellaneous Paper M-76-14, Jun 1976, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

an overall program to develop new methods for rapidly surveying roof moisture conditions and to define the capabilities and limitations of the methods. The purpose of this report is to document the use of a combined thermal IR-nuclear meter roof survey technique to survey roof moisture conditions on 110 buildings at Pease AFB, New Hampshire, and on 128 buildings at Offutt AFB, Nebraska. The following parts of the report discuss the steps listed in paragraph 2, as they were applied at these two Air Force bases.

PART II: DESIGN AND EXECUTION OF MISSIONS TO OBTAIN THERMAL IR IMAGERY

Mission Design

Design criteria

4. The primary questions to be answered when planning a thermal IR imagery mission are:

   a. When should the mission be flown?

   b. What sensor system should be used?

   c. How high should the aircraft fly?

Criteria for answering the questions above are discussed in detail in WES Miscellaneous Paper M-76-14. The following paragraphs describe the work conducted to answer these questions for Pease and Offutt AFB's.

Mission design for Pease AFB

5. When. The thermal IR imagery should be obtained at the time when the temperature contrast between "wet" (roof areas with entrapped moisture) and "dry" roof areas is at a maximum. The time of maximum temperature contrast was determined by obtaining temperature data for known wet and dry areas on selected roofs. Pease AFB civil engineering personnel selected three buildings (Nos. 112, 119, and 130) with a high probability of having areas with entrapped roof moisture. Nuclear meter and core sample data were used to establish known wet and dry areas on each roof, and sample points were selected for acquiring temperature data. The sample points were positioned (when possible) to cover edge, expansion joint, and central roof areas for both wet and dry conditions. Figures 1-3 show the positions for the temperature sample points on buildings Nos. 112, 119, and 130, respectively. Temperature data were obtained at each sample position approximately every 30 min as follows:

Building No.	Date 1976	Period of Measurements hr*
112	11 May	1730-2230
119	12 May	1730-2200
130	11 May	1730-2430

* In each case, this is the time in hours in the time zone in which the mission was executed.

6. The actual roof surfaces were comprised of gravel plus some areas of exposed bituminous material where the gravel did not completely cover the surface. Thus, temperature measurements were made at each sample position for both the gravel and the exposed areas of bituminous material with surface temperature (pyrometer) devices. Plots of the data are presented in Figures 4-6, which represent the averages for all wet and all dry sample positions on each building for only the measurements made on the areas of exposed bituminous material (tar). The temperature measurements for the gravel surfaces at any given time were slightly lower than those for the bituminous material, but they followed the same trend; thus, only the data for the bituminous material are presented. The temperature readings taken for edge, joint, and center roof areas did not differ significantly.

7. Examination of the temperature data in Figures 4 and 6 reveals that a considerable temperature contrast occurred between wet and dry roof areas from approximately 2030 to 2130 hr for building No. 112 and from approximately 1930 to 2330 hr for building No. 130. The time of maximum temperature contrast (considering both buildings) occurred between 1930 and 2130 hr. Examination of Figure 5 reveals that there was very little temperature contrast between the wet and dry roof areas on building No. 119. The lack of contrast was hypothesized to be caused by the persistently cloudy, hazy weather conditions that occurred on the day of measurement, and is a good example of the influence of the weather on the magnitude of the wet-dry temperature contrast and, thus, the potential influence of the weather on the successful delineation of wet and dry roof areas on thermal IR imagery.

8. Based on the temperature data in Figures 4 and 6, the time-of-day for the thermal IR imagery mission at Pease AFB was selected to be approximately 2200 hr.

9. What. For the purpose of this study, two items were given prime consideration for the selection of a sensor system: (a) a thermal IR sensor system be used that was readily available within the military; and (b) the output of the sensor system be readily interpretable by "roof" oriented personnel rather than "remote sensor" experts. This combination was found in the AN/AAS-18 thermal IR scanner system used in the Air National Guard RF4C jet aircraft. This aircraft-scanner combination is often used by the U. S. Air Force Tactical Air Command (TAC) Reconnaissance Groups. The basic output of the sensor is a photographic image of the areas over which the aircraft is flown. Processed imagery (developed film negatives) is available within hours after the flight, and the film magazine is designed to use a mat for inflight processing of the film, if necessary.

10. How high. The altitude for the IR imagery mission was selected to be 1000 ft (305 m), the same altitude used for the previous imagery mission at Dyess AFB, Texas, since this altitude results in a good image scale for imagery interpretation and does not require an unreasonable number of flight lines (WES Miscellaneous Paper M-76-14).

Mission design for Offutt AFB

11. When. The best time for acquiring thermal IR imagery (for a roof moisture survey) at Offutt AFB was specified in a manner similar to that used at Pease AFB (paragraphs 5 through 8). Buildings Nos. 407 and 324 were selected for acquiring temperature data, and nuclear meter and core sample data were used to identify wet and dry roof areas. Sample sites for temperature measurements were selected as shown in Figures 7 and 8, and roof temperature data were obtained on 18 May 1976 from 1930 to 2400 hr. The temperature data (for the bituminous material (tar)) are presented in Figures 9 and 10.

12. Examination of the temperature data for building No. 407 (Figure 9) reveals that a significant temperature contrast between wet and dry roof areas occurred after 2030 hr with a maximum occurring

between 2130 and 2330 hr. The temperature data for building No. 324 (Figure 10) did not have as much contrast as the data in Figure 9, but good control separation occurred from 2130 to 2330 hr as in Figure 9. Based on these data, the time-of-day for the thermal IR imagery mission at Offutt AFB was selected to be approximately 2130 hr.

13. What. The combination of the AN/AAS-18 thermal IR scanner system and the Air National Guard RF4C jet aircraft was selected for obtaining the thermal IR imagery at Offutt AFB.

14. How high. The mission altitude was selected to be 1000 ft (305 m) to conform with the previous missions at Dyess and Pease AFB's.

Mission Execution

Mission execution at Pease AFB

15. The flight to obtain thermal IR imagery of the buildings at Pease AFB was flown at 2145 hr on 13 May 1976 at an altitude of approximately 1000 ft (305 m). The flight was made and the IR imagery processed by personnel of the 155th TAC Reconnaissance Group of the Nebraska Air National Guard, Lincoln, Nebraska. In addition to the thermal IR imagery, conventional panchromatic aerial photography of the installation was obtained during the daytime to provide information concerning physical roof features (e.g. position of vents, etc.). It should also be noted that approximately 50 percent overlap was requested for the imagery on adjacent flight paths to allow stereo viewing of the imagery. Figure 11 presents an uncontrolled mosaic of the thermal IR imagery obtained at Pease AFB. The original imagery is at a scale of approximately 1:10,000, while the mosaics are at a scale of approximately 1:15,000 and 1:22,000 for Pease and Offutt AFB's, respectively.

Mission execution at Offutt AFB

16. The flight to obtain thermal IR imagery of the buildings at Offutt AFB was flown at approximately 2100 hr on 19 May 1976 at an altitude of approximately 1000 ft (305 m). The mission was flown prior to the optimum time because of flight crew and aircraft maintenance crew time constraints. The imagery was obtained and processed by personnel of the 155th TAC Reconnaissance Group of the Nebraska Air National

Guard, Lincoln, Nebraska. In addition to the thermal IR imagery, conventional panchromatic aerial photography of the installation was obtained during the daytime to provide information concerning physical roof features (e.g. positions of vents, etc.). Overlap of 50 percent was requested between adjacent flight paths to facilitate stereo viewing of the imagery. Figure 12 presents an uncontrolled mosaic of the thermal IR imagery obtained for Offutt AFB.

PART III: IMAGERY INTERPRETATION AND NUCLEAR MOISTURE METER SURVEYS TO OBTAIN ROOF MOISTURE CONDITION MAPS

Imagery Interpretation and Detailed Roof Surveys

17. Interpretation of the imagery to identify roof areas suspected of having entrapped moisture and subsequent nuclear meter surveys to verify the presence of entrapped water in the suspect areas were conducted as described in WES Miscellaneous Paper M-76-14. The thermal IR imagery (original negatives) for two adjacent flight paths was placed on a light table and arranged to allow stereo viewing with a pocket stereoscope. Each roof was quickly examined to identify any dark anomalous areas (the dark areas on the negative represent warm areas on the roof; on a positive print of the imagery, the warm areas appear as light tones) that may have been caused by entrapped moisture. Viewing the imagery in stereo provided the interpreter a three-dimensional view of the scene, making it possible to see major changes in roof levels and, at times, major elevated items on the roofs, such as large vents. All anomalous dark areas (i.e. those whose source could not be determined) were documented for detailed investigation with the nuclear meter.

18. As discussed in the miscellaneous paper mentioned above, warm anomalies observed on nighttime thermal IR imagery may be caused by things other than entrapped moisture. Thus, not all of the warm anomalies observed can be assigned to be entrapped moisture. Many of the nonmoisture-related warm areas can be identified during the imagery interpretation as physical features such as large vents or walls where changes in roof elevation occur. Those anomalies that are questionable as to their origin (i.e. entrapped moisture or some physical feature on the roof) need to be checked in more detail. The more detailed survey can best be conducted with a nuclear moisture meter. However, it can be conducted with hand-held IR viewers, or by cutting a hole in the roof to physically determine the presence or absence of moisture. The low cost of the nuclear meter ($3,000 to $4,000), i.e. relative to the cost of currently available hand-held IR devices ($25,000 to $40,000 per

unit), the fact that it can be used during daylight hours, and the fact that the nuclear meter uses a different physical phenomenon to detect moisture (providing an evaluation independent of the phenomenon used for IR imagery) are three strong points for its use. The hand-held IR devices, notwithstanding have been shown to be effective for detailed roof moisture surveys and can be used for additional purposes, such as surveying electrical utility equipment (insulators, transformers, etc.). The most straightforward means of verifying the presence of entrapped moisture is by cutting a core sample in each anomalous area. The core samples, however, are a destructive test and do not define the extent of the entrapped moisture.

19. For the purposes of the surveys at Pease and Offutt AFB's, both the nuclear meter and core samples were used to examine all warm roof areas (as identified on the imagery) suspected to have entrapped moisture. The comprehensiveness of the on-the-roof detailed surveys was necessary to help define the true capabilities and limitations of the airborne IR imagery for detecting roof areas with entrapped moisture. In addition, the acquisition of core samples provided a check on the performance of the nuclear meter and gave conclusive evidence of the actual presence or absence of entrapped moisture. The on-the-roof detailed studies were conducted from 1 to 4 June 1976 at Pease AFB and from 26 to 30 May 1976 at Offutt AFB. The following paragraphs present the results of the surveys to produce roof moisture condition maps for the two installations.

Roof Moisture Conditions

20. As stated in paragraph 3, the thermal IR imagery was used to examine 110 buildings at Pease AFB and 128 buildings at Offutt AFB. Of these a total of 14 buildings at Pease AFB and 9 buildings at Offutt AFB were determined to have anomalous "warm" roof areas suspected to be due to entrapped moisture. It should be emphasized that many other "warm" anomalies occurred on the imagery that were identified as being caused by physical features of the buildings or items on the roofs. Areas

suspected of having entrapped moisture were examined with the nuclear meter, and core samples were obtained both within and adjacent to the anomalous areas to establish the presence, shape, and extent of the areas of entrapped moisture. Figures 13-35 present the results of the surveys. The top portion of each figure is an enlargement of the thermal IR image of each building on which areas suspected of having entrapped moisture were identified. The bottom portion of each figure shows a corresponding plan view of each roof and identifies the causes of the anomalies, which were initially suspected to be due to entrapped moisture. The anomalies identified as areas with entrapped moisture have been confirmed by both the nuclear meter and core samples. The following paragraphs present, by installation, a brief summary of the information presented in Figures 13-35.

Survey results at Pease AFB

21. Figures 13-26 present the results of the roof moisture survey at Pease AFB. Areas on 14 buildings were examined in detail with the nuclear meter and core samples to verify the presence of entrapped moisture. Of the 14 buildings examined, 9 had areas with entrapped moisture.

22. Examination of the uncontrolled mosaic in Figure 11 shows that the IR imagery for Pease AFB was not of the best quality. The "hazy" appearance of the imagery was caused by fogging of the film (the creation of a significant neutral density on the film by a source other than the planned exposure of the film). The cause of the fogging was not determined, but it may have been due to excess heat near the film or some aspect of the film development process. The fog level on the film was an obstacle for the image interpreter, because it effectively reduced the contrast between the wet and dry roof areas and at times made it difficult to determine the precise outer boundaries of the roofs. The effect of the fogging is especially evident in the imagery enlargements presented for the individual buildings in Figures 13-26.

23. Table 1 presents a summary of the results of the roof moisture survey at Pease AFB. The table shows that a large proportion of the areas suspected were confirmed to have entrapped moisture. In a few

instances, anomalies due to vents were misinterpreted as possible wet areas; however, the frequency of this type of "false alarm" was much lower than for the Dyess AFB study reported in WES Miscellaneous Paper M-76-14. This reduction in false alarms was attributed to increased experience in interpreting the IR imagery (gained in the Dyess AFB study). The major source of false alarms or misinterpretations of the Pease AFB imagery was on buildings Nos. 85, 46, and 6 which are "in-flight" kitchens with raised roof structures with windows venting hot air from the kitchen areas below. Prior knowledge of the building's function and the presence of these features would have prevented the misinterpretation of the anomalies. It should be noted that such anomalies as those on these buildings could mask the presence of areas of entrapped moisture, and roof surveys with a device such as a nuclear meter (non-IR device) would be necessary to detect such areas of entrapped moisture.

24. Standing water was a partial cause of an anomaly on the image of building No. 36. This emphasizes the fact that thermal IR imagery missions should not be flown when large areas of roofs are covered with standing water (e.g. immediately after a period of rainfall).

Survey results at Offutt AFB

25. Figures 27-35 present the results of the roof moisture survey at Offutt AFB. Areas on 9 buildings were examined in detail with the nuclear meter and core samples to verify the presence of entrapped moisture. Of the 9 buildings examined, 5 had areas with entrapped moisture.

26. Examination of the uncontrolled mosaic in Figure 12 shows that the IR imagery for Offutt AFB appeared to be of good quality. The major factor, if any, that may have influenced the quality of the imagery for the purposes at hand was the fact that it was obtained prior to the time specified (at 2100 instead of 2130) to be the optimum based on the roof temperature measurements.

27. Table 2 presents a summary of the results of the roof moisture survey at Offutt AFB. The major causes for false alarms, or misinterpretations, on the imagery were vents, roof surface changes, standing water, and roof structures. The false alarms due to vents

and roof structures could have been eliminated with some prior knowledge of their presence on the roofs. The roof surface changes observed at Offutt AFB (exposed insulation and deck material character, such as gravel color) are difficult to determine a priori. Standing water can be a problem at times, and it is clearly beneficial to obtain the IR imagery when there is a minimum of standing water on the roofs.

PART IV: SUMMARY AND RECOMMENDATIONS

Summary

28. The application of the thermal IR-nuclear meter roof survey technique was considered to be a very effective means of detecting roof areas with entrapped moisture. The IR imagery was used to rapidly examine roof moisture conditions on 238 buildings (128 at Pease AFB and 110 at Offutt AFB). The imagery interpretation resulted in the identification of 23 buildings (approximately 10 percent of all buildings examined on the imagery) that had roof areas suspected to have entrapped moisture. Detailed surveys with a nuclear meter and core samples revealed that 14 of the 23 buildings (9 at Pease AFB and 5 at Offutt AFB) did indeed have areas with entrapped moisture. Thus, the technique provided a maximum of information with a minimum of detailed on-the-roof survey effort.

29. Such features as vents, elevated roof structures, standing water, and changes in roof surface characteristics caused anomalies on the imagery interpreted to be possible areas with entrapped moisture. A major portion of the anomalies caused by vents and elevated roof structures could have been identified correctly during the imagery interpretation if the interpreter had had prior knowledge of their presence on the roofs. It is significant to note that the WES personnel interpreting the IR imagery were not familiar with the individual roofs at Pease and Offutt AFB's and are not roof experts. It is reasonable to assume that personnel at these bases involved in roof maintenance and repair would have identified fewer false alarms because of their experience and familiarity with roof conditions. Stereo viewing was not available for all the buildings, especially those on the outer half of the flight paths on the edges of the installation and in some instances where the requested 50 percent overlap was not achieved. However, the stereo viewing capability did help to distinguish the warm anomalies produced by some of the air vents and roof structures. The anomalies due to

standing water emphasize the need to plan the imagery acquisition mission when standing water is at a minimum.

Recommendations

30. Based on the results of this study, it is recommended that a first-generation manual be prepared for the operational application of the thermal IR-nuclear meter roof moisture survey technique by Air Force personnel. Some questions remain concerning the technological aspects of this technique; however, it is felt that the benefits that can be derived by the immediate application of the technique warrant its use. The technological questions can be approached and answered during the initial operational applications of the technique.

Table 1

Summary of Roof Moisture Survey

Pease AFB, New Hampshire

Building No.	Cause of Warm Anomalies	Remarks
31	Entrapped moisture (two areas)	Figure 13. Moisture anomalies are quite evident on IR image; building boundaries are not always evident partially because of fogging of film
130	Entrapped moisture (four areas)	Figure 14. Moisture and vent anomalies are evident on IR image; small area of entrapped moisture located in south corner of building was not observable on imagery but was located with nuclear meter during detailed study
119	Entrapped moisture	Figure 15. One small area found with entrapped moisture; anomalies due to vents were easily identified as to source during image interpretation
35	Entrapped moisture (two areas)	Figure 16. Building outline is difficult to determine without information on actual shape; moisture anomalies are very evident on imagery
36	Entrapped moisture, roof surface change, standing water	Figure 17. Moisture anomaly is very evident on IR image; a warm anomaly (suspected at first to be caused by entrapped moisture) caused by a combination of a change in roof material characteristics (gravel color) and standing water
112	Entrapped moisture	Figure 18. Moisture anomaly is very evident on IR image; building outline is not easily discernable because of fog level on image
227	Entrapped moisture	Figure 19. Moisture anomalies are vague on blowup of image in figure but appear more clearly on original imagery negative; degradation in image quality is due to fog level and enlargement process

(Continued)

Table 1 (Concluded)

Building No.	Cause of Warm Anomalies	Remarks
43	Entrapped moisture	Figure 20. Building outline is very difficult to delineate on IR image without prior knowledge of shape; moisture anomaly is evident after building outline determined
85	Entrapped moisture, elevated roof structures with vent windows	Figure 21. This building is an in-flight kitchen with elevated structures on the roof that have large windows. The walls of the elevated structures and hot-air vents from the windows created significant anomalies on the image. Prior knowledge of these conditions would have reduced the possibility of interpreting these anomalies as possible areas with entrapped moisture. One area with entrapped moisture was identified correctly
46	Elevated roof structures with vent windows	Figure 22. Same as Figure 21, building No. 85
6	Elevated roof structures with vent windows	Figure 23. Same as Figure 21, building No. 85
26	Vent	Figure 24. Building outline is difficult to delineate on image without knowledge of building shape. Scalloped effect on edges of building is due to sensor system noise; anomaly on west end of building is due to a vent
38	Entrapped moisture	Figure 25. Building outline is somewhat difficult to delineate on enlarged image but more easily identified on original negative; entrapped moisture anomaly is evident on IR image
120	Entrapped moisture	Figure 26. Area with entrapped moisture is quite small and does not show up well on enlarged image in the figure, but it is evident on original negative of IR imagery

Table 2

Summary of Roof Moisture Survey

Offutt AFB, Nebraska

Building No.	Cause of Warm Anomalies	Remarks
301	Entrapped moisture; roof surface change	Figure 27. Only the three bays on which anomalies are outlined in the figure were surveyed in detail. Moisture anomalies are quite evident on the IR imagery. Anomalies designated as "roof surface change" are areas where the insulation and deck of the roof are exposed
526	Air vents	Figure 28. Anomaly identified during the detailed study to be caused by air vent is not readily visible on the enlargement in the figure, but it does appear on the original IR negative
418	Evaporator and standing water	Figure 29. Anomaly suspected to be caused by entrapped moisture was due to a large evaporator on the roof and some associated standing water on the roof around it. This anomaly would have been less likely to be identified as entrapped moisture if the interpreter had had prior knowledge of the presence of the evaporator
500	Standing water	Figure 30. Areas suspected to have entrapped moisture are slight depressions and had significant standing water. Spot checks with the nuclear meter did not reveal any entrapped moisture
306	Elevated roof structure (control tower)	Figure 31. Anomaly suspected to be entrapped moisture was due to a control tower on the roof. This "false alarm" would have been averted if the interpreter had been aware of the presence of this feature on the roof

(Continued)

Table 2 (Concluded)

Building No.	Cause of Warm Anomalies	Remarks
323	Entrapped moisture (three areas), standing water, change in roof surface	Figure 32. Some scan-line noise is evident on the image (in the figure), which degraded the interpretability of the image to some extent. Moisture anomalies are more obvious on the original IR imagery negative than on the enlargement in the figure. Anomalies due to some standing water were evident as well as a small anomaly due to a change in the gravel surface (mostly color)
324	Entrapped moisture (three areas), vents	Figure 33. Moisture anomalies are evident on IR imagery; some small anomalies created by vents originally suspected to be caused by entrapped moisture. Southern portion of the building has new roof and presents a good example of the uniform dark tone that is representative of a good roof
407	Entrapped moisture (two areas)	Figure 34. Moisture-induced anomalies are evident on the IR imagery
307	Entrapped moisture, valley with sediment buildup	Figure 35. Entrapped moisture anomaly is evident on the IR imagery. Anomaly on on north section of roof is due to a valley (the roof has two major peaks) filled with fine materials washed off higher portions of the roof

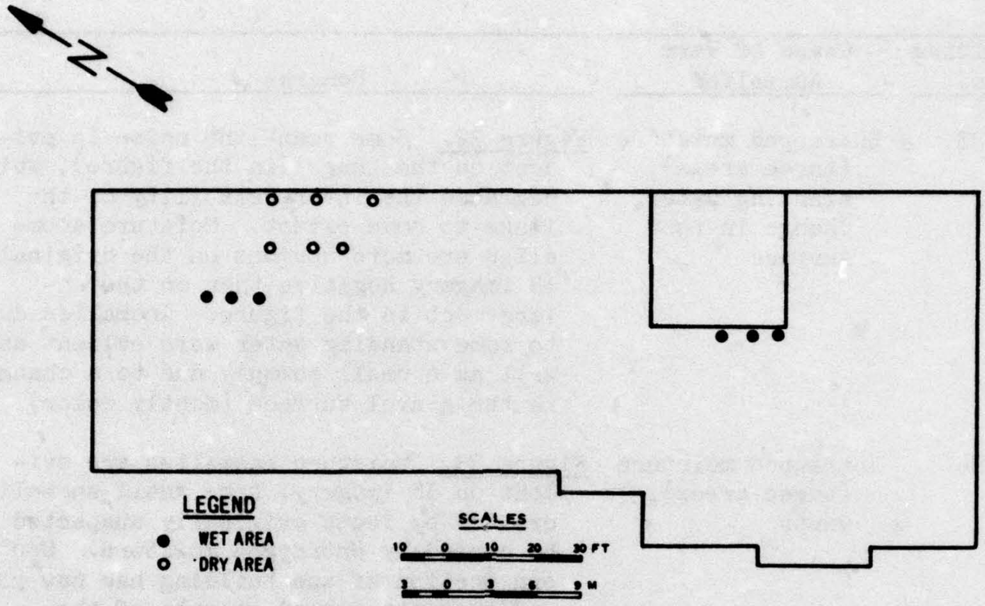


Figure 1. Locations for obtaining roof temperature measurements, building No. 112, Pease AFB, New Hampshire

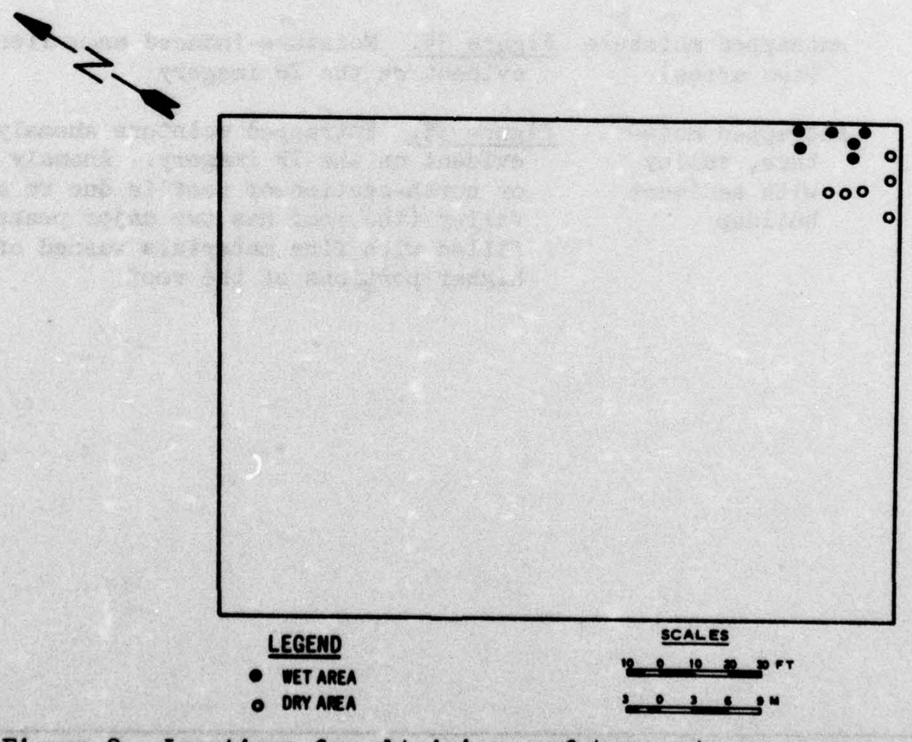


Figure 2. Locations for obtaining roof temperature measurements, building No. 119, Pease AFB, New Hampshire

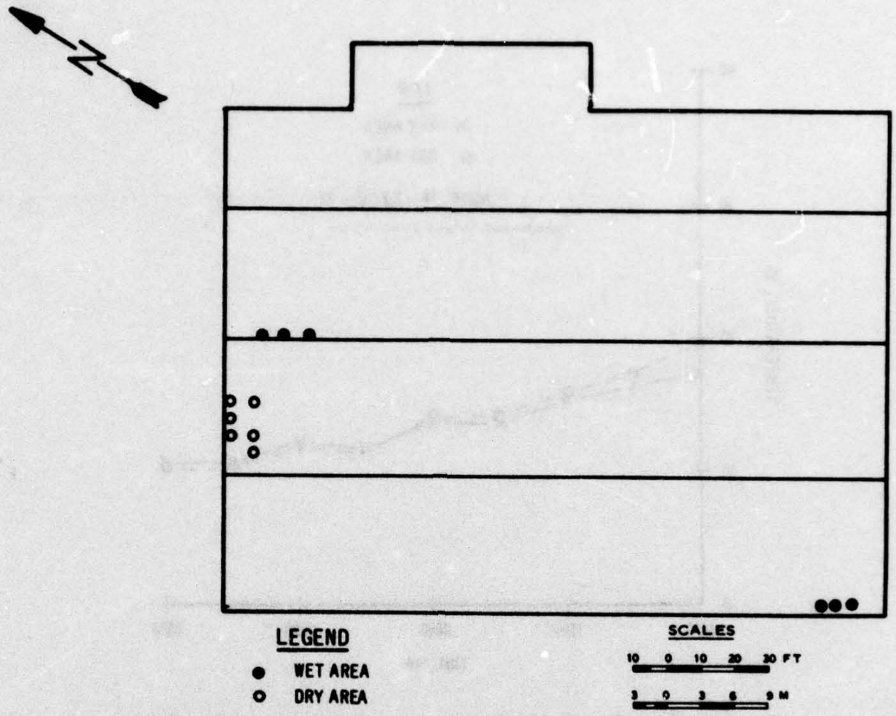


Figure 3. Locations for obtaining roof temperature measurements, building No. 130, Pease AFB, New Hampshire

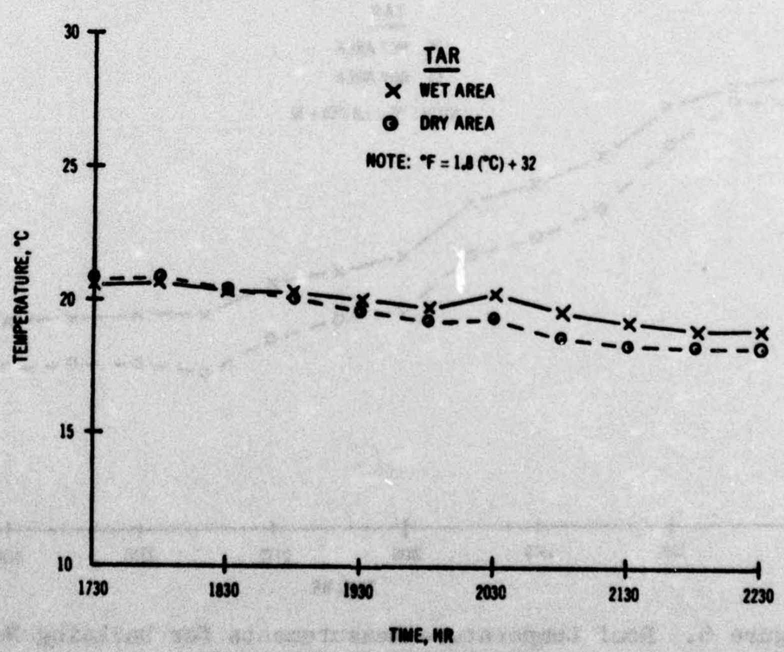


Figure 4. Roof temperature measurements for building No. 112, Pease AFB, New Hampshire

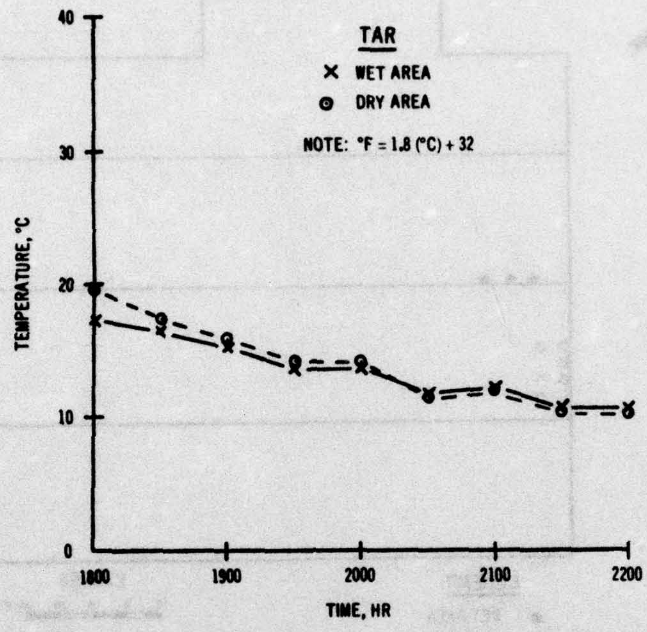


Figure 5. Roof temperature measurements for building No. 119, Pease AFB, New Hampshire

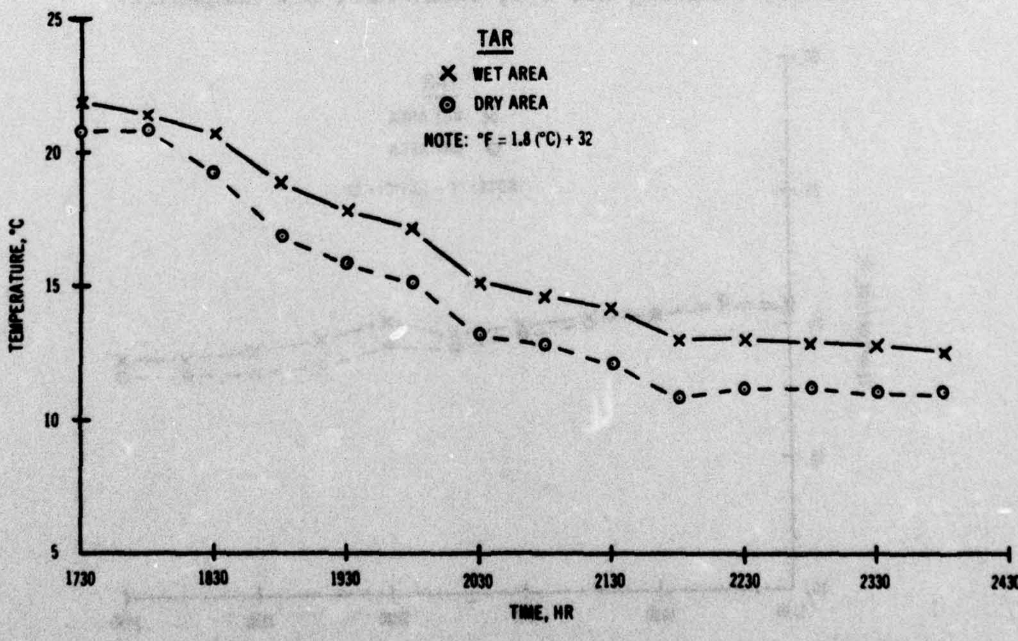


Figure 6. Roof temperature measurements for building No. 130, Pease AFB, New Hampshire

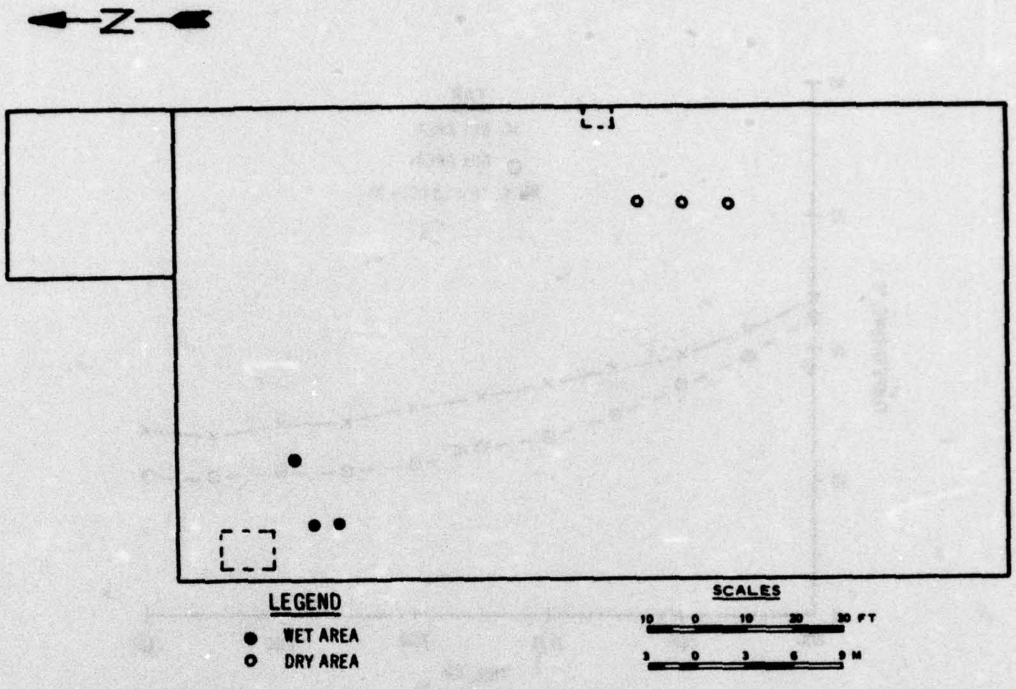


Figure 7. Locations for obtaining roof temperature measurements, building No. 407, Offutt AFB, Omaha, Nebraska

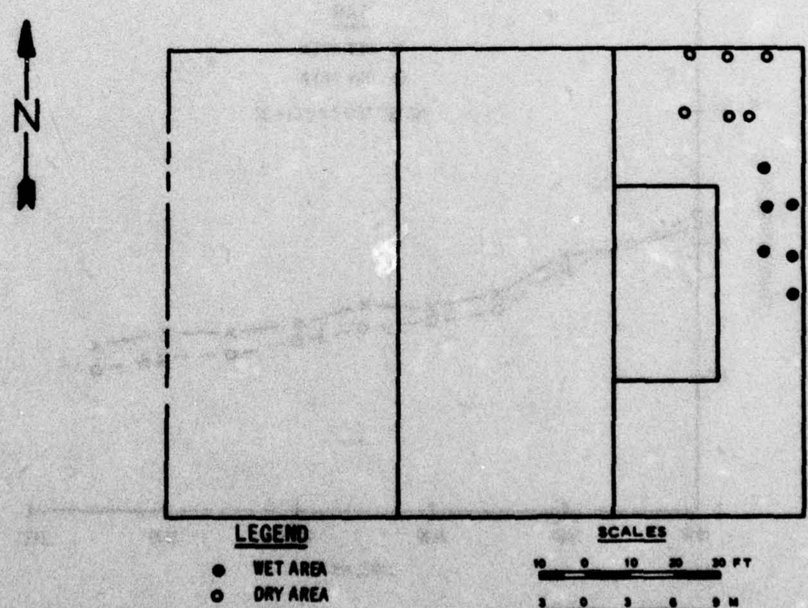


Figure 8. Locations for obtaining roof temperature measurements, building No. 324, Offutt AFB, Omaha, Nebraska

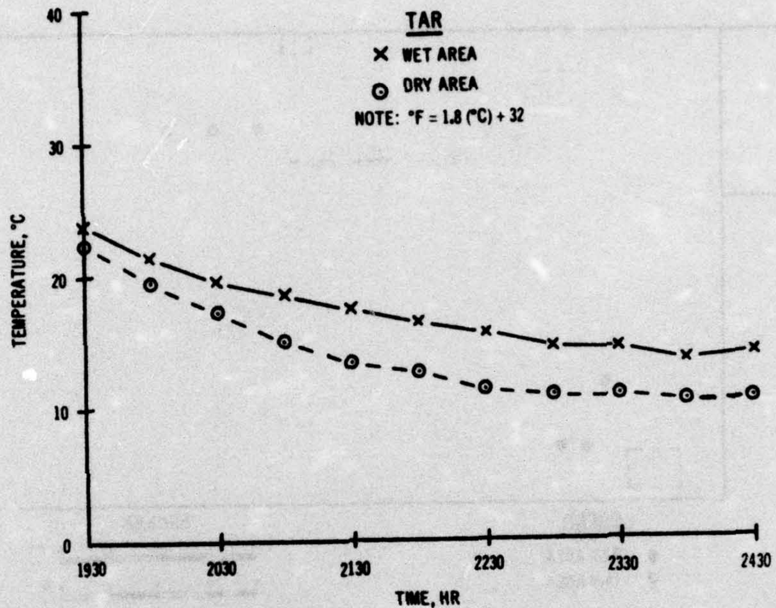


Figure 9. Roof temperature measurements for building No. 407, Offutt AFB, Nebraska

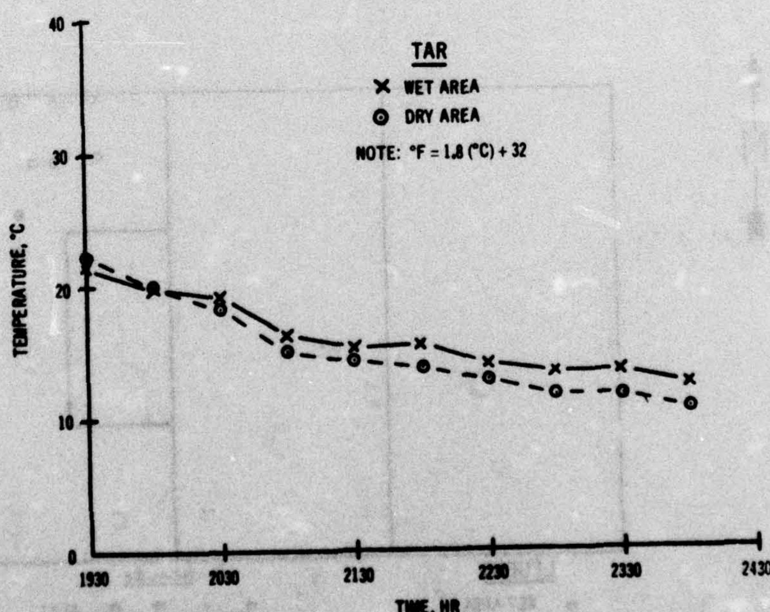


Figure 10. Roof temperature measurements for building No. 324, Offutt AFB, Nebraska

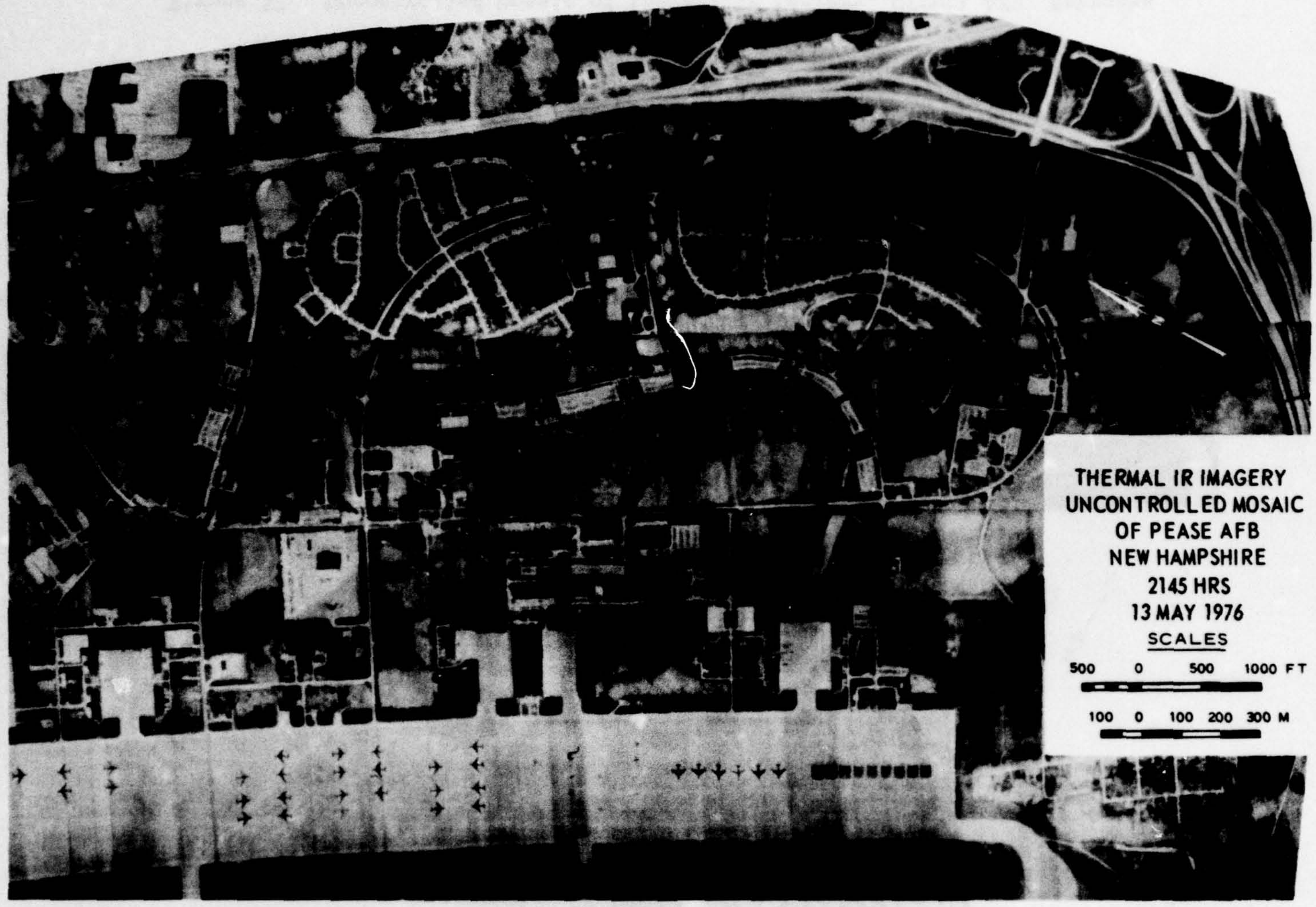
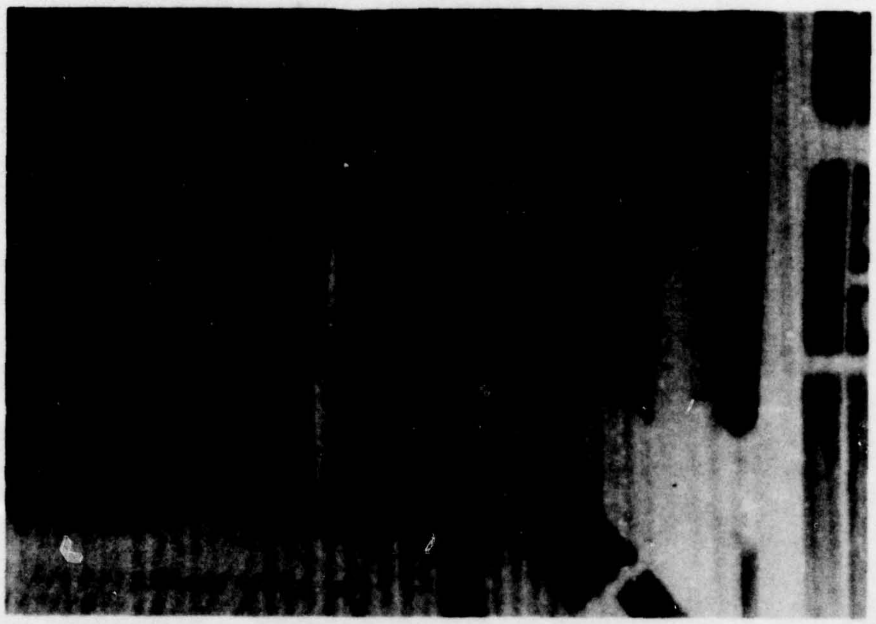
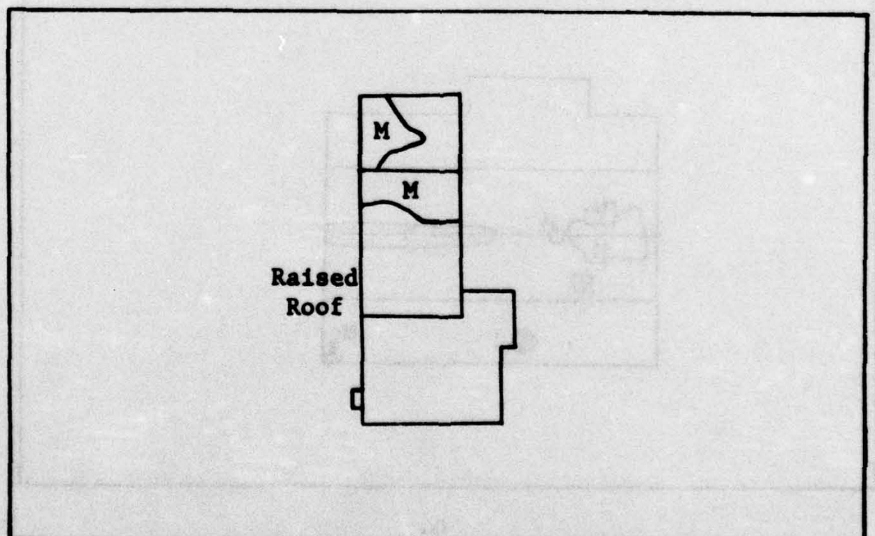


Figure 11. Uncontrolled mosaic of thermal IR imagery, Pease AFB, New Hampshire

Figure 12. Uncontrolled mosaic of thermal IR imagery, Offutt AFB, Nebraska



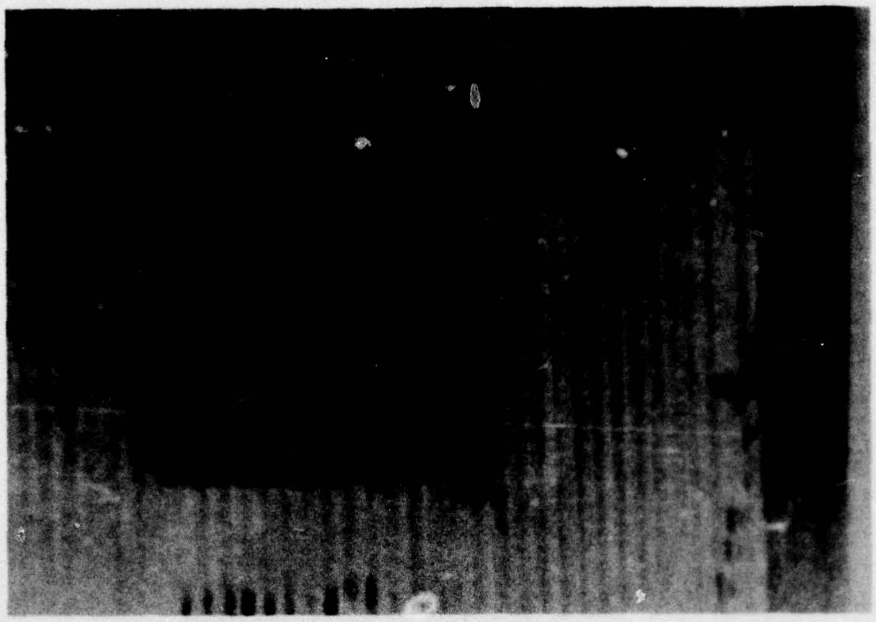
a.



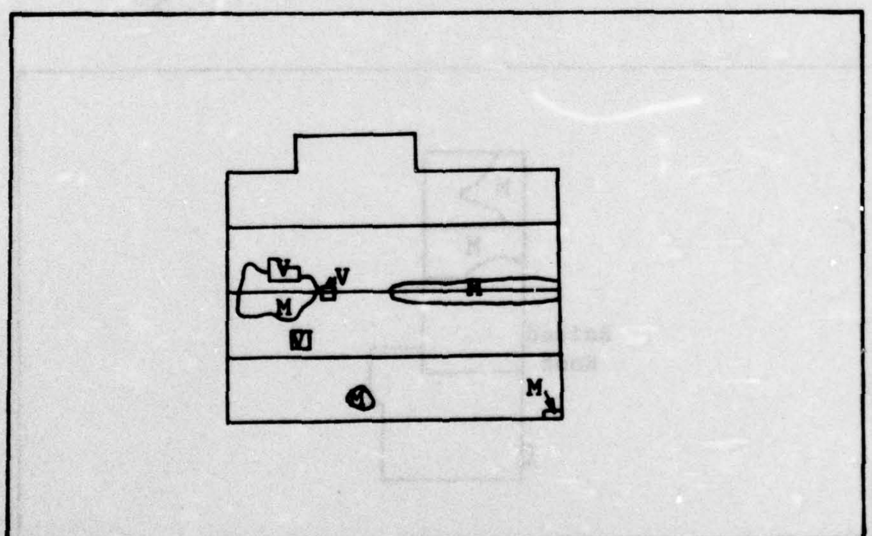
NOTE: M = Entrapped moisture.

b.

Figure 13. Thermal IR image (a) and identification of anomalies (b) for building No. 31, Pease AFB, New Hampshire



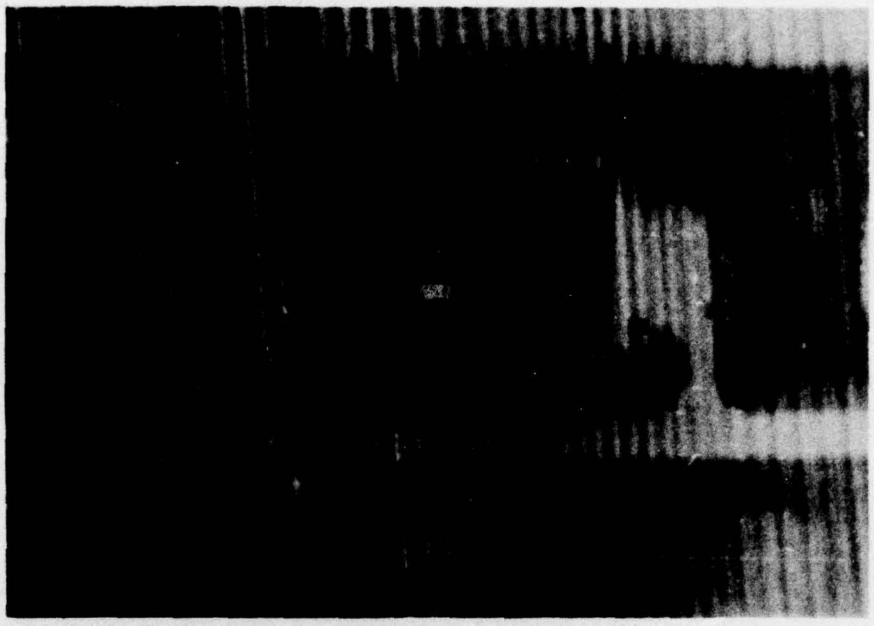
a.



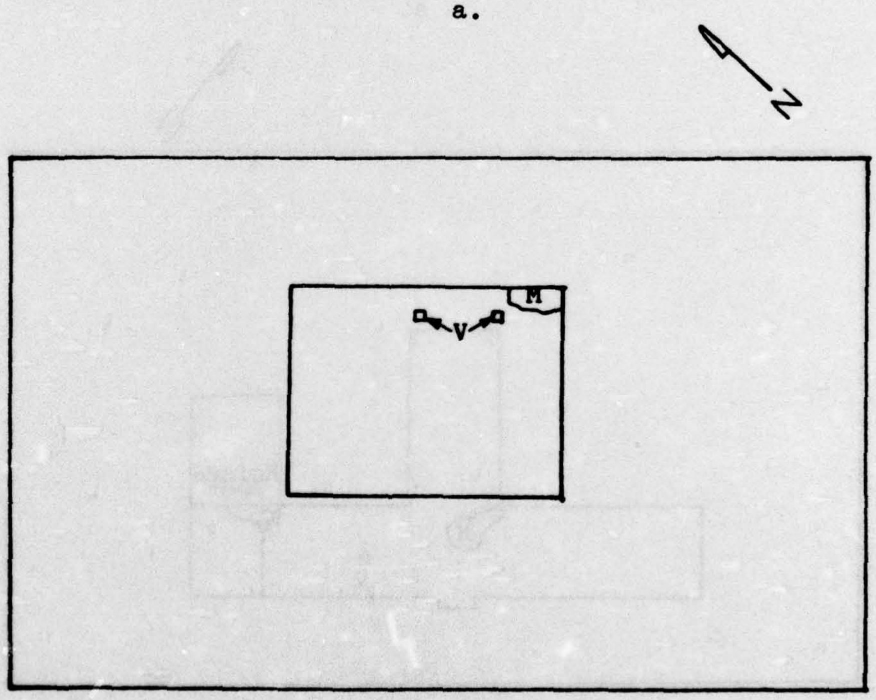
b.

NOTE: M = entrapped moisture.
V = air vent.
Small wet area in south corner of building was found with the nuclear meter; it was not obvious on the imagery.

Figure 14. Thermal IR image (a) and identification of anomalies (b) for building No. 130, Pease AFB, New Hampshire



a.

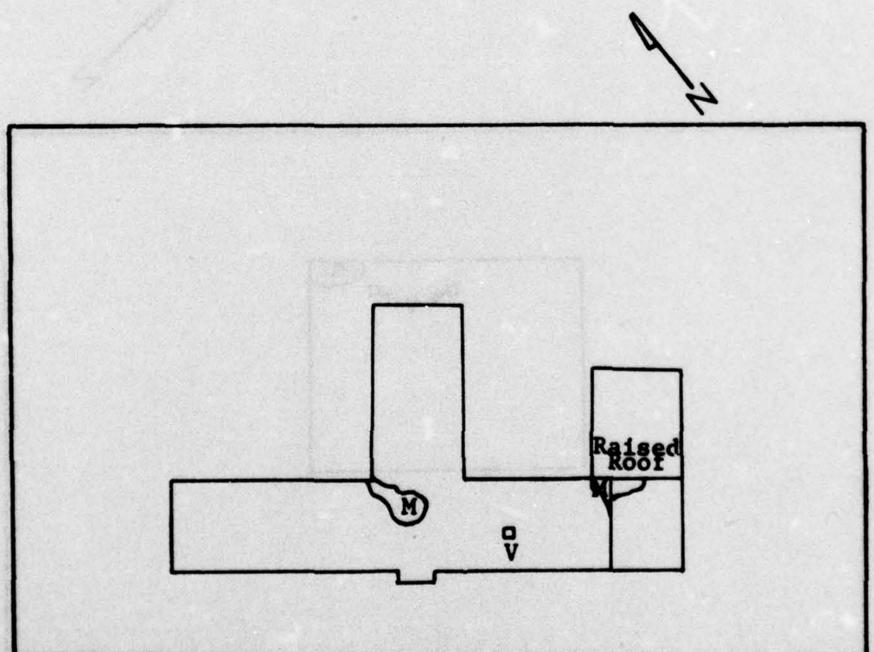


NOTE: M = entrapped moisture.
V = air vent.

b.

Figure 15. Thermal IR image (a) and identification of anomalies (b) for building No. 119, Pease AFB, New Hampshire

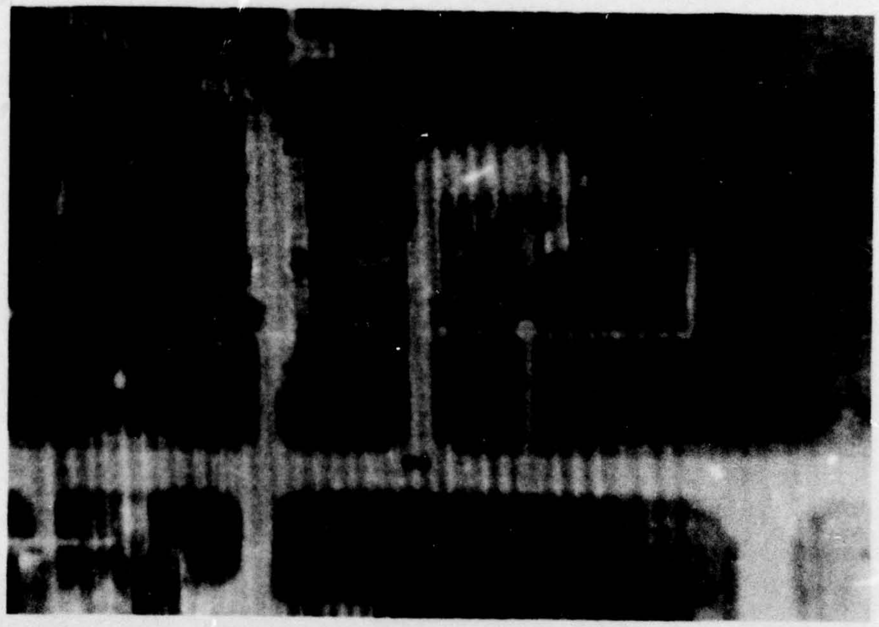
a.



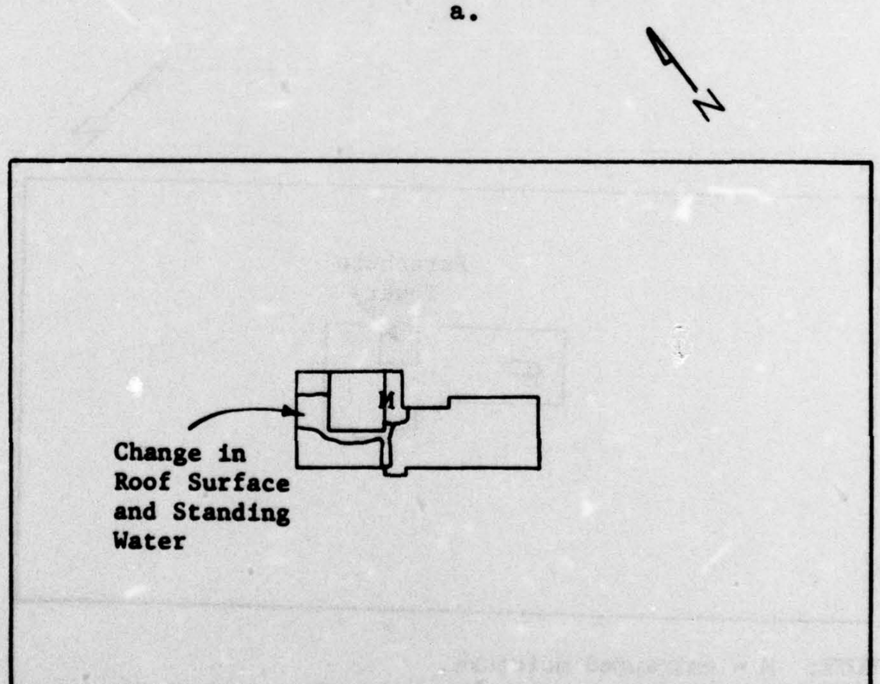
NOTE: M = entrapped moisture.
V = air vent.

b.

Figure 16. Thermal IR image (a) and identification of anomalies (b) for building No. 35, Pease AFB, New Hampshire



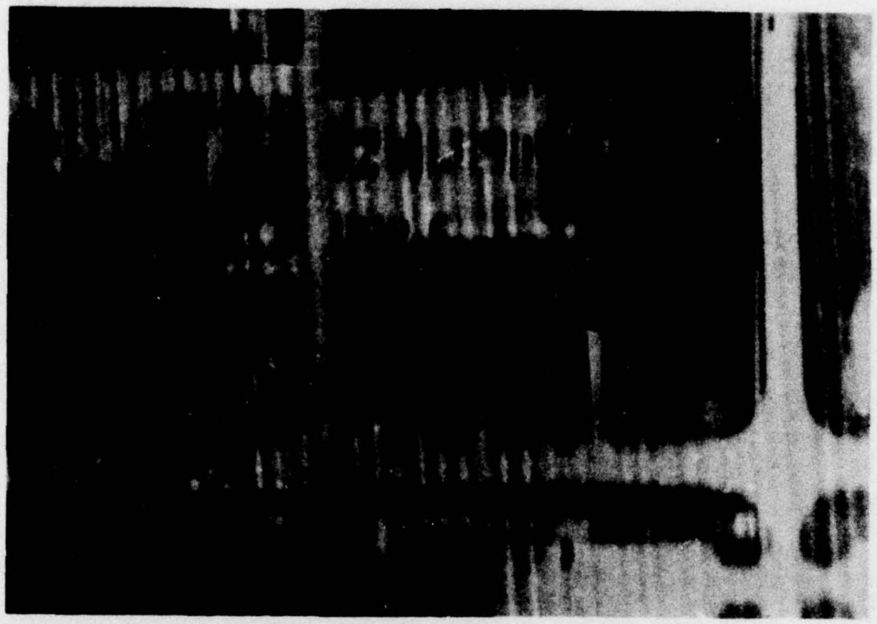
a.



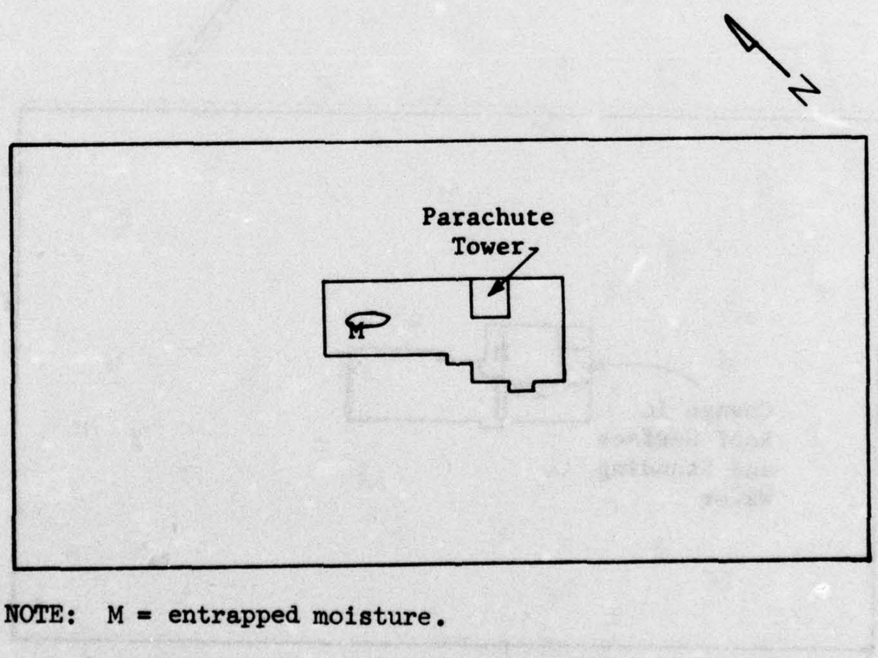
NOTE: M = entrapped moisture.

b.

Figure 17. Thermal IR image (a) and identification of anomalies (b) for building No. 36, Pease AFB, New Hampshire



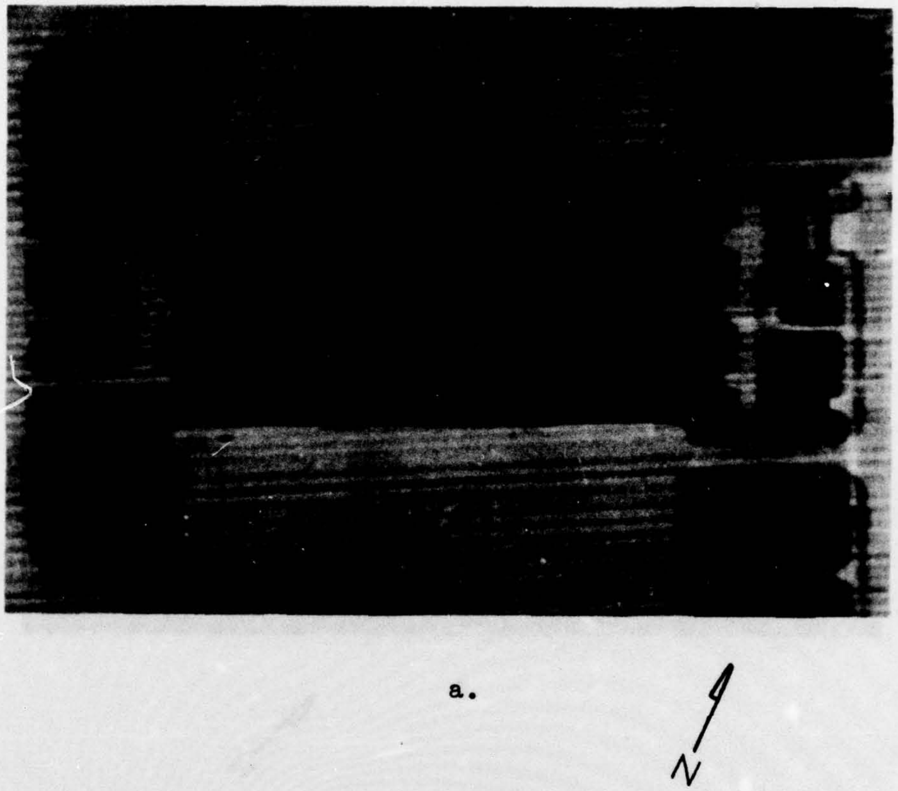
a.



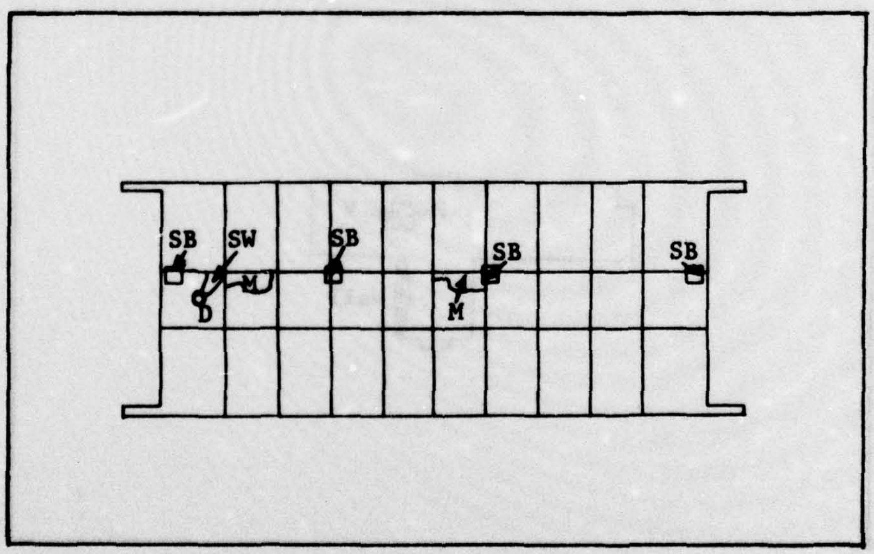
NOTE: M = entrapped moisture.

b.

Figure 18. Thermal IR image (a) and identification of anomalies (b) for building No. 112, Pease AFB, New Hampshire



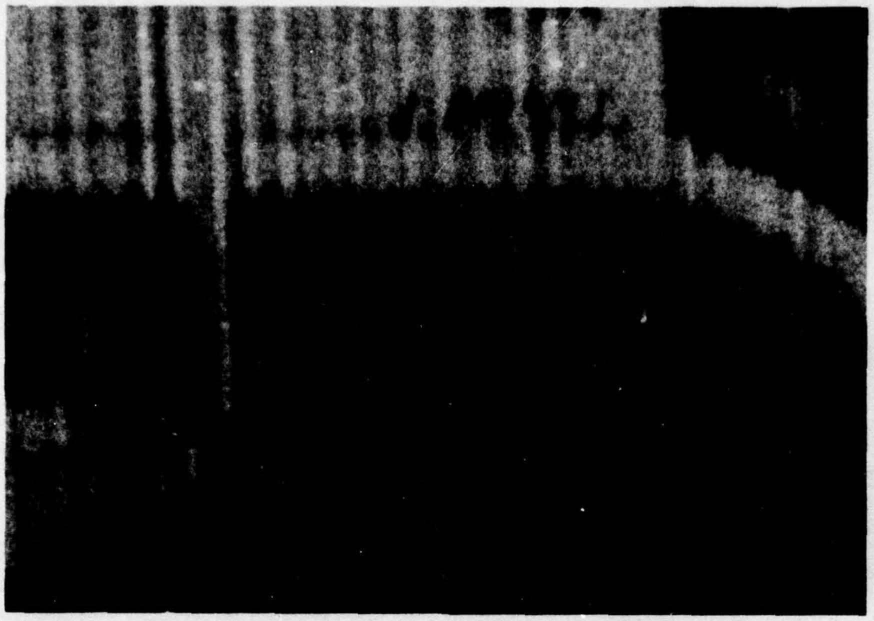
a.



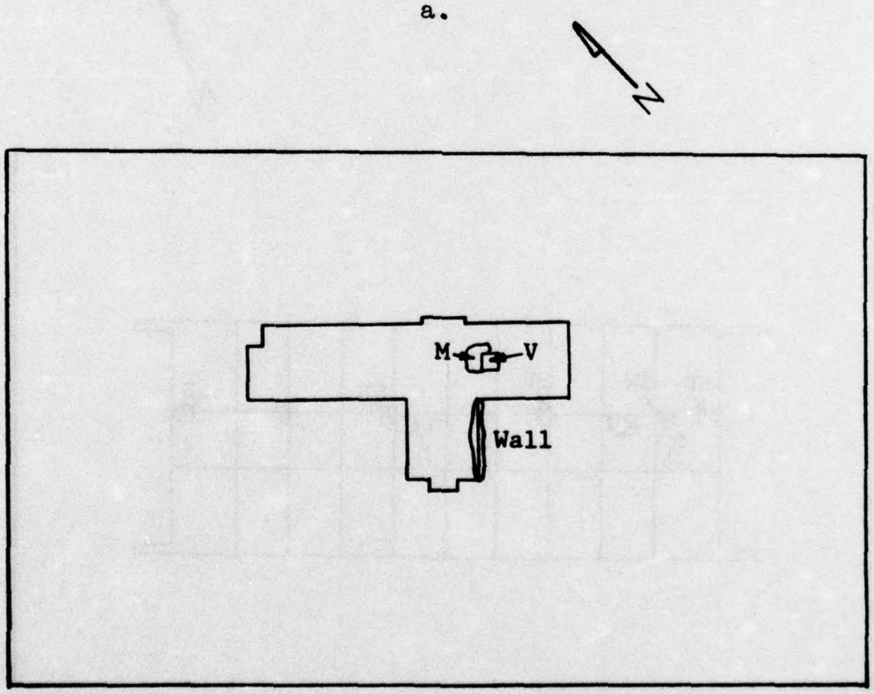
NOTE: SW = standing water.
M = entrapped moisture.
D = drainage structure.
SB = stairway building.

b.

Figure 19. Thermal IR image (a) and identification of anomalies (b) for building No. 227, Pease AFB, New Hampshire



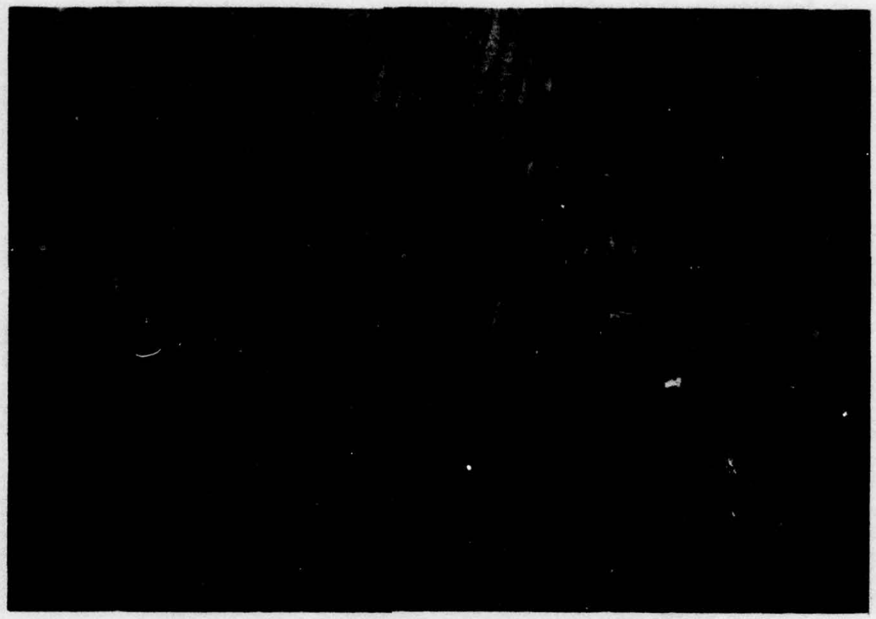
a.



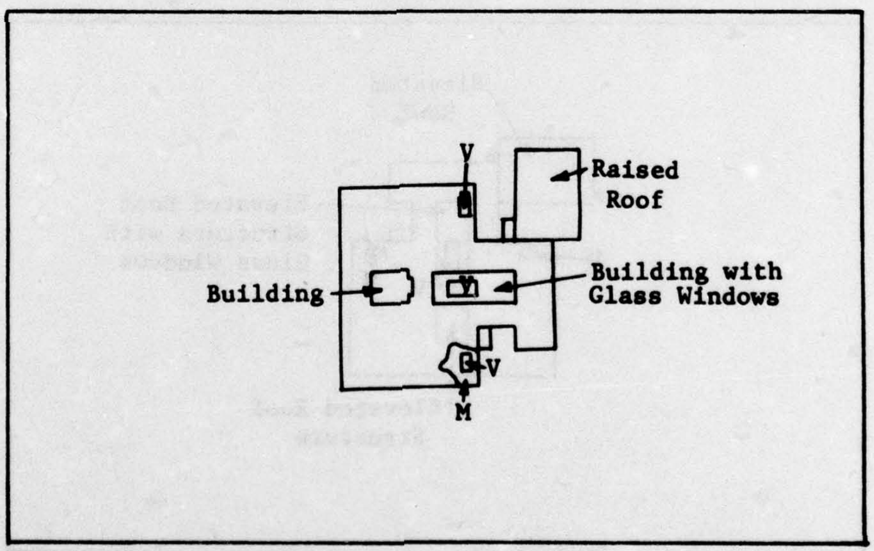
NOTE: M = entrapped moisture.
V = air vent.

b.

Figure 20. Thermal IR image (a) and identification of anomalies (b) for building No. 43, Pease AFB, New Hampshire



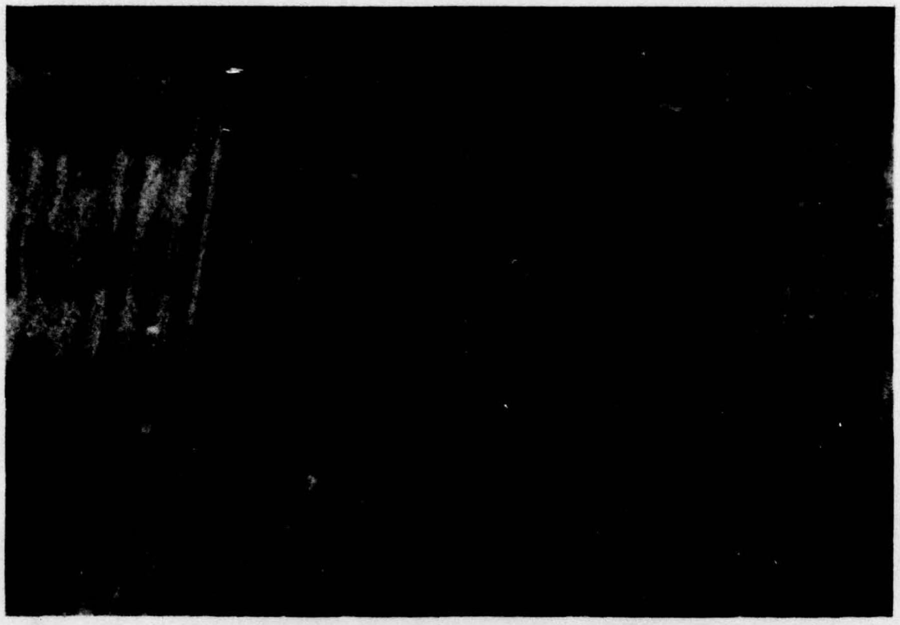
a.



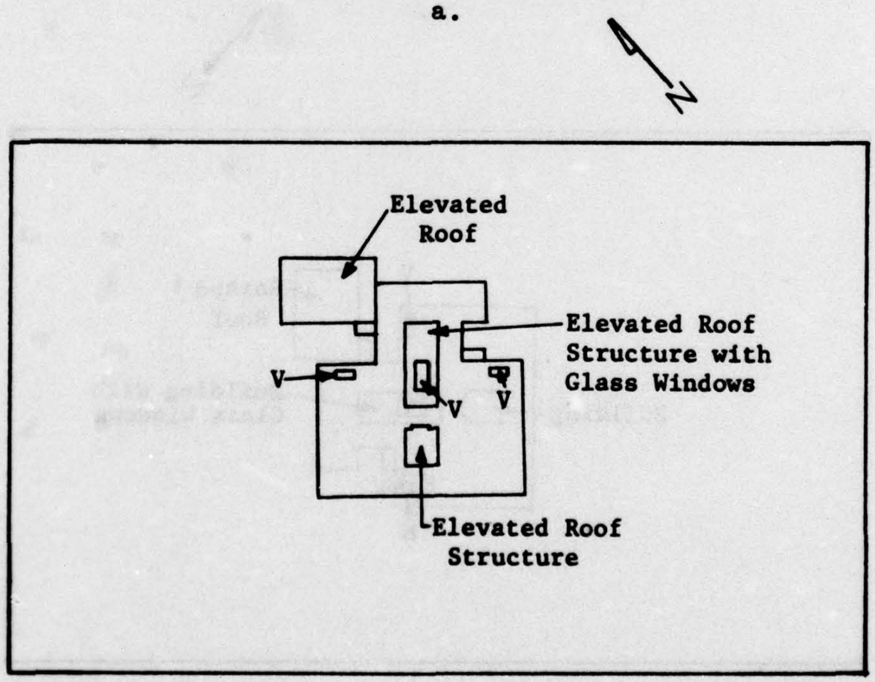
NOTE: M = entrapped moisture.
V = air vent.

b.

Figure 21. Thermal IR image (a) and identification of anomalies (b) for building No. 85, Pease AFB, New Hampshire



a.

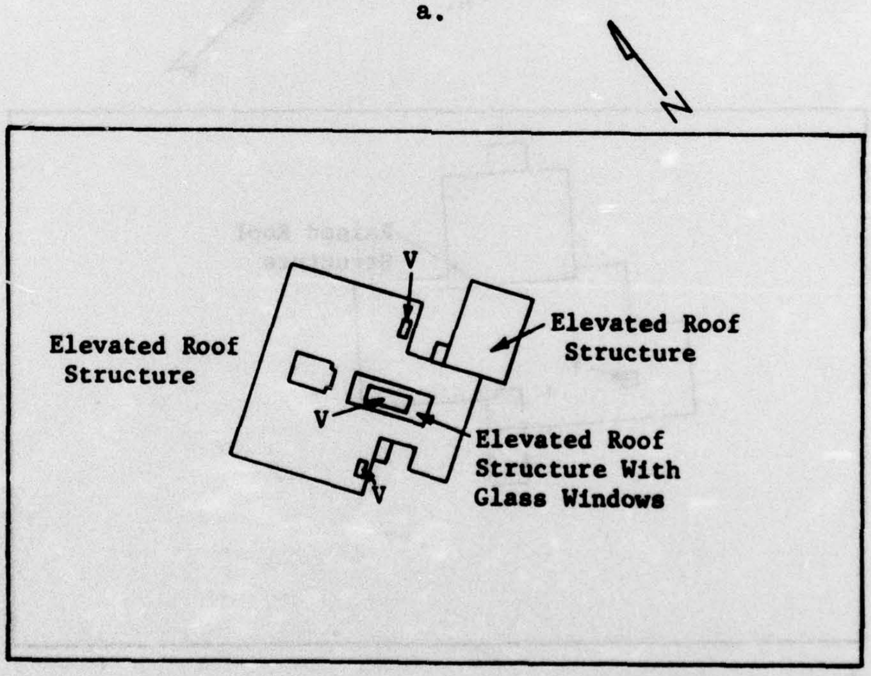


NOTE: V = air vent.

b.

Figure 22. Thermal IR image (a) and identification of anomalies (b) for building No. 46, Pease AFB, New Hampshire

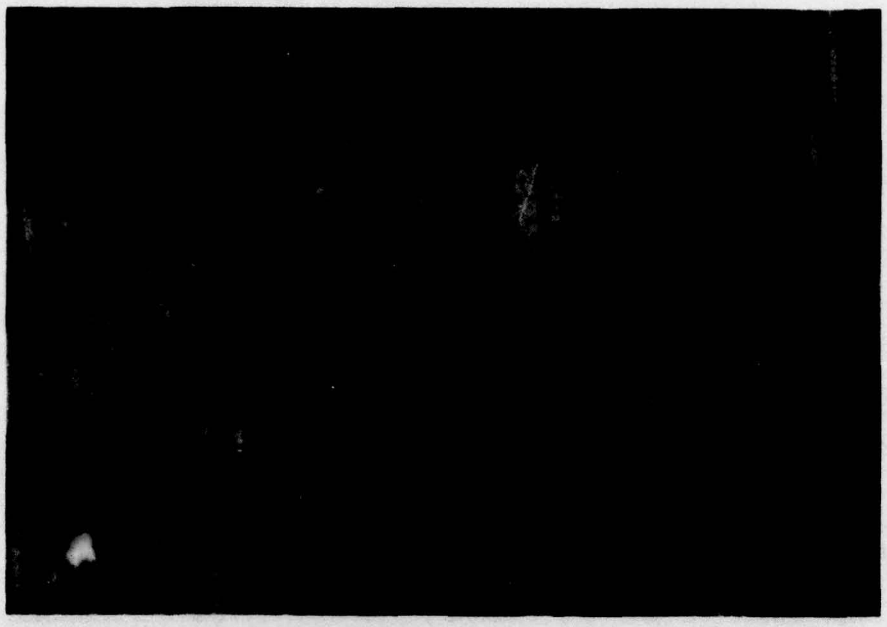
a.



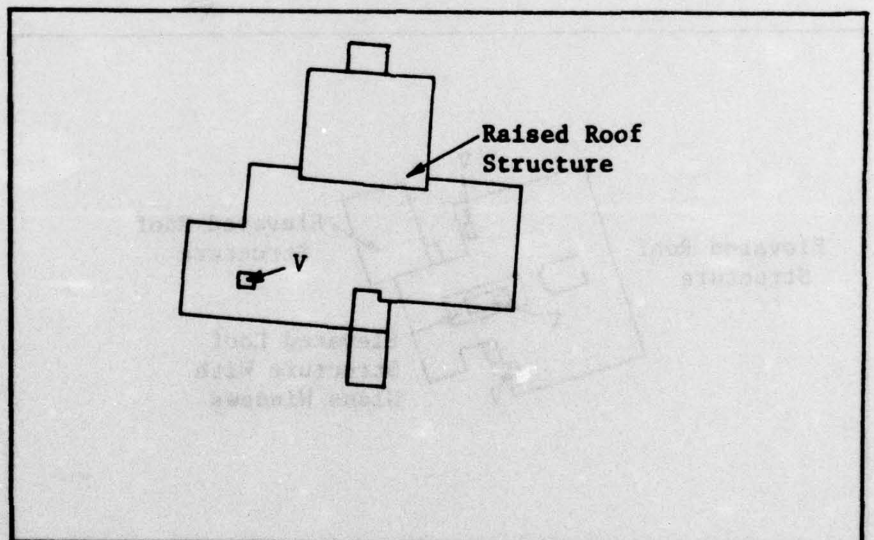
NOTE: V = air vent.

b.

Figure 23. Thermal IR image (a) and identification of anomalies (b) for building No. 6, Pease AFB, New Hampshire



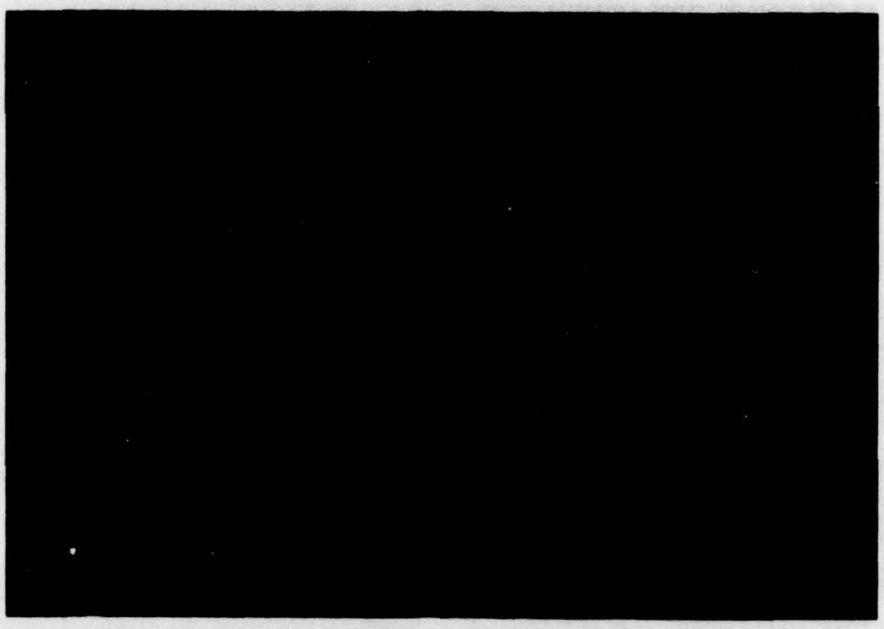
a.



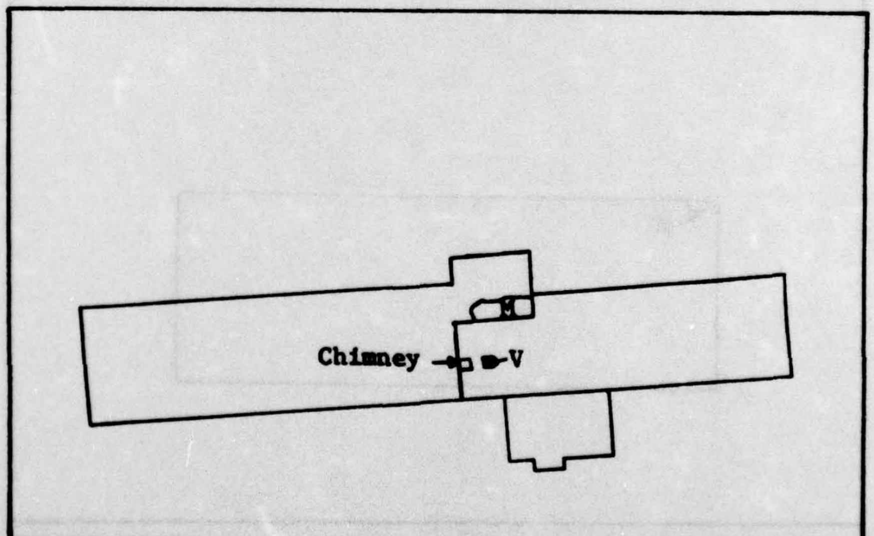
Note: V = air vent.

b.

Figure 24. Thermal IR image (a) and identification of anomalies (b) for building No. 26, Pease AFB, New Hampshire



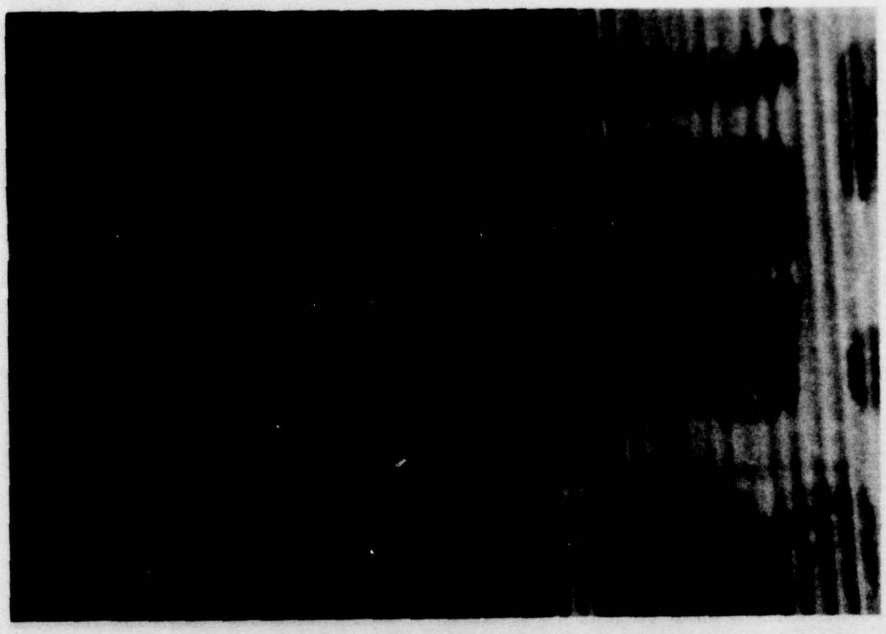
a.



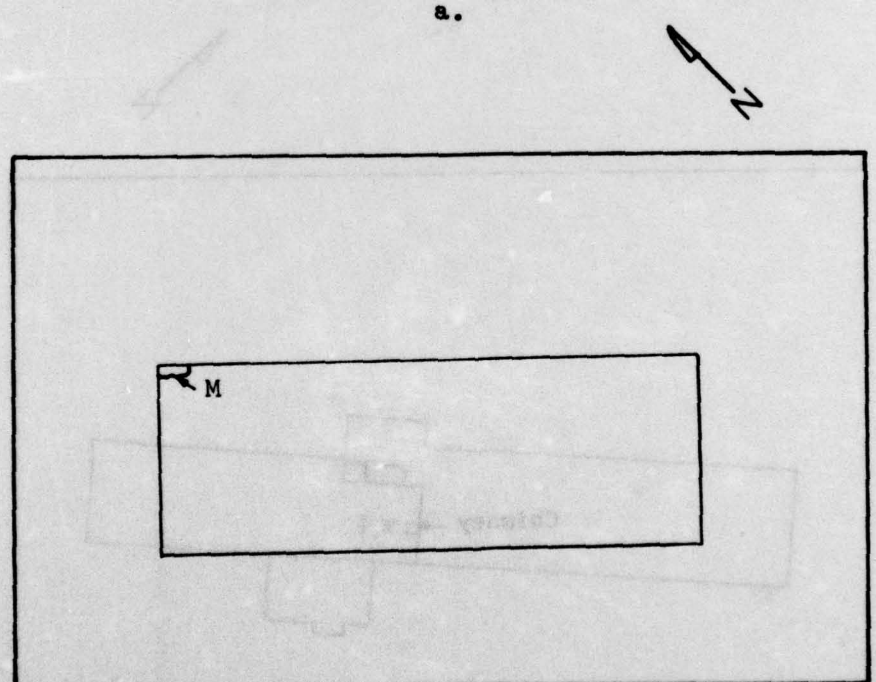
NOTE: M = entrapped moisture.
V = air vent.

b.

Figure 25. Thermal IR image (a) and identification of anomalies (b) for building No. 38, Pease AFB, New Hampshire



a.

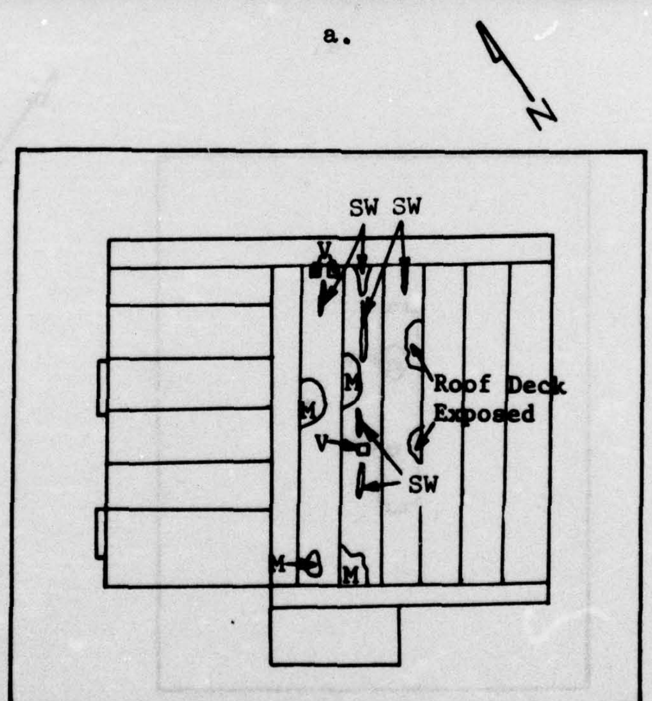


NOTE: M = entrapped moisture.

b.

Figure 26. Thermal IR image (a) and identification of anomalies (b) for building No. 120, Pease AFB, New Hampshire

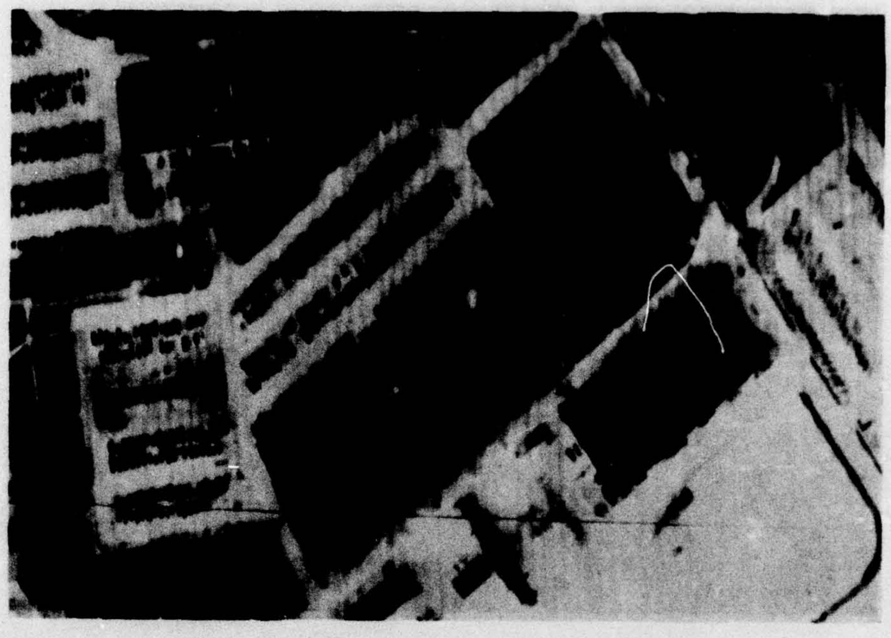
a.



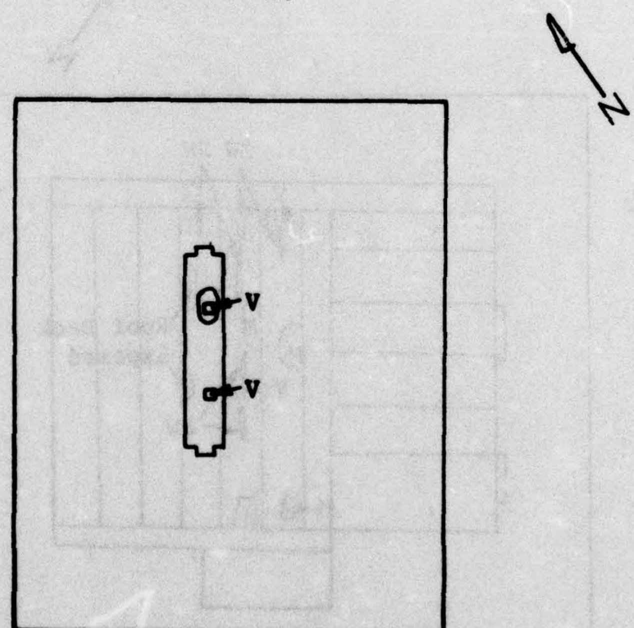
NOTE: V = air vent.
M = entrapped moisture.
SW = standing water.

b.

Figure 27. Thermal IR image (a) and identification of anomalies (b) for building No. 301, Offutt AFB, Omaha, Nebraska



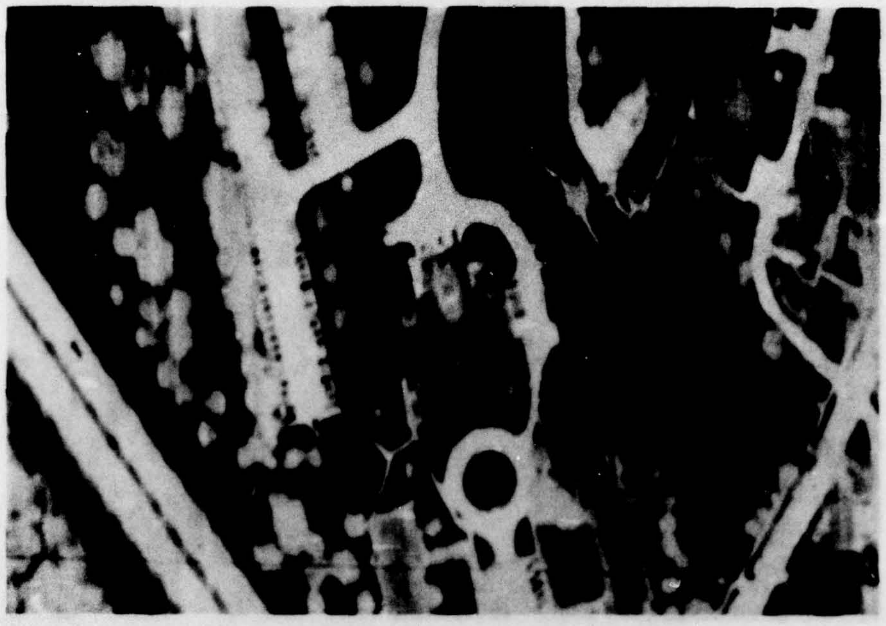
a.



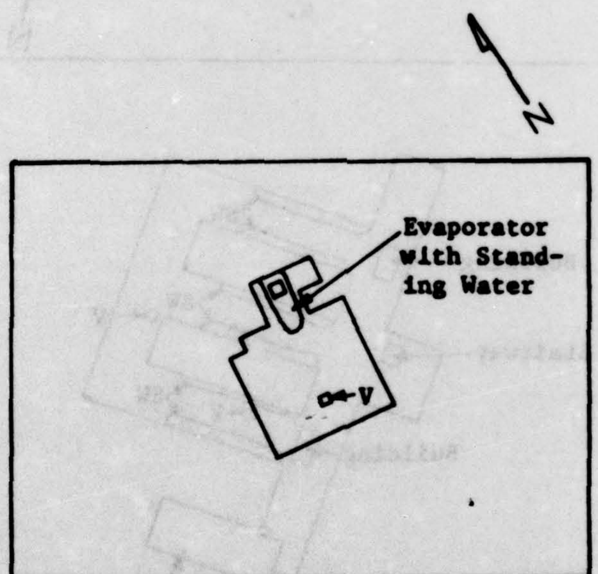
NOTE: V = air vent.

b.

Figure 28. Thermal IR image (a) and identification of anomalies (b) for building No. 526, Offutt AFB, Omaha, Nebraska



a.

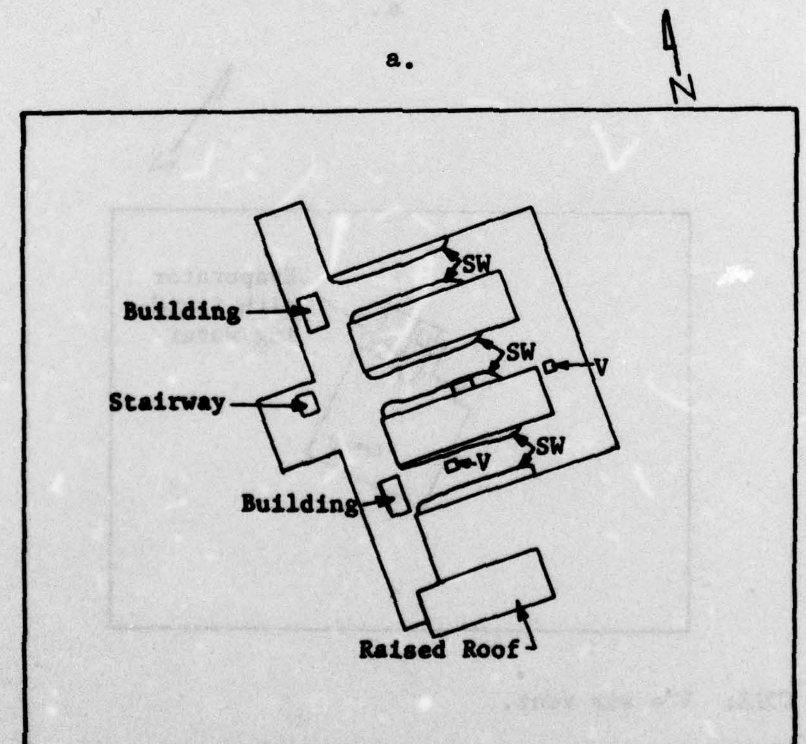


NOTE: V = air vent.

b.

Figure 29. Thermal IR image (a) and identification of anomalies (b) for building No. 418, Offutt AFB, Omaha, Nebraska

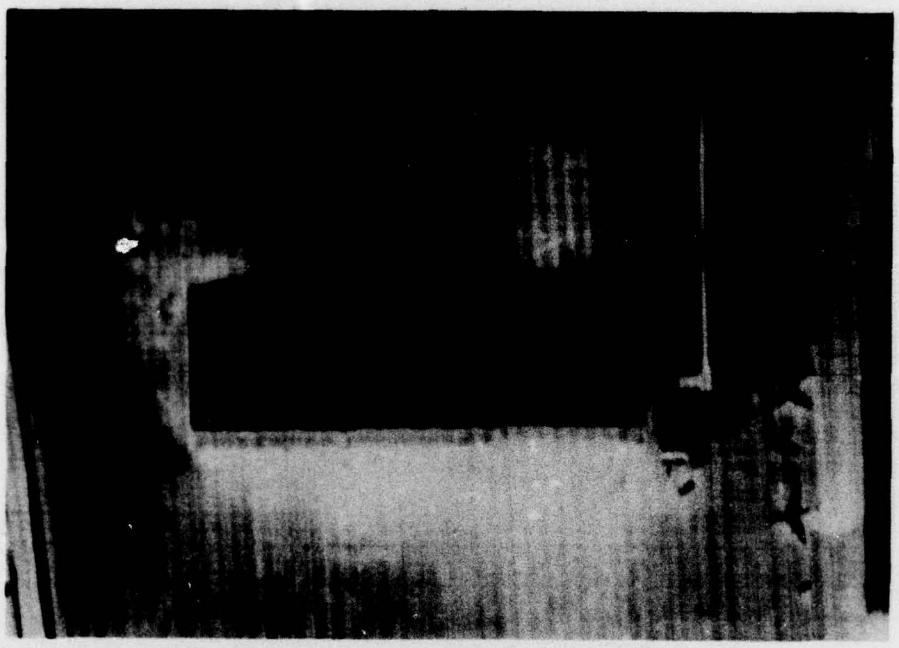
a.



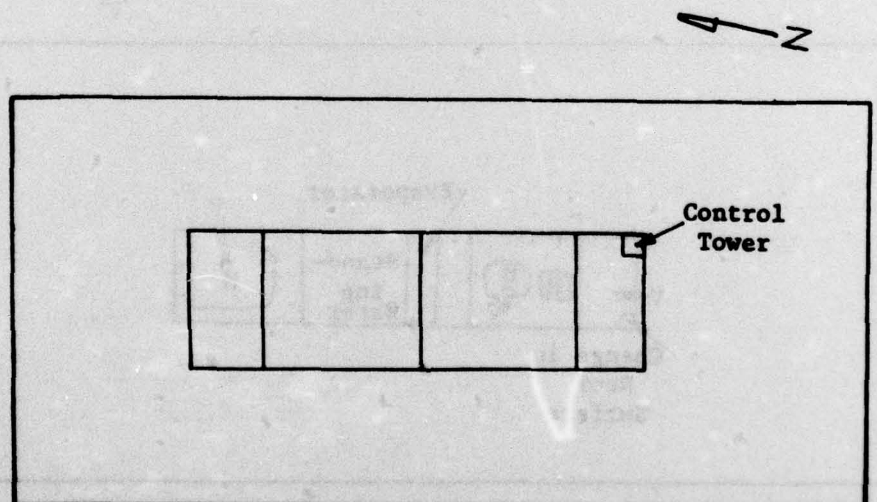
NOTE: SW = standing water.
V = air vent.

b.

Figure 30. Thermal IR image (a) and identification of anomalies (b) for building No. 500, Offutt AFB, Omaha, Nebraska

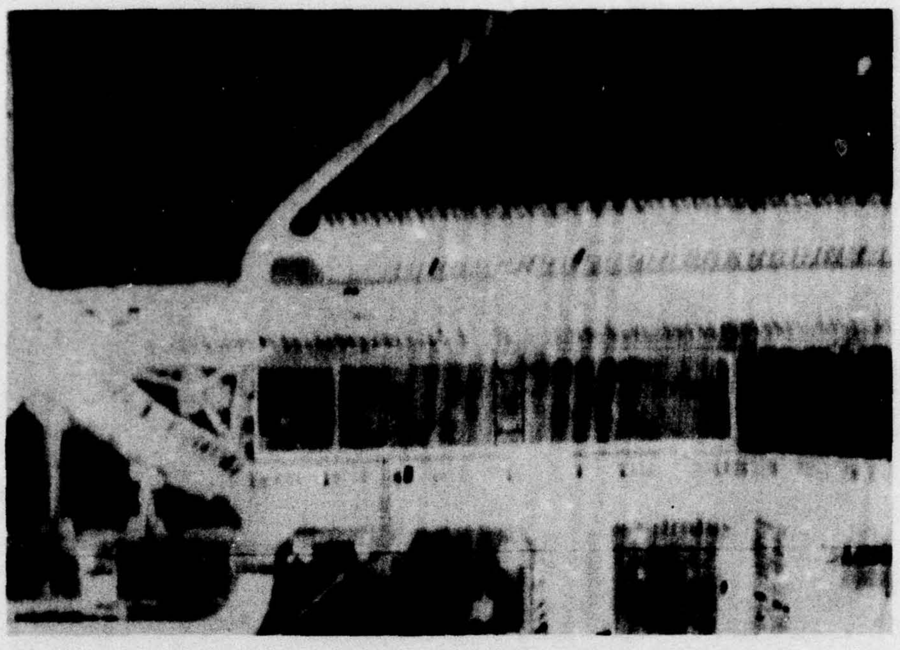


a.

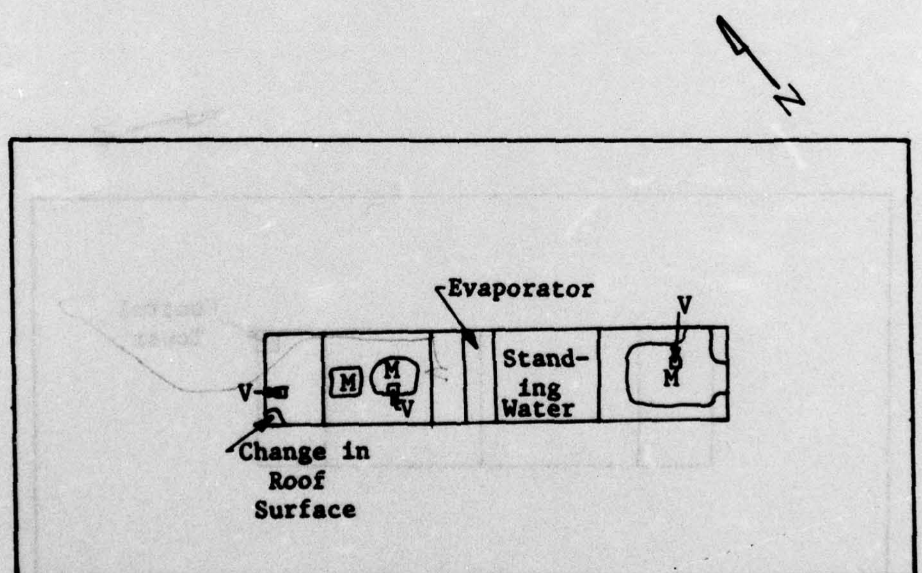


b.

Figure 31. Thermal IR image (a) and identification of anomalies (b) for building No. 306, Offutt AFB, Omaha, Nebraska



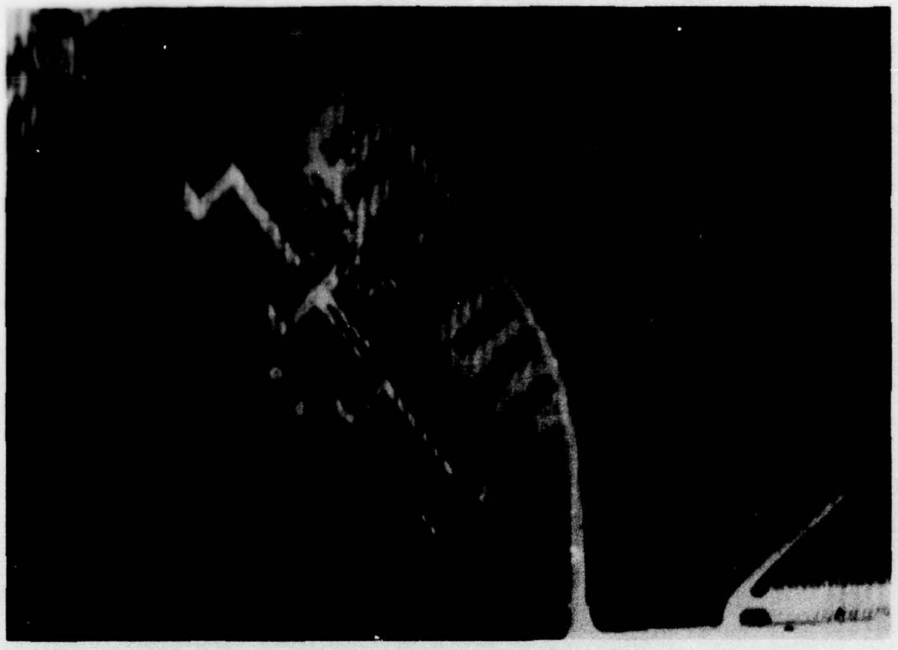
a.



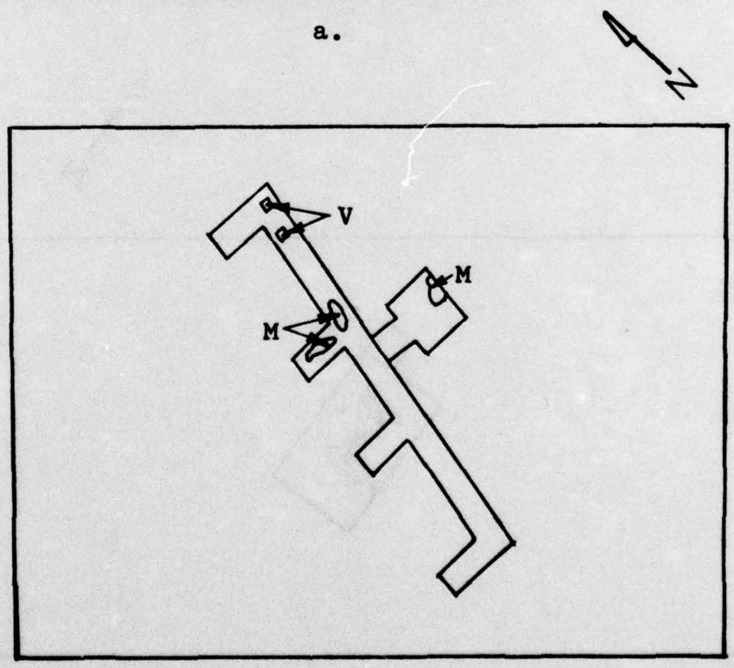
NOTE: M = entrapped moisture.
V = air vent.

b.

Figure 32. Thermal IR image (a) and identification of anomalies (b) for building No. 323, Offutt AFB, Omaha, Nebraska



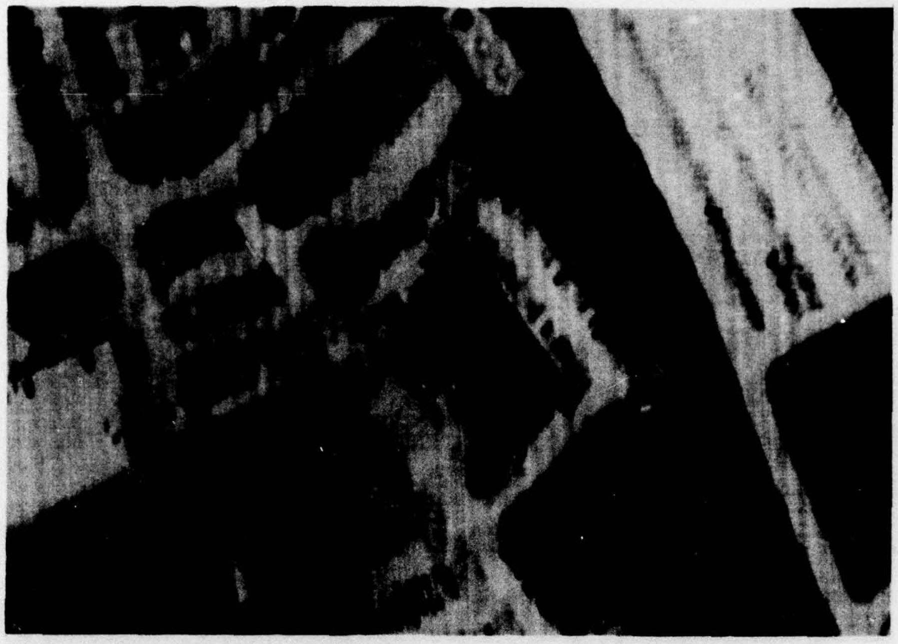
a.



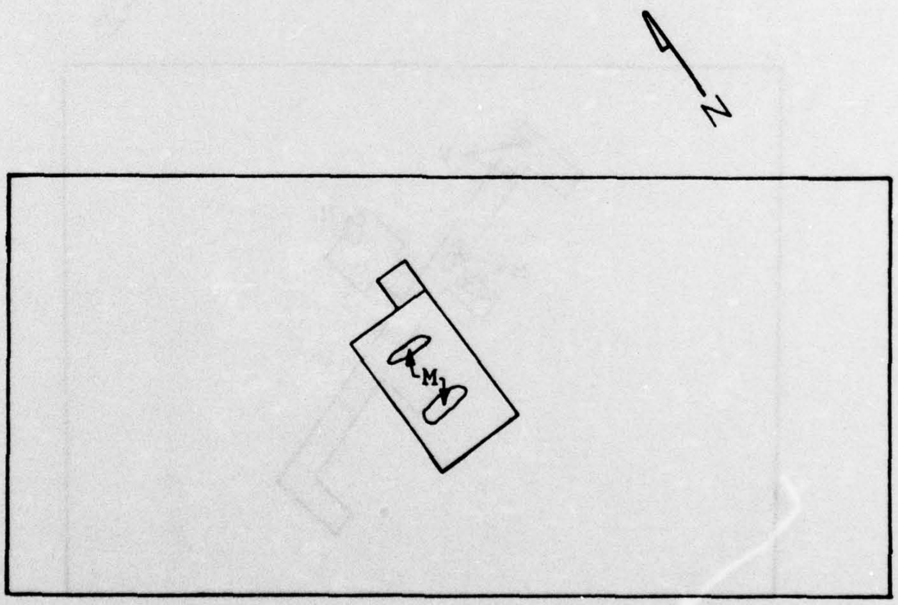
NOTE: M = entrapped moisture.
V = air vent.

b.

Figure 33. Thermal IR image (a) and identification of anomalies (b) for building No. 324, Offutt AFB, Omaha, Nebraska



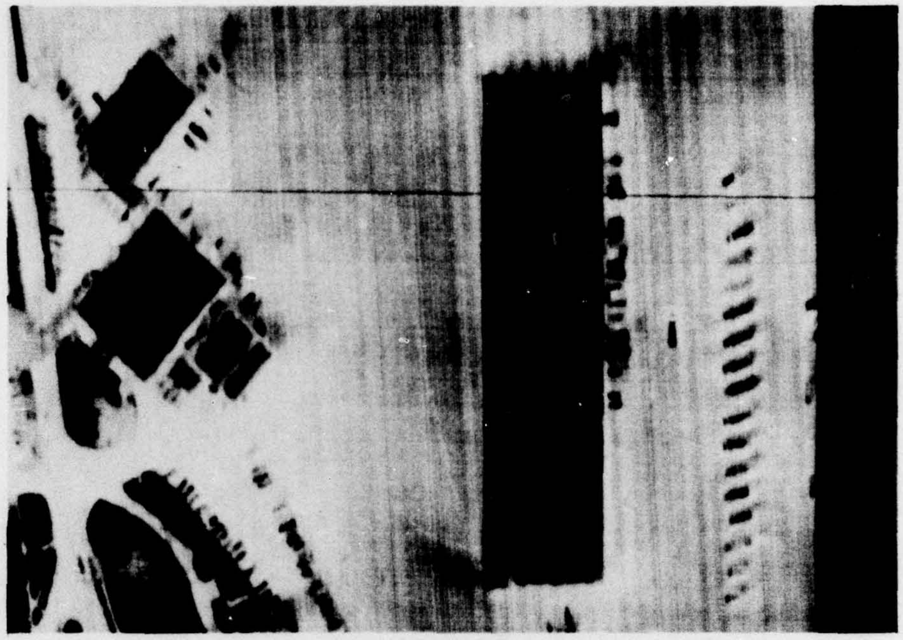
a.



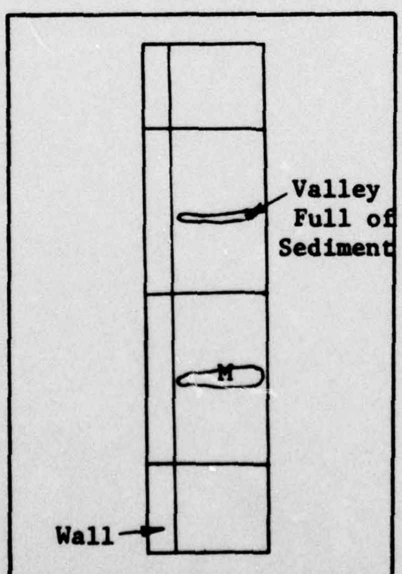
NOTE: M = entrapped moisture.

b.

Figure 34. Thermal IR image (a) and identification of anomalies (b) for building No. 407, Offutt AFB, Omaha, Nebraska



a.



NOTE: M = entrapped moisture.

b.

Figure 35. Thermal IR image (a) and identification of anomalies (b) for building No. 407, Offutt AFB, Omaha, Nebraska

In accordance with ER 70-2-3, paragraph 6c(1)(b), dated 15 February 1973, a facsimile catalog card in Library of Congress format is reproduced below.

Link, Lewis E

Roof moisture surveys at Pease AFB, New Hampshire, and Offutt AFB, Nebraska, by Lewis E. Link, Jr. Vicksburg, U. S. Army Engineer Waterways Experiment Station, 1977.

1 v. (various pagings) illus. 27 cm. (U. S. Waterways Experiment Station. Miscellaneous paper M-77-2)

Prepared for U. S. Air Force Strategic Air Command, Offutt Air Force Base, Omaha, Nebraska.

1. Moisture. 2. Nuclear meters. 3. Offutt Air Force Base, Nebr. 4. Pease Air Force Base, N. H. 5. Roofs. 6. Thermal infrared imagery. I. U. S. Air Force. Strategic Air Command. (Series: U. S. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper M-77-2)

TA7.W34m no.M-77-2