Thermal Roof Systems Performance Study

Part of the National Program for Building Thermal Envelope Systems and Insulating Materials

Prepared for the U.S. Department of Energy Office of Buildings Energy R & D Building Systems Division

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NATIONAL ROOFING CONTRACTORS ASSOCIATION

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THERMAL ROOF SYSTEMS PERFORMANCE STUDY

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FORWARD

This study identifies problems with roofing systems which may be related to high thermal value usage. It reflects the continuing concern and commitment of the National Roofing Contractors Association (NRCA) for early detection and identification of problems in order to prevent the installation of large volumes of latently defective and thermally inefficient roofing systems.

NRCA is confident that the Department of Energy and Oak Ridge National Laboratory share this concern and commitment. We all are well aware of the critical importance of thermally efficient roofing systems that adequately perform for the expected life of the roof. The energy resource savings and the dollar savings that are possible through efficiency in the nation's roofing of commercial or industrial buildings is tremendous. This study is an active step towards realization of these savings.

NRCA provides a unique resource. The expertise and experience of NRCA's 2500 members is reflected in this study by the contribution of many of it's members in assisting with inspections and analysis. This report serves as an early and continuing warning of the critical importance of proper roofing system design practice, mechanical equipment fabrication, and systematic and frequent inspections and maintenance of roofing systems. Dramatic energy savings are available. Continued study of the nation's roofing and implementation of on-going preventive maintenance are the direction that is indicated.

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Last, but not least, the authors want to acknowledge the assistance, cooperation and efforts of the member contractors on the roofing jobs inspected throughout the country.

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EXECUTIVE SUMMARY

The primary purpose of this project was to determine the effect of high R-value roof insulation on the service life of built-up roofing membranes used on the low slope roofs of commercial and industrial buildings. Limitations imposed by the scope of this project prevented conducting a statistically valid sampling of this type of roof construction. Instead, an in depth visual inspection of the roofs selected was conducted by experienced roofing professionals.

During the past decade, rising energy costs have created a demand for increased thermal insulating values in roofing systems. Increasing the thermal efficiency of roofing is a critical concern of the U.S. Department of Energy, as outlined in The National Program Plan for Thermal Performance of Building Envelope Systems and Insulating Materials [1]*. Since the roofing system comprises about one-third of a building's envelope and since an estimated three billion square feet of roofing systems are applied on commercial and industrial buildings each year in the United States, the Department of Energy is further concerned about problems and failures of built-up roofing membranes installed over high R-value insulation. Questions have also been raised about prolonged energy efficiency throughout the life of a roof, especially where leaks allow water to penetrate into insulation and seriously reduce its thermal performance. The scope of this contract was limited to a visual inspection for moisture in the roofing membrane. No attempt was made to quantify the moisture in the roofing membrane or the roof insulation by instruments; i.e. infrared, nuclear or capacitance methods of moisture detection.

Very little comprehensive information has been published on roofing problems related to material performance, installation techniques and environmental service conditions as they relate to energy efficiency. In June 1981, the U.S. Department of Energy entered into a contract with the National Roofing Contractors Association (NRCA) to use NRCA's expertise in the roofing industry for an in depth field study of insulated built-up roofing performance. A select group of NRCA member contractors chose 41 roofs for in-depth visual examination in this study.

The roofs encompassed a wide range of roofing systems, deck types and service environments in 13 states representing all major geographical and climatic conditions in this country. Each of these roofs were thoroughly evaluated by at least two individuals experienced in roofing using a uniform inspection and reporting format developed by NRCA. The findings were then analyzed by members of the NRCA Task Force assigned to this DOE study in order to determine why problems or potential problems existed and to identify corrective practices. The findings of this study indicate that increasing the R-value of roof insulation in order to conserve energy does not appear to have any appreciable effect on the service life of the roof membrane or on its ability to function as a waterproof covering. However, this study indicated that certain material combinations appeared to be less forgiving in their ability to provide substantially problem-free, long term performance of insulated roofs. Physical abuse, improper roof drainage, and faulty mechanical equipment design and installation were cited as major causes for poor roof performance. These problem sources can be virtually eliminated by implementation of the design and maintenance considerations set forth in the NRCA Roofing & Waterproofing Manual [2], NRCA Handbook of Accepted Roofing Knowledge (HARK) [3] and NRCA/ARMA Manual of Roof Maintenance and Roof Repair [4].

The need for all building owners to have a good periodic inspection and maintenance program was indicated by the results of this visual field study.

Recommendations are presented for ways and means to implement the results of the study. Recommendations are also given for further investigative studies to support energy conservation objectives related to low slope roofs.

*Numbers in brackets refer to references cited at the end of this report.

BACKGROUND AND INTRODUCTION

The low slope roof system used on a typical commercial or industrial building comprises about one-third of the building's envelope. This portion of the building must offer thermal resistance to heat loss or gain in addition to providing water tight integrity. It is estimated that the United States has an inventory of 25-30 billion square feet of roofing and that over three billion square feet of commercial/industrial roofing systems are applied each year.

Rising energy costs have created a demand for increased thermal insulating value in building envelope systems. This need has produced many significant changes in the design and construction of roofing systems. Changes range from the increasing use of plastic foam insulations as well as increased thickness of the more traditional insulations under bituminous roofing membranes to the introduction of completely new roofing systems utilizing plastic foam insulations with elasto/plastic (single-ply) membranes. The scope of this contract does not include the study of elasto/plastic (single-ply) membranes. Because they may be applied as a loose laid system with ballast or with other unconventional methods of installation not used for hot applied built-up roofing membranes, the results of this study may or may not apply to elasto/plastic (single-ply) roofing. Additional research is recommended for elasto/plastic (single-ply) roofing.

This dramatic change in roofing technology has intensified the concern about roof system problems and failures, and it has raised questions about prolonged energy efficiency throughout the life of a roof. While some problems which occur are severe enough to require complete replacement of the roof membrane and insulation, others lead to increasing the moisture content of the insulation material thus reducing its thermal insulation capacity.

While some research has been directed toward the solution of specific roofing problems, very little comprehensive information has been published on roofing problems and failures relating to material performance, installation techniques and environmental factors, such as geographical location, as they relate to energy efficiency.

Since the mid-1970's the National Roofing Contractors Association's Project Pinpoint has been compiling information gathered from member surveys regarding roofing installed and roofing problems. Data is generated by contractors responding to NRCA questionnaires and reporting on the materials they have installed and the problems they have observed in the field. There is great promise as to the usefulness and the validity of Project Pinpoint as a diagnostic tool for the identification of roofing problems.

The limited amount of reliable field performance data available makes it difficult for owners, specifiers and contractors to evaluate the suitability of various systems for a particular application in energy terms. Without reliable information on material and system performance, roofing problems will continue to be unnecessarily frequent and repetitive, and rational design of new roofing systems for energy efficiency will be hampered.

A need exists for a systematic study of the performance of energy efficient roofing systems in order to identify and correct roofing problems and to assure that the national effort to improve the thermal performance of buildings will be successful at large energy and cost savings.

PURPOSE AND OBJECTIVES OF STUDY

In June 1981, the United States Department of Energy (DOE) and the National Roofing Contractors Association (NRCA) entered into contract to conduct an in-depth visual field study of hot applied built-up roofing performance. The overall objective of this study was to identify relationships between materials design, construction and roof service environment that effect not only the thermal efficiency but also the durability of roofing systems commonly used on low slope non-residential buildings. It was intended that the results of this study would provide practical and realistic information that would enable architects, engineers and contractors to design and apply energy efficient roofs capable of maintaining their weatherproof integrity and thermal performance throughout the expected life of the roof. Limitations imposed by the scope of this project prevented conducting a statistically valid sampling of this type of roof construction. Instead, an in depth visual inspection of the roofs selected was conducted by experienced roofing professionals.

More specifically, the scope of this study was limited to conventional hot-applied bituminous built-up roofing systems. On-site visual examinations of selected roofs throughout the United States were made by experienced personnel using an inspection format that would insure uniformity of reporting. The investigators thoroughly examined and documented all pertinent facts about each roofing installation and identified problem areas. Since a relatively small sample was used, the following factors were given priority in selecting roofs for this study:

1) High thermal value roof systems which had experienced problems.
2) High thermal value roof systems with no apparent problems.
3) Roofs with problems regardless of thermal value.

Information obtained in these roof examinations was analyzed to determine why problems or potential problems existed and to identify corrective practices.

FIELD INSPECTION METHODOLOGY

NRCA member contractors, geographically dispersed over the entire United States, selected the 41 roofs in 13 states that were included in this study. These roofs represented all major geographic areas with accompanying climatic conditions as shown in Figure 1. The sampling plan was designed to include a wide range of typical roofing systems, deck types and service environments as given in Table 1, with a deliberate inclusion of roofs with and without problems. The validity of this type of information depends primarily on the skill of experienced roofing personnel to thoroughly evaluate each roof, using a uniform reporting format, and then to analyze the findings to identify causes of roofing problems and practical corrective action.

The sample roofs included fiber glass, organic and asbestos felt multi-ply bituminous membranes, employing both asphalt and coal tar pitch. Three of the roofs consisted of lightweight concrete decks with no additional roof insulation. Various insulations, including fiberglass, perlite, wood fiber, polyurethane foam and expanded polystyrene foam, with R-values as high as 29, were used on the other thirty-eight roofs. Insulation boards were applied in a single layer on the majority of roofs. Where insulation was applied in multiple layers, a number of different material combinations were used. More than half of the roofs examined had R-values of 10 or more.

Prior to 1974, roof insulation of minimal R-value (R = 5 or less) was normally used in the majority of the built-up roofs applied. For this reason, the majority of the roofs inspected were less than eight years old. An R-value of 10 was arbitrarily selected as a "high R-value" for purposes of this report because R-values of 10 or more were seldom used prior to 1974. It is also the value recommended in the ASHRAE Handbook of Fundamentals [9]. The youngest roof was only four months old and the oldest roof was over eleven years old. Sizes of the roofs inspected were generally in the range between 100 to 360 squares, (1 square = 100 sq. ft.) but roofs varying in size from 2 to 2375 squares were included.

Thirty-two of the roofs inspected were on buildings that were both heated and air conditioned. Six of the buildings were not air conditioned, and one building was neither heated nor air conditioned. For the remaining two buildings, one was air conditioned but only a portion of the building was heated, and the other was heated but only a portion air conditioned.

In all cases, the NRCA member contractors who applied the roof, or one of their knowledgeable employees, participated in the inspection. In addition, at least one member of the NRCA Task force assigned to this DOE study or the NRCA Technical staff participated in each inspection.

A uniform reporting format, consisting of two questionnaire forms prepared by NRCA, was used for every inspection. Information on the composition of the entire roof and deck system, obtained from design and construction records supplied by the roofing contractor or building owner, was tabulated on the first form titled "Building Roof Assembly Information". The second form, titled "Roof Inspection Form", was used to tabulate all observations concerning the appearance and behavior of the roof when it was inspected. Additional information concerning roof performance history was recorded in narrative form. Appendix I contains the inspection information recorded at the Armed Services Building Center in Broken Arrow, Oklahoma, as an example of how each inspection was handled.

Pertinent information on each roof was subsequently verified by phone with the roofing contractor or building owner so that the analysis of information obtained on all roofs in the study would provide a reliable basis for identifying and correcting serious roof problems.

RESULTS OBTAINED

Data collected from the 41 roofs inspected are summarized in Appendix II. Tables 2 through 7 provide a convenient comparison of the relationships between several design characteristics of the roofs studied and the roof problems that were most frequently encountered. Leaks, of course, are a major performance concern because water tightness is the ultimate criteria of roof system performance and leaks are the basis of major owner complaints. Flashing problems were included in the comparisons because they are perceived in the roofing industry as the source for more than half of all customer complaints. NRCA Project Pinpoint [5] information showed that blistering and splitting are the most common problems with roofing together with leakage and flashing deficiencies. Consequently, Tables 2 through 7 provide information on these roofing problems as well.

A. ROOF PERFORMANCE RELATIONSHIP TO INSULATION R-VALUES

Data in Table 2 provides a comparison of the effect of insulation R-value with leaks and other common roofing problems. This analysis by experienced contractors suggests that roof performance is not significantly affected by using highly thermally efficient roof insulation.

However, the data suggests that an incompatibility between specific membranes and insulation types may affect roof performance. For example, data as shown in Appendix II points to a relatively high incidence of membrane blisters when certain materials or combinations of materials were present. In all, 18 roofs showed evidence of blistering. Blisters occurred in the membranes on 14 of the 22 roofs using bituminous impregnated or coated organic felt in the membrane, 2 of the 13 roofs using glass fiber felt membranes, and 2 of the 6 roofs using asbestos felt membranes. The data shows that polyurethane foam roof insulation was present in 11 of the 18 blistered roofs. On the other hand it was used in four roofs that did not blister. Fiberglass roof insulation was used in 13 of the roofs, five of which evidenced blistering. One of two roofs with expanded polystyrene foam insulation had blisters, and one of five roofs with perlite board insulation had blisters. No membrane blisters were observed in the two roofs using wood fiber board insulation or in the four roofs where the membrane was in direct contact with lightweight insulating concrete. Polyurethane foam roof insulation appears to be involved in an inordinate number of the roofs reporting blisters in the roofing membrane. This conclusion is substantiated by a report prepared for NRCA by the Southwest Research Institute [6]. The blistering, as indicated by this visual inspection and confirmed by the Southwest Research Institute report, occurs regardless of the thickness of the polyurethane foam insulation used. A correct method of installation of the roofing membrane over polyurethane roof insulation is described in NRCA Technical Bulletin #9 [7]. No test cuts were made during the course of the inspections. Therefore, neither the location of the blisters within the roof systems nor the actual source of the blisters were determined.

Membrane splits were observed on three jobs, but this survey indicated no relationship between the incidence of this problem and R-value. One split occurred in the mineral surfaced cap sheet only and was attributed to a material problem and was not related to the roof insulation R-value. The other two roofing membrane splits were the result of poor design of the roof expansion joints. The expansion joints were installed at the roof line and were not elevated, allowing water to enter the system in heavy rains. Severe physical abuse also permitted water to enter the roofing system. One of these roofs had been reroofed with the design problems corrected. The splitting on this building has not reoccurred.

B. ROOF PERFORMANCE RELATIONSHIP TO AGE OF ROOF

The relationship between age and the incidence of the four common problems is shown in Table 3. The eleven year old roof had a history of problems since application. Roof expansion joints, which had been a continuing problem, were replaced and the replacement flashings raised above the roof line. It is noteworthy that problems were observed on four roofs less than one year old. Two of these roofs were located in Arizona and were constructed with a fiber glass membrane and a cap sheet. Roof leaks occurred when these roofs were only four months old. However, the leaks which occurred on one of these roofs was attributed to damage done by university students holding parties on the roof.

On the second roof, leaks were attributed to mechanical equipment and sheet metal scuppers. The other problem roofs less than one year old were located in Florida. They did not leak, but they did evidence blister problems. Both of these roof membranes were applied over polyurethane foam roof insulation which could account for the blistering found.

This investigation indicated that age was not the cause of the problems found but they were the result of other causes such as incompatability of materials, design deficiencies and abuse.

C. ROOF PERFORMANCE RELATIONSHIP TO DECK TYPE

In one case, there seemed to be an apparent relationship between membrane blistering and the type of deck used, in that all four roofs applied over poured gypsum decks evidenced roof blister problems as shown in Table 4. A large number of membrane problems were observed in roofs over metal decks. This was not surprising since metal decks were used under roughly half of the roofs observed. Furthermore, the data shows that leaks on roofs with metal decks were often related to such items as: mechanical units, roof expansion joints, poor drainage, and other readily identified factors. Deck type was not indicated as the cause of the roof problems except for the blistering over poured gypsum, a wet applied deck. Because of the moisture that remains in a wet fill type roof deck, the roofing membrane must be vented by pressure relief vents or by the method of installation of the roofing membrane to reduce blistering of the membrane.

Table 5 presents a comparison between the incidence of membrane leaks and the slope of the roof deck. Roofs with little or no slope showed a much greater incidence of leakage than roofs with greater slope. It is noteworthy that more than half the roofs inspected showed evidence of ponding. Positive drainage of the roof surface is recommended by the roofing manufacturers, NRCA and others involved in the design of roofing systems. This survey appears to support that theory.

D. ANALYSIS OF ROOFS WITH LEAKS

Eight roofs experienced water leakage. Possible sources for these leaks were identified and are listed in Table 6. In general, this visual analysis suggests nothing to indicate that water leakage resulted from the type of membrane, insulation or deck used in the roof system. Jobs with leaks included fiberglass, organic and asbestos membranes employing both asphalt and coal tar pitch. As far as insulations are concerned, fiberglass, perlite, and polyurethane foam were used in some roofs that leaked.

Of the eight roofs which had a history of leakage, six could be considered to be of major proportion. Of these, four were traced to leaks through defective mechanical equipment design and roof expansion joints that were not installed above the water line. One was attributed to a leaking metal panel wall, and the source of the leaks on the sixth roof had been repaired over two years ago without leakage recurrence. It was noted that on three of the roofs, leaks were reported at the base flashing and were the result of insufficient height of the base flashing (1), pulling away from the wall due to poor attachment (1), and damage from roof traffic (1).

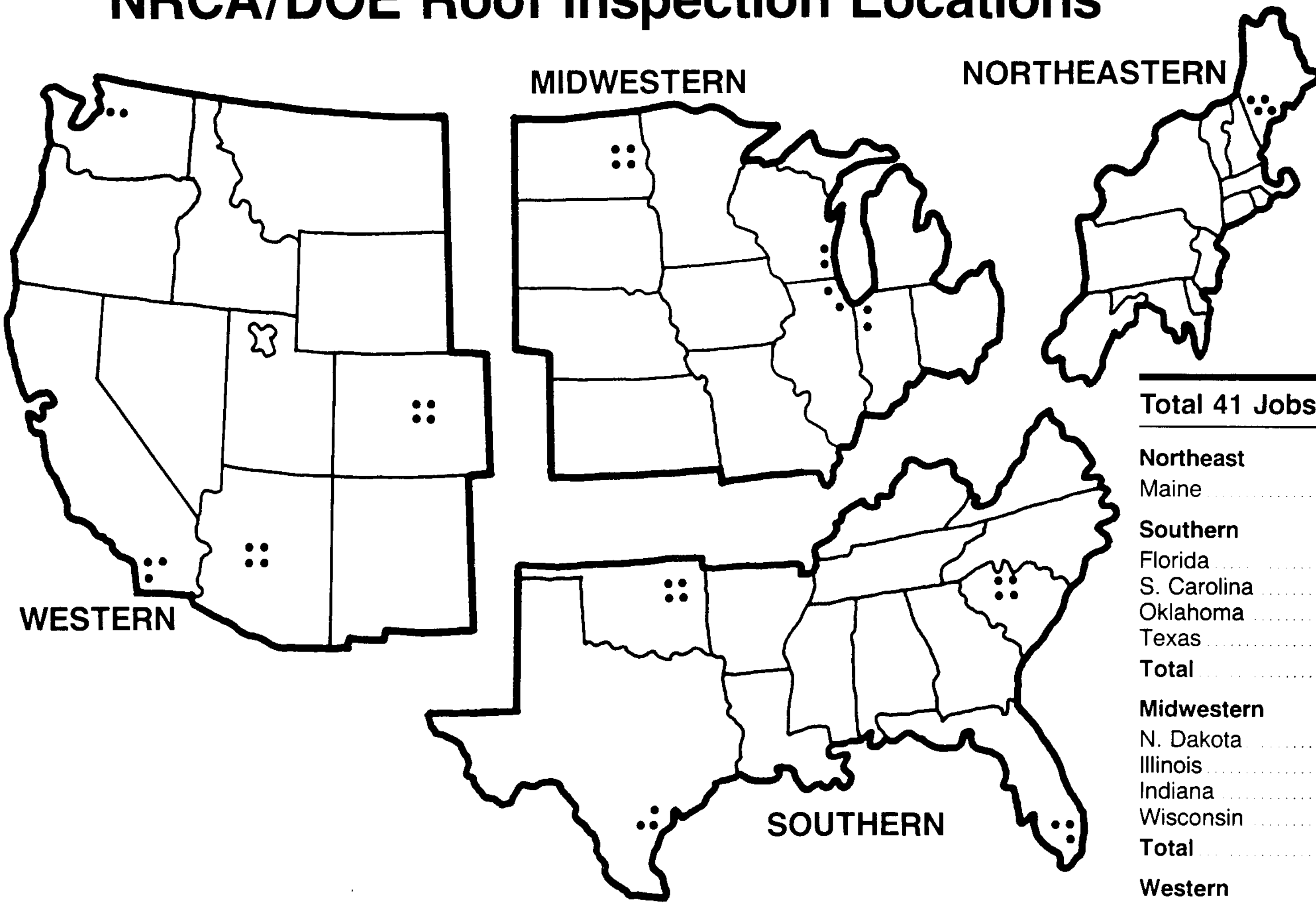
None of the leaks were the result of the roofing system components, but were the result of design deficiencies. Attention to design of the mechanical equipment installed on the roof deck, proper design of roof expansion joints, proper built-up flashing height and watertight design for metal wall panels would have eliminated all of the leaks this survey found.

Seventeen jobs reported various flashing problems which had not as yet resulted in leaks. Potential base flashing problems which were identified included: weather deterioration (6), separation from the wall (5), vertical joints separating (4), holes or punctures (4), water or blisters in flashing (3), slippage of surfacings (2), racking (2), flashing positioned too low (2), flaking of protective surfaces (1), and corners opened (1). Each job reported more than one of these deficiencies. In addition to the above deficiencies with base flashing, it was predicted that future problems may be caused by counter flashings (5), pitch pans (3), inadequate drainage, roof abuse and other causes as listed in Table 7. None of the potential problems found were the result of increasing the roof insulation R-value. They were the result of faulty workmanship, abuse to the roofing and flashing system by others or causes not related to roof insulation thermal value. These problems are typical of the problems that could be corrected during a yearly maintenance program. Such repairs could help prevent moisture from entering the system and decreasing the thermal efficiency of the system. Inspections are recommended after any severe storm to allow damage to be repaired before the entrance of moisture in the roofing system. Yearly inspections are also suggested because of the extreme weather and temperature conditions the roof system is subjected to during a one year period.

It is worthy of special note that five of the eight roofs that experienced leakage also showed evidences of ponding water due to inadequate slope to drain. This is particularly significant on roofs designed to provide for thermal efficiency, because ponding water promotes an ever present risk of water entry into roof insulation through defects in the membrane reducing the thermal performance of the roofing system.

Figure 1

NRCA/DOE Roof Inspection Locations



Total 41 Jobs Inspected

Northeast	
Maine	4
Southern	
Florida	3
S. Carolina	4
Oklahoma	4
Texas	3
Total	**14**
Midwestern	
N. Dakota	4
Illinois	2
Indiana	2
Wisconsin	2
Total	**10**
Western	
Washington	2
Colorado	4
Arizona	4
California	3
Total	**13**

TABLE 1

CONSTRUCTION VARIETY COVERED BY ALL ROOFS IN STUDY

Size:

Total Squares	20,384.6
Largest Job	2375 sq.
Smallest Job	1.6 sq.
Average Size Job	497.2 sq.

Heating in Buildings:

Buildings Heated	39
Buildings Not Heated	1
Buildings Partially Heated	1

Roof Surfacing Types:

Aggregate	30 Jobs*
Slag	2 Jobs
Cap Sheet	2 Jobs
Smooth Surfaced	3 Jobs
Aluminum Coating	4 Jobs

*One Job Double Poured & Aggregate

Interply Moppings:

Asphalt Type I	10 Jobs
Asphalt Type II	4 Jobs
Asphalt Type III	19 Jobs
Asphalt Type IV	4 Jobs
Coal Tar Pitch	4 Jobs

Ceilings:

Jobs with Ceilings & No Insulation	16
Jobs with Ceilings & Insulation	5
Jobs without Ceilings	16
Jobs with Partial Ceilings	4

Taped Insulation Joints:

Jobs With Taped Joints	8
Jobs Without Taped Joints	33

Types of Roof Insulation:

Urethane	7 Jobs
Perlite/Urethane	7 Jobs
Fiberglass	12 Jobs
Tapered EPS	2 Jobs
Fiberglass & Urethane	1 Job
Perlite	2 Jobs
Fibergalss/Urethane & Fiberglass	1 Job
Tapered EPS & Fiberboard	1 Job
EPS & Perlite	1 Job
Perlite/Urethane & Perlite	2 Jobs
EPS & Fiberboard	1 Job
L.W.C. With Insulation in Deck	1 Job
L.W.C. (No Additional Insulation)	3 Jobs

Note: Insulations listed in sequence from deck up. Insulations separated by (/) are composite type.

Slopes:

0"/ft. (minimum)	3 Jobs
1/16"/ft. (minimum	4 Jobs
1/8"/ft. (minimum)	26 Jobs
1/4"/ft. (minimum)	7 Jobs
1/2"/ft. (minimum)	1 Job

Air Conditioning in Buildings:

Buildings Air Conditioned	33
Buildings Not Air Conditioned	7
Buildings Partially Air Conditioned	1

Roof Finishing Felt Types:

Asphalt Organic, Saturated	16 Jobs*
Tarred Organic, Saturated	4 Jobs
Asphalt Organic, Coated	2 Jobs
Asphalt Asbestos, Saturated	6 Jobs
Fiberglass	13 Jobs

*One Job Directly Over Old Roof

Surface Coatings:

Asphalt Type I	17 Jobs
Asphalt Type II	3 Jobs
Asphalt Type III	15 Jobs
Asphalt Type IV	2 Jobs
Coal Tar Pitch	4 Jobs

Vapor Retarders:

Jobs With Vapor Retarders	16
Jobs With Partial Vapor Retarders	1
Jobs Without Vapor Retarders	24

Roof Vents:

Jobs With Roof Vents	8
Jobs Without Roof Vents	33

Roof Insulation Method of Application:

Jobs with Multiple Layers	12
Jobs With Single Layer	26
No Roof Insulation Used	3

Note: 3 Jobs had Tapered Insulation

TABLE 2

Insulation R-Value As Related To
Leaks & Other Problems On Jobs Inspected

R-Value of Rigid Roof Insulation in System [1]	Jobs Inspected	Number of Jobs With . . . Leaks	Flashing Problems	Blisters	Splits
0	3	0	1	0	0
5.3	3	0	1	1	0
6.7	2	0	1	1	0
7.4	1	1	1	1	1
8.3	3	0	0	0	0
9.1	5	1	2	3	0
9.3	1	0	0	0	0
9.5	1	1	1	0	0
10.0[2]	4	1	2	2	1[3]
10.5[2]	1	0	0	1	0
11.1	3	0	2	3	0
12.5	1	0	0	0	0
13.7	1	1	1	1	0
13.9	2	0	0	0	0
14.3	1	0	0	1	0
15.4	2	1	2	2	1
16.4	1	0	0	0	0
16.7	1	1	1	1	0
17.1	1	0	0	0	0
17.2	1	0	1	1	0
18.2	1	1	0	0	0
22.9	1	0	1	0	0
29.2	1	0	0	0	0
	41	8	17	18	3[4]

Notes:

1. R-values for all insulations are based on manufacturer's information.
2. On the two jobs where two insulation R-values were involved for different roof areas, more than 90% of the total area for each job was for one of the R-values. That R-value was used for the entire roof in this table.
3. The split in the roof with 10.0 R-value was in the fiber glass cap sheet only and not through the entire membrane.
4. The number of jobs with splits shown in this table does not include two jobs that had a history of previous splits which had been repaired and had not reoccurred.

TABLE 3

Age Of Roofs Inspected As It Relates To Leaks & Other Problems

Age	Jobs Inspected	Number of Jobs With . . . Leaks	Flashing Problems	Blisters	Splits
Less than 1 year	4	2	3	3	1
1 year but less than 2 years	2	0	1	0	0
2 years but less than 3 years	4	0	0	1	0
3 years but less than 4 years	6	2	1	1	0
4 years but less than 5 years	6	0	1	1	0
5 years but less than 6 years	4	1	4	2	0
6 years but less than 7 years	11	1	5	7	0
7 years but less than 8 years	2	1	1	2	1
8 years but less than 9 years	0	0	0	0	0
9 year but less than 10 years	0	0	0	0	0
10 years but less than 11 years	1	0	0	0	0
11 years but less than 12 years	1	1	1	1	1
TOTALS	41	8	17	18	3

Total Years For All Roofs Inspected	190 years 8 months
Oldest Roof Inspected	11 years 5 months
Newest Roof Inspected	4 months
Average Age of All Roofs Inspected	4 years 8 months

TABLE 4

Deck Type Of Roofs Inspected As It Relates To Leaks & Other Problems

Deck Type	Jobs Inspected	Number of Jobs With . . . Leaks	Flashing Problems	Blisters	Splits
Poured Gypsum	4	0	1	4	0
Poured Concrete	4	0	2	1	0
Precast Concrete	2	0	0	0	0
Lightweight Concrete	5	0	2	0	0
Wood Plank	3	0	0	0	0
Metal Deck	18	6	7	8	2
Firecode Metal Deck	1	0	1	1	0
Wood Fiber (90%) & Poured Concrete (10%)	1	1	1	1	1
Metal Deck (30%) & Precast Concrete (70%)	1	0	1	1	0
Metal Deck (40%) & Precast Concrete (60%)	1	0	1	1	0
Lightweight Concrete over Poured Concrete	1	1	1	1	0
	41	8	17	18	3

TABLE 5

Deck Slope Of Roofs Inspected As Related To Leaks & Ponding

Slope	0″	1/16″	1/8″	1/4″	1/2″
Number of jobs inspected	**3**	**4**	**26**	**7**	**1**
Number with leaks	2	1	3	2	0
Number with ponding	3	2	14	4	0

Note: Five of the eight leaking roofs also showed evidence of ponding.

TABLE 6

Possible Source Of Reported Leaks

Jobs Reporting Leaks ——— 8

Possible Sources

Membrane	2
Base Flashing	3
Gravel Stops	1
Roof Expansion Joints	3
Drainage System	3
Walls	3
Mechanical Equipment	6
	21*

*Some jobs reported more than one leak source.

TABLE 7

Items Listed As Potential Causes For Future Membrane Leaks

Item	Number of Jobs
Debris on Roof	10
Physical Abuse	9
Lack Of Maintenance	7
Ponding Water	23
Fair or Poor Drainage Systems	14

Fourteen comments were also received on poorly designed, serviced, installed or manufactured mechanical equipment as potential causes for future leaks.

SUMMARY AND CONCLUSIONS

The roofing system being about one-third of a building's envelope system plays a vital role as far as the thermal performance of a building is concerned. Initially, the roof should be thermally efficient and, more importantly, it should be capable of maintaining it's thermal efficiency over the roofs expected service life. The question frequently arises as to the relationship between high thermal efficiency (high R-value) and the long-term performance of the roofing membrane. Obviously, if a membrane's integrity is harmed, water enters the insulation and it's efficiency is reduced. Conversely, it has been postulated that the use of a high R-value insulation may result in the early deterioration of the membrane. If either of these points are valid then a condition exists where large amounts of energy may be lost due to a defective membrane. On the other hand, a wet insulation component may contribute to the physical problems of the entire roofing system to such an extent that it must be removed and replaced. This again is at a high energy cost because manufacturing and applying roofing materials uses significant energy.

A primary objective of this program was to address the points raised above. In brief, the objective was to determine as far as practicable from visual inspection the effect of using high R-value insulation on the performance of a roofing system over its expected life.

An analysis of the data which were collected from the 41 roofs observed, indicated that roofing systems having a high R-value insulating component performed equally as well as those systems with lower R-values. None of the problems encountered such as leaks were attributed to increasing the R-value of the insulating component. In brief, the results of the visual survey indicate that increased R-values of insulations does not appear to shorten the expected life of the membrane component or to have an appreciable effect on it's waterproofing integrity.

The results of this visual survey also indicates that the use of high R-values to obtain an energy efficient system and to have it maintain its high thermal efficiency as well as its watertight integrity for its expected service life do not appear to be a major concern. Rather, it appears to be the more reasonable approach to concentrate attention to the four basic principles of a durable and economical roof: 1) proper design 2) proper and compatible materials 3) good workmanship, and 4) timely maintenance.

In the course of the survey, several of the problems observed were attributed to design deficiencies. For example, on 23 of the buildings, ponding water was reported which often resulted in leaks. Other examples of design deficiencies which were observed included insufficient height of base flashings, faulty mechanical equipment design and installation, and the use of pitch pans for waterproofing projections through the roofing system. These deficiencies are easily corrected during the design stages by a well informed and knowledgeable design professional.

Materials selection plays another significant role in obtaining a durable and energy efficient roofing system. The specifier has the responsibility to select proper materials for the purposes intended and to make sure that the materials selected are compatible with other materials used in the various components of the roofing system. Again, the survey revealed such deficiencies as blistering which seemed to indicate that material incompatibility was implicated at least in part.

Once the design parameters are correct and compatible materials have been chosen, it becomes extremely important that the materials are applied in accordance with the design and application specifications. Obviously, this is a workmanship concern and this should be no less professional than the other aspects of good roofing practice. In the course of the observations of the 41 roofs covered in the program, it was concluded that workmanship was generally good. However, there were areas that needed improvement.

The owners or facility managers too often assume that once the roofing operations have been completed in accordance with proper design, proper materials and professional workmanship parameters, it will need no further attention. The results of the survey show that this is a false assumption indeed. For example, 32 of the 41 roofs inspected showed potential problem areas which could appreciably shorten the expected life of the roof. These potential problems included lack of maintenance and inspection and physical abuse to the roof. During the survey of each roof, potential problems were discussed with the building owner or his representative. In almost every case the owners were not aware of these potential problems which could be quite easily eliminated by preventive or corrective maintenance procedures. Cost and energy savings could be realized by extending the useful roof life by implementation of an inspection and maintenance program.

RECOMMENDATIONS

1) Encourage the use of thermally efficient roofing systems for use on low slope commercial and industrial buildings as an effective means to conserve energy.

2) The Department of Energy is encouraged to conduct an indepth study to confirm the results of this study and then implement programs to make the private and public sectors of the economy aware that large energy savings are available by increasing the energy efficiency of the roofing system with little or no sacrifice to the long-term durability of the system.

3) Make the design profession aware of the importance of many design parameters such as roof slope, materials selection, etc. to the attainment of a durable and energy efficient roofing system.

4) Materials manufacturers and specifications writers should be provided with information regarding the requirements for energy efficient and durable roofing systems. Encourage them to work with standards and specification generating bodies to develop material and design standards which are commensurate with the design, application and maintenance aspects of energy efficient, low slope roofs.

5) Implement programs to make building owners aware of the advantages of and need of timely maintenance of roofing systems. They need to be informed of the cost and energy savings that can be achieved by rather simple and inexpensive preventive maintenance procedures. Strongly advocate periodic (at least yearly) inspections by competent and knowledgeable personnel and promptly carry out the corrective measures as recommended by them. Yearly inspections are recommended to allow a full cycle of temperature and weather extremes. Inspections should also occur after any severe storm. There are several excellent roof maintenance and repair documents available from various sources.

6) Encourage the roofing contractor sector of the industry, to continue their efforts to increase the professionalism of the applicators through the many educational and training programs which are available throughout the industry.

7) The increasing use of single-ply roofing membranes in lieu of multi-ply bituminous membranes suggest that a similar type of survey program should be conducted addressing the relationship of high R-value insulating components on the durability of single-ply membranes. This would be an appropriate area for DOE to sponsor or co-sponsor.

Implementation of these recommendations can be enhanced through the use of the reference materials that follow. Additional information is available through the American Institute of Architects, the Construction Specifications Institute, and other professional organizations. The NRCA Roofing & Waterproofing Manual (Reference 2) is particularly recommended as a most comprehensive reference document.

REFERENCES

1. *The National Program Plan for the Thermal Performance of Building Envelope Systems and Insulating Materials,*
   Oak Ridge National Laboratory, March 1981

2. *NRCA Roofing & Waterproofing Manual,*
   National Roofing Contractors Association, 1981

3. *NRCA Handbook of Accepted Roofing Knowledge (HARK),*
   National Roofing Contractors Association, 1980

4. *NRCA/ARMA Manual of Roof Maintenance and Roof Repair,*
   National Roofing Contractors Association and the Asphalt Roofing Manufacturers Association, 1981

5. *NRCA Project Pinpoint,*
   The Roofing Spec, May 1981 published by National Roofing Contractors Association

6. *Effects of the Application of Hot Asphalt to Roof Insulations*
   Southwest Research Institute, 1980, in cooperation with National Roofing Contractors Association and Midwest Roofing Contractors Association

7. *NRCA Technical Bulletin #9*
   National Roofing Contractors Association and Roof Insulation Committee of Thermal Insulation Manufacturers Association

8. *NRCA Energy Manual*
   National Roofing Contractors Association, 1982

9. *ASHRAE Handbook of Fundamentals*
   American Society of Heating, Refrigerating and Air-Conditioning Engineers.

NRCA/Department of Energy Contract
for Thermal Roof Systems Performance Study
Building Roof Assembly Information

1. Date: March 3, 1982
2. Inspected By: John Mish & Ray Johnson
3. Building Location: Armed Services Building Center
   Lynn Lane & Broken Arrow Expressway
   Broken Arrow, Oklahoma
4. Building Used For: Past Offices Present Offices
5. Is The Building: Heated - Yes X No ___
   Air Conditioned - Yes X No ___
6. Month and Year Roof was Applied: Oct., 1978 Age of Roof 3yrs., 5 mo
7. Access To Roof: Ladder ______ Scuttle X Other ______
8. Ceiling Type: Acoustical Drop
   Insulated - Yes ___ No X
   Vented - Yes X No ___
   R-Factor ______
9. Type of Deck:
   ______Lightweight Insulating Concrete Thickness______
   Polystyrene: Yes:______ No______ Other______ Thickness______
   ______Thermo-Setting Insulating Fill. Thickness______
   ______Foamed Concrete. Thickness______
   ______Poured Gypsum Concrete. Thickness______ Formboard Type______
   Thickness______

   (note substrate for above fills on deck types below. If not fill type check deck type)

   Structural Deck:
   ______Side Vented Steel
   ______Slotted Steel
   ______Cement-Wood Fiber Panels
   ______Precast Concrete
   ______Prestressed Concrete
   ______Poured Reinforced Concrete
   X Structural Steel Deck Gauge 22 Span 5'0" Depth 1½" Type B
   ______Wood Plank
   ______Plywood
10. Slope of Roof: ½" Inch per foot max.
    ¼" Inch per foot min.
11. Area of Roof: 532 Squares (one square equals 100 sq. ft.)
12. Type of Built-Up Roof:
    Asphalt: Aggregate Surfaced X Smooth Surfaced______
    Coal Tar______ Cold Process______ Other______

13. Type of Interply Bitumen: __Asphalt__ __Coal Tar__

Asphalt	Coal Tar
Type I ______	Type I ______
Type II ______	
Type III__X__	Type III______
Type IV______	

Type of Surfacing Bitumen:

Asphalt	Coal Tar
Type I ______	Type I ______
Type II ______	
Type III__X__	Type III______
Type IV______	

14. Kind of Surfacing: Aggregate__X__ Slag______ Crushed Stone______

Paver Blocks______ Slate Slabs______ Mineral-Surfaced Cap Sheet______

Smooth-Surfaced Cap Sheet______ Other (explain)______

Type of ASTM D-1863 Aggregate #6______ #7______ #67__X__

15. Base Sheet Type (if used): __#43 organic—solid mopped with asphalt__

16. Type and Number of Finishing Plies:

Organic __X__	Coated _____	Uncoated__X__	Number__3__	Approx. Weight __#15__
Asbestos _____	Coated _____	Uncoated_____	Number_____	Approx. Weight _____
Glass Fiber _____	Type III _____	Type IV _____	Number_____	Approx. Weight _____

17. Vapor Retarder Used: Yes______ No__X__ Type______

18. Insulation: Yes__X__ No______ Thickness______

Protected Membrane Assembly__No__

Insulation Vents: Yes______ No__X__

1st Layer Type __Ure + Per__	Thickness __3″__	Sheet Size __3′x4′__	Staggered Joints __Yes__
2nd Layer Type ______	Thickness _____	Sheet Size _____	Staggered Joints ____
3rd Layer Type ______	Thickness _____	Sheet Size _____	Staggered Joints ____

Type of Attachment: 1st Layer__Mechanical Fasteners__

2nd Layer______

3rd Layer______

Offset Joints Between Layers: Yes__D.A.__ No______

Taped: Yes______ No__X__ Which Layer______

19. Perimeter Type:

Gravel Stop_____ At Water Line_____ Tapered Edge_____ Raised Cap Type_____

Parapet Wall__X__ Height__var.__ Type__P.C.__ Canted__Yes__ Coping Cap_____

Concrete Reglet_____ Counter Flashing_____ Receiver & Counter Flashing__X__

Built-In_____ Surface Mounted__X__ Type of Metal__galv.__

Other_____ Describe______

20. Curb Flashing:

Height 12″ Canted Yes

Counter Flashed By: Equipment Base X Metal Cap Flashing _____

Type & Gauge of Metal _____

Other (describe) _____

21. Base Flashing:

Perimeter

Base Flashings: Reinf. Asbestos X Neoprene _____ Other (describe) _____
Height var.

Cant Strip: Yes X No _____ Other (describe) _____

Curb & Interior

Base Flashings: Reinf. Asbestos X Neoprene _____ Other (describe) _____
Height 12″

Cant Strip: Yes X No _____ Other (describe) _____

22. Type of Drainage: Interior Drains Yes Number 30

Scuppers _____ Number _____

Downspouts _____ Number _____

Gutters _____ Lineal Feet _____

23. Mechanical Equip:

No. of Units 2 Original XX Added _____ Year _____

Mounting Type?

Rails X Height above Roof 18″ Curbed X Other _____

Canted & Flashed Yes Flashing Height 12″ Type Asb. reinf.

Pitch Pans Yes _____ No X

Condensate Drainage on Roof Yes X No _____

24. Penetrations:

	TV/Ant.	Stacks	Conduit	Gas Line	Lightning Rods	Refrig. Lines	Other
Number:	1	10	1				
How Flashed:	conc. pad	trowel	P.P.				
Original:	X	X	X				
Added:							

25. Expansion Joints: Yes X No _____ Type Expand-O-Flash

ROOF INSPECTION FORM
THERMAL ROOF SYSTEM PERFORMANCE STUDY

Date of Inspection: March 3, 1982 Time: 11:00 am Inspector: Mish & Johnson

Building Name: Armed Services Building Center Location: Broken Arrow, OK

Weather Conditions: Cloudy — cool Age of Roof: 3 yrs, 5 mo.

1. ROOFING SYSTEMS (GENERAL)

A. General Appearance: Good X Fair ____ Poor ____

B. Watertightness: (ignore previous patching or temporary repairs)

a. no leaks		d. leaks with continued rain	
b. leaks every rain	X	e. leaks stop when rain stops	X
c. leaks in high wind		f. leaks continued after rain	

C. Suspected Leak Location (note: as "none", "minor" or "major" problems)

a. roof membrane		f. roof expansion joints	X-major
b. base flashing		g. drainage system	
c. metal counterflashing		h. adjoining walls	X
d. gravel stops		i. other ____	
e. mechanical equipment			

D. Maintenance & Upkeep

a. debris on roof	No	c. lack of maintenance	
b. physical abuse	No	d. other ____	

E. Drainage

a. ponding water evident	No	c. deflection evident	
b. ponding stain evident		d. other ____	

Comments: ____

2. SURFACINGS

A. General Appearance: Good X Fair ____ Poor ____

A. Loss of Aggregate/Slag Yes ____ No X

a. corners		c. main roof area	
b. edges		d. other ____	

2. **SURFACINGS** (continued)

C. Coating Deterioration: Yes______ No______

a. inadequate flood coat ______
b. slippage ______
c. alligatoring ______
d. cracking ______
e. bubbling ______
f. felts exposed ______
g. felts curled ______
h. felts disintegrating ______
i. other ______________ ______

D. Cap Sheet Deterioration: Yes______ No______

a. blistered ______
b. shrinkage ______
c. cracking/splitting ______
d. other ______________ ______

Comments: ______________________________

____

3. **ROOF MEMBRANE**

A. General Appearance: Good__X__ Fair______ Poor______

B. Blistering Yes______ No__X__

a. maximum size ______
b. minimum size ______
c. frequency per square ______
d. punctured ______
e. at insulation interface ______
f. interply location ______
g. other ______________ ______

C. Ridging Yes______ No__X__

a. perpendicular to felts ______
b. parallel to felts ______
c. at insulation joints ______
d. picture framing ______
e. other ______________ ______

D. Splitting Yes______ No__X__

a. at structural joint ______
b. at insulation joint ______
c. at addition tie-in ______
d. other ______________ ______

E. Slippage of Felts Yes______ No__X__

a. all plies ______
b. finishing plies ______
c. other ______________ ______
d. distance slipped (inches) ______

Comments: ______________________________

____

4. BASE FLASHINGS

A. General Appearance: Good ___X___ Fair_______ Poor_______

B. Surfacing Deterioration Yes_______ No___X___

a.	coating slippage	_______	d.	coating damaged	_______
b.	coating weathered	_______	e.	other ____________________	_______

C. Flashing Felt Deterioration Yes_______ No___X___

a.	separated from wall	_______	h.	splitting	_______
b.	sagging from wall	_______	i.	blistering & water present	_______
c.	slippage down wall	_______	j.	blistering & air present	_______
d.	inadequately nailed	_______	k.	vertical lap separated	_______
e.	strike damage	_______	l.	racking (diagonal wrinkles)	_______
f.	severe weathering	_______	i.	other ____________________	_______

Comments: ____

____

5. METAL COUNTERFLASHINGS

A. General Appearance: Good ___X___ Fair_______ Poor_______

B. Reglet/Receiver Problems Yes_______ No___X___

a.	pulled from wall	_______	c.	reglet/wall joint open	_______
b.	holds water	_______	d.	other ____________________	_______

C. Counterflashing Problems Yes_______ No___X___

a.	slipped from receiver	_______	d.	not covering base flashing	_______
b.	inadequate fastening	_______	e.	rusted/deteriorated	_______
c.	wind damaged	_______	f.	other ____________________	_______

D. Gravel Stop Problems Yes_______ No___D.A.___

a.	gravel stop face loose	_______	d.	nail pulling	_______
b.	flashing flange loose	_______	e.	aggregate/surface slippage	_______
c.	joint cracking	_______	f.	other ____________________	_______

E. Penetration Flashing Problems Yes_______ No___X___

a.	rusted/deteriorated	_______	e.	pitch boxes	_______
b.	cap flsg not in place	_______	f.	pitch box ponding	_______
c.	insufficient height	_______	g.	poor detailing	_______
d.	inadequate fastening	_______	h.	other ____________________	_______

Comments: ____

____

6. **DRAINAGE SYSTEMS**

A. General Appearance: Good__X__ Fair____ Poor____

B. Specific Problems Yes____ No__X__

a. drains not sumped	____	f. strainers not in place	____
b. drains plugged debris	____	g. flashing separated/split	____
c. inadequate size	____	h. no lead drain flashing	____
d. drains poorly placed	____	i. downspout/leader problems	____
e. too few drains (1/40)	____	j. other ____	____

Comments: ____

7. **WALLS ADJOINING ROOFS**

A. General Appearance Good__X__ Fair____ Poor____

B. Specific Problems: Yes____ No__X__

a. coping joints open	____	f. porous masonry units	____
b. coping cracked/damaged	____	g. mortar deteriorated	____
c. coping ponds water	____	h. hairline wall cracking	__X__
d. masonry deteriorated	____	i. major wall cracking	____
e. exposed brick ledges	____	j. other ____	____

Comments: ____

8. **ROOF EXPANSION JOINTS**

A. General Appearance: Good____ Fair____ Poor__X__

B. Specific Problems: Yes__X__ No____

a. above water line	____	d. poor design	____
b. poorly located	____	e. does not allow movement	____
c. joint separation	____	f. other Bellows splitting	__X__

Comments: ____

9. **MECHANICAL EQUIPMENT**

A. General Appearance Good__X__ Fair____ Poor____

Specific Problems: Yes____ No__X__

a. poorly designed	____	d. excessive vibration	____
b. poorly constructed	____	e. condensate drains on roof	____
c. maintenance abuse roof	____	f. other ____	____

Comments: ____

ARMED FORCES BUILDING CENTER

Upon checking with the Navy Commander for permission to inspect the roof, we were advised that this roof leaked "all over". Upon checking with the Chief Petty Officer in charge of maintenance, he advised us that the only leaks occurred at the roof expansion joint. Originally there had been minor leaking at the joints of the precast concrete walls. These leaks had been stopped by the general contractor.The Chief Petty Officer advised that some repairs had been made to the roof drains and valleys, but that they had not been able to find any problems with the roof when the gravel was removed. After careful examination, it was concluded that the leaks at the roof drains were probably caused by leaks at the perimeter walls and the water was running down the flutes of the metal deck to the roof drains where it could escape. Upon examination of the roof expansion joints, splits or cuts were found in the bellows. Some splits were perpendicular to the run of the expansion joint and some were parallel. The cuts were smooth enough to have been cut with a knife, however, the Chief Petty Officer was sure that no one had been on the roof.

The built-up roof, gravel surfacing, flashing and other items seemed to be in excellent condition. No blisters or other defects could be found. The flashing receiver is surface mounted and needs to be recaulked.

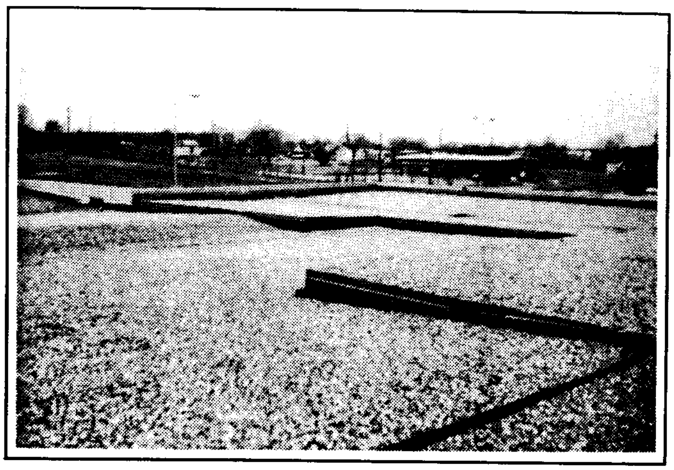


Illustration 1

West View of Roof

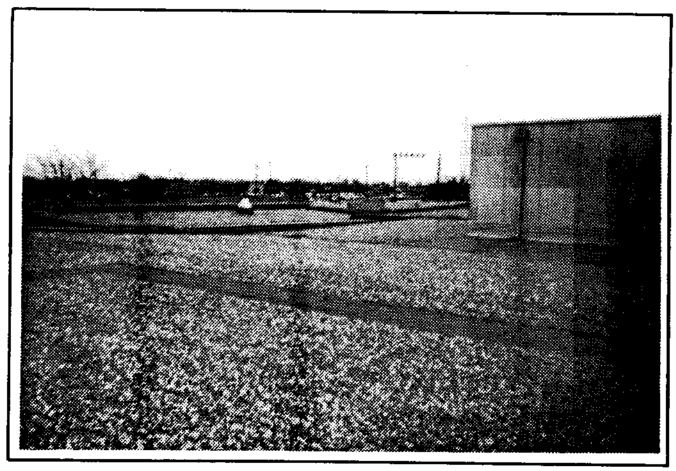


Illustration 2

South View of Roof

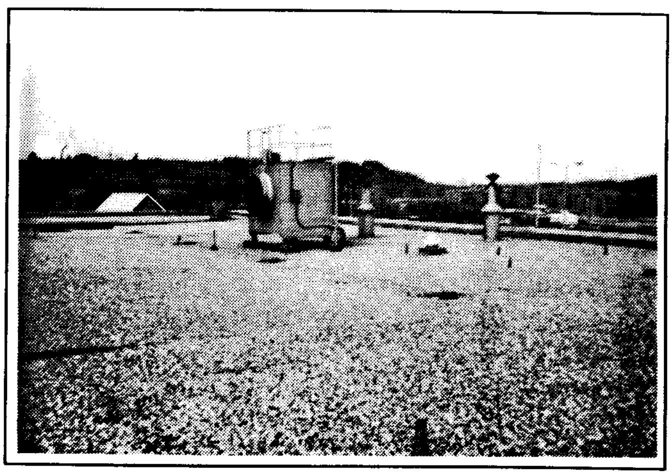


Illustration 3

North View of Roof

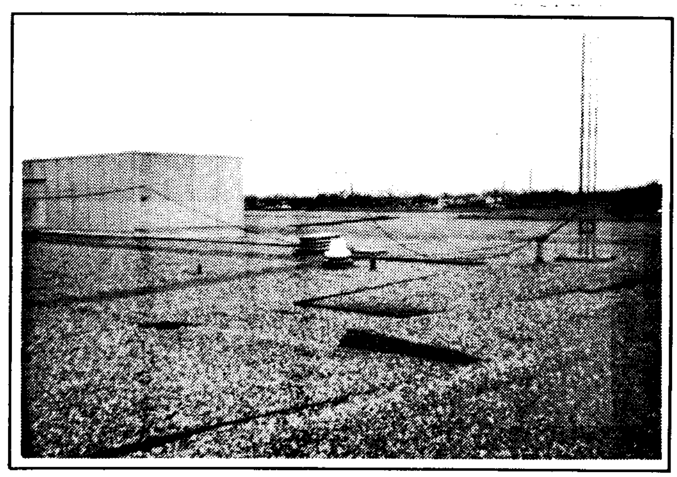


Illustration 4

East View of Roof

ROOF DESIGN CRITERIA

Section a

ITEM:	Job Number / Job Location	1 IL.	2 IL.	3 IN.	4 IN.	5 WI.	6 WI.	7 AZ.
1	Month & Year of Installation	6-74	12-77	7-75	2-77	8-77	9-75	8-79
2	Area (Squares)	238	160	116	42	700	65	1203
3	Ceiling	YES	YES	YES	YES	YES	YES	NO
4	Ceiling Insulation	—	—	3-1/2″ batts	—	—	—	—
5	Air Conditioned	YES	YES	NO	YES	YES	YES	YES
6	Heated	YES	YES	YES	YES	YES	YES	YES
7	Type of Deck	P.G.	M.D.	P.G. on M.D.	Wood Plank	M.D.	M.D.	M.D.
8	Metal Deck Span	—	5′0″	5′0″	—	5′0″	5′0″	6′0″
9	Metal Deck Gauge	—	22	22	—	22	22	22
10	Metal Deck Type & Depth	—	Int. Rib-1½″	B-1½″	—	B-1½″	A-1½″	N-3″
11	Minimum Slope	1/16″	1/16″	1/4″	1/4″	1/16″	1/16″	1/8″
12	Interply Bitumen	PI	PI	AIII	AIII	AI	AI	AIII
13	Surfacing Bitumen	PI	PI	AIII	AIII	AI	AI	AIII
14	Type of Surfacing	Agg.	Agg.	Smooth Surface	Smooth Surface	Agg.	Agg.	Smooth Alum.
15	Type of Base Felt	—	—	#43 Org.	#40 Asb. Base	—	#43 Org.	—
16	Number of Plies	—	—	1	1	—	1	—
17	Type of Finishing Felt	#20 T.	#15 T.	#15 Asb.	#15 Asb.	Glass	#15 Org.	Glass
18	Number of Plies	2	4	3	3	3	3	3
19	Total Number of Plies	2	4	4	4	3	4	3
20	Vapor Retarder	NO	NO	NO	Old Roof-Yes	NO	NO	NO
21	Insulation Vents	NO	NO	YES	NO	NO	NO	YES
22	Type of Insulation-1st Layer	Glass	Glass	Tapered EPS	Tapered EPS	Glass/Ure.	Per./Ure.	Glass
23	Thickness of Insul.-1st Layer	2-1/4″	2-1/4″	1-1/2″-6″	2-5/8″-4-1/2″	2″	2″	2-7/16″
24	Sheet Size-1st Layer	3′x4′	3′x4′	3′x4′	3′x4′	3′x4′	3′x4′	3′x4′
25	Adhesion of Insul.-1st Layer	Solid Mop	FM 1-28	Solid Asph.	Solid Asph.	Strip Mop	Strip Mop	Mech.
26	Type of Insulation-2nd Layer	—	—	—	Tapered EPS	Glass	—	—
27	Thickness of Insul.-2nd Layer	—	—	—	2-5/8″-4-1/2″	3/4″	—	—
28	Sheet Size-2nd Layer	—	—	—	3′x4′	3′x4′	—	—
29	Adhesion of Insul.-2nd Layer	—	—	—	Solid Asph.	Strip Mop	—	—
30	Type of Insulation-3rd Layer	—	—	—	—	—	—	—
31	Thickness of Insul.-3rd Layer	—	—	—	—	—	—	—
32	Sheet Size-3rd Layer	—	—	—	—	—	—	—
33	Adhesion of Insul.-3rd Layer	—	—	—	—	—	—	—
34	Taped Joints	YES	NO	NO	NO	YES	NO	YES
35	Flashing Type	Asb.	Asb.	Asb.	Asb.	Asb.	Asb.	Glass
36	Perimeter Type	Para.	Para. & Gr. Stop	Para.	Para. & Gr. Stop	Gr. Stop	Gr. Stop	Para.
37	Roof Drainage Type	R.D.	R.D.	R.D.	Gutter	R.D.	R.D. Edge	R.D.
38	Number of Roof Drains	22	4	4	—	17	2	12
39	Number of Mech. Equip.	6	20	4	4	22	—	12
40	Number of Penetrations	17	42	19	7	11	3	12
41	Expansion Joint Type	Exp-O-Flash	—	—	—	Exp-O-Flash	—	NRCA C-1
42	Total Insulation "R"	9.09	9.09	14.30	29.20	17.06	10.00	10.00

ROOF DESIGN CRITERIA

Section a

ITEM: Job Number / Job Location	8 AZ.	9 AZ.	10 AZ.	11 CA.	12 CA.	13 CA.	14 OK.
1 Month & Year of Installation	6-80	8-81	8-81	1-80	5-75	10-79	10-78
2 Area (Squares)	686	300	676	272	160	2200	532
3 Ceiling	NO	YES	NO	YES	YES	YES	YES
4 Ceiling Insulation	—	—	—	Batts	Batts	Batts	—
5 Air Conditioned	YES	YES	YES	YES	YES	YES	YES
6 Heated	YES	YES	YES	YES	YES	YES	YES
7 Type of Deck	L.W.C.	L.W.C. on P.C.	M.D.	P.C.	P.C.	L.W.C.	M.D.
8 Metal Deck Span	—	—	6′0″	—	—	—	5′0″
9 Metal Deck Gauge	—	—	22	—	—	—	22
10 Metal Deck Type & Depth	—	—	N-3″	—	—	—	B-1½″
11 Minimum Slope	1/8″	1/8″	1/8″	1/8″	1/8″	1/8″	1/4″
12 Interply Bitumen	AIII	AIII	AIII	AI	AI	AI	AIII
13 Surfacing Bitumen	AIII	AIII	AIII	AI	AI	AI	AIII
14 Type of Surfacing	Smooth Alum.	Cap Sheet	Cap Sheet	Slag	Agg.	Slag	Agg.
15 Type of Base Felt	—	—	—	#25 Glass Base	Asbestos Base	Glass Base	#43 Org.
16 Number of Plies	—	—	—	1	1	1	1
17 Type of Finishing Felt	Glass	Glass & Cap	Glass & Cap	Glass	#15 Asb.	Glass	#15 Org.
18 Number of Plies	3	2+1	2+1	2	3	3	3
19 Total Number of Plies	3	3	3	3	4	4	4
20 Vapor Retarder	NO	NO	NO	NO	NO	NO	NO
21 Insulation Vents	YES	NO	NO	YES	NO	NO	NO
22 Type of Insulation-1st Layer	Glass	Per./Ure.	Glass	Tapered EPS	Per./Ure.	L.W.C.	Per./Ure.
23 Thickness of Insul.-1st Layer	2-7/16″	2.8″	2-7/16″ or 1-1/16″	3-1/4″ avg.	1-1/2″	—	3″
24 Sheet Size-1st Layer	3′x4′	3′x4′	3′x4′	4′x8′	3′x4′	—	3′x4′
25 Adhesion of Insul.-1st Layer	Solid Mop	Mech.	Mech.	Solid Mop	Solid Mop	—	Mech.
26 Type of Insulation-2nd Layer	—	—	—	Fiberboard	—	—	—
27 Thickness of Insul.-2nd Layer	—	—	—	1/2″	—	—	—
28 Sheet Size-2nd Layer	—	—	—	2′x4′	—	—	—
29 Adhesion of Insul.-2nd Layer	—	—	—	Solid Mop	—	—	—
30 Type of Insulation-3rd Layer	—	—	—	—	—	—	—
31 Thickness of Insul.-3rd Layer	—	—	—	—	—	—	—
32 Sheet Size-3rd Layer	—	—	—	—	—	—	—
33 Adhesion of Insul.-3rd Layer	—	—	—	—	—	—	—
34 Taped Joints	YES	YES	YES	NO	NO	NO	NO
35 Flashing Type	Glass	Glass	Glass & Cap	Asb.	Asb.	Asb.	Asb.
36 Perimeter Type	Para.	Gr. Stop & Para.	Gr. Stop	Gr. Stop & Para.	Para. & Gr. Stop	Gr. Stop & Para.	Para.
37 Roof Drainage Type	R.D.	R.D. & Edge	Gutter, R.D. & Scup.	R.D. & Scuppers	R.D.	R.D.	R.D.
38 Number of Roof Drains	5	1	5	12	5	72	30
39 Number of Mech. Equip.	7	4	10	6	3	33	2
40 Number of Penetrations	23	61	11	22	2	99	12
41 Expansion Joint Type	—	Exp-O-Flash	Exp-O-Flash	Exp-O-Flash	Exp-O-Flash	Curbed Met.	Exp-O-Flash
42 Total Insulation "R"	10.00	16.67 aged	10.00 or 4.17	13.89	6.67	—	18.16 aged

ROOF DESIGN CRITERIA

ITEM:	Job Number / Job Location	15 OK.	16 OK.	17 OK.	18 TX.	19 TX.	20 TX.	21 FL.
1	Month & Year of Installation	9-75	11-75	9-75	2-78	4-76	3-77	3-77
2	Area (Squares)	271	153	156	176	1520	173	300
3	Ceiling	NO	YES	NO	YES	NO	YES	NO
4	Ceiling Insulation	—	?	—	—	—	—	—
5	Air Conditioned	YES	YES	YES	YES	YES	YES	NO
6	Heated	Part-YES	YES	YES	YES	YES	YES	NO
7	Type of Deck	Pre.Conc.	M.D.	P.C.	L.W.C.	Firecode	L.W.C.	M.D.
8	Metal Deck Span	—	5′0″	—	—	5′0″	—	5′0″
9	Metal Deck Gauge	—	24&?	—	—	22	—	22
10	Metal Deck Type & Depth	—	B-1½″ & 3″ Ac.	—	—	A-1½″	—	1-1/2″?
11	Minimum Slope	1/8″	1/8″	1/8″	1/8″	1/8″	1/8″	1/8″
12	Interply Bitumen	AIV	AI	AIV	AIV	AIII	AIV	AIII
13	Surfacing Bitumen	AI	AI	AI	AIV	AI	AIV	AIII
14	Type of Surfacing	Agg.	Agg.	Agg.	Agg.	Double Agg.	Agg.	Agg.
15	Type of Base Felt	#43 Org.	#43 Org.	—	#43 Org.	#43 Org.	#43 Org.	#43 Org.
16	Number of Plies	1	1	—	1	1	1	1
17	Type of Finishing Felt	#15 Org.	#15 Org.	#30 Coat. Org.	#15 Asb.	#15 Org.	#15 Org.	#15 Org.
18	Number of Plies	3	3	3	2	3	3	3
19	Total Number of Plies	4	4	3	3	4	4	4
20	Vapor Retarder	NO	YES	NO	NO	NO	NO	YES
21	Insulation Vents	NO	NO	NO	NO	NO	NO	NO
22	Type of Insulation-1st Layer	EPS	Per./Ure.	Ure.	L.W.C.	Ure.	L.W.C.	Ure.
23	Thickness of Insul.-1st Layer	5″	1-1/2″	1-3/16″	—	2.4″	—	1.4″
24	Sheet Size-1st Layer	??	3′x4′	2′x4′	—	4′x8′	—	3′x4′
25	Adhesion of Insul.-1st Layer	??	Cold Adh.	Solid Mop	—	Solid Mop	—	Solid Mop
26	Type of Insulation-2nd Layer	Perlite	—	—	—	—	—	—
27	Thickness of Insul.-2nd Layer	3/4″	—	—	—	—	—	—
28	Sheet Size-2nd Layer	2′x4′	—	—	—	—	—	—
29	Adhesion of Insul.-2nd Layer	Solid Asph.	—	—	—	—	—	—
30	Type of Insulation-3rd Layer	—	—	—	—	—	—	—
31	Thickness of Insul.-3rd Layer	—	—	—	—	—	—	—
32	Sheet Size-3rd Layer	—	—	—	—	—	—	—
33	Adhesion of Insul.-3rd Layer	—	—	—	—	—	—	—
34	Taped Joints	NO	NO	NO	NO	NO	NO	NO
35	Flashing Type	Asb.	Asb.	Asb.	Asb.	Asb.	Asb.	Asb.
36	Perimeter Type	Para.	Gr. Stop & Para.	Gr. Stop & Para.	Para.	Para.	Para.	Gr. Stop & Para.
37	Roof Drainage Type	Scuppers	R.D.	R.D.	Scuppers	R.D.	R.D.	R.D. & Scuppers
38	Number of Roof Drains	—	4	4	—	20	10	20
39	Number of Mech. Equip.	11	4	—	13	10	19	6
40	Number of Penetrations	13	22	4	14	32	15	10
41	Expansion Joint Type	—	—	—	Exp-O-Flash	Exp-O-Flash	Exp-O-Flash	—
42	Total Insulation "R"	22.88	6.67	9.13	—	17.24 aged	—	11.11

ROOF DESIGN CRITERIA

Section a

ITEM	Job Number / Job Location	22 FL.	23 FL.	24 WA.	25 WA.	26 ME.	27 ME.	28 ME.
1	Month & Year of Installation	6-81	6-81	10-71	10-80	9-77	9-75	12-75
2	Area (Squares)	200	200	2375	800	76	362	972
3	Ceiling	NO	NO	YES	YES	YES	1/3 YES	Part YES
4	Ceiling Insulation	—	—	—	—	—	—	6″ Blankets
5	Air Conditioned	YES	YES	YES	YES	YES	1/3 YES	YES
6	Heated	YES	YES	YES	YES	YES	YES	YES
7	Type of Deck	P.G.	P.G.	Pre. Conc.	M.D.	M.D.	M.D.	M.D.
8	Metal Deck Span	—	—	—	6′0″	5′4″	5′6″	5′6″
9	Metal Deck Gauge	—	—	—	20	20	22	22
10	Metal Deck Type & Depth	—	—	—	B-1½″	BW-1½″	BW-1½″	BW-1½″
11	Minimum Slope	1/8″	1/8″	1/8″	1/8″	1/4″	1/8″	1/4″
12	Interply Bitumen	AIII	AIII	AI	AI	PI	AIII	PI
13	Surfacing Bitumen	AIII	AIII	AI	AI	PI	AIII	PI
14	Type of Surfacing	Agg.	Agg.	Agg.	Smooth Alum.	Agg.	Agg.	Agg.
15	Type of Base Felt	#43 Org.	#43 Org.	—	—	—	#43 Org.	—
16	Number of Plies	1	1	—	—	—	1	—
17	Type of Finishing Felt	#15 Org.	#15 Org.	Glass	Glass	#15 T.	#15 Org.	#15 T.
18	Number of Plies	3	3	2	4	4	3	4
19	Total Number of Plies	4	4	2	4	4	4	4
20	Vapor Retarder	NO	NO	YES	NO	NO	YES	95 Sq. YES
21	Insulation Vents	YES	YES	NO	NO	NO	NO	NO
22	Type of Insulation-1st Layer	Ure.	Ure.	Glass	Per./Ure.	Per./Ure.	Glass	Glass
23	Thickness of Insul.-1st Layer	1.4″	1.4″	1-5/16″	2-1/2″	2-1/4″	15/16″	1-5/16″
24	Sheet Size-1st Layer	3′x4′	3′x4′	4′x8′	2′x4′	3′x4′	3′x4′	3′x4′
25	Adhesion of Insul.-1st Layer	Solid Mop	Solid Mop	Solid Asph.	Mech.	Strip Asph.	Solid Asph.	Solid Asph.
26	Type of Insulation-2nd Layer	—	—	—	Per.	—	Ure.	Glass
27	Thickness of Insul.-2nd Layer	—	—	—	3/4″	—	1.2″	1-5/16″
28	Sheet Size-2nd Layer	—	—	—	2′x4′	—	3′x4′	3′x4′
29	Adhesion of Insul.-2nd Layer	—	—	—	Solid Asph.	—	Solid Asph.	Solid Asph.
30	Type of Insulation-3rd Layer	—	—	—	—	—	—	Glass (95 Sq.)
31	Thickness of Insul.-3rd Layer	—	—	—	—	—	—	1-5/16″
32	Sheet Size-3rd Layer	—	—	—	—	—	—	3′x4′
33	Adhesion of Insul.-3rd Layer	—	—	—	—	—	—	Solid Asph.
34	Taped Joints	NO	NO	YES	NO	NO	NO	YES
35	Flashing Type	Asb.	Asb.	Min. Sur.	#15 Asb.	Asb.	Asb.	Asb.
36	Perimeter Type	Para.	Para.	Para.	Para.	Gr. Stop	Gr. Stop	Gr. Stop
37	Roof Drainage Type	Scuppers	Scuppers	R.D.	R.D.	R.D.	R.D. & Gutter	R.D.
38	Number of Roof Drains	—	—	25	16	4	6 for 108 Sq.	27
39	Number of Mech. Equip.	22	10	8	10	2	7	19
40	Number of Penetrations	40	20	?	?	6	7	24
41	Expansion Joint Type	—	—	Exp-O-Flash	Exp-O-Flash	—	—	M.M.
42	Total Insulation "R"	11.11	11.11	5.26	16.37	12.50	13.70	10.52 & 15.78

ROOF DESIGN CRITERIA

Section a

ITEM:	Job Number / Job Location	29 ME.	30 SC.	31 SC.	32 SC.	33 SC.	34 ND.	35 ND.
1	Month & Year of Installation	4-76	8-75	8-78	4-79	6-77	1-77	?-76
2	Area (Squares)	238	600	490	450	800	775	104
3	Ceiling	NO	NO	NO	NO	NO	25% YES	40% YES
4	Ceiling Insulation	—	—	—	—	—	—	—
5	Air Conditioned	NO	YES	YES	YES	YES	NO	NO
6	Heated	YES	YES	YES	YES	YES	YES	YES
7	Type of Deck	M.D.	M.D.	M.D.	Wood Plank	Wood Plank	M.D.	60% PreConc 40% M.D.
8	Metal Deck Span	5′5″	5′6″	5′6″	—	—	5′0″	4′0″
9	Metal Deck Gauge	22	22	22	—	—	22	22
10	Metal Deck Type & Depth	BW-1½″	B-1½″	B-1½″	—	—	B-1½″	B-1½″
11	Minimum Slope	1/8″	1/8″	1/8″	1/8″	1/8″	1/4″	0″
12	Interply Bitumen	AIII	AIII	AIII	AIII	AIII	AI	AI
13	Surfacing Bitumen	AIII	AI	AI	AIII	AIII	AI	AI
14	Type of Surfacing	Agg.	Agg.	Agg.	Smooth Surface	Smooth Alum.	Agg.	Agg.
15	Type of Base Felt	—	—	—	—	—	#43 Org.	#43 Org.
16	Number of Plies	—	—	—	—	—	1	1
17	Type of Finishing Felt	#30 Coated	Glass	Glass	Glass	Glass	#15 Org.	#15 Org.
18	Number of Plies	3	3	3	4	4	3	3
19	Total Number of Plies	3	3	3	4	4	4	4
20	Vapor Retarder	YES	YES	YES	YES	YES	YES	YES
21	Insulation Vents	NO	NO	NO	NO	NO	NO	NO
22	Type of Insulation-1st Layer	Per./Ure.	Glass	Glass	Glass	Glass	Per./Ure.	Ure.
23	Thickness of Insul.-1st Layer	1-3/4″	2-1/4″	2-1/4″	2-1/16″	2-1/16″	1-1/2″	1″
24	Sheet Size-1st Layer	3′x4′	3′x4′	4′x8′	3′x4′	3′x4′	3′x4′	3′x4′
25	Adhesion of Insul.-1st Layer	Solid Asph.	Solid Asph.	FM 1-28	Solid Asph.	Solid Asph.	Solid Asph.	Solid Asph.
26	Type of Insulation-2nd Layer	—	—	—	—	—	Perlite	Urethane
27	Thickness of Insul.-2nd Layer	—	—	—	—	—	1″	1″
28	Sheet Size-2nd Layer	—	—	—	—	—	2′x4′	3′x4′
29	Adhesion of Insul.-2nd Layer	—	—	—	—	—	Solid Asph.	Solid Asph.
30	Type of Insulation-3rd Layer	—	—	—	—	—	—	—
31	Thickness of Insul.-3rd Layer	—	—	—	—	—	—	—
32	Sheet Size-3rd Layer	—	—	—	—	—	—	—
33	Adhesion of Insul.-3rd Layer	—	—	—	—	—	—	—
34	Taped Joints	NO	NO	NO	NO	NO	NO	NO
35	Flashing Type	Asb.	Asb.	Asb.	Asb.	Asb.	Asb.	Min. Surf.
36	Perimeter Type	Gr. Stop	Gr. Stop	Gr. Stop	Gr. Stop	Para.	Para.	Gr. Stop
37	Roof Drainage Type	R.D.	R.D. & Gutter	Gutter	Gutter	R.D.	R.D.	Scuppers
38	Number of Roof Drains	4	4	—	—	14	22	—
39	Number of Mech. Equip.	1	7	4	1	11-?	21	15
40	Number of Penetrations	6	101	1	12	33-?	11	12
41	Expansion Joint Type	—	Shop Fab Curb	Shop Fab Curb	—	Shop Fab Curb	Exp-O-Flash	—
42	Total Insulation "R"	8.33	9.09	9.09	8.33	8.33	9.45	15.38

ROOF DESIGN CRITERIA

ITEM:	Job Number Job Location	36 ND.	37 ND.	38 CO.	39 CO.	40 CO.	41 CO.
1	Month & Year of Installation	8-74	1-71	4-79	2-78	11-78	2-80
2	Area (Squares)	342	1004	1.6	137	118	241
3	Ceiling	YES	NO	NO	YES	YES	YES
4	Ceiling Insulation	—	—	—	—	—	—
5	Air Conditioned	NO	NO	YES	YES	YES	YES
6	Heated	YES	YES	YES	YES	YES	YES
7	Type of Deck	90% W.F. 10% P.C.	M.D.	P.C.	Pre. Conc. & M.D.	L.W.C.	M.D.
8	Metal Deck Span	—	8'0"	—	5'0"	—	5'6"
9	Metal Deck Gauge	—	20	—	22	—	22
10	Metal Deck Type & Depth	—	B.Ac.-1½"	—	B-1½"	—	B-1½"
11	Minimum Slope	0"	0"	1/2"	1/8"	1/8"	1/4"
12	Interply Bitumen	AIII	AIII & AI	AII	AII	AII	AII
13	Surfacing Bitumen	AIII	AI	AII	AI	AII	AII
14	Type of Surfacing	Agg.	Agg.	Agg.	Agg.	Agg.	Agg.
15	Type of Base Felt	Asb. Base	#43 Org.	Asb. Base	Asb. Base	Vent Base	—
16	Number of Plies	1	1	1	1	1	—
17	Type of Finishing Felt	3-Asb. & 2-Org.	#15 Org.	#15 Asb.	#15 Asb.	#15 Org.	#15 Org.
18	Number of Plies	5	3	3	2	3	4
19	Total Number of Plies	6	4	4	3	4	4
20	Vapor Retarder	YES	YES	YES	YES	NO	NO
21	Insulation Vents	NO	YES	NO	NO	YES	NO
22	Type of Insulation-1st Layer	Ure.	Glass	Per.	Per.	Insul. in L.W.C.	EPS
23	Thickness of Insul.-1st Layer	1"	15/16"	2"	2"	1-1/2"	3-1/4"
24	Sheet Size-1st Layer	3'x4'	3'x4'	2'x4'	2'x4'	?	4'x4'
25	Adhesion of Insul.-1st Layer	Solid Asph.	Solid Mop	Solid Mop	Solid Mop	Slurry	Mech.
26	Type of Insulation-2nd Layer	Urethane	Glass	—	—	—	Fiberboard
27	Thickness of Insul.-2nd Layer	1"	15/16"	—	—	—	1/2"
28	Sheet Size-2nd Layer	3'x4'	3'x4'	—	—	—	2'x4'
29	Adhesion of Insul.-2nd Layer	Solid Asph.	Solid Mop	—	—	—	AII
30	Type of Insulation-3rd Layer	—	—	—	—	—	—
31	Thickness of Insul.-3rd Layer	—	—	—	—	—	—
32	Sheet Size-3rd Layer	—	—	—	—	—	—
33	Adhesion of Insul.-3rd Layer	—	—	—	—	—	—
34	Taped Joints	NO	NO	NO	NO	NO	NO
35	Flashing Type	Asb.	Min. Surf.	Asb.	Asb.	Asb.	Asb.
36	Perimeter Type	Para.	Para. & Gr. Stop	Para. & Gr. Stop	Para.	Para.	Para.
37	Roof Drainage Type	R.D.	R.D. & Scuppers	Edge	R.D. & Scuppers	R.D. & Scuppers	R.D.
38	Number of Roof Drains	12	16	—	8	5	6
39	Number of Mech. Equip.	35	47	—	1	2	8
40	Number of Penetrations	—	30	—	10	34	23
41	Expansion Joint Type	Exp-O-Flash	Exp-O-Flash	—	Curbed Galv.	Neoprene	—
42	Total Insulation "R"	15.38	7.40	5.26	5.26	9.34	13.89

EXISTING ROOF CONDITIONS

Section b

ITEM: Job Number / Job Location	1 IL.	2 IL.	3 IN.	4 IN.	5 WI.	6 WI.	7 AZ.
1 Leakage Reported	NO	YES	NO	NO	NO	NO	NO
2 Roof Related Leakage	—	YES	—	—	—	—	—
3 @ Membrane	—	YES	—	—	—	—	—
4 @ Base Flashing	—	YES	—	—	—	—	—
5 @ Metal Counterflashing	—	—	—	—	—	—	—
6 @ Gravel Stop	—	—	—	—	—	—	—
7 @ Roof Expansion Joint	—	—	—	—	—	—	—
8 @ Drainage System	—	—	—	—	—	—	—
9 @ Walls	—	—	—	—	—	—	—
10 @ Mech. Equip.	—	YES	—	—	—	—	—
11 General Cond. of System	GOOD	FAIR	GOOD	GOOD	GOOD	GOOD	FAIR
12 Debris on Roof	—	—	—	—	—	—	—
13 Physical Abuse	—	—	—	—	—	—	—
14 No Maintenance	—	—	—	—	—	—	—
15 Ponding	—	YES	YES	YES	—	YES	—
16 Surface Condition	GOOD	FAIR	GOOD	GOOD	GOOD	GOOD	GOOD
17 Membrane Condition	GOOD	FAIR	GOOD	GOOD	GOOD	GOOD	GOOD
18 Blistering	MINOR	YES	MINOR	—	—	YES	YES
19 Ridging	—	—	—	—	—	—	—
20 Splitting	—	—	—	—	—	—	—
21 Slippage	—	—	—	—	—	—	—
22 Flashing Condition	GOOD	FAIR	GOOD	GOOD	GOOD	NONE	GOOD
23 Membrane/Metal Connection	GOOD	POOR	GOOD	GOOD	GOOD	GOOD	GOOD
24 Drainage System	GOOD	GOOD	FAIR	GOOD	GOOD	FAIR	GOOD
25 Drains Sumped	—	—	—	—	—	—	—
26 Too Small	—	—	—	—	—	—	—
27 With Debris	—	YES	—	—	—	—	—
28 Poorly Placed	—	—	—	—	—	—	—
29 Age of Roof	7 yr. 2 mo.	3 yr. 9 mo.	6 yr. 3 mo.	4 yr. 8 mo.	4 yr. 2 mo.	6 yr. 1 mo.	2 yr. 5 mo.

Job # 1 - Roof equipment has been added and not properly installed.
Job # 2 - The flashing is weathering and pulling away from the wall. There were no leaks now but there have been in the past.
Job # 3 - There were small amounts of bare felts and the mechanical equipment was poorly designed and installed.
Job # 7 - The equipment wood sleepers were poorly installed and the aluminum coating has cracks and is browning.

EXISTING ROOF CONDITIONS

Section b

Job Number	8	9	10	11	12	13	14
Job Location	AZ.	AZ.	AZ.	CA.	CA.	CA.	OK.
ITEM:							
1 Leakage Reported	NO	YES	YES	NO	NO	NO	YES
2 Roof Related Leakage	—	YES	YES	—	—	—	YES
3 @ Membrane	—	—	—	—	—	—	—
4 @ Base Flashing	—	YES	—	—	—	—	—
5 @ Metal Counterflashing	—	—	—	—	—	—	—
6 @ Gravel Stop	—	—	YES	—	—	—	—
7 @ Roof Expansion Joint	—	—	—	—	—	—	YES
8 @ Drainage System	—	YES	YES	—	—	—	—
9 @ Walls	—	—	—	—	—	—	YES
10 @ Mech. Equip.	—	—	YES	—	—	—	—
11 General Cond. of System	FAIR	FAIR	FAIR	FAIR	GOOD	GOOD	GOOD
12 Debris on Roof	—	YES	—	—	—	—	—
13 Physical Abuse	—	YES	—	YES	—	YES	—
14 No Maintenance	—	—	—	—	—	—	—
15 Ponding	YES	—	YES	YES	YES	YES	—
16 Surface Condition	FAIR	FAIR	FAIR	FAIR	GOOD	GOOD	GOOD
17 Membrane Condition	FAIR	FAIR	FAIR	GOOD	GOOD	GOOD	GOOD
18 Blistering	—	YES	—	—	—	—	—
19 Ridging	—	—	—	—	—	—	—
20 Splitting	—	—	YES	—	—	—	—
21 Slippage	—	—	—	—	—	—	—
22 Flashing Condition	FAIR	FAIR	FAIR	FAIR	GOOD	GOOD	GOOD
23 Membrane/Metal Connection	GOOD	FAIR	FAIR	GOOD	GOOD	GOOD	GOOD
24 Drainage System	GOOD	GOOD	FAIR	FAIR	FAIR	FAIR	GOOD
25 Drains Sumped	—	—	—	YES	—	—	—
26 Too Small	—	—	—	YES	—	—	—
27 With Debris	—	YES	—	—	—	—	—
28 Poorly Placed	—	—	—	YES	YES	YES	—
29 Age of Roof	1 yr. 6 mo.	4 mo.	4 mo.	2 yr. 7 mo.	6 yr. 8 mo.	2 yr. 3 mo.	3 yr. 5 mo.

Job # 8 - The flashing coating is wearing off.
Job # 9 - There was severe roof abuse - parties, etc. - minor cap sheet buckling and the counter flashing did not have enough lap.
Job #10 - The scuppers need sealing, the mechanical equipment had poor design and installation and there was some deterioration of the surface. The flashing needs coating and the gravel stop flange is lose. The splitting is in the cap sheet only.
Job #11 - There was abuse by the mechanical equipment service and the old roof was too rough for the tapered system to work.
Job #12 - Some minor aggregate thin spots.
Job #13 - The drains are located outside the valleys.
Job #14 - The roofs expansion joints are splitting badly, the counter flashing needs recaulking and reports of roof drains leaking in the past are not correct.

EXISTING ROOF CONDITIONS

Section b

ITEM:	Job Number Job Location	15 OK.	16 OK.	17 OK.	18 TX.	19 TX.	20 TX.	21 FL.
1	Leakage Reported	NO	NO	NO	NO	NO	NO	NO
2	Roof Related Leakage	—	—	—	—	—	—	—
3	@ Membrane	—	—	—	—	—	—	—
4	@ Base Flashing	—	—	—	—	—	—	—
5	@ Metal Counterflashing	—	—	—	—	—	—	—
6	@ Gravel Stop	—	—	—	—	—	—	—
7	@ Roof Expansion Joint	—	—	—	—	—	—	—
8	@ Drainage System	—	—	—	—	—	—	—
9	@ Walls	—	—	—	—	—	—	—
10	@ Mech. Equip.	—	—	—	—	—	—	—
11	General Cond. of System	FAIR	FAIR	GOOD	GOOD	GOOD	GOOD	FAIR
12	Debris on Roof	—	YES	—	YES	MINOR	YES	—
13	Physical Abuse	YES	YES	YES	YES	—	—	—
14	No Maintenance	YES	YES	YES	YES	—	—	—
15	Ponding	—	YES	MINOR	MINOR	—	—	YES
16	Surface Condition	GOOD	FAIR	GOOD	GOOD	GOOD	GOOD	FAIR
17	Membrane Condition	GOOD	FAIR	GOOD	GOOD	GOOD	GOOD	GOOD
18	Blistering	—	YES	MINOR	—	MINOR	—	YES
19	Ridging	—	—	—	—	—	—	—
20	Splitting	—	—	—	—	—	—	—
21	Slippage	—	—	—	—	—	—	—
22	Flashing Condition	POOR	FAIR	GOOD	GOOD	GOOD	GOOD	GOOD
23	Membrane/Metal Connection	GOOD	FAIR	FAIR	GOOD	GOOD	GOOD	GOOD
24	Drainage System	GOOD	FAIR	FAIR	GOOD	GOOD	GOOD	GOOD
25	Drains Sumped	—	—	—	—	—	—	—
26	Too Small	—	YES	—	—	—	—	—
27	With Debris	—	YES	—	—	—	—	—
28	Poorly Placed	—	YES	YES	—	—	—	—
29	Age of Roof	6 yr. 6 mo.	6 yr. 4 mo.	6 yr. 6 mo.	4 yr. 1 mo.	5 yr. 11 mo.	5 yr.	5 yr.

Job #15 - There was maintenance abuse (oil) to the roof and the flashing needs repairs.
Job #16 - The drains are not in the low spots, the walls are deteriorated and the mechanical equipment was poorly constructed. The edge detail has improper design, the built-up flashing is in bad shape and the gravel stop joints split.
Job #17 - Oil spillage and window washing equipment has damaged the roof. The gravel stop joints have split and the wall joints are cracking.
Job #18 - Maintenance abuse to the roof. No crickets between scuppers.
Job #19 - Minor cracks in lead sumps.
Job #21 - Coating slipping on flashing.

EXISTING ROOF CONDITIONS

Section b

ITEM:	Job Number / Job Location	22 FL.	23 FL.	24 WA.	25 WA.	26 ME.	27 ME.	28 ME.
1	Leakage Reported	NO	NO	NO	NO	NO	YES	NO
2	Roof Related Leakage	—	—	—	—	—	YES	—
3	@ Membrane	—	—	—	—	—	—	—
4	@ Base Flashing	—	—	—	—	—	YES	—
5	@ Metal Counterflashing	—	—	—	—	—	—	—
6	@ Gravel Stop	—	—	—	—	—	—	—
7	@ Roof Expansion Joint	—	—	—	—	—	—	—
8	@ Drainage System	—	—	—	—	—	—	—
9	@ Walls	—	—	—	—	—	YES	—
10	@ Mech. Equip.	—	—	—	—	—	—	—
11	General Cond. of System	GOOD	GOOD	GOOD	GOOD	FAIR	FAIR	GOOD
12	Debris on Roof	—	—	—	—	—	—	MAJOR
13	Physical Abuse	—	—	—	—	—	—	MAJOR
14	No Maintenance	—	—	—	—	YES	—	—
15	Ponding	YES	YES	—	—	—	—	—
16	Surface Condition	GOOD	GOOD	GOOD	GOOD	FAIR	GOOD	GOOD
17	Membrane Condition	FAIR	FAIR	GOOD	GOOD	FAIR	FAIR	GOOD
18	Blistering	YES	YES	—	—	—	YES	MINOR
19	Ridging	—	—	—	—	YES	—	—
20	Splitting	—	—	—	—	—	—	—
21	Slippage	—	—	—	—	—	—	—
22	Flashing Condition	GOOD	GOOD	GOOD	GOOD	GOOD	FAIR	GOOD
23	Membrane/Metal Connection	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD
24	Drainage System	GOOD	GOOD	GOOD	GOOD	FAIR	GOOD	GOOD
25	Drains Sumped	—	—	—	—	—	—	—
26	Too Small	—	—	—	—	—	—	—
27	With Debris	—	—	—	—	—	—	MINOR
28	Poorly Placed	—	—	—	—	—	—	—
29	Age of Roof	9 mo.	9 mo.	10 yr. 6 mo.	1 yr. 6 mo.	4 yr. 8 mo.	6 yr. 8 mo.	6 yr. 5 mo.

Job #22 - Lots of blisters; no leaks.
Job #23 - Lots of small blisters; no leaks.
Job #26 - Aggregate loss at corner.
Job #27 - Base flashing at wall is too low, metal wall leaks.
Job #28 - Loose gravel washed to gravel stop.

EXISTING ROOF CONDITIONS

Section b

ITEM:		29	30	31	32	33	34	35
	Job Number	29	30	31	32	33	34	35
	Job Location	ME.	SC.	SC.	SC.	SC.	ND.	ND.
1	Leakage Reported	NO	NO	NO	NO	NO	YES	NO
2	Roof Related Leakage	—	—	—	—	—	—	—
3	@ Membrane	—	—	—	—	—	—	—
4	@ Base Flashing	—	—	—	—	—	—	—
5	@ Metal Counterflashing	—	—	—	—	—	—	—
6	@ Gravel Stop	—	—	—	—	—	—	—
7	@ Roof Expansion Joint	—	—	—	—	—	—	—
8	@ Drainage System	—	—	—	—	—	—	—
9	@ Walls	—	—	—	—	—	—	—
10	@ Mech. Equip.	—	—	—	—	—	MAJOR	MINOR
11	General Cond. of System	GOOD	GOOD	GOOD	GOOD	GOOD	FAIR	GOOD
12	Debris on Roof	—	—	—	—	YES	YES	—
13	Physical Abuse	—	—	—	—	—	—	—
14	No Maintenance	—	—	—	—	—	—	—
15	Ponding	—	—	—	MINOR	YES	YES	YES
16	Surface Condition	GOOD	GOOD	GOOD	GOOD	FAIR	FAIR	GOOD
17	Membrane Condition	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD
18	Blistering	—	—	—	—	—	—	MINOR
19	Ridging	—	—	—	—	—	—	MINOR
20	Splitting	—	—	—	—	—	—	—
21	Slippage	—	—	—	—	—	—	—
22	Flashing Condition	GOOD	GOOD	GOOD	GOOD	GOOD	FAIR	GOOD
23	Membrane/Metal Connection	GOOD	GOOD	GOOD	GOOD	GOOD	FAIR	GOOD
24	Drainage System	GOOD	GOOD	GOOD	GOOD	POOR	FAIR	POOR
25	Drains Sumped	—	—	—	—	—	—	—
26	Too Small	—	—	—	—	—	—	—
27	With Debris	—	—	—	—	YES	—	—
28	Poorly Placed	—	—	—	—	—	—	—
29	Age of Roof	6 yr. 1 mo.	6 yr. 9 mo.	3 yr. 9 mo.	3 yr. 1 mo.	4 yr. 11 mo.	5 yr. 4 mo.	6 yrs.

Job #29 - Roof drain strainers missing, minor aggregate loss from wind.
Job #32 - Gravel Stop joints split but no leaks.
Job #34 - Not enough drains & the original expansion joint was flush. Is being reroofed now; some surface slippage and loss of aggregate. No crickets between drains.
Job #35 - No crickets between roof drains. Some counter flashing face not long enough. Minor aggregate loss. Minor base flashing repairs needed.

EXISTING ROOF CONDITIONS

ITEM: Job Number / Job Location	36 ND.	37 ND.	38 CO.	39 CO.	40 CO.	41 CO
1 Leakage Reported	YES	YES	NO	NO	NO	NO
2 Roof Related Leakage	YES	YES	—	—	—	—
3 @ Membrane	—	YES	—	—	—	—
4 @ Base Flashing	—	—	—	—	—	—
5 @ Metal Counterflashing	—	—	—	—	—	—
6 @ Gravel Stop	—	—	—	—	—	—
7 @ Roof Expansion Joint	YES	YES	—	—	—	—
8 @ Drainage System	—	YES	—	—	—	—
9 @ Walls	—	YES	—	—	—	—
10 @ Mech. Equip.	YES	YES	—	—	—	—
11 General Cond. of System	POOR	POOR	GOOD	GOOD	GOOD	GOOD
12 Debris on Roof	MINOR	MAJOR	—	—	—	—
13 Physical Abuse	—	MAJOR	—	—	—	—
14 No Maintenance	YES	MAJOR	—	—	—	—
15 Ponding	MINOR	YES	—	YES	—	YES
16 Surface Condition	GOOD	FAIR	GOOD	FAIR	GOOD	GOOD
17 Membrane Condition	POOR	POOR	GOOD	GOOD	GOOD	GOOD
18 Blistering	MAJOR	YES	—	MINOR	—	—
19 Ridging	—	YES	—	—	—	—
20 Splitting	YES	YES	—	—	—	—
21 Slippage	—	—	—	—	—	—
22 Flashing Condition	POOR	FAIR	GOOD	GOOD	GOOD	GOOD
23 Membrane/Metal Connection	POOR	GOOD	GOOD	GOOD	GOOD	GOOD
24 Drainage System	GOOD	POOR	GOOD	GOOD	GOOD	FAIR
25 Drains Sumped	—	—	—	—	—	—
26 Too Small	—	YES	—	—	—	—
27 With Debris	—	—	—	—	—	—
28 Poorly Placed	—	YES	—	—	—	—
29 Age of Roof	7 yr. 10 mo.	11 yr. 5 mo.	3 yr. 3 mo.	4 yr. 4 mo.	3 yr. 6 mo.	2 yr. 3 mo.

Job #36 - Original roof split - none now. Base flashing too low and roof expansion joints not raised.
Job #37 - This roof is in very poor condition - too many problems to list here.
Job #39 - No crickets between drains; two blisters on the entire roof; some holes in flashing from window washing.
Job #40 - Roof drains not elevated.
Job #41 - No crickets between roof drains.

KEY TO ABBREVIATIONS

Ac.	=	Acoustical
Adh.	=	Adhesive
Agg.	=	Aggregate
Asb.	=	Asbestos
Asph.	=	Asphalt
AI	=	Asphalt - ASTM D312 Type I
AII	=	Asphalt - ASTM D312 Type II
AIII	=	Asphalt - ASTM D312 Type III
AIV	=	Asphalt - ASTM D312 Type IV
Alum.	=	Aluminum
EPS	=	Expanded Polystyrene
Exp-O-Flash	=	Expand-O-Flash (Proprietary)
Galv.	=	Galvanized Iron
Glass	=	Fiberous Glass
Gr. Stop	=	Gravel Stop
Int.	=	Intermediate
L.W.C.	=	Lightweight Insulating Concrete
M.D.	=	Metal Deck
Mech.	=	Mechanical
Min.Surf.	=	Mineral Surface
M.M.	=	M M Systems Corporation (Proprietary)
N.R.C.A.	=	National Roofing Contractors Association
Para.	=	Parapet
P.C.	=	Poured Concrete
Per.	=	Perlite
P.G.	=	Poured Gypsum
Pre.Conc.	=	Precast Concrete
PI	=	Coal Tar Pitch - ASTM D450 Type I
R.D.	=	Roof Drain
T.	=	Tarred
Ure.	=	Urethane
W.F.	=	Wood Fiber