ARMA/NRCA Research Report on the Performance of Asphalt-Saturated Underlayment Felts

Assessment of Field Exposures of Seven Underlayment Felts at Five Sites Across the United States

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1.0 ABSTRACT

This multifaceted field and laboratory research project evaluated seven different types of asphalt-saturated underlayment felts that are typically used with steep-slope watershedding roof coverings, such as asphalt shingles. The underlayment felts were exposed to the effects of outdoor conditions on actual full-scale roofing projects in five different climatic areas of the United States.

Laboratory analysis was done initially to characterize the seven types of underlayment felts. The field research was conducted to investigate each product's performance during exposure to weathering conditions. After installation, the underlayment felts were exposed at each site for a few days with one site exposing the underlayment felts for 28 days. During exposure, data on the underlayment's susceptibility to wrinkling and buckling were recorded. The underlayment's watershedding capabilities also were examined.

The field exposures resulted in varying degrees of wrinkling of most underlayments under differential exposures (i.e., various weather conditions and orientations). A rating system was used to report the degree of wrinkling observed.

This report documents the materials included in the evaluation, the field exposure conditions, the materials' response to the exposure, and the laboratory evaluations. Conclusions are drawn as to the factors that contribute to the wrinkling or buckling, and recommendations are presented as to how to improve the underlayments' performance.

2.0 KEYWORDS

Asphalt-saturated felt, buckling, felts, field exposure, humidity, moisture, roofing, saturation, steep-slope roofs, underlayment, wrinkling.

3.0 INTRODUCTION

This report presents research on the in-situ exposure performance and comparative laboratory testing of seven different types of asphalt-saturated underlayment felts.

3.1 Purpose

The purpose of the research was to test common asphalt-saturated underlayment felts in various climatic areas of the United States to determine the products' susceptibility to wrinkling and/or buckling and to examine the felts' watershedding capabilities. The research compared laboratory data (obtained from physical property tests run on the underlayment materials) with the performance data obtained from field exposure.

3.2 Background Information

Asphalt-saturated felts have been used as underlayment in steep-slope roof systems throughout the different climatic regions of the United States for decades. Originally, the organic felts used as steep roofing underlayment were composed primarily of cotton fibers saturated with asphalt. Since the late 1940s, the majority of asphalt-saturated felts have been composed of cellulose fibers saturated with asphalt.

In recent years, there have been increasing reports of wrinkling and/or buckling problems with various types of asphalt-saturated felts. These problems have occurred during application of the asphalt-saturated felts, prior to the application of asphalt shingles over the underlayment, and after asphalt shingles have been installed.

In 1989, the National Association of Home Builders (NAHB) submitted a code change proposal to the Council of American Building Officials (CABO) and the three model building code groups (Building Officials and Code Administrators, International, Inc. [BOCA], the International Conference of Building Officials [ICBO], and the Southern Building Code Congress International, Inc. [SBCCI]). The proposal called for the elimination of the requirement to provide underlayment felt beneath asphalt shingles.[1]

In support of the proposal, NAHB presented several reasons to justify the elimination of underlayment. However, the Asphalt Roofing Manufacturers Association (ARMA) and the National Roofing Contractors Association (NRCA) viewed all but one of the reasons to be without merit. The exception was underlayment wrinkling. Instead of eliminating the underlayment to solve the wrinkling problem, ARMA and NRCA recommended that underlayments comply with applicable ASTM standards and further recommended that these standards be re-evaluated.

ARMA and NRCA opposed NAHB's proposal. The proposal was disapproved by the three code bodies, and NAHB withdrew the proposal from the fourth body. Following defeat of the proposal, NAHB expressed a willingness to meet with ARMA and NRCA. The meeting occurred in 1990, with the primary issue being the variable performance of the underlayments with respect to wrinkling. ARMA and NRCA followed up by initiating a joint research project, which began with detailed project planning in 1991.

This research was undertaken by ARMA and NRCA with the primary goal of identifying the nature and cause of the wrinkling and buckling problems and then attempting to recommend solutions to the steep-slope roofing industry.

3.3 Summary of Literature Survey

In general, there have not been many articles or research reports written about underlayment felts as they relate to steep roofing applications. However, there is a wealth of research and associated reports on organic felts used in roofing. In the 1950s and 1960s, several government agencies, academic institutions, and private individuals conducted various research programs on organic felts. These reports were prompted by the increase of premature built-up roof failures being experienced within a few years after installation. At that time, the researchers focused attention on the felts used as the reinforcing plies—namely organic, asbestos, and, to a limited extent, glass fiber plysheets—for built-up roofing.

The correlation between the historic research on built-up roofing ply felts and the organic felts currently used for steep roofing underlayments is that they are used in similar applications today. However, composition of the products has been changed over the years because of raw material supply differences.

A literature survey encompassed 21 references dating from 1929 to 1993. Asphalt-saturated organic felt was the predominant review subject because it is the product used most frequently for shingle underlayment materials. The majority of authors described research results and often related them to performance experience. Most papers discussed cause and effect(s) of the asphalt-saturated organic felt's changing moisture content on the felt's performance in various roofing applications. This moisture change in organic felts causes dimensional changes. Of importance is that the researchers of the 1950s and 1960s noted the impact that the percent of bitumen saturation and moisture absorption had on the organic felts.

The literature survey revealed that felt composition has changed constantly throughout the materials' history. The researchers described changes in the various types of wood, rag, and paper fibers used to produce the base felts. They related how the base felt is saturated with asphalt to produce the finished asphalt-saturated organic felt product, the major component of asphalt shingles, built-up roofing organic ply felts, and shingle underlayments. The fibers of the base felt are hygroscopic, causing the felt to expand and shrink as the fibers absorb and lose moisture under changing moisture conditions. The literature related how asphalt saturants protect the base felt's fibers, thus decreasing their ability to take on moisture. The authors concluded that the more thorough the bitumen saturation, the less movement is likely to occur under changing ambient moisture conditions.

In brief, the consensus among the authors clearly demonstrates that moisture changes in organic felts result in dimensional changes of the material, often resulting in wrinkling and/or buckling. In general, the conclusion is that these changes are functions of the base felt's ability to hold asphalt (i.e., kerosene value and, therefore, saturation efficiency) and the amount of asphalt saturant in the base felt (i.e., percent saturation). The literature concludes that deficiencies in saturation efficiency and percent saturation are key to the dimensional changes experienced under changing moisture conditions. Some authors suggested minimum percent saturation of 140 percent and minimum saturation efficiency of 70 percent.

As early as 1959, K. G. Martin recommended to the industry that performance tests be used in standards for felt products. He even offered a *Laboratory Shrinkage Test for Saturated Felts*.[2]

The previous research work cited herein provides some revealing data, similar conclusions among several researchers, and proposed recommendations. A complete discussion of the literature survey can be found in Appendix D. The following points can be drawn from the previous research:

- The actions of the saturated felts (e.g., expanding, shrinking, ridging, and wrinkling) are caused by changes in moisture content.[2,3,4,5,6,7]
- When moisture penetrates a saturated felt, the felt swells and subsequently shrinks upon drying out.[2,3,4,5,8]
- Moisture causes a higher degree of movement in the cross-machine direction (width) of the saturated felts compared with the machine direction (length).[2,5,6,7,9]
- Coefficient of linear thermal expansion obtained in the cross-machine direction (width) of the saturated felts is appreciably greater than that obtained in the machine direction (length).[10]
- Moisture absorption, if accomplished nonuniformly throughout a roll of saturated felt, also can lead to temporary or permanent distortions of the saturated felt.[8]
- Failure of 1950s 210-lb. organic asphalt shingles was found to be caused by alternating cycles of wetting and drying of the undersaturated organic base felt, which resulted in the distortion of the shingle.[4]
- Saturated felts are not truly saturated, because they contain small voids with only 75 percent of the volume of voids filled in organic felts.[11]
- Saturated felts move in response to both temperature and humidity variations.[6]
- Thermal movement is not linear with temperature but increases as the temperature is decreased for saturated felts.[10]
- Humidity changes are so great relative to temperature changes that they predominate and often obscure the thermal effect for saturated felts.[6,7]
- Test data indicate that complete equilibrium in regard to moisture content of saturated felts exposed to a constant relative humidity is approached very slowly. On a roof, because the weather is never a constant, it is unlikely that saturated felts are ever in a state of equilibrium.[6]
- While exposure to moisture is a factor, duration of exposure is often the most significant factor that affects performance of the saturated felts.[7]
- Saturated felts respond promptly to changes in relative humidity, regardless of temperature, between -20°F (-29°C) and 160°F (71°C).[7]

- The motion of saturated felts depends on the moisture history and the duration of changed environment.[7]
- There are difficulties in achieving complete saturation commercially so compromise saturations are required. Commercially, a saturation of 195 is realistic.[8]
- Moisture content [at time of manufacture] has to be 3 percent minimum and 7 percent maximum for asphalt-saturated organic felts.[8]
- Data shows that saturated felts respond rapidly to changes in relative humidity.[7]
- At all relative humidities, moisture absorption proceeded rapidly.[8]
- "Equilibrium" moisture content decreased as the saturation of the felt was increased.[8]
- "Equilibrium" moisture content increased with the relative humidity to which the felts were exposed.[8]
- Saturated felt, as it is furnished, is not protected from moisture entrance and swelling.[5]
- Organic fiber felts with all voids full of bitumen still will absorb water and swell, and poorly saturated felts, therefore, are likely to swell to a greater extent.[12]
- Even most highly saturated felts in this study absorbed moisture.[8]
- It is necessary to front- and back-coat roofing products to isolate and protect the felts from moist environments.[8]
- Even under the most favorable conditions, only 82 percent of the theoretically possible saturation was attained. [8]

3.4 Underlayment Use in the United States

With most types of watershedding roof systems, the underlayment is an important component and should not be overlooked for inclusion within steep-slope roof systems. Underlayment may be composed of various types of materials. However, in the United States, the vast majority of steep-slope projects use asphalt-saturated felt as the predominant underlayment material.

Following are the primary reasons for using underlayments with steep-slope roof systems:

- Underlayment provides protection from moisture for the roof deck during construction.
- It provides secondary protection for the building in case the primary roof covering is damaged or blown off.
- It sheds water in case of moisture migration (e.g., wind-driven rain) into the finished roof system.
- It is a component in the tested assembly of many roof coverings that have a Class-A fire rating.
- The three model building codes require the use of underlayment.

On lower slope projects and projects in severe climates, the underlayment can be extremely critical for long-term successful roof system performance.

In general, however, in order for the underlayment to help the roof to perform successfully, the underlayment material must:

- be capable of shedding water
- be able to withstand roof system temperatures without premature degradation
- remain durable within the roof assembly so that it can function for the life of the roof system
- not telegraph minor irregularities in underlying deck construction
- be relatively traffic resistant and safe to traffic over during roof construction

In order to perform the above functions, one additional characteristic is important: it must lay relatively flat, not wrinkled or buckled.

3.5 Project Limitations

This particular research project was quite complicated, involving numerous variables, with many different persons performing important functions. Complicated research with variables usually means that there will be limitations with the study.

Because this research involved full-scale exposure of the underlayment felts in several climatic and geographic regions of the United States, many variables were an accepted part of the study. In order to compare laboratory-tested physical properties of the felts with actual documented performance in the field, certain variables and limitations must be tolerated.

This research project focused primarily on the issues of wrinkling, buckling, and watershedding capabilities of the underlayments commonly being used (and reported as sometimes being problematic) in the United States. To allow the results of this study to be utilized accurately, it is important to realize the project's limitations. Following is a list of some of these limitations:

- The research did not include all of the different construction conditions where underlayments may be applied.
- Weathering conditions that the felts were exposed to were not all-inclusive.
- Materials tested did not include all of the different asphalt-saturated underlayment formulations that can be produced and are in use today.
- Underlayment exposure was conducted on relatively large roofing projects. (This was done so anomalies in materials would be lesser.)

- Actual exposure in-situ on roofs in different climates is not the same as a controlled laboratory environment.
- Evaluations of dimensional change in the materials (i.e., extent of wrinkling) were difficult to quantify because of the evaluators' subjectivity in assigning a rating (variances due to human choice) and evaluations occurring at different times of the day (differences in performance from morning to afternoon were documented in some instances).
- A fastening pattern for the underlayment felts was not prescribed because each site needed a case-by-case evaluation, based on slope and other important factors.

3.6 Summary of Testing Protocol

To limit the variables in this research, a testing protocol was developed by ARMA's and NRCA's residential/steep roofing committees. This testing protocol outlined the items involved in the study, and the various criteria important for the success of the research. The following is a brief list of the items included in the protocol:

- geographical areas where the fieldwork would be conducted
- acceptable roof slopes
- acceptable substrates
- the seven types of underlayment felts to be tested
- the acceptable installation exposures (e.g., acceptable roof deck area or size, opposing exposures to the weather, etc.)
- application particulars, such as alignment of felts, etc.
- data collection intervals and how moisture readings and samples would be taken
- examination of samples

For further specifics regarding the testing protocol, refer to Appendix A of this report.

4.0 LABORATORY TESTING

The underlayment felts for this test project were donated by several ARMA member manufacturers and were selected to provide a sampling of the types of products available to the market. These included products that were manufactured to meet each of the two existing ASTM specifications, products that were non-classified†, and one glass-fiber-reinforced product that is unique.

The two ASTM standard specifications that currently apply to the felts used for shingle underlayment are ASTM D 226-89, titled "Standard Specification for Asphalt-Saturated Organic Felt Used in Roofing and Waterproofing"[13] and ASTM D 4869-88 (Reapproved 1993), titled "Standard Specification for Asphalt-Saturated Organic Felt Shingle Underlayment Used in Roofing"[13]. These specifications are similar, but not identical, in their requirements. As the titles state, D 226 covers a broader range of uses for felts while D 4869 specifically relates to underlayment used with asphalt shingles. Refer to the ASTM standard specifications for specific differences each has in the test methods and criteria included.

Each specification identifies two types of products, Type I and Type II††, which are more commonly referred to today as No. 15 and No. 30, respectively. Historically, these products were referred to as 15 pound and 30 pound felts because, per square, the felts actually weighed that much. A product readily available on the market was selected for each category and type.

The following table lists the products selected and the designation key to be used for reviewing the test results:

SAMPLE	CATEGORY
A30	Non-classified, Type II†
B15	ASTM D 226, Type I
C15	Non-classified, Glass-fiber-reinforced†
D15	ASTM D 4869, Type I
E30	ASTM D 4869, Type II
F15	Non-classified, Type II
G30	ASTM D 226, Type II

† Non-classified products are those materials that are manufactured in the same manner as the ASTM labeled products except that the material may not have the same physical properties that the ASTM standard requires.

†† Type I refers to all No. 15 products (non-classified, D 226 and D 4869) and Type II refers to all No. 30 products (non-classified, D 226 and D 4869).

4.1 Summary of Laboratory Testing

Four laboratories participated in the evaluation of the underlayments used in this project. In addition to the test methods outlined in the ASTM standards already noted, a proposed ASTM method for measuring the effect of moisture also was utilized. This method, titled "Standard Method of Test for Moisture Conditioning and Related Testing of Roofing Felts and Membranes"[14] calls for water immersion of the specimens for an extended period of time and subsequent measurement of the moisture, dimensional gain, and tensile strength. This method is intended for use as a research tool in evaluating roofing felts, and the results included here should be interpreted accordingly. However, this type of test could be developed into a performance test for use in future ASTM material standards for underlayment felts.

The laboratory results are summarized in the tables and graphs of Section 4.2. The graph presentations also can be used for a comparison with the ASTM physical property criteria. These results are discussed in the following paragraphs.

Finished Weight/Mass of Saturated Felt/Mass of Saturant: The finished weight, mass of saturated felt, and mass of saturant specifications were met by Samples B15, D15, and G30, but Sample E30 fell short of the criteria for ASTM D 4869. The results of these measurements also were used to calculate the saturation efficiency and percent saturation, which are important properties in regard to wrinkling. Again, all of the ASTM products met the criteria, except Sample E30. It is interesting to note that the non-classified products, except Sample C15, met the ASTM D 4869 criteria for saturation efficiency and percent saturation.

Percent Loss on Heating: Loss on heating is a measure of the volatiles in the product that are removed when the underlayment is exposed for five hours at a temperature of 221°F (105°C), minus the amount of moisture present, as measured by the solvent extraction test. The requirement is the same for both ASTM specifications. All of the products, except Sample C15, met the criteria. Of course, the ASTM specifications do not apply to Sample C15 because it is a non-classified, glass-fiber-reinforced product.

Kerosene Number: Kerosene number is a measure of the amount of kerosene held per 100 grams of felt and relates to the saturating capacity of the felt for any bituminous saturant. It is another property that is known to be related to moisture absorption and wrinkling performance. Neither ASTM specification lists a required value for this property, but the measured values are reported here, for information and comparison.

Percent Moisture Criteria: By reviewing the data, it can be observed that neither of the D 4869 felts met the percent moisture criteria; however, this criteria applies to material as manufactured, and these measurements were made after shipment and sample cutting. Therefore, the results are not surprising and should not be cause for concern. However, a test could be developed, for future standards, that could be applied after manufacture under restricted conditions of exposure.

Percent Ash Criteria: All of the products met the percent ash criteria specified in ASTM D 226 and ASTM D 4869.

Tensile Strength and Pliability: Tensile strength and pliability are indicators of an underlayment's ability to resist damage during application or under wind stress conditions. ASTM D 4869 does not have a requirement for tensile strength. All of the products essentially met the ASTM D 226 criteria for both directions: with the fiber grain and across the fiber grain. Note that the underlayments exhibit anisotropic tensile properties; that is, they do not have the same properties in both directions. This is not unusual and is done by design for various manufacturing or field requirements. Also, all samples passed the pliability test.

Tear Resistance: Tear resistance is another property that relates to application and wind stress performance. It is specified in ASTM D 4869, but not in ASTM D 226. Examination of the data shows that all of the products exceeded the specified tear resistance criteria.

Percent Linear Gain/Percent Moisture Gain: As noted earlier in this report, a proposed ASTM method was used to evaluate the changes in moisture, tensile strength, and dimensions after exposure to water for an extended period of time. These properties also are not included in the ASTM specifications but are reported here for information. Dimensional stability plays a major role in providing smooth, uniform, and stable underlayment prior to and after shingles are applied. Caution should be taken when using the reported results, because the test method is not officially established as a standard. In fact, some manufacturers believe the exposure time in this study is extraordinarily long. In any case, the results for all products indicate a substantial drop in tensile strength, a substantial moisture gain, and a small dimensional gain, especially in the machine direction.

Water Transmission Test: The water transmission test is another test specified in ASTM D 4869 but not in ASTM D 226. This test method measures the ability of the shingle underlayment to resist the transmission of water and visible deterioration. Note that two of the Type I felts (D15 and F15) failed the water transmission test. Upon further inspection of the test specimens, one of these had obvious pinholes, which is a defect and can be cause for concern.

Summary: Generally speaking, the selection of underlayment samples met the objective for the project, which was to have a sampling of the products available on the market and a range of properties for comparison with the field results. One exception is that Sample E30 did not meet several of the criteria for ASTM D 4869, Type II, as intended. Sample A30 (non-classified, Type II) and Sample E30 were very similar in laboratory measured properties.

Although samples were taken from the underlayment felts after exposure, there was no laboratory testing done on these samples.

The laboratory results clearly demonstrate that the properties of the seven underlayment materials varied widely notwithstanding the fact that all products are expected to perform the same function as shingle underlayments.

4.2 Tabulation of Laboratory Results

- FROM DATA REPORTED BY THE PARTICIPATING ARMA LABORATORIES

Type I (No. 15) Products:

Physical Properties Test Method	ASTM D 226 Value	ASTM D 4869 Value	B15 (D 226)	D15 (D 4869)	F15 (N-C)†	C15 (N-C)†
Tensile: Average breaking strength, min. lbf/in. of width (ASTM D 146):						
With fiber grain	30	n/a	44.5	47.00	39.1	40.4
Across fiber grain	15	n/a	23.8	26.4	13.5	16.1
Pliability at 77°F (25°C) over ½ in. radius (ASTM D 146):	100	100	100	100	100	100
Loss on heating at 221°F (105°C) for 5 hours, max. %	4	4	2.4	3.5	3.7	4.8
Moisture, max. % at time of manufacture (ASTM D 95) [Note: measured after delivery]	4.3	2.0	2.7	4.4	3.2	3.4
Net mass of saturated felt, min., lb/100 ft²	11.5	8.0	13.21	10.08	9.05	7.2
Mass of saturant, min., lb/100 ft²	6.2	4	7.77	5.59	5.01	2.7
[Implied calculation: Mass of saturantshould not be less than 1.2 times mass of dry (desaturated) felt.]						
$1.2 \times w_{df}$	[6.24]	n/a	[6.528]	[5.388]	[4.848]	[5.4]
Mass of desaturated felt, min., lb/100 ft²	5.2	4.0	5.44	4.49	4.04	4.5
Ash, max. %	10.0	10.0	9.9	2.5	2.9	9.6

† (N-C) represents Non-Classified.

Type I (No. 15) Products: [continued]

Physical Properties Test Method	ASTM D 226 Value	ASTM D 4869 Value	B15 (D 226)	D15 (D 4869)	F15 (N-C)[†]	C15 (N-C)[†]
Saturation efficiency [D 4869 value implied from D 226 k]	70%	[58%]	76	72	69	43
Percent saturation	120%	100%	143	124	124	60
Elmendorf Tear Resistance (ASTM D 689) grams						
MD	n/a	200 (0.44 lbf)	391	469	305	270
CD	n/a	200 (0.44 lbf)	448	511	394	340
Water transmission	n/a	pass	pass	fail	fail	pass
Water vapor transmission, min., permeance, perm	n/a	5	NOT TESTED			
Kerosene number [171.5 implied in D 226]	n/a	n/a				
ASTM D 727 [reported]			189	172	180	141
UL 55B [calculated]			[195.6]	[178.02]	[186.3]	[145.9]
b=wt. of kerosene absorbed plus felt [12.33 implied] [calculated from D 727 k number]			[13.66]	[10.66]	[9.85]	[9.57]
Asphalt capacity (k (d/c)) d/c=1.29375 [using ASTM k]			[244.5]	[222.5]	[232.9]	[182.4]
Saturating capacity d x k [using ASTM k]			[195.6]	[178.02]	[186.3]	[145.9]
Tensile (after moisture conditioning)						
MD			21.5	15.1	18.3	14.5
CD			10.5	8.8	6.7	5.1
Percent Moisture Gain (after moisture conditioning)						
MD			47.9	65.5	51.0	79.7
CD			50.8	64.0	51.3	82.0
Percent Dimensional Gain (after moisture conditioning)						
MD			0.05	0.20	0.27	0.26
CD			1.17	1.75	2.32	1.89

Note: Values in brackets [ ] are implied or are calculated using a value obtained by working a formula backwards from a reported result.

Implied k for D 226:

$$k = \frac{\text{percent saturation}}{\text{saturation efficiency}/100}$$

[†] (N-C) represents Non-Classified.

Type II (No. 30) Products:

Physical Properties Test Method	ASTM D 226 Value	ASTM D 4869 Value	G30 (D 226)	E30 (D 4869)	A30 (N-C)[†]
Tensile: Average breaking strength, min. lbf/in. of width (ASTM D 146):					
With fiber grain	40		65.0	56.2	75.2
Across fiber grain	20		39.9	21.3	34.5
Pliability at 77°F (25°C) over ¾ in. radius (ASTM D 146):	100	100	100	100	100
Loss on heating at 221°F (105°C) for 5 hours, max. %	4	4	3.3	3.9	3.8
Moisture, max. % at time of manufacture (ASTM D 95) [Note: measured after delivery]	4.1	2.0	3.4	4.6	4.00
Net mass of saturated felt, min., lb/100 ft²	26	20	26.35	17.42	15.7
Mass of saturant, min., lb/100 ft²	15.0	10.8	15.99	9.16	8.35
[Implied calculation: Mass of saturant should not be less than 1.5 times mass of dry (desaturated) felt.] $1.5 \times w_{df}$	[15.0]	n/a	[15.54]	[12.39]	[11.02]
Mass of desaturated felt, min., lb/100 ft²	10.0	9.0	10.36	8.26	7.35
Ash, max. %	10.0	10.0	3.9	1.2	3.3

[†] (N-C) represents Non-Classified.

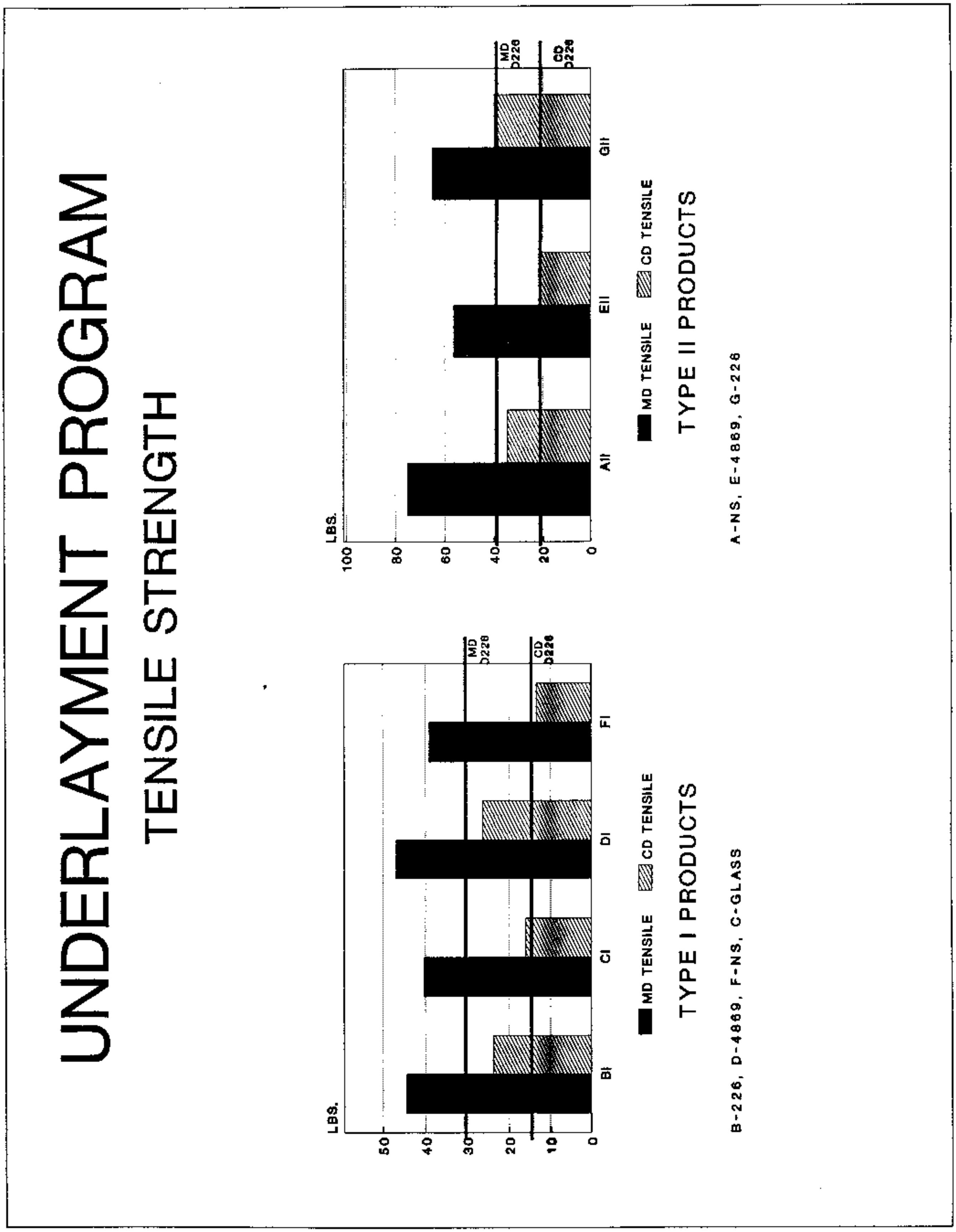
Type II (No. 30) Products: [continued]

Physical Properties Test Method	**ASTM D 226 Value**	**ASTM D 4869 Value**	**G30 (D 226)**	**E30 (D 4869)**	**A30 (N-C)**[1]
Saturation efficiency [D 4869 value implied from D 226 k]	70%	[56%]	74	60	65
Percent saturation	150%	120%	154	111	143
Elmendorf Tear Resistance (ASTM D 689) grams					
MD	n/a	400 (0.88 lbf)	864	720	584
CD	n/a	400 (0.88 lbf)	948	914	658
Water transmission	n/a	pass	pass	pass	pass
Water vapor transmission, min., permeance, perm	n/a	3	NOT TESTED		
Kerosene number [214.3 implied in D 226]	n/a	n/a			
ASTM D 727 [reported]			208	184	175
UL 55B [calculated]			[215.29]	[190.46]	[181.13]
b=wt. of kerosene absorbed plus felt [27.14 implied] [calculated from D 727 number]			[27.6]	[20.42]	[17.64]
Asphalt capacity (k (d/c)) d/c=1.29375 [using ASTM k]			[269.1]	[238.05]	[226.41]
Saturating capacity d x k [using ASTM k]			[215.28]	[190.44]	[181.13]
Tensile (after moisture conditioning)					
MD			26.5	25.5	20.3
CD			15.0	9.1	11.2
Percent Moisture Gain (after moisture conditioning)					
MD			55.0	70.4	69.5
CD			55.0	71.9	67.0
Percent Dimensional Gain (after moisture conditioning)					
MD			0.07	0.45	0.33
CD			0.68	2.03	1.36

Note: Values in brackets [ ] are implied or are calculated using a value obtained by working a formula backwards from a reported result.

Implied k for D 226: $k = \frac{\text{percent saturation}}{\text{saturation efficiency}/100}$

[1] (N-C) represents Non-Classified.


UNDERLAYMENT PROGRAM
TENSILE STRENGTH
LBS.
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10
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TYPE I PRODUCTS
B-226, D-4869, F-NS, C-GLASS
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100
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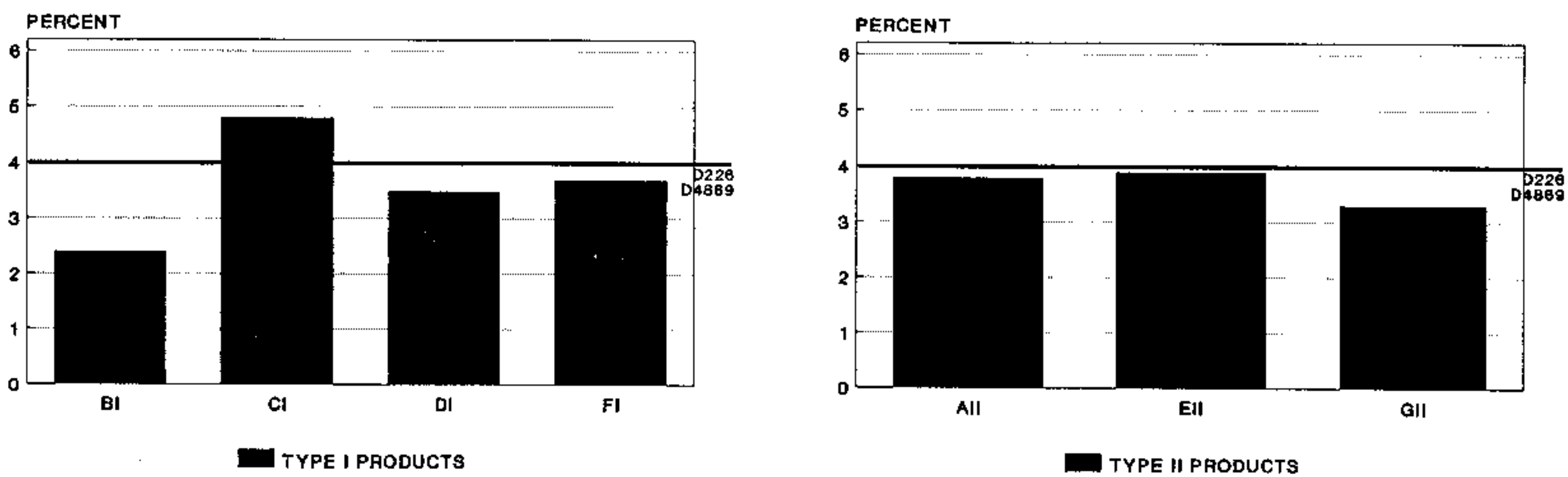
A-NS, E-4869, G-226

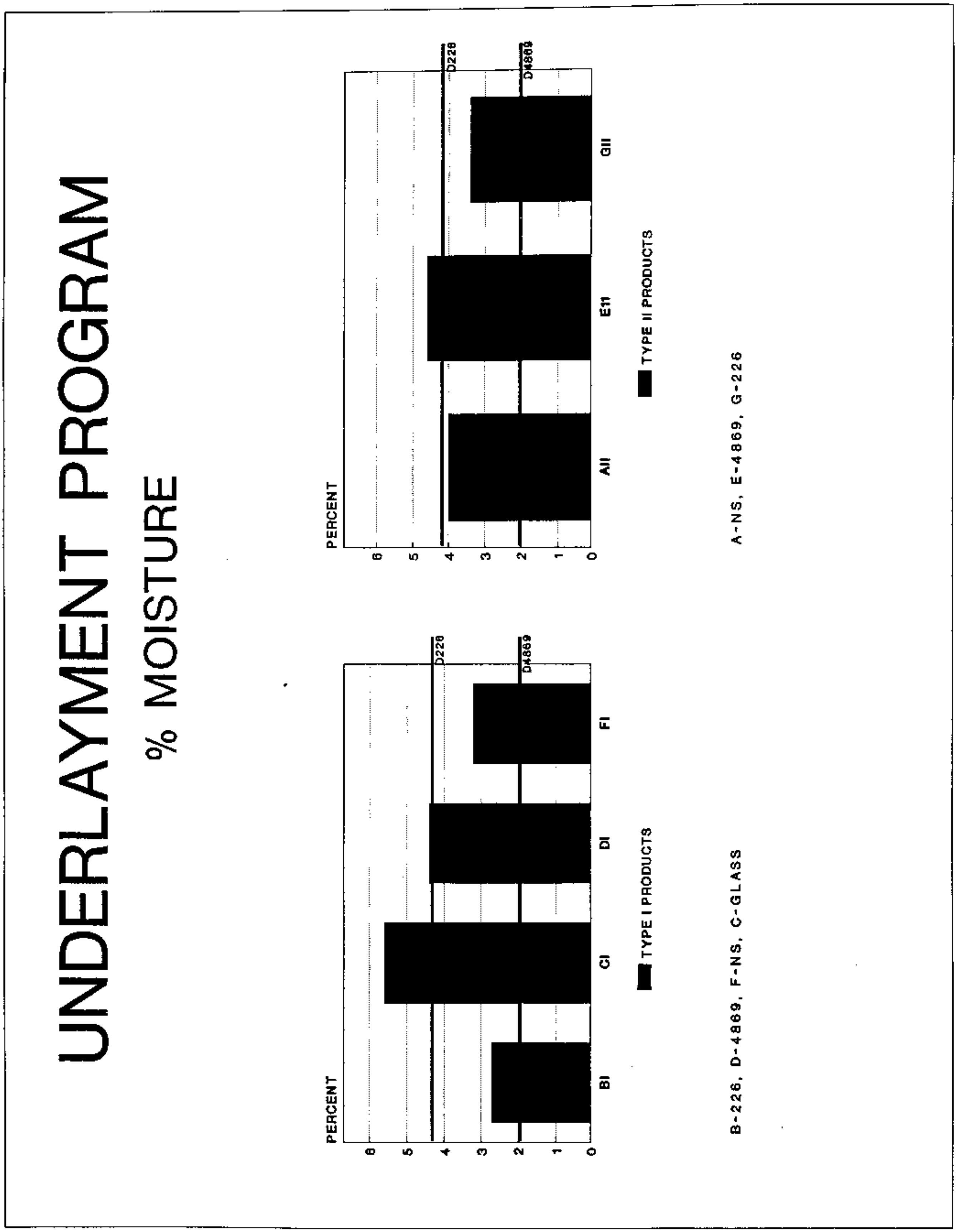
UNDERLAYMENT PROGRAM

% LOSS ON HEATING



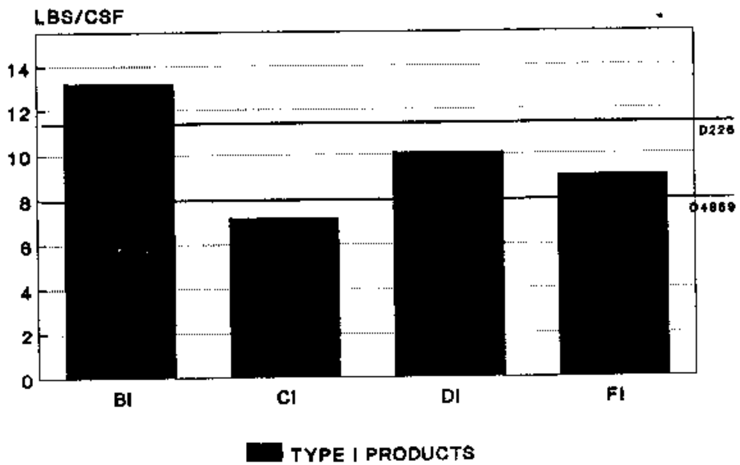
B-226, D-4869, F-NS, C-GLASS

A-NS, E-4869, G-226

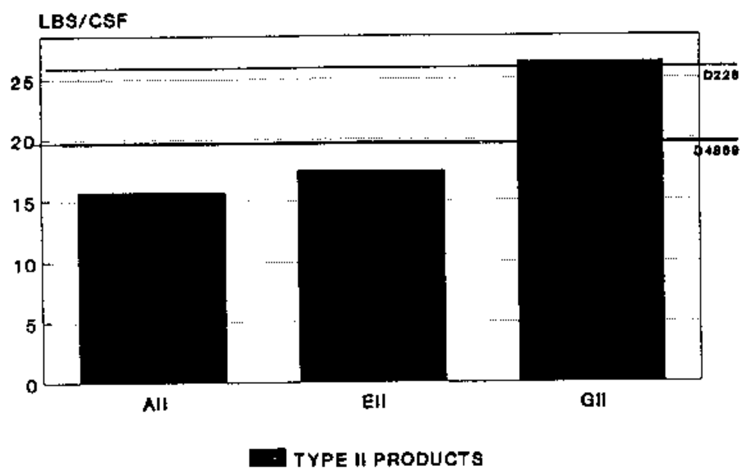

UNDERLAYMENT PROGRAM
% MOISTURE
PERCENT
0
1
2
3
4
5
6
BI
CI
DI
FI
D226
D4869
TYPE I PRODUCTS
B-226, D-4869, F-NS, C-GLASS
PERCENT
0
1
2
3
4
5
6
AII
E11
GII
D226
D4869
TYPE II PRODUCTS
A-NS, E-4869, G-226

UNDERLAYMENT PROGRAM

Finished Weight, Lbs./CSF



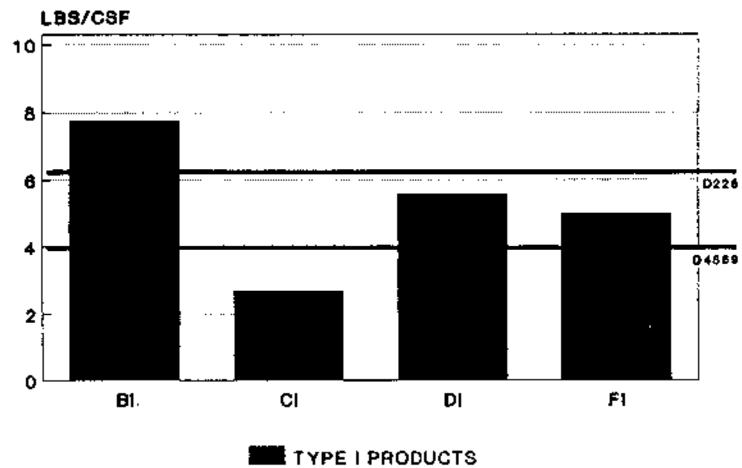
B-226, D-4869, F-NS, C-GLASS



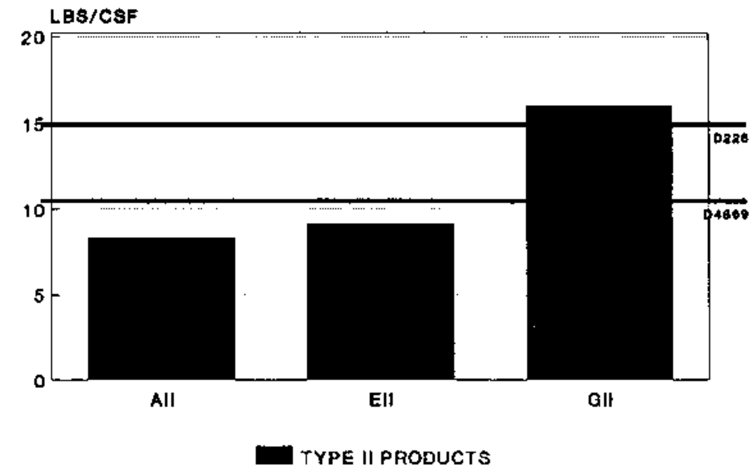
A-NS, E-4869, G-226

UNDERLAYMENT PROGRAM

Saturant Mass, CSF



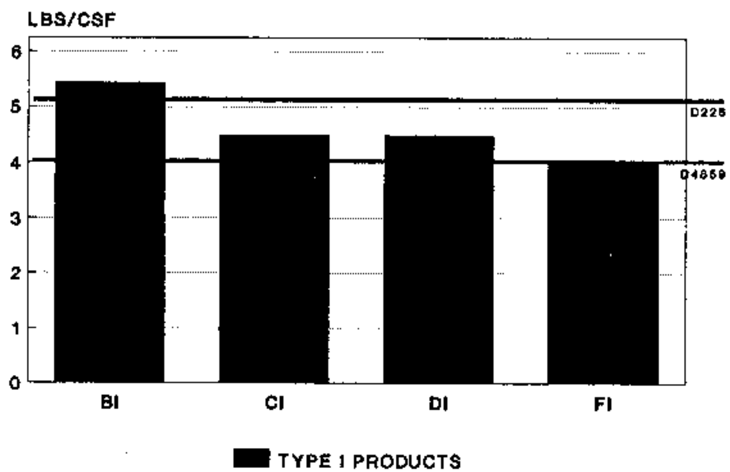
B-226, D-4869, F-NS, C-GLASS



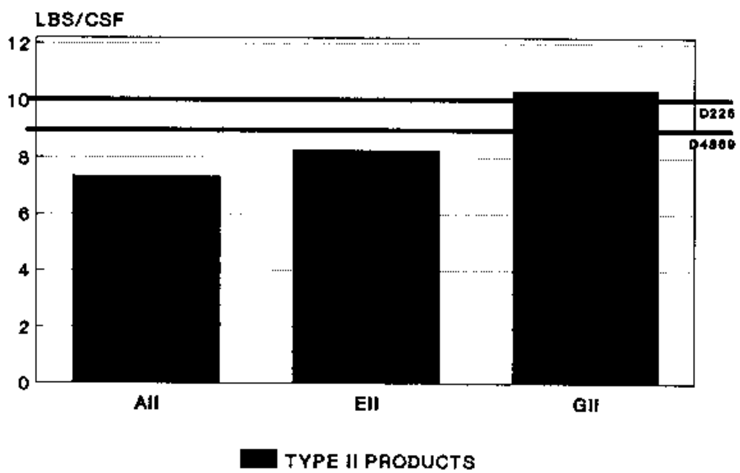
A-NS, E-4869, G-226

UNDERLAYMENT PROGRAM

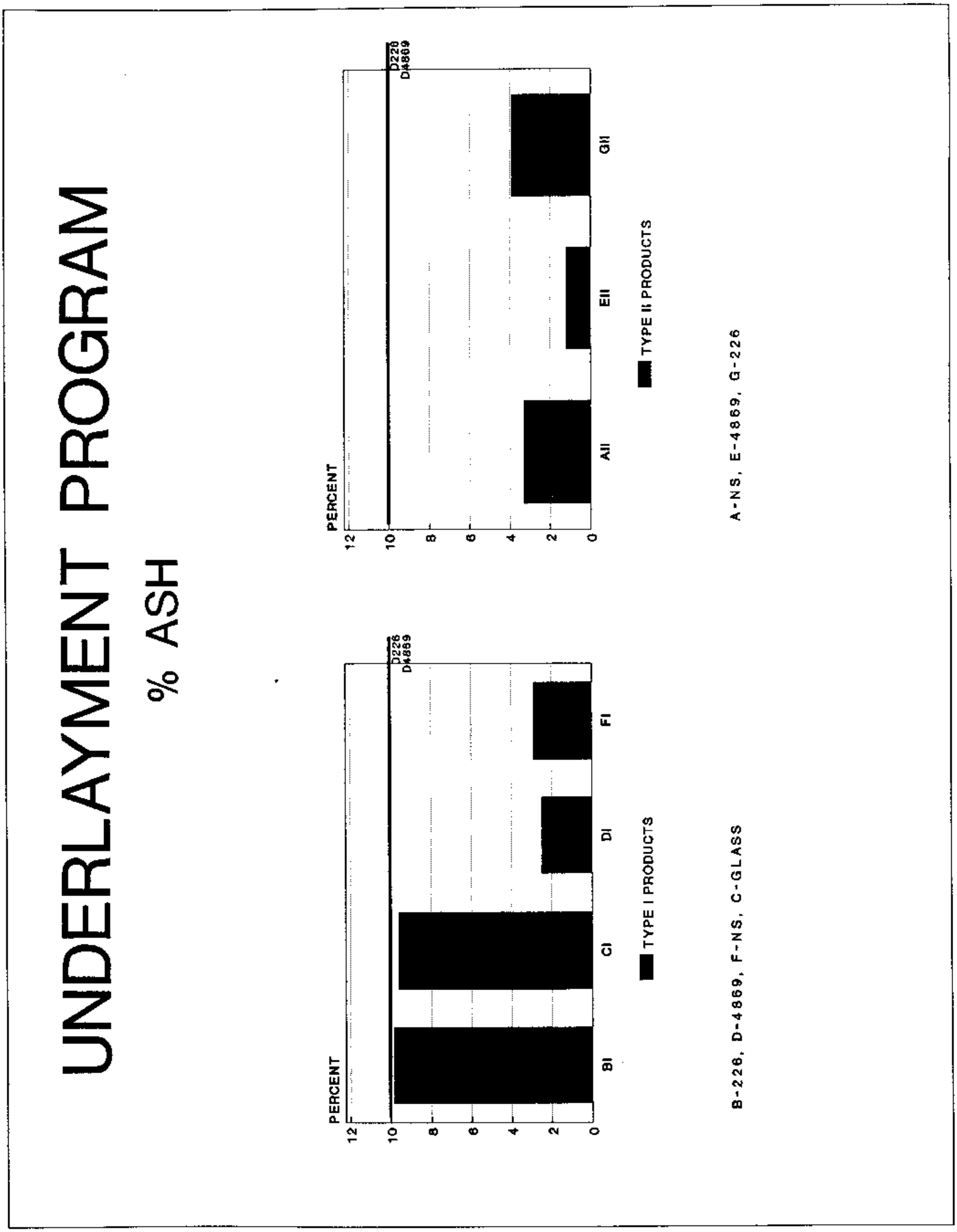
DRY FELT WEIGHT/ CSF

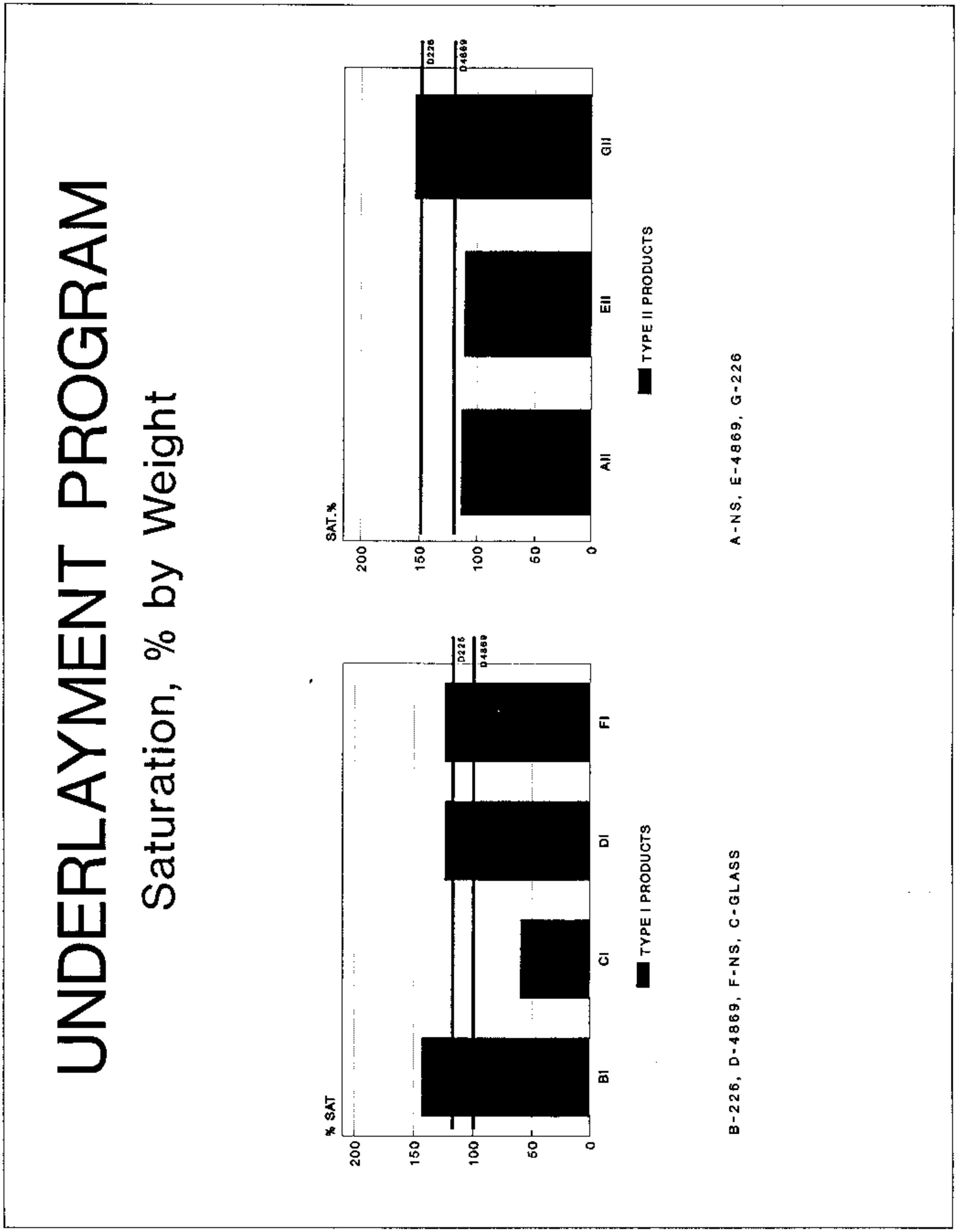


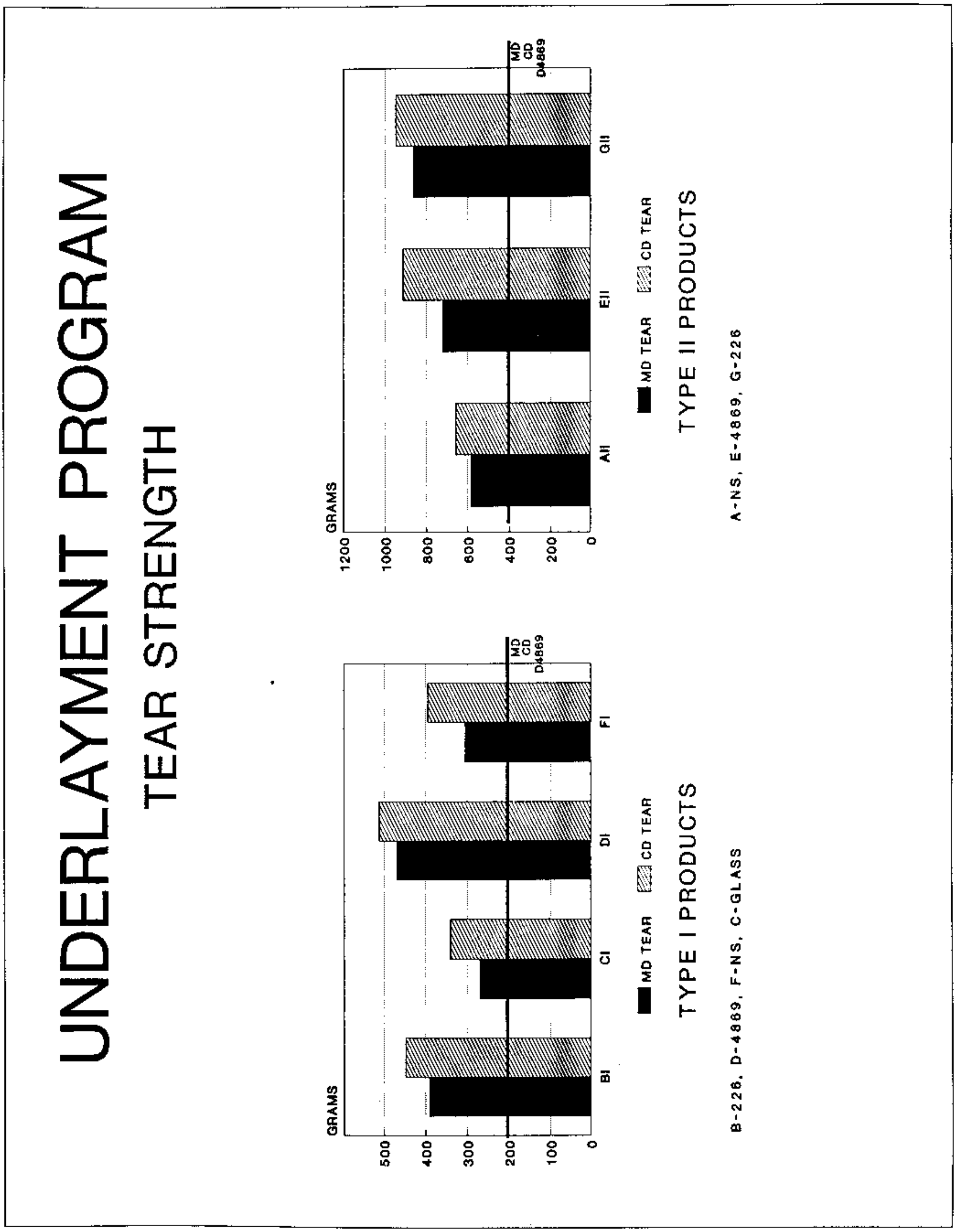
B-226, D-4869, F-NS, C-GLASS



A-NS, E-4869, G-226

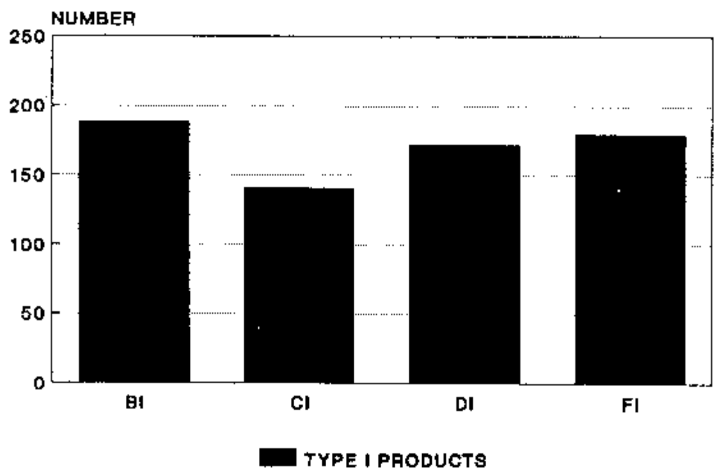

UNDERLAYMENT PROGRAM
% ASH
PERCENT
12
10
8
6
4
2
0
D226
D4869
BI
CI
DI
FI
TYPE I PRODUCTS
B-226, D-4869, F-NS, C-GLASS
PERCENT
12
10
8
6
4
2
0
D226
D4869
AII
EII
GII
TYPE II PRODUCTS
A-NS, E-4869, G-226


UNDERLAYMENT PROGRAM
Saturation, % by Weight
% SAT
200
150
100
50
0
D226
D4869
BI
CI
DI
FI
TYPE I PRODUCTS
B-226, D-4869, F-NS, C-GLASS
SAT.%
200
150
100
50
0
D226
D4869
AII
EII
GII
TYPE II PRODUCTS
A-NS, E-4869, G-226

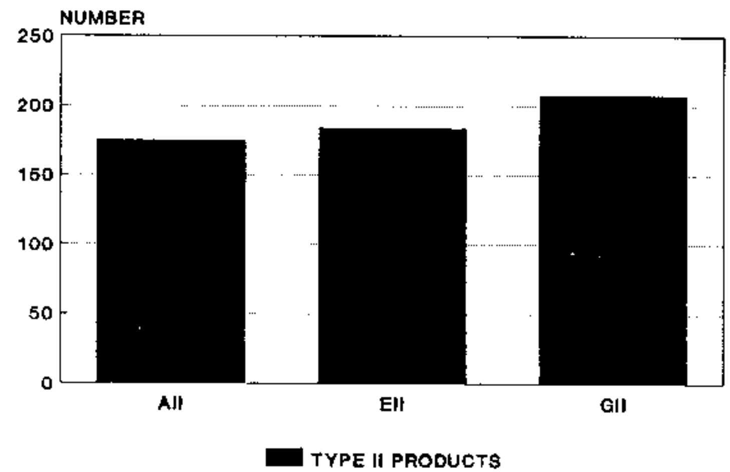

UNDERLAYMENT PROGRAM
TEAR STRENGTH
GRAMS
500
400
300
200
100
0
BI
CI
DI
FI
MD
CD
D4869
MD TEAR
CD TEAR
TYPE I PRODUCTS
B-226, D-4869, F-NS, C-GLASS
GRAMS
1200
1000
800
600
400
200
0
AII
EII
GII
MD
CD
D4869
MD TEAR
CD TEAR
TYPE II PRODUCTS
A-NS, E-4869, G-226

UNDERLAYMENT PROGRAM

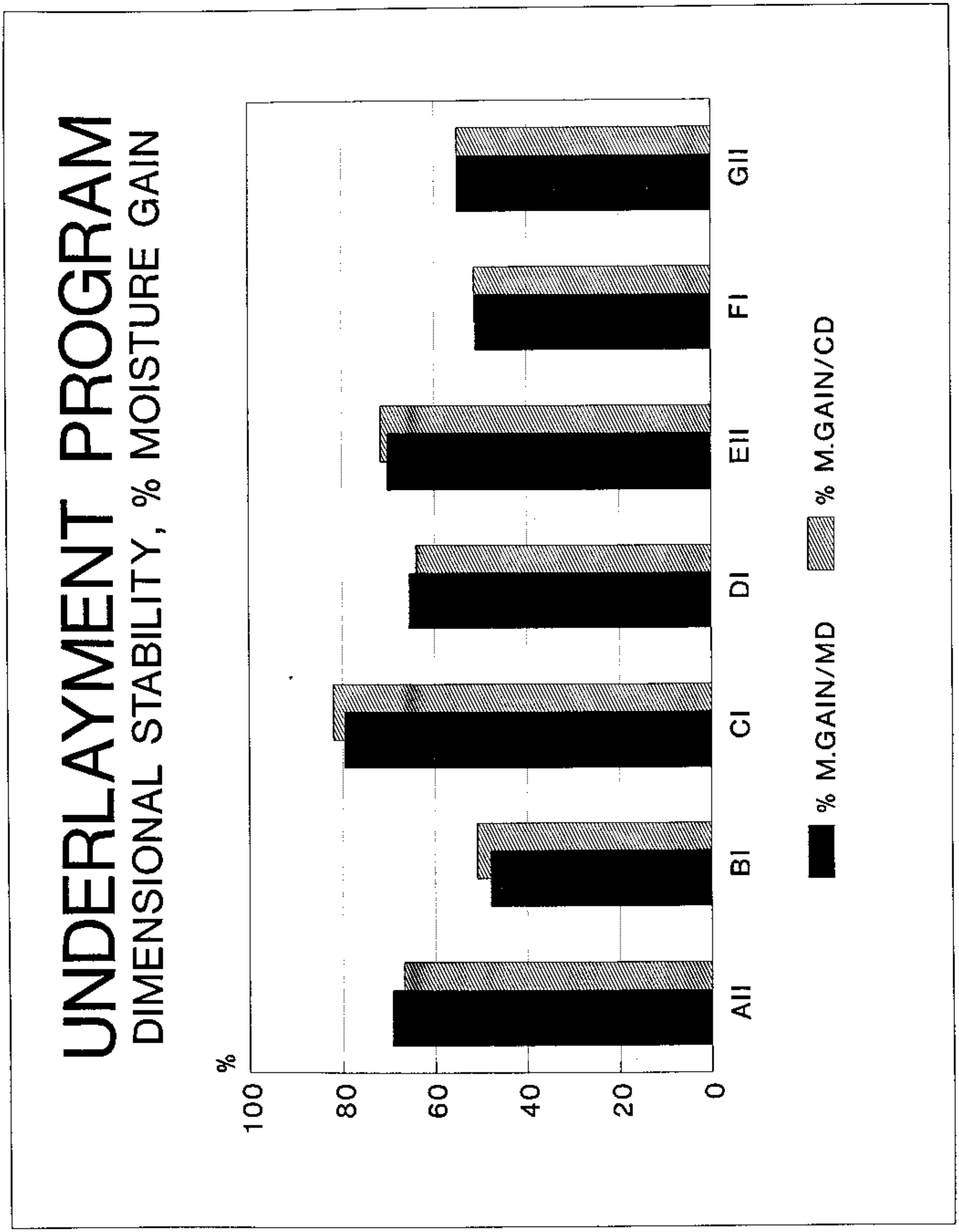
KEROSENE

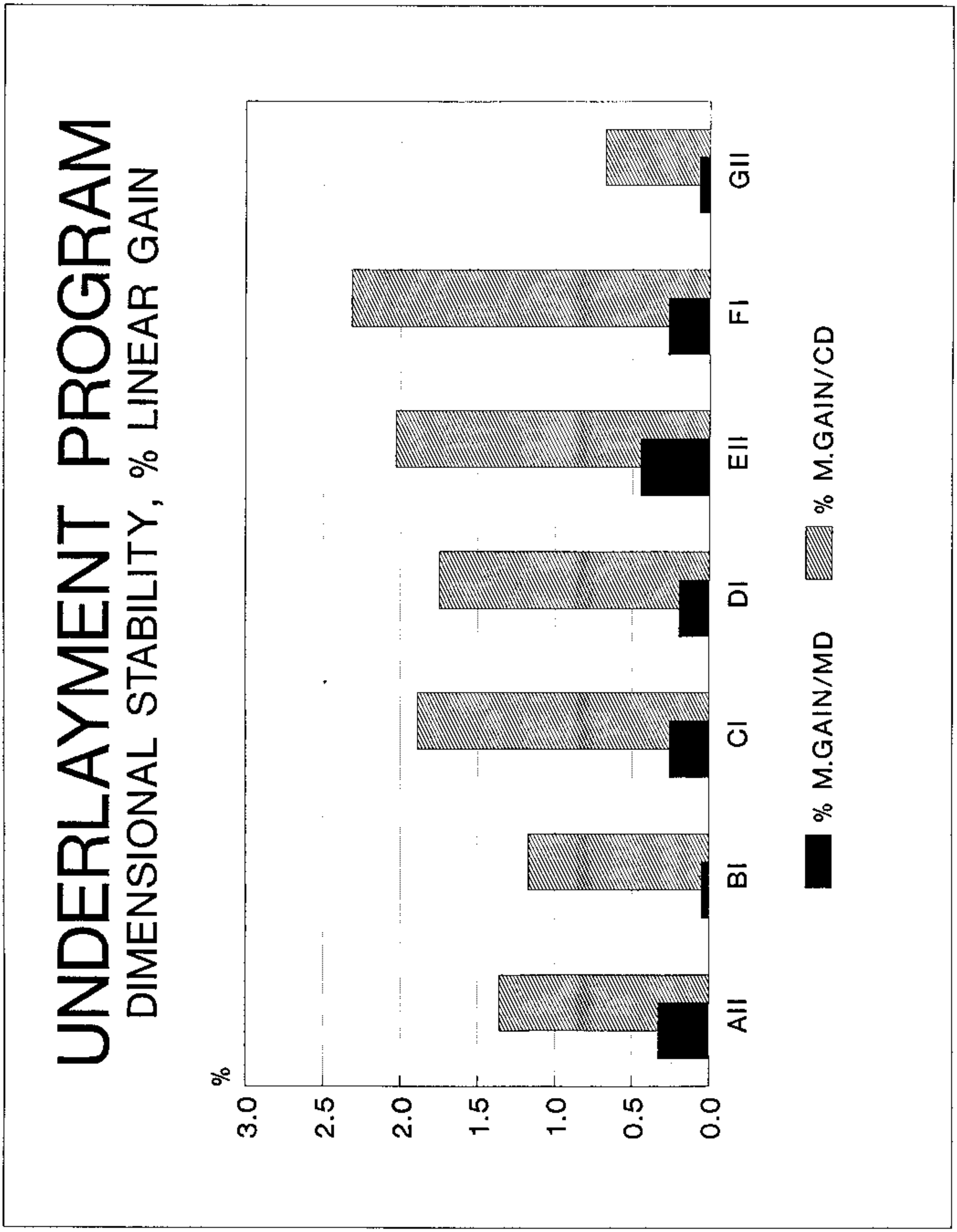


B-226, D-4869, F-NS, C-GLASS



A-NS, E-4869, G-226


UNDERLAYMENT PROGRAM
DIMENSIONAL STABILITY, % MOISTURE GAIN
%
100
80
60
40
20
0
AII
BI
CI
DI
EII
FI
GII
% M.GAIN/MD
% M.GAIN/CD


UNDERLAYMENT PROGRAM
DIMENSIONAL STABILITY, % LINEAR GAIN
%
3.0
2.5
2.0
1.5
1.0
0.5
0.0
AII
BI
CI
DI
EII
FI
GII
% M.GAIN/MD
% M.GAIN/CD

5.0 FIELD EXPOSURE SITES, CLIMATIC DATA, AND OBSERVATIONS

When selecting the sites for field exposure, climates of differing temperatures, humidity, and rainfall were sought. Combinations of the variables of hot, cool, dry, and humid/wet were put together to arrive at desirable weather characteristics for the sites.

5.1 Project Locations/Climatic Areas

The climatic areas were selected based on their typical summer/fall temperatures and humidities. The areas included: Boulder, Colorado (cool temperatures and dry); Neenah, Wisconsin (cold temperatures and damp); Phoenix, Arizona (hot temperatures and dry); Seattle, Washington (moderate temperatures and damp); and Tampa, Florida (hot temperatures and high humidities).

5.2 Weather Data During Field Exposure of Felts

The following is a brief summary of the local weather during the exposures at the sites:

Site: **Boulder, Colorado**
Each felt type was exposed for three to five days during a period from August 1993 to December 1993. High temperatures were in the 80°F (27°C) range in August, while only reaching 40°F (4°C) in December. During the maximum daily temperature, relative humidity was generally around 30 percent for the time period.

Site: **Neenah, Wisconsin**
Each felt type was exposed for five days, from January 21, 1994, to January 25, 1994. High temperatures were in the 20°F (-7°C) range. During the maximum daily temperature, relative humidity was in the 50 percent to 80 percent range. Heavy frost was noted during the exposure, and snow occurred toward the end of the exposure period.

Site: **Phoenix, Arizona**
Each felt type was exposed for three to five days during a period from September 1993 to January 1994. High temperatures were in the 80°F (27°C) to 95°F (35°C) range. During the maximum daily temperature, relative humidity was generally below 20 percent. Rain occurred during only one product's exposure.

Site: **Seattle, Washington**
Each felt type was exposed for three to four days during a period from July 1993 to September 1993. High temperatures were in the 60°F (16°C) to 70°F (21°C) range. The relative humidity fluctuated greatly during the exposures. Fog, dew, and light mist were reported during the exposure of some felts.

Site: Tampa, Florida
Each felt type was exposed during the period from August 5, 1993, to September 1, 1993. High temperatures were in the 90°F (32°C) range with relative humidity during the maximum daily temperature in the 80 percent range. A total of 10¾ inches of rain fell during the exposure period.

5.3 Comments on Weather During Field Exposure of Felts

As can be seen from the preceding information, the underlayment felts were exposed to a wide range of weather conditions. Although each product was not exposed during the same time to the same weather conditions at the Boulder, Phoenix, and Seattle sites, the variety of conditions to which the products were exposed presented an excellent opportunity for evaluation of the underlayment felts' performance. At the Neenah and Tampa sites, each of the products was exposed at the same time on the same building, which allowed for cross comparison of the performance of the products relative to each other.

Specific weather data were obtained from the National Weather Service for each of the sites for the days of exposure and are included as a reference in Appendix B.

5.4 Buildings Used for Exposures

The testing protocol set forth guidelines for the type of building construction that could be used for exposure of the underlayment felts. The testing protocol had guidelines for slope, decking (including an exclusion for nonvented cathedral type ceilings), opposing exposures (i.e., north and south, east and west), minimum square footage of roof area size, and ventilation. A fastening pattern for the underlayment felts was not prescribed, because each site needed a case-by-case evaluation, based on slope and other important factors. At each site, the underlayment felts were installed shingle-fashion up the slope.

The following is a brief summary of the buildings used for the exposures at the sites:

Site: **Boulder, Colorado**
The underlayment felts were installed as part of reroofing projects on enclosed, occupied houses. No ventilation problems were reported.

Samples D15 and E30 were installed on the same building and exposed at the same time. The remaining samples (A30, B15, C15, F15, and G30) were installed on separate buildings and exposed on different days.

Site: **Neenah, Wisconsin**

The underlayment felts were installed as part of a new construction project of an apartment building. The structure was not fully enclosed during the exposure. All seven of the products were exposed at the same time. Each product was installed from eave to ridge on two opposing slopes. On each slope, the seven products were installed side by side across the length of the deck.

Site: **Phoenix, Arizona**

The underlayment felts were installed as part of reroofing projects on enclosed, occupied houses. No ventilation problems were reported. Samples C15, D15, and E30 were exposed on the same days but on separate buildings. Samples A30, F15, and G30 were installed on separate buildings and exposed on different days. Sample G30 was installed over spaced sheathing composed of wood planks. Sample B15 was not evaluated.

Site: **Seattle, Washington**

The underlayment felts were installed as part of reroofing projects on enclosed, occupied condominiums. No ventilation problems were reported. Samples A30, C15, and G30 were installed for two separate exposures, each lasting about a week, with both exposures occurring over a consecutive two-week period. Samples A30, C15, and G30 were installed on separate buildings, with G30's exposures occurring on two different buildings. Samples B15 and E30 were installed on separate buildings and exposed on different days. Samples D15 and F15 were not evaluated.

Site: **Tampa, Florida**

The underlayment felts were installed as part of a reroofing project for a multifamily, single-story building. The structure was enclosed and occupied during the exposure. No ventilation problems were reported. All seven of the products were exposed at the same time. Each product was installed from eave to ridge on two opposing slopes (eastern and western exposures). On each slope, the seven products were installed side by side across the length of the deck.

5.5 Observations From Field Exposures

Each contractor that exposed underlayment felts for this research project designated an experienced individual to oversee the installation of the underlayment felts, to collect the data, and to report the observations. The diligence of these individuals brought forth information about the performance of the underlayment felts that went beyond what the protocol had expected. One important observation noted was the daily cycle of wrinkling in the morning and laying flat in the afternoon.

While some variations exist in the way each observer reported the Underlayment Condition Index (i.e., wrinkling rating), the overall results showed that every product experienced wrinkling to some degree under varying conditions. The observers did not have comparative photographs to guide them in rating the observed wrinkling, only the written description provided with the Underlayment Condition Index in the testing protocol.

The Underlayment Condition Index used was as follows:

Rating	Description
1	Laying smooth, no apparent wrinkling
2	No longer laying smooth, minimal wrinkling
3	Apparent wrinkling throughout
4	More than wrinkled, actually buckled in locations
5	Severe buckles/ridging

The research project steering committee† selected from the photos submitted by the contractors what it felt were representative examples of the five different levels of the Underlayment Condition Index. The following photographs are those selected as representative of the ratings:

† The research project steering committee was composed of ARMA technical staff, representatives of ARMA's research and residential committees, NRCA technology and research staff, and representatives of NRCA's participating contractors.

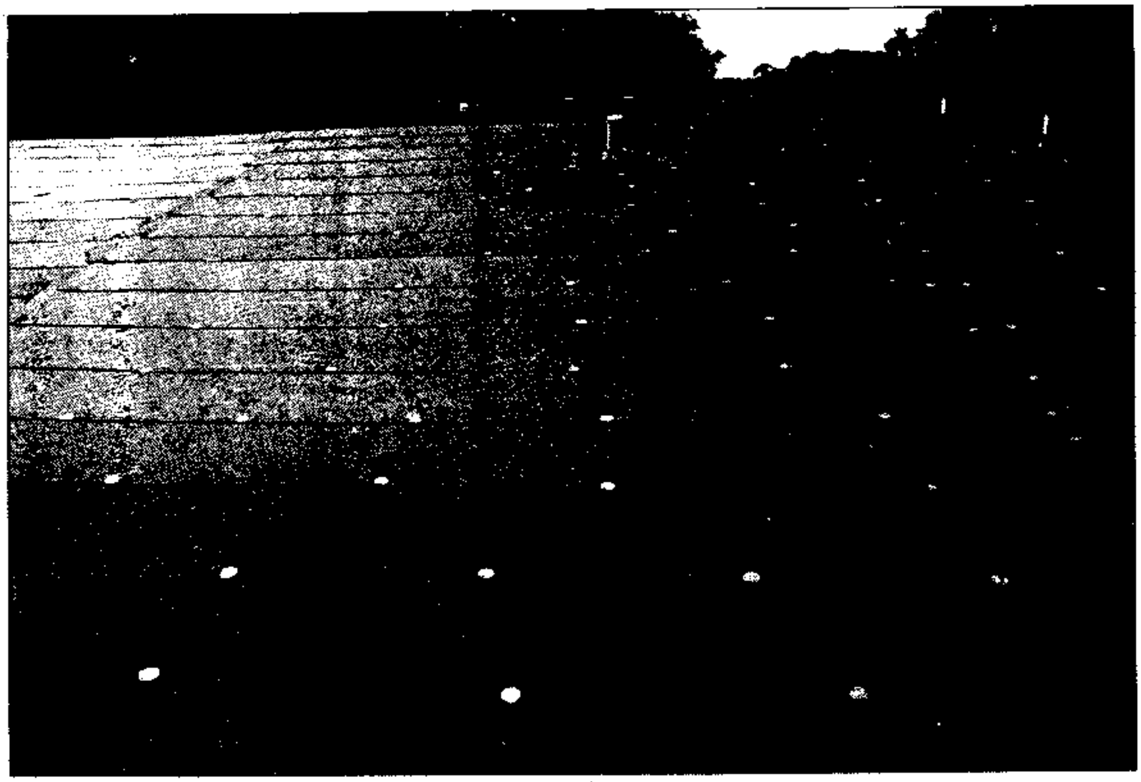


Photo 5.5.1 Rating 1: Laying smooth, no apparent wrinkling.

Photo 5.5.2 Rating 2: No longer laying smooth, minimal wrinkling.

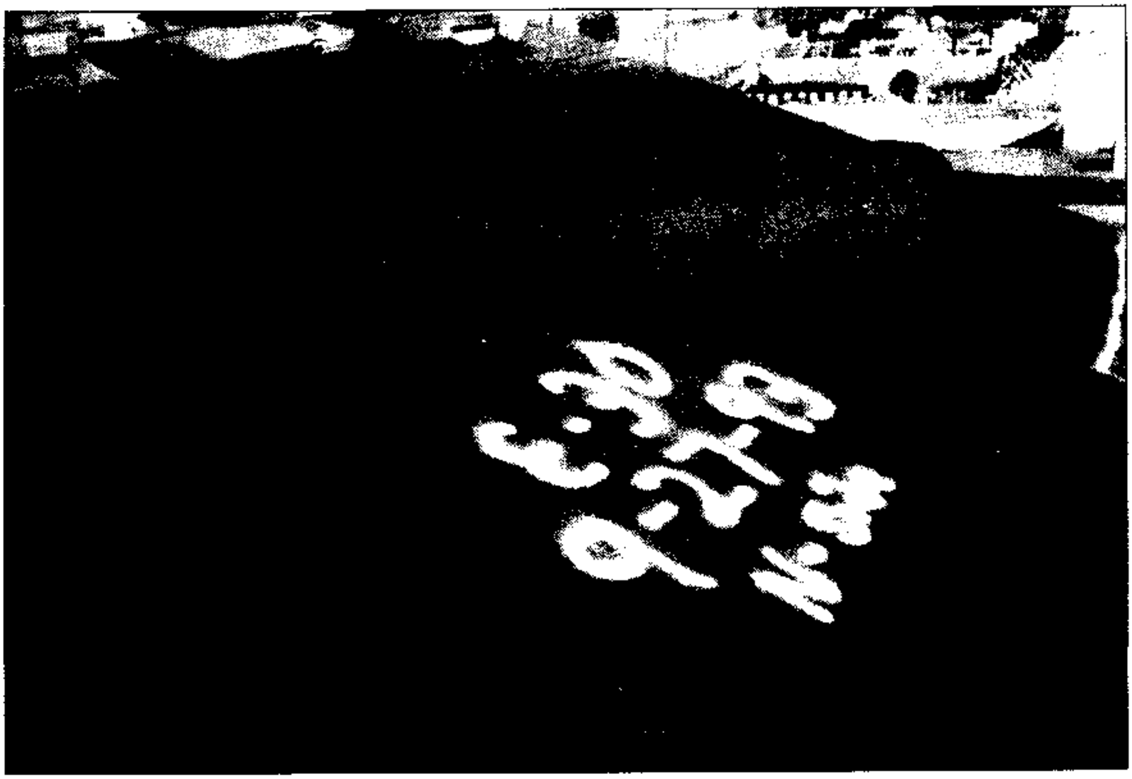


Photo 5.5.3 Rating 3: Apparent wrinkling throughout.

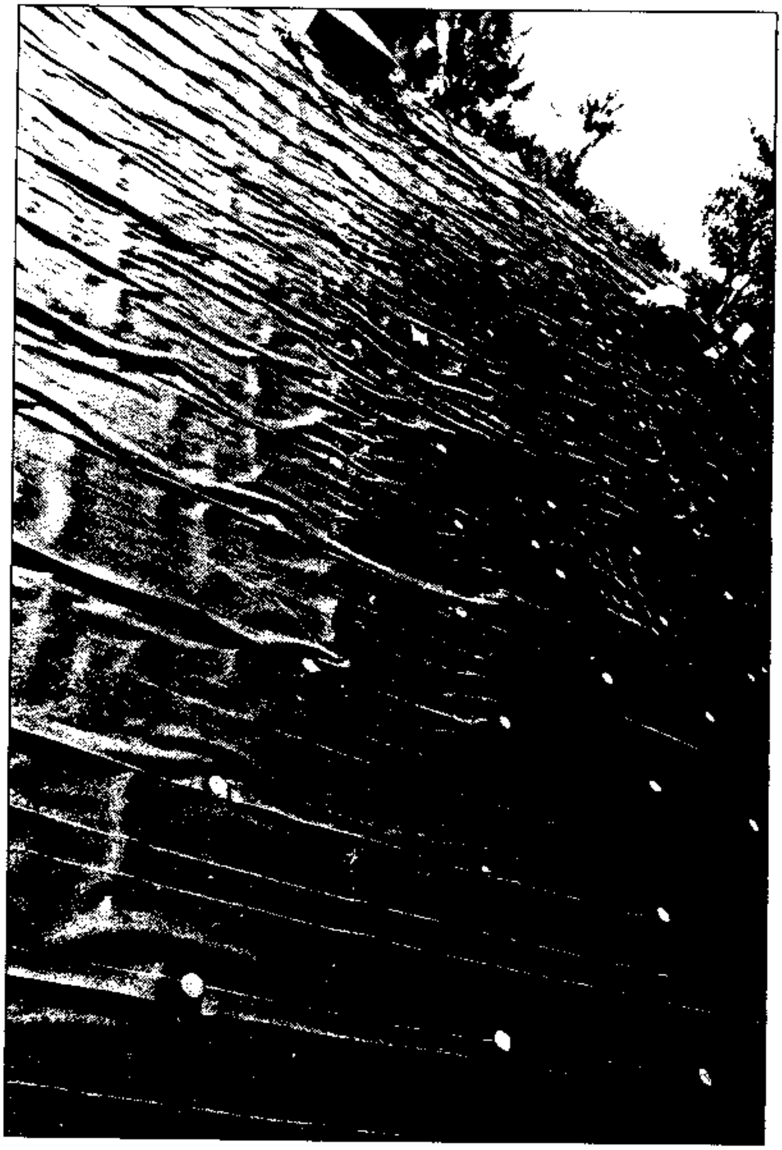


Photo 5.5.4 Rating 4: More than wrinkled, actually buckled in locations.

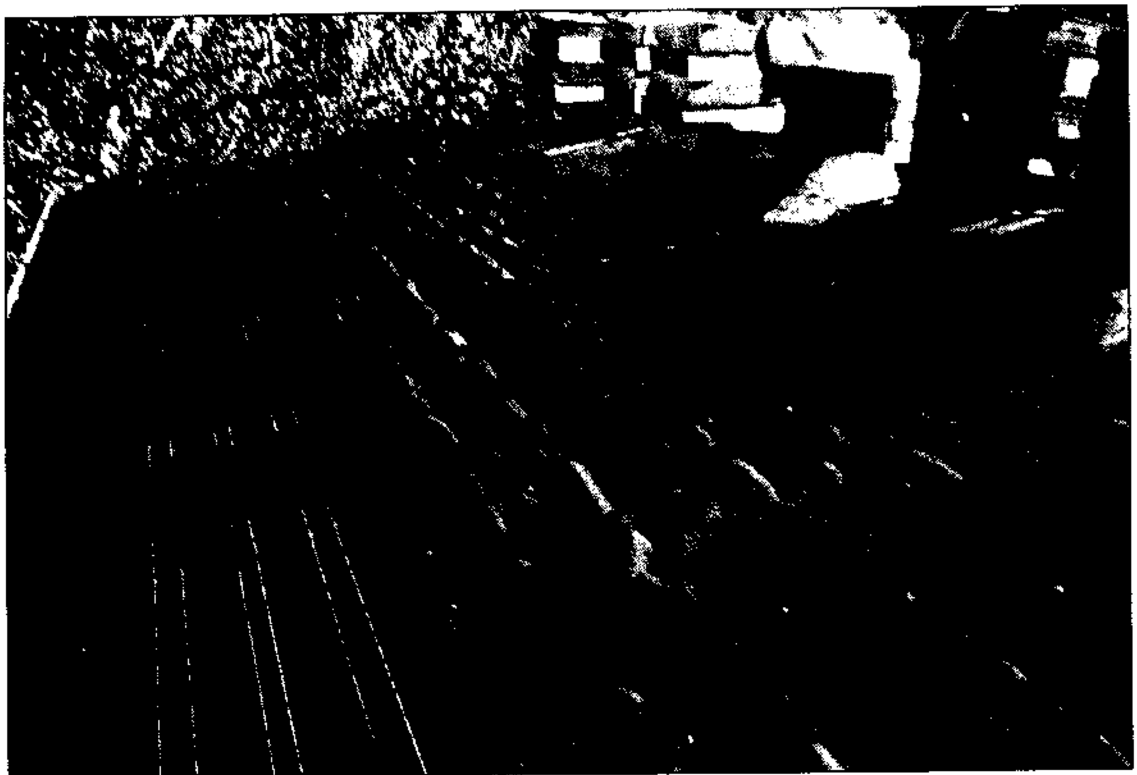


Photo 5.5.5 Rating 5: Severe buckles/ridging.

5.5.1 Summation of Field Observations by Climatic Area

The following is a summary of the specific observations noted for each climatic area. A detailed list of the products with the corresponding Underlayment Condition Index rating received for each day of exposure is included in Appendix C.

Site: **Boulder, Colorado**

- All underlayment felts performed reasonably well, except C15.
- Sample C15 showed severe wrinkling when wet but smoothed out in sunshine.

Site: **Neenah, Wisconsin**

- All underlayment felts wrinkled after three days under the same climatic conditions.
- Samples B15 and A30 showed the least wrinkling. (Note: The lab results for the two were similar.)
- Wrinkling increased as relative humidity decreased and temperature increased.
- The ambient temperature was below freezing throughout the exposure.
- The workability and handling of the different product types were noticeably different in the cold weather. The workmen installing the products reported that the Type I products were easier to work with in the cold weather than the Type II products.

Site: **Phoenix, Arizona**

- All samples laid flat when installed.
- All underlayment felts wrinkled to some extent even though the relative humidity was low.
- Many of the underlayment felts wrinkled within approximately one day. The wrinkling was more prevalent in the morning than in the afternoon.
- All the data were collected in the morning.

Site: **Seattle, Washington**

- Wrinkling occurred under some differential exposure conditions (i.e., different day, weather, and orientation).
- Samples C15 and E30 showed significant wrinkling from the day of application. Fog and dew were present when these products wrinkled.
- Underlayment felts wrinkled in the presence of fog and/or mist.
- Surface moisture was visible and was recorded by the capacitance meter, as reflected in the unusually high readings reported.

Site: **Tampa, Florida**

- All underlayment felts wrinkled and/or buckled to varying degrees under the same climatic conditions.
- Type II products showed less wrinkling and/or buckling than Type I products.
- More wrinkling and/or buckling occurred in the morning than in the afternoon.
- Wrinkling and/or buckling was much more pronounced on the western exposure than the eastern exposure for all felts.
- The amount of wrinkling and laying flat lessened as time went on.
- Type I felts retained more residual wrinkling (i.e., wrinkling became "set") than Type II felts.
- Little difference was observed in wrinkling between all felts (Type I and II) on eastern exposures.
- B15 showed more stability than D15, C15, and F15 (respectively).
- G30 showed more stability than E30 and A30 (respectively), while A30 was much worse.

5.6 Discussion of Field Exposures

Roof exposures played a major part of the investigation. The underlayment materials were applied by professional roofing contractors and observed by members of the project team. Parameters such as temperature, humidity, solar radiation, and moisture condition of deck and underlayment materials were monitored during application and the test exposure period.

The amount of wrinkling and buckling, predominant defects associated with the performance of shingle underlayments, that occurred during exposure was observed and rated. Ratings were recorded, and underlayment conditions were photographed. (For an explanation of the ratings, reference the discussion earlier in this section on the Underlayment Condition Index.)

Most of the exposed products wrinkled to some degree at all of the sites. Wrinkling was not a serious problem in all cases. However, the fact that the felts responded to the moisture to the extent they did is cause for concern, especially considering the asphalt shingle materials that are being produced today.

The observed performance of the underlayment felts in Boulder, Colorado (cool temperatures with relatively dry conditions), was the best of all sites in that the extent and severity of the wrinkling was the least, except for one product. Sample C15 exhibited the worst wrinkling noted of all products, at any site, according to the reviewers of the field data. As shown in Photo 5.6.1, the C15 felt wrinkled extensively after an overnight dew, rising off the deck a few inches. (Another product that was not part of the test but had been installed next to the C15 product did not wrinkle.) Sample F15 exhibited similar wrinkling when dew occurred during its exposure. Both products were reported to lay flat once the moisture had dissipated and the sun was shining on the roof area. This is an example of the cycle of wrinkling and then laying flat when changes in moisture are experienced.

In Neenah, Wisconsin, the weather was cold and damp, typical late-January weather. Although the air temperature was low enough that it could not hold much moisture, changes in the relative humidity of about 30 percent were experienced, and wrinkling of the felts was observed. When snow fell at the end of the exposure period, the wrinkling was pronounced enough that blowing snow was trapped in the valleys between the wrinkles, as shown in Photo 5.6.2. Even before the snow fell, the felts had wrinkled to some degree, as shown in Photo 5.6.3. The contractor reported that the felts wrinkled when frost occurred overnight and would tend to lessen in severity in the afternoon. This is another example of cycling.

Similar to the results noted in Colorado, the observed wrinkling in the products exposed in Phoenix, Arizona, was not severe but was apparent throughout all products. Although the temperatures were hot, the relative humidity was low. The humidity did fluctuate as much as 30 percent to 40 percent. As can be seen in Photos 5.6.4 and 5.6.5, wrinkling resulted. The contractor noted that the cycling was very noticeable, further stating that the Type I products would relax (i.e., lay flat) quickly.

Moisture in Seattle, Washington, was a major factor. Fog and mist in July would last until noon. Wrinkling occurred during installation in some cases. The products would lay flat when the moisture dissipated in the afternoon. The wrinkling occurred on most exposures (i.e., northern and southern) so relationship to the sun did not seem to have as great an effect in this climate area. As seen in Photos 5.6.6, 5.6.7, and 5.6.8, the wrinkling was significant.

Because of the extensive data reporting and lengthy exposure time, the data received from Tampa, Florida, provided insight into areas not perceived by the testing protocol. The underlayment felts were exposed for 28 days, during which high temperatures were in the 90s and high relative humidities were in the 80 percent range. More than 10 inches of rain fell during the exposure. All of the samples wrinkled and cycled. As shown in Photo 5.6.9, Sample F15 was severely wrinkled at 9:30 in the morning of the fourth day of exposure. However, as shown in Photo 5.6.10, by 2:00 that afternoon, most of the wrinkling had subsided. No rainfall occurred during the exposure. The humidity went from 65 percent (at 90°F [32°C]) in the morning to 80 percent (at 95°F [35°C]) in the afternoon. The wetting conditions experienced overnight caused the felt to expand and wrinkle, and the drying conditions of the daytime caused the felt to shrink and lay flat. The contractor indicated that the felts were still cycling at the end of the 28-day exposure but not to the same degree as they were immediately after installation. Also, felts exposed on the western face of the roof deck wrinkled more than those on the eastern face. The severity of wrinkling, therefore, may be related to the amount of sunlight (and heat) received. E. G. Long, in his research, noted that exposing organic felts to high temperatures and low humidities was a more effective drying tool than desiccation with calcium chloride at room temperature for the same length of time.[6]

An item to note regarding the use of underlayment felt on "real-life" projects is the aesthetically objectionable result that can occur when the underlayment felt wrinkles. By delaying application of the shingles over the underlayment felt, dimensional changes in the underlayment felt can occur. These changes then can telegraph through the shingle, making them appear buckled. It is not always possible to install shingles over the entire roof area by the end of the day's work, thus necessitating that some of the underlayment felt be exposed for a period of time under normal working situations. A possible solution to this is to tear off underlayment felt that has been exposed and has experienced dimensional changes and replace it with new felt. However, this work practice will not help situations where underlayment felt wrinkles after the installation of the shingles.

The results of this study showed significant differences in the response of underlayment felt to changing moisture exposure and temperature conditions.

Photo 5.6.1 Colorado: Product C15—morning of the fifth day, western exposure, after dew overnight.

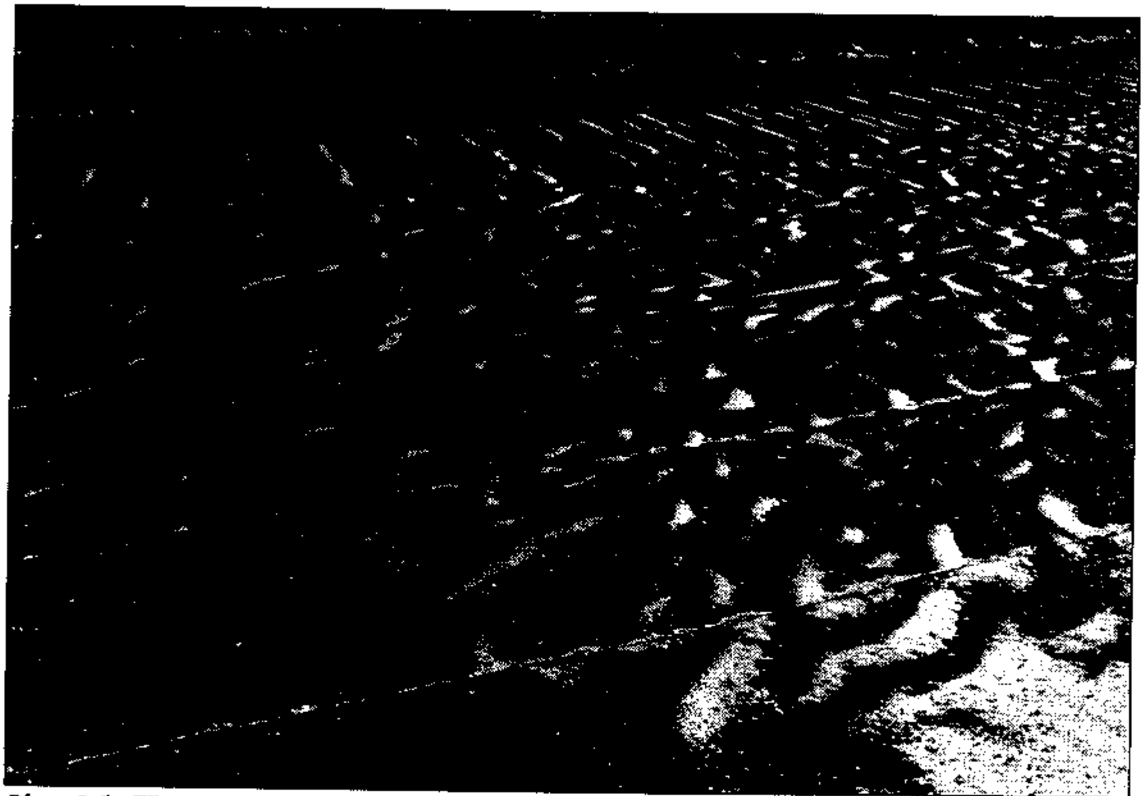


Photo 5.6.2 Wisconsin: Product B15—morning of the third day, eastern exposure, after snow.

Photo 5.6.3 Wisconsin: Product F15—morning of the day after installation, southern exposure.

Photo 5.6.4 Arizona: Product E30—morning of the fourth day after installation, northern exposure.

Photo 5.6.5 Arizona: Product G30—morning after the day of installation, northern exposure.

Photo 5.6.6 Washington: Product G30—morning of the second day, northern exposure.

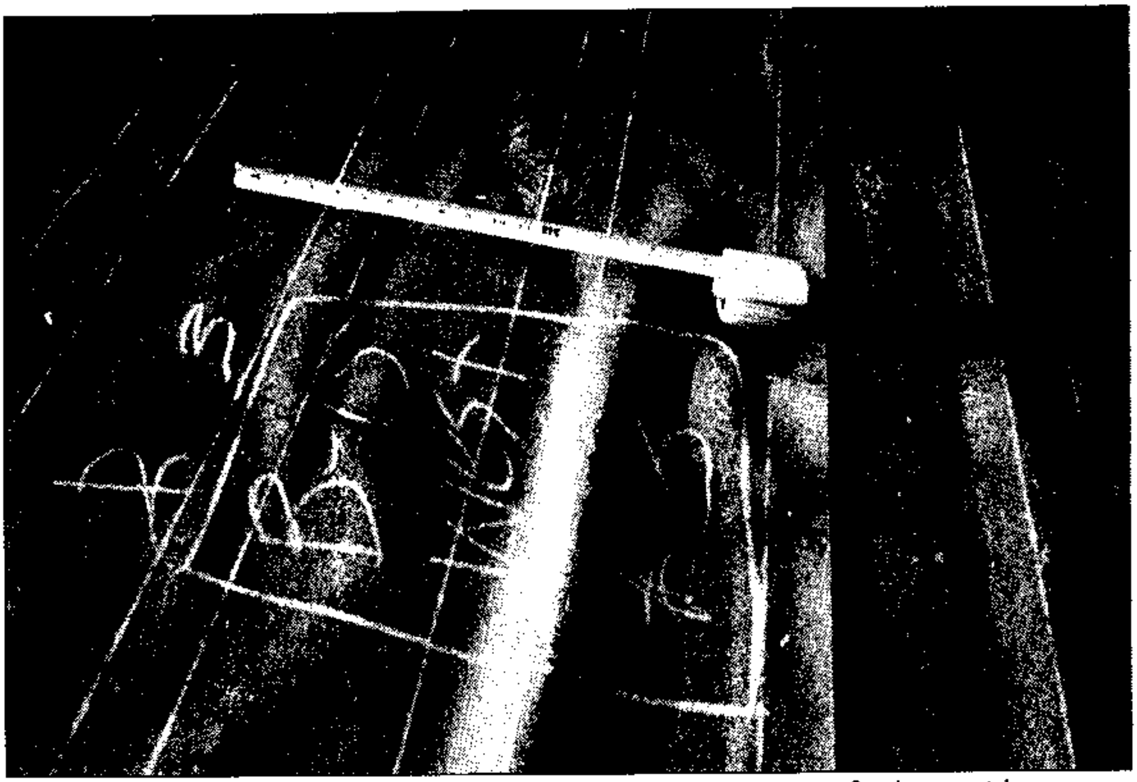


Photo 5.6.7 Washington: Product B15—morning of the third day, western exposure, after dew overnight.

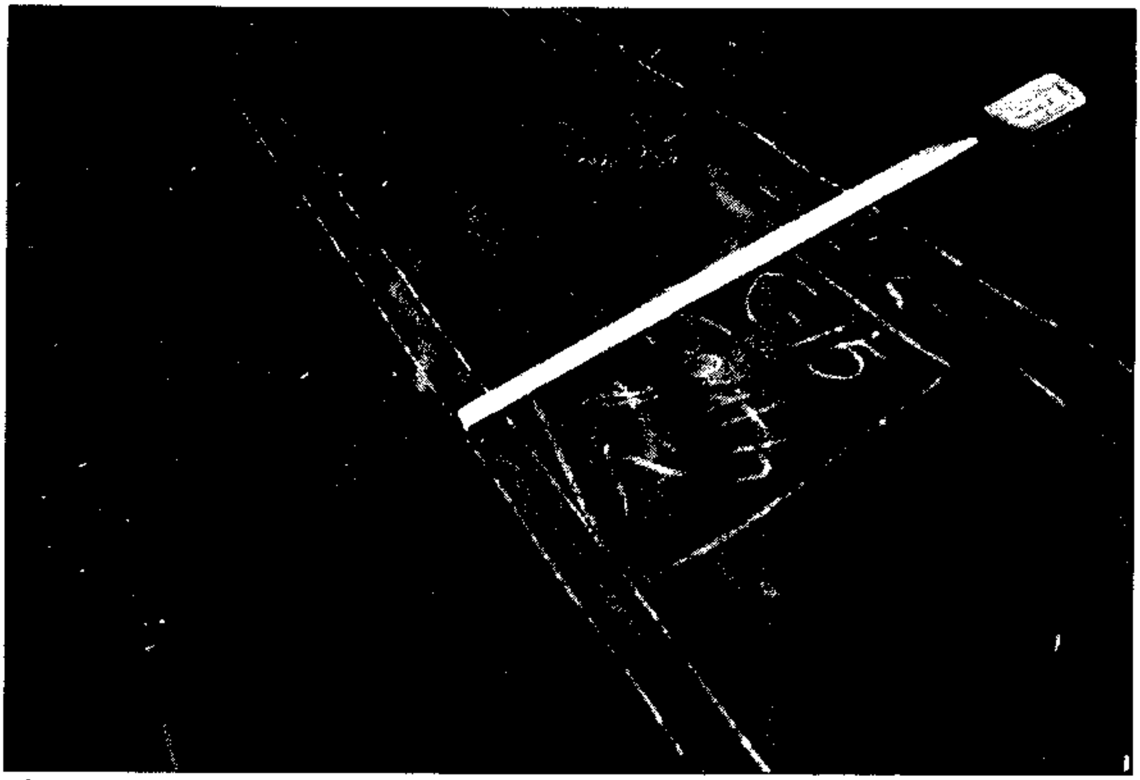


Photo 5.6.8 Washington: Product C15—morning of the day after installation, southern exposure, after dew.

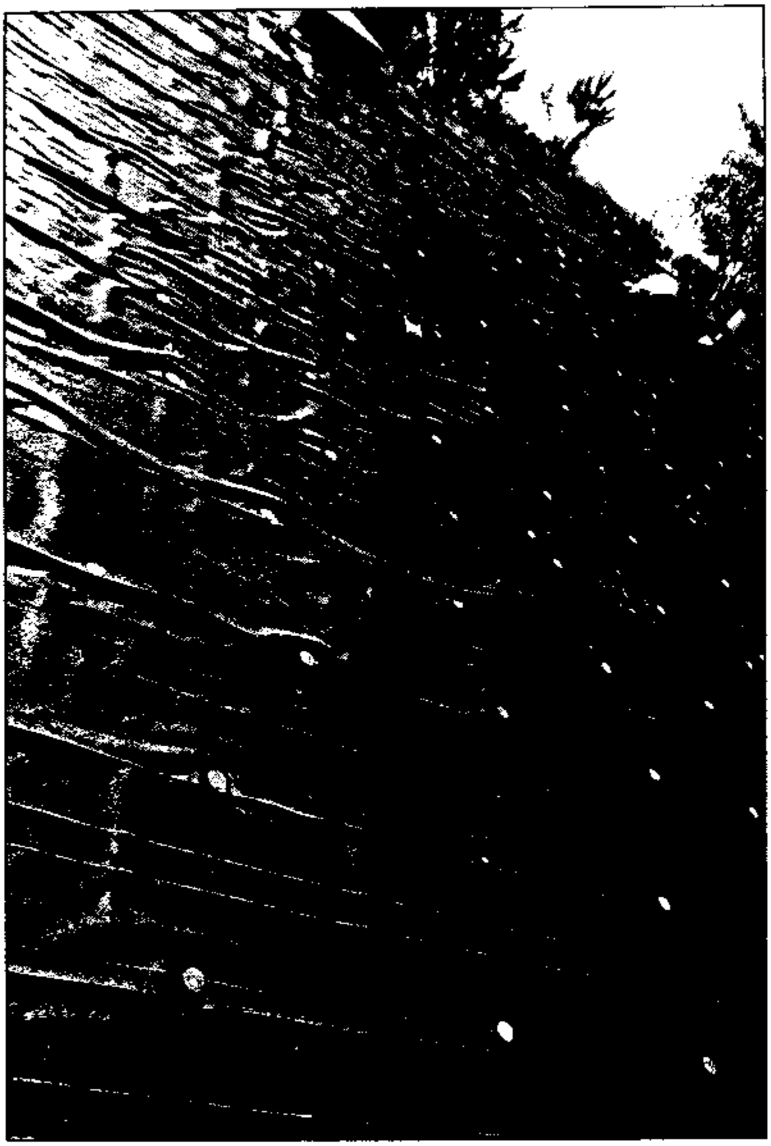


Photo 5.6.9 Florida: Product F15—third day after installation, 9:30 a.m., western exposure.

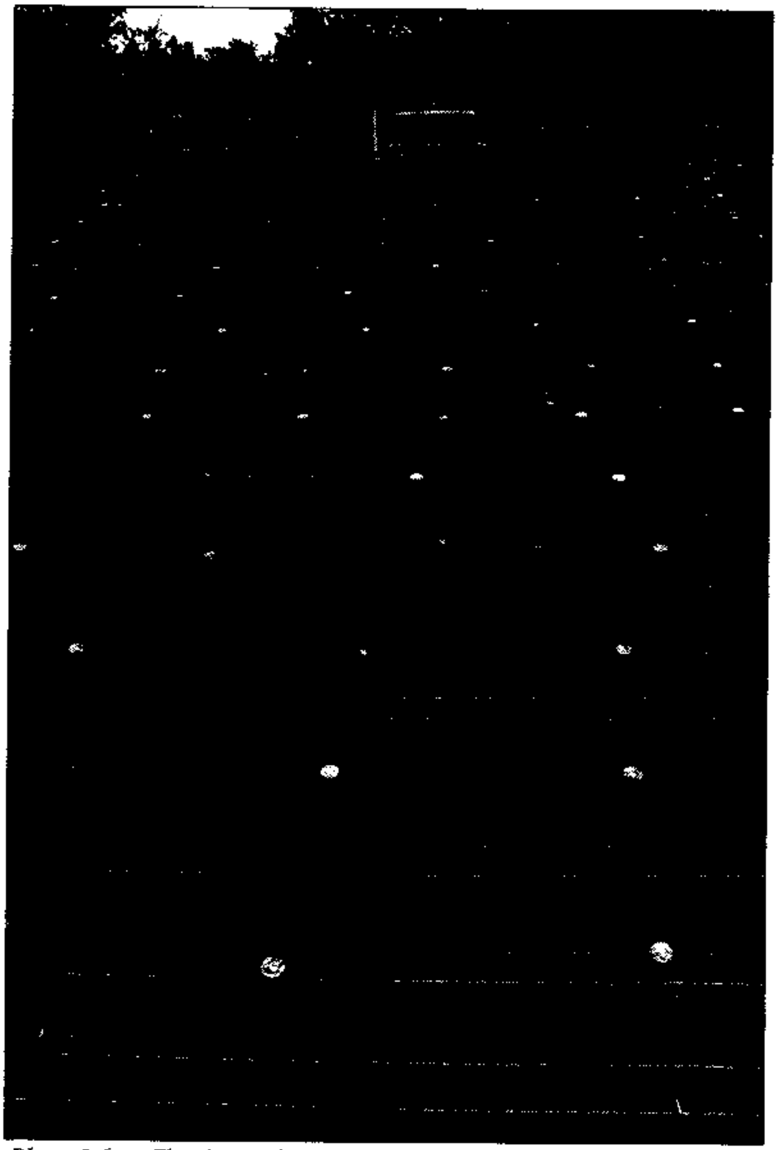


Photo 5.6.10 Florida: Product F15—third day after installation, 2:00 p.m., western exposure.

6.0 CONCLUSIONS

An analysis of the data from the research indicates that the wrinkling effect of the felts is related to their susceptibility to moisture, most notably, their saturation efficiency (i.e., the ability of organic felts to hold asphalt and the amount of asphalt absorbed). The dimensional stability of the felt after moisture exposure is also a characteristic.

The conclusions from this research are summarized as follows:

- All underlayment felts in the test program wrinkled to some degree.
- The nature and severity of the wrinkling varied in the different geographical areas evaluated.
- No individual underlayment felt performed well (with regard to wrinkling) in all climatic conditions evaluated. Climatic and exposure variations resulted in performance variations.
- Variability in the underlayment felt materials, conditions, application, and observations limited the data results, not allowing for consistent conclusions.
- In most cases, moisture from dew in the evening or early morning was associated with more pronounced wrinkling, especially on northern and western exposures.
- The wrinkling would dissipate depending on ambient drying conditions (usually by afternoon).
- Seasonal differences (between winter and summer) affected workability, ease of handling, and performance.

7.0 RECOMMENDATIONS

ARMA and NRCA recommend the following to minimize wrinkling and/or buckling of asphalt-saturated underlayment felts:

1. Based on the field study, improvements in the ASTM D 226 and D 4869 material standards are necessary.
2. Based on the laboratory analysis, the literature survey, and the field study, product improvements that will lead to underlayment felts being less susceptible to wrinkling should be considered by individual manufacturers.
3. Based on this study, field experience, and previous research, asphalt-saturated underlayment felts with a higher level of saturation efficiency should minimize wrinkling caused by climatic conditions in the field. It is recommended that further research be undertaken, under more controlled conditions, to compare the wrinkling effects of currently produced underlayment felt products with those of products manufactured with higher saturation efficiencies.
4. Performance criteria should be established by a third-party standards organization to gauge the asphalt-saturated underlayment felts' response to moisture. When this criteria is established, the test methods and correlating values should be incorporated into consensus material standards sponsored by ASTM or the American National Standards Institute (ANSI).
5. Underlayment products should be selected based on their ability to shed water and to remain dimensionally stable.

8.0 GLOSSARY

Asphalt—A dark brown or black substance found in a natural state or, more commonly, left as a residue after evaporating or otherwise producing crude oil or petroleum. Asphalt may be refined further to conform to various roofing grade specifications, like those of ASTM D 312.

Asphalt capacity—The kerosene number multiplied by the ratio of the specific gravity of the asphalt saturant to the specific gravity of the kerosene used. When no specific saturant is being considered, 1.035 is used as the specific gravity of the saturant.

asphalt capacity = *kerosene number* x (d ÷ c)

where: d = specific gravity of saturant

c = specific gravity of kerosene

Buckle—An upward, elongated tenting displacement of a felt. A buckle may be an indication of movement within the felt.

Built-up roof—A continuous, semiflexible multi-ply roof membrane, consisting of plies or layers of saturated felts, coated felts, fabrics, or mats between which alternate layers of bitumen are applied.

Coated felt—An asphalt-saturated felt that also has been coated on both sides with harder "coating" asphalt.

Dimensional stability—The ability of a material to resist change in length and/or width and/or thickness that results from exposure to elevated or freezing temperatures, and moisture, over time.

Dry felt—Unsaturated felt in an oven-dry condition.

Felt—A paper-like material made by a felting process, rather than a weaving process. Felts may be of asbestos, paper, wood, rags, glass, etc. Note: Those in this study were made from a mixture of paper, rags, and wood fibers.

Felt number—Also referred to as *felt mill ream* or *point weight*—The mass in pounds of 480 square feet of dry, unsaturated felt.

Furnish—The composition of the felt in terms of fiber types (e.g., rag, wood, and paper).

Impregnate—To coat, saturate, and/or surround the fibers of a reinforcing fabric or felt with an enveloping liquid material (e.g., bitumen).

Kerosene number—The relative saturating capacity of felt papers for roofing. The kerosene number of felt is computed from the maximum weight of a kerosene of known specific gravity retained by the felt after displacement of all the air from the interior voids. It is the milliliters of kerosene held per 100 grams of felt and thus is a measure of the quantity of saturant that a given felt will absorb. (The kerosene number varies with the procedure by which it has been determined.) A high kerosene number is considered desirable. Refer to ASTM D 727, "Standard Test Method for Kerosine Number of Roofing and Flooring Felt by Vacuum Method."

kerosene number = $[(b \div w_{df}) - 1] \times 125$

where: w_{df} = weight of dry felt, in grams

b = weight of felt plus absorbed kerosene, in grams

The kerosene value may also be computed by the method described in UL 55B.

kerosene value = $e \times (b_k / a) \times 100$

where: a = weight of dry felt

b_k = weight of kerosene absorbed

e = conversion factor

conversion factor = e = d/c

where: d = specific gravity of saturant (can use 1.035)

c = specific gravity of kerosene (can use 0.8)

Organic—Being composed of hydrocarbons or their derivatives, or matter of plant or animal origin.

Percent saturation—The ratio of the weight of the saturant to that of the dry felt, expressed as a percentage. Calculate the percent saturation by dividing the mass of the saturant by the mass of the dry felt, and multiply the result by 100.

percent saturation = $[(W_{sf} - w_{df}) \div w_{df}] \times 100$

where: W_{sf} = weight of saturated felt

w_{df} = weight of dry felt

Prepared roof covering materials—Prepared materials that can be applied directly to a roof deck in accordance with the manufacturer's instructions provided with the product. These coverings usually are considered "watershedding" and not waterproof. They are usually "units," such as shingles or tiles, that are assembled to create a "system."

Relative humidity—The ratio of the weight of moisture in a given volume of air-vapor mixture to the saturated (maximum) weight of water vapor at the same temperature, expressed as a percentage.

Saturant—A relatively soft asphalt used to impregnate felts.

Saturated felt—Felt containing some asphalt saturant, not necessarily as much as it can hold.

Saturating capacity—Calculate the percent saturating capacity of the felt for any bituminous saturant as follows:

saturating capacity = d x *kerosene number*

where: d = specific gravity of saturant

Saturation—The impregnation of a felt with a saturant. To accomplish this, during manufacture, the felt goes into a saturator tank on a roofing machine, where it is immersed in hot saturant to impregnate the fibers.

Saturation efficiency—Calculate the saturation efficiency as follows:

saturation efficiency = (*percent saturation* ÷ *kerosene number*) x d x 100

where: d = specific gravity of saturant

A suitable method for determining the specific gravity of bitumen is ASTM D 70.

Steep-slope roofing—A generic category of roofing that includes all watershedding types of roof coverings.

Underlayment—An asphalt-saturated felt or other sheet material installed between the roof deck and the roof system, usually used in steep-slope roof construction under prepared roof covering materials. Underlayment is used to separate the roof covering from the roof deck, to shed water, and to provide secondary weather protection for the roof area of the building.

Water or moisture absorption—The penetration of water (vapor or liquid) into the felt, including both adsorption and absorption.

Wrinkling—See *Buckling*.

9.0 APPENDICES

Appendix A. Testing Protocol and Data Collection Form

August 1992

Purpose:

Test various underlayment products in various climatic areas of the United States to determine susceptibility to wrinkling or buckling, and to examine the products' water shedding capabilities (i.e. compare water percolation rates for organic/glass fiber reinforced, and various asphalt saturated organic felt underlayments).

Test Conditions:

I. ARMA to Provide Test Materials and Initial Laboratory Characterization of Samples:

- Provide underlayment materials to mutually agreed project sites for installation by participating NRCA contractors.
- Perform initial laboratory work in two or three ARMA members' labs to characterize samples.

II. Test Sites:

Test underlayment materials in various climatic zones as determined by ARMA and NRCA.

Test Sites:

–Phoenix, Arizona
–Tampa, Florida
–Neenah, Wisconsin

–Seattle, Washington
–Boulder, Colorado

III. Slopes Applicable for Tests:

Underlayments will be installed on roof decks of 4:12 to 12:12 slope. Underlayments will be tested in single layer configurations only, so the "felts" experience true exposed conditions over the majority of the width of the roll.

IV. Substrates Suitable for Underlayment Testing Are:

–Exposure I rated APA plywood, min. 15/32" thickness

–Oriented Strand Board, (OSB), min. 7/16", APA rated for roof sheathing, (15/32" is preferred)

–Oriented Waferboard, min. 15/32" thickness

–Nominal sized sheathing lumber, (e.g., 1" x 8")

Note: jobs with enclosed, non-ventilated cathedral ceilings are not applicable for testing underlayments for this research project.

V. Test Material Types:

The seven types of materials to be tested for exposure at each site are:

A) ASTM D-226-89 Asphalt-Saturated Organic Felt Used in Roofing:
1. Type I, (non-perforated), commonly called No. 15 asphalt felt,
and
2. Type II, (non-perforated), commonly called No. 30 asphalt felt

B) ASTM D-4869-88 Asphalt-Saturated Organic Felt Shingle Underlayment Used in Roofing:
3. Type I, "Shingle Underlayment",
and
4. Type II, "Heavy Duty Shingle Underlayment"

C) Non-Specification Asphalt Saturated Organic Felt:
5. No. 15, "Residential Grade Felt"
and
6. No. 30, "Residential Grade Felt"

D) Non-Specification Glass Fiber Reinforced Organic Felt:
7. Glass fiber reinforced organic asphalt saturated felt

VI. Installation Exposures:

- Each type of underlayment is to be installed in each climatic test zone.
- Install only one type of underlayment on each building.
- Underlayments shall be installed on at least two separate roof decks per building with opposing exposures to the weather, (e.g. north and south, or east and west).
- Deck size suitable for data collection shall be a minimum of 500 sq. ft., (5 squares).
- Monitor, collect and report performance data during test time-frame per Data Collection Form. (Note: Although the purpose of this research project is to test underlayments, do not jeopardize the structure or integrity of the roof by exposure to weather for the sake of testing.)
- Remove test underlayments prior to installation of any other underlayment and steep slope roof system that has been specified or selected as the building's roof system. In other words, do not shingle or "roof-over" the test underlayment materials at close of test.

VII. Underlayment Application:

During the project's Initial Coordination Meeting, held on August 20, 1992, it was mutually agreed between ARMA, NRCA and the participating contractors that each contractor shall determine the suitable fastening pattern for the underlayments being used.

Due to varying slopes, climates, winds, safety procedures, and different material characteristics — the type of fastener and fastening pattern was deemed not to be a significant factor for whether or not an underlayment wrinkled. However, the attachment pattern is anticipated to be a factor in the orientation of any wrinkles or buckles.

In light of the lack of manufacturers' application instructions and the lack of established fastening schedules for common underlayments, each individual contractor is to use care to align rolls so that underlayments are installed without initial mis-alignment wrinkles or buckles, but so that each material's prescribed side-lap is achieved. Any irregularity of the previously applied underlayment will be accessed as being a function of the performance properties of that type of underlayment.

VIII. Exposure Data Collection:

Attached is a copy of the Data Collection Form that is to be used by each contractor's Designated Field Representative, (DFR). Data

Collection Forms are to be used to record each underlayment's performance at each test site in each climatic region. Information is to be recorded at the following intervals:

A. Prior to Installation

B. At Time of Installation

Note to Designated Field Representatives: When noting condition of deck at underlayment application, be sure standing water droplets, snow, etc. are broomed-off prior to underlayment application.

C. At Intervals After Underlayment Application:

- As specific project conditions allow: record changes to the underlayment on first and third day after application, or first day and again the day of or after precipitation. On projects where prolonged exposure is possible, (such as large housing developments in temperate climates where tile is often specified), record conditions again on the fifth, and up to the fifteenth day after application.
- On Projects of Prolonged Exposure: record changes in underlayment, duration of exposure, major weather changes, and note if there are relatively large amounts of curing interior concrete, plaster or joint compound. If by chance the structure is completely enclosed and temporarily occupied, note if humidifier and/or high energy/efficiency heater in use, and record changes in underlayment.

D. If Deemed Necessary By ARMA, To Assure Manufacturer's Agreement with Underlayment Application:

- A technical representative provided by ARMA or manufacturer shall meet roofing contractor's Designated Field Representative on site to assist in data collection and recording.
- If test site is in remote location, and/or if a technical representative will not be available to assist in recording data, the equipment needed for accurate data collection, (e.g., Delmhorst Meter, weather radio, postage scale, 35mm camera), shall be loaned to the participating contractor.

Final Examination of Exposed Samples:

I. After underlayments have been exposed, and the in-field portion of the testing is completed, three 12 inch-by-12 inch samples of each type of exposed underlayment shall be collected from each climate test region. The specimens shall be individually double-bagged in zip-lock type plastic bags, label the bags (date, site, length of exposure, and type of underlayment), then seal the outermost bags' top with duct tape, and send to NRCA Headquarters for final examination by NRCA and ARMA representatives along with the Data Collection Forms and photos.

Upon receipt of samples, data, and photos, NRCA's staff will assemble a preliminary report for review by NRCA and ARMA Residential/Steep Committees.

II. If deemed beneficial by ARMA and NRCA, all or a portion of test samples will be sent to a designated ARMA member laboratory for final analysis.

*****

End of Protocol

UNDERLAYMENT IN-SITU TESTING DATA COLLECTION FORM

July, 1993

Site Address: ______________________________

City: ______________ County: ______________ State: ______________

Recorded by: ______________ Company: ______________

FILL-IN PRIOR TO INSTALLATION:

Date: ______________

Underlayment Sample Type (circle one):

1. D226-Type I (#15) 2. D226-Type II (#30) 3. D4869-Type I (#15)
4. D4869-Type II (#30) 5. Non-Spec #15 6. Non-Spec #30
7. Glass Fiber Reinforced Organic

Cut 3 Samples, each from a different roll, cut each sample 3'-4" (long) x 3' (roll width)

	Length	Width	Weight
	(measure to nearest 1/16 inch)		(fold & weigh)
Sample #1:	____ ft. ____ in.	____ ft. ____ in.	____ lbs. ____ oz.
Sample #2:	____ ft. ____ in.	____ ft. ____ in.	____ lbs. ____ oz.
Sample #3:	____ ft. ____ in.	____ ft. ____ in.	____ lbs. ____ oz.

Relative Moisture Content of Felt (moisture meter): ____ %
(average of 3 readings taken at different locations)

NOTE: Although the purpose of this research project is to test underlayments, do not jeopardize exposure of structure or integrity of roof for the sake of testing.

FILL-IN AT INSTALLATION:

Date: ______________ Time Started: __________ a.m. p.m.

Roof Deck Material (circle one): Plywood Oriented Strand Board (OSB) Oriented Waferboard
Other: ______________

Roof Deck Thickness: ________ in.

Deck Condition Prior to Underlayment Application (circle one): Smooth Uneven

Deck joints properly spaced (circle one): Yes No

Surface Condition of Deck just prior to underlayment application (circle one):

Dry Surface damp (e.g., dew droplets) Wet (e.g., left out untarped)

Test Roof Orientation (circle one): North South East West

Relative Moisture Content of Deck (moisture meter): ________ % (North) ________ % (East) (average of 3 readings taken
________ % (South) ________ % (West) at different locations)

Total Roof Area of Structure: ________ sq. ft.

Test Roof Area: ________ sq. ft. Test Roof Slope: ________ :12
(verify with bubble level and tape measure)

Net (free) Area of Soffit Vents: ________ sq. ft. (total for all soffit/eave vents)

Net (free) Area of Roof Vents: ________ sq. ft. (total for all roof/ridge vents)

Total Floor Area of Attic: ________ sq. ft. Floor Area of Test Roof Only: ________ sq. ft

Comments: ____

____

____

Roof Cavity Ventilation Ratio (to be calculated @ NRCA office):________

CONDITIONS DURING UNDERLAYMENT APPLICATION:

Temperature:________ F Relative Humidity:________ % Wind Speed: ________ mph
(from NOAA Weather Radio)

General Weather Conditions (circle one):

Clear Cloudy Light Precipitation (mist, Not rain)

Relative Moisture Content of Felt (moisture meter): ________ %
(average of 3 readings)

Sketch of Underlayment Fastening Pattern:

Underlayment Fastening Method (circle one):
Hand-nailed Pneumatic Nailer
Tack/Stapler Pneumatic Stapler

Describe General Fastening Pattern Used:

________ inches o.c. straight or staggered in field ________ inches o.c. along side laps.

Is Uncured concrete, plaster or joint compound in structure (circle one): Yes No

Is This (circle one): New Construction or Reroofing Project

Is Structure Enclosed (circle one): Yes No

Is Structure Occupied (circle one): Yes No

Comments: ____

____

____

Please attach:

1. A photo of installation.

2. A sketch of roof—(indicate test area by shading and show test cut locations #1, #2, and #3).

AFTER APPLICATION—*1st Day After Application:*

Date: ______________________ Time: __________a.m. p.m.

Relative Moisture Content of Felt (moisture meter): ________%
(average of 3 readings—lift felt so deck surface is not measured)

Major Change in Weather (circle one): Yes No

If "Yes", Describe Change: ____

____

Relative Humidity Change greater than 20%? (circle one): Yes No
(check NOAA Weather Radio)

If "Yes", What is the Relative Humidity? ________% Temperature ________F

Circle the description that best describes the underlayment condition:

1. Laying smooth, No apparent wrinkling
2. No longer laying smooth, minimal wrinkling
3. Apparent wrinkling throughout
4. More than wrinkled, actually buckled in locations
5. Severe buckles/ridging

Average Size of Wrinkles/Buckles:

length:________in. width:________in. height:________in.

Wrinkles/Buckles extend in (circle one):

Machine direction Cross machine direction Both Random

Relative Foot Traffic on Roof (circle one):

None
Light (e.g., only roofing mechanics)
Heavy (e.g., other trades completing masonry or siding work, etc.)

Despite protocol, does contractor intend to leave test felt in place prior to shingle/finished roofing installation (circle one): Yes No

Photos

Include one of the entire job; close-ups of typical conditions and one of the felt—**write directly on the felt the code number and date photo is being taken.** (Include general measurements by including tape measure in photo to indicate length, width, height—of any buckles or wrinkles)

3rd Day or First Day of Precipitation After Application

Date: ____________________ Time: ________a.m. p.m.

Relative Moisture Content of Felt (moisture meter): ________%
(average of 3 readings—lift felt so deck surface is not measured)

Major Change in Weather (circle one): Yes No

If "Yes", Describe Change: ____

____

Relative Humidity Change greater than 20%? (circle one): Yes No
(check NOAA Weather Radio)

If "Yes", What is the Relative Humidity? ________% Temperature ________F

Circle the description that best describes the underlayment condition:

1. Laying smooth, No apparent wrinkling
2. No longer laying smooth, minimal wrinkling
3. Apparent wrinkling throughout
4. More than wrinkled, actually buckled in locations
5. Severe buckles/ridging

Average Size of Wrinkles/Buckles:

length:________in. width:________in. height:________in.

Wrinkles/Buckles extend in (circle one):

Machine direction Cross machine direction Both Random

Relative Foot Traffic on Roof (circle one):

None
Light (e.g., only roofing mechanics)
Heavy (e.g., other trades completing masonry or siding work, etc.)

Despite protocol, does contractor intend to leave test felt in place prior to shingle/finished roofing installation (circle one): Yes No

Photos

Include one of the entire job; close-ups of typical conditions and one of the felt—**write directly on the felt the code number and date photo is being taken.** (Include general measurements by including tape measure in photo to indicate length, width, height—of any buckles or wrinkles)

IF CONDITIONS ALLOW—*5th Day After Application:*

Date: ____________________ Time: ________a.m. p.m.

Relative Moisture Content of Felt (moisture meter): ________%
(average of 3 readings—lift felt so deck surface is not measured)

Major Change in Weather (circle one): Yes No

If "Yes", Describe Change: ____

____

Relative Humidity Change greater than 20%? (circle one): Yes No
(check NOAA Weather Radio)

If "Yes", What is the Relative Humidity? ________% Temperature ________F

Circle the description that best describes the underlayment condition:

1. Laying smooth, No apparent wrinkling
2. No longer laying smooth, minimal wrinkling
3. Apparent wrinkling throughout
4. More than wrinkled, actually buckled in locations
5. Severe buckles/ridging

Average Size of Wrinkles/Buckles:

length:________in. width:________in. height:________in.

Wrinkles/Buckles extend in (circle one):

Machine direction Cross machine direction Both Random

Relative Foot Traffic on Roof (circle one):

None
Light (e.g., only roofing mechanics)
Heavy (e.g., other trades completing masonry or siding work, etc.)

Despite protocol, does contractor intend to leave test felt in place prior to shingle/finished roofing installation (circle one): Yes No

Photos

Include one of the entire job; close-ups of typical conditions and one of the felt—**write directly on the felt the code number and date photo is being taken.** (Include general measurements by including tape measure in photo to indicate length, width, height—of any buckles or wrinkles)

IF PROJECT CONDITIONS ALLOW—*After Prolonged Exposure (up to 15 days)*:

Date: ______________________ Time: _________a.m. p.m.

Relative Moisture Content of Felt (moisture meter): ________%
(average of 3 readings—lift felt so deck surface is not measured)

Major Change in Weather (circle one): Yes No

If "Yes", Describe Change: ____

____

Relative Humidity Change greater than 20%? (circle one): Yes No
(check NOAA Weather Radio)

If "Yes", What is the Relative Humidity? ________% Temperature ________F

Circle the description that best describes the underlayment condition:

1. Laying smooth, No apparent wrinkling
2. No longer laying smooth, minimal wrinkling
3. Apparent wrinkling throughout
4. More than wrinkled, actually buckled in locations
5. Severe buckles/ridging

Average Size of Wrinkles/Buckles:

length:________in. width:________in. height:________in.

Wrinkles/Buckles extend in (circle one):

Machine direction Cross machine direction Both Random

Relative Foot Traffic on Roof (circle one):

None
Light (e.g., only roofing mechanics)
Heavy (e.g., other trades completing masonry or siding work, etc.)

Despite protocol, does contractor intend to leave test felt in place prior to shingle/finished roofing installation (circle one): Yes No

Photos

Include one of the entire job; close-ups of typical conditions and one of the felt—**write directly on the felt the code number and date photo is being taken.** (Include general measurements by including tape measure in photo to indicate length, width, height—of any buckles or wrinkles)

Appendix B. Weather Data Obtained from National Weather Service

OBSERVATIONS AT 3-HOUR INTERVALS

DEC 1993
DENVER, CO
23062

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY: WHOLE MILES	VISIBILITY: 16THS MILE	WEATHER	TEMPERATURE: AIR °F	TEMPERATURE: WET BULB °F	TEMPERATURE: DEW POINT °F	REL HUMIDITY %	WIND: DIRECTION	WIND: SPEED (KNOTS)
DEC 19th											
02	8	170	20			23	20	12	63	17	4
05	10	110	20			20	18	14	78	14	4
08	8	200	60			21	19	16	81	32	5
11	6	250	60			32	26	14	47	09	10
14	10	45	20		SW	29	25	17	61	05	10
17	10	10	0	12	S	25	24	23	92	36	8
20	10	44	3		S	23	22	20	88	06	5
23	10	32	7		S	17	16	14	88	13	4
DEC 20th											
02	0	UNL	15			13	12	9	84	15	4
05	0	UNL	20			9	8	5	84	19	6
08	0	UNL	70			13	11	5	70	20	7
11	0	UNL	70			31	24	11	43	16	5
14	0	UNL	60			39	29	10	30	11	4
17	1	UNL	60			32	25	13	45	00	0
20	0	UNL	20			34	27	14	44	25	11
23	0	UNL	20			32	24	6	33	20	7
DEC 21st											
02	0	UNL	25			24	19	8	50	09	8
05	3	UNL	25			18	15	7	62	03	6
08	6	180	60			25	20	9	51	08	9
11	10	37	40			29	25	17	61	08	9
14	10	32	2		SW	25	23	19	78	10	12
17	10	13	0	8	SW	24	23	22	92	06	8
20	10	24	10		SW	20	19	16	84	12	6
23	8	48	5		SW	14	13	10	84	13	5
DEC 22nd											
02	0	UNL	15			7	6	3	84	15	4
05	0	UNL	20			4	3	-1	80	18	3
08	0	UNL	70			9	7	2	73	16	5
11	1	UNL	70			25	20	7	46	20	5
14	1	UNL	60			33	25	10	38	22	3
17	3	UNL	50			24	19	8	50	10	4
20	7	250	20			19	17	11	71	20	7
23	10	90	20			24	20	12	60	11	7
DEC 23rd											
02	10	80	20			19	17	14	81	33	5
05	10	18	1		S	22	21	19	88	33	4
08	10	70	15		S	24	21	14	66	02	10
11	9	80	20			24	20	10	55	02	13
14	9	60	25			28	22	7	41	01	15
17	5	UNL	20			20	17	11	68	10	6
20	0	UNL	20			14	13	10	84	17	8
23	0	UNL	20			12	10	4	70	18	11
DEC 24th											
02	3	UNL	25			15	12	1	54	18	9
05	1	UNL	25			20	16	4	50	20	9
08	9	250	75			24	19	7	48	20	4
11	10	150	75			40	31	16	38	30	10
14	9	250	75			44	34	18	35	29	10
17	3	UNL	60			41	32	18	40	28	11
20	0	UNL	30			38	30	16	41	26	15
23	0	UNL	30			38	30	16	41	26	14
DEC 25th											
02	0	UNL	30			31	25	15	52	19	8
05	0	UNL	30			27	23	15	61	18	8
08	2	UNL	80			41	31	14	33	27	13
11	4	UNL	80			50	36	14	24	30	19
14	2	UNL	80			52	37	15	23	29	16
17	6	UNL	70			48	34	12	23	30	11
20	6	240	30			35	28	17	48	19	7
23	8	UNL	30			38	29	14	37	16	6
DEC 26th											
02	9	230	25			35	28	17	48	15	5
05	9	230	30			35	28	16	46	13	6
08	8	UNL	75			34	28	16	48	12	6
11	8	280	75			49	36	16	27	13	11
14	8	260	75			57	42	23	27	01	6
17	10	260	60			44	36	25	47	09	8
20	9	250	30			38	32	24	57	02	8
23	9	250	30			33	31	27	79	08	4
DEC 27th											
02	9	200	30			31	29	26	92	14	4
05	6	200	30			31	29	25	79	00	0
08	8	95	60			28	27	24	85	30	6
11	10	85	40			32	29	24	72	29	6
14	10	13	15			33	31	27	79	32	7
17	10	7	6		SF	30	29	27	89	36	10
20	10	4	1	8	SF	28	28	27	96	36	6
23	10	10	5		F	28	28	27	36	00	0
DEC 28th											
02	4	UNL	4		F	27	26	25	92	13	4
05	0	UNL	3		F	22	22	21	96	00	0
08	0	UNL	40			23	22	19	85	11	4
11	0	UNL	50			41	33	22	47	16	5
14	0	UNL	12			48	38	25	41	01	6
17	0	UNL	10			36	33	28	73	35	7
20	0	UNL	10			29	28	26	89	16	6
23	0	UNL	10			33	29	22	64	13	9
DEC 29th											
02	0	UNL	10			22	21	19	88	32	5
05	0	UNL	5		F	23	22	20	88	19	6
08	1	UNL	50			22	20	15	74	19	7
11	1	UNL	60			38	30	16	41	18	9
14	4	UNL	60			44	34	17	34	17	8
17	2	UNL	50			37	30	19	48	13	4
20	2	UNL	20			30	27	21	69	15	6
23	3	UNL	20			25	23	20	81	21	4
DEC 30th											
02	0	UNL	20			22	20	16	78	19	5
05	2	UNL	25			24	20	12	60	15	7
08	4	UNL	60			27	21	8	45	17	5
11	3	UNL	60			48	34	11	22	19	6
14	5	UNL	60			58	38	6	12	04	3
17	9	UNL	50			43	34	21	42	04	4
20	10	250	25			32	28	22	57	15	4
23	8	UNL	20			32	27	19	59	00	0
DEC 31st											
02	7	250	30			32	26	15	50	14	5
05	5	UNL	30			33	26	12	42	15	9
08	8	250	60			35	27	12	39	13	5
11	2	UNL	50			49	34	10	21	32	24
14	0	UNL	60			47	34	11	23	29	25
17	0	UNL	60			42	31	11	28	31	18
20	0	UNL	25			40	30	13	33	27	10
23	2	UNL	25			38	29	12	34	28	10

WEATHER CODES

*	TORNADO	SW	SNOW SHOWERS	GF	GROUND FOG
T	THUNDERSTORM	SG	SNOW GRAINS	BD	BLOWING DUST
Q	SQUALL	SP	SNOW PELLETS	BN	BLOWING SAND
R	RAIN	IC	ICE CRYSTALS	BS	BLOWING SNOW
RW	RAIN SHOWERS	IP	ICE PELLETS	BY	BLOWING SPRAY
ZR	FREEZING RAIN	IPW	ICE PELLET SHOWERS	K	SMOKE
L	DRIZZLE	A	HAIL	H	HAZE
ZL	FREEZING DRIZZLE	F	FOG	D	DUST
S	SNOW	IF	ICE FOG		

CEILING: UNL INDICATES UNLIMITED
WIND DIRECTION: DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH 27 FOR WEST. AN ENTRY OF 00 INDICATES CALM.
SPEED: THE OBSERVED AVERAGE ONE-MINUTE VALUE, EXPRESSED IN KNOTS (MPH=KNOTS X 1.151).

SUMMARY BY HOURS

HOUR L.S.T.	AVERAGES: SKY COVER (TENTHS)	STATION PRESSURE (INCHES)	TEMPERATURE: AIR TEMP °F	TEMPERATURE: WET BULB °F	TEMPERATURE: DEW POINT °F	REL HUMIDITY %	WIND SPEED (MPH)	RESULTANT WIND: DIRECTION	RESULTANT WIND: SPEED (MPH)
02	3	24.670	27	23	15	64	7.3	[illegible]	2.4
05	3	24.660	27	22	14	61	7.3	[illegible]	2.6
08	4	24.680	29	23	14	57	7.6	22	[illegible]
11	5	24.685	42	31	14	36	10.6	23	2.7
14	4	24.630	45	33	15	34	10.6	[illegible]	5.0
17	4	24.655	37	30	18	49	8.2	34	2.7
20	4	24.680	32	27	18	60	8.6	[illegible]	2.3
23	4	24.680	31	25	16	58	8.2	[illegible]	2.4

OBSERVATIONS AT 3-HOUR INTERVALS

NOV 1993 DENVER, CO 23062

Date	Hour L.S.T.	Sky cover (tenths)	Ceiling in hundreds of feet	Visibility: whole miles	Visibility: 16ths mile	Weather	Air °F	Wet bulb °F	Dew point °F	Rel humidity %	Wind: direction	Wind: speed (knots)
NOV 19th	02	10	100	20			29	25	19	66	03	11
	05	0	UNL	20			24	22	18	78	18	6
	08	0	UNL	70			26	23	18	72	16	10
	11	0	UNL	60			34	28	17	50	15	12
	14	0	UNL	40			42	33	18	38	32	5
	17	0	UNL	40			31	28	24	75	04	7
	20	0	UNL	15			28	26	23	82	19	5
	23	0	UNL	12			25	24	22	88	18	4
NOV 20th	02	0	UNL	20			23	21	18	81	16	5
	05	0	UNL	20			20	19	17	88	33	4
	08	1	UNL	60			32	26	16	52	18	8
	11	1	UNL	70			52	37	16	24	19	5
	14	6	230	60			56	39	15	20	07	5
	17	7	UNL	40			45	35	19	35	14	7
	20	6	250	20			36	31	23	59	12	5
	23	0	UNL	20			38	30	18	44	15	6
NOV 21st	02	0	UNL	30			33	27	17	52	13	
	05	0	UNL	30			29	25	18	64	15	
	08	3	UNL	80			39	30	16	39	18	
	11	1	UNL	80			56	40	18	23	17	
	14	8	180	70			58	43	24	27	14	
	17	8	250	60			48	37	23	37	15	
	20	8	160	20			41	35	26	55	19	
	23	8	160	20			38	33	25	60	17	
NOV 22nd	02	9	250	30			35	31	24	64	23	3
	05	4	UNL	30			33	29	24	70	13	6
	08	6	250	70			33	29	24	70	11	4
	11	4	UNL	70			59	42	20	22	16	3
	14	5	UNL	60			62	43	19	19	19	6
	17	5	UNL	40			48	40	31	52	36	9
	20	2	UNL	20			37	34	30	76	33	5
	23	1	UNL	20			33	32	30	89	00	0
NOV 23rd	02	10	1	0	2	F	28	28	28	100	36	3
	05	10	1	0	2	F	28	28	28	100	35	7
	08	10	1	0	2	ZLF	27	27	27	100	03	6
	11	10	5	0	8	SF	24	24	23	96	05	10
	14	10	4	1	4	ZLF	19	19	18	96	01	12
	17	10	7	3		SF	17	16	14	88	04	8
	20	10	24	1	8	SF	14	13	11	88	04	8
	23	10	8	0	12	SF	10	9	7	88	07	6
NOV 24th	02	10	45	4		SF	6	5	1	80	05	
	05	10	48	4		SF	5	4	0	80	06	
	08	10	24	1		SF	4	3	-1	80	05	
	11	10	13	0	12	SF	4	3	-2	76	06	
	14	10	35	10			6	4	-2	69	02	
	17	3	UNL	20			2	1	-4	76	05	
	20	2	UNL	15			-2	-3	-5	87	16	
	23	5	UNL	15			-6	-7	-11	79	12	
NOV 25th	02	10	32	10		SW	1	0	-5	76	13	5
	05	10	21	10		SW	3	2	-4	72	13	5
	08	4	UNL	20			3	2	-2	79	15	7
	11	8	UNL	4		F	5	4	-2	73	36	9
	14	0	UNL	7			15	12	4	62	12	4
	17	10	UNL	7			10	9	6	84	07	3
	20	10	80	7			8	7	4	84	36	4
	23	10	80	10			13	11	6	73	17	5
NOV 26th	02	6	110	20			18	13	-1	43	27	9
	05	10	80	20			10	8	3	73	18	2
	08	10	110	60			24	18	3	40	25	12
	11	8	150	60			29	22	6	38	29	15
	14	6	230	60			32	24	9	38	29	22
	17	7	230	60			31	24	8	38	28	16
	20	8	230	30			30	23	9	41	30	15
	23	9	100	20			31	24	9	40	29	18
NOV 27th	02	1	UNL	20			30	23	8	39	26	
	05	0	UNL	20			31	23	6	35	27	
	08	0	UNL	70			35	26	8	32	25	
	11	0	UNL	70			46	33	12	25	27	
	14	1	UNL	70			51	34	4	15	32	
	17	0	UNL	60			42	32	14	32	22	
	20	2	UNL	25			37	28	13	37	22	
	23	4	UNL	25			35	28	14	42	15	
NOV 28th	02	3	UNL	25			29	25	18	64	10	6
	05	4	UNL	25			29	25	17	61	16	6
	08	8	UNL	60			34	28	18	52	16	4
	11	8	UNL	60			53	39	20	27	10	4
	14	7	UNL	70			54	40	22	29	15	5
	17	9	250	60			40	33	23	51	15	5
	20	8	140	20			38	33	25	60	16	5
	23	8	UNL	25			34	30	25	70	18	3
NOV 29th	02	8	100	20			31	29	26	82	18	2
	05	9	110	25			34	31	27	76	19	3
	08	9	100	70			36	32	27	70	16	5
	11	5	UNL	70			52	40	25	35	19	5
	14	1	UNL	60			57	41	19	23	12	4
	17	0	UNL	60			47	38	25	42	12	6
	20	0	UNL	20			40	35	27	60	17	8
	23	4	UNL	25			34	31	26	73	17	6
NOV 30th	02	4	UNL	30			34	31	27	76	00	
	05	10	230	30			34	30	23	64	2[illegible]	
	08	10	230	50			37	30	20	50	19	
	11	9	230	40			42	35	24	49	00	
	14	2	UNL	20			51	40	27	40	36	
	17	0	UNL	70			38	34	28	67	10	
	20	1	UNL	20			36	32	27	70	16	
	23	5	UNL	20			31	29	25	79	1[illegible]	

WEATHER CODES

Code	Meaning	Code	Meaning	Code	Meaning
*	TORNADO	SW	SNOW SHOWERS	GF	GROUND FOG
T	THUNDERSTORM	SG	SNOW GRAINS	BD	BLOWING DUST
Q	SQUALL	SP	SNOW PELLETS	BN	BLOWING SAND
R	RAIN	IC	ICE CRYSTALS	BS	BLOWING SNOW
RW	RAIN SHOWERS	IP	ICE PELLETS	BY	BLOWING SPRAY
ZR	FREEZING RAIN	IPW	ICE PELLET SHOWERS	K	SMOKE
L	DRIZZLE	A	HAIL	H	HAZE
ZL	FREEZING DRIZZLE	F	FOG	D	DUST
S	SNOW	IF	ICE FOG		

CEILING: UNL INDICATES UNLIMITED
WIND DIRECTION: DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH 27 FOR WEST. AN ENTRY OF 00 INDICATES CALM.
SPEED: THE OBSERVED AVERAGE ONE-MINUTE VALUE, EXP RESSED IN KNOTS (MPH=KNOTS X 1.151).

SUMMARY BY HOURS

Hour L.S.T.	Averages: Sky cover (tenths)	Averages: Station pressure (inches)	Temperature: Air temp °F	Temperature: Wet bulb °F	Temperature: Dew point °F	Rel humidity %	Wind speed (MPH)	Resultant wind: Direction	Resultant wind: Speed (MPH)
02	5	24.690	27	24	19	72	5.8	16	2.0
05	5	24.680	26	23	18	72	6.1	18	3.3
08	5	24.700	30	26	18	64	7.5	17	3.6
11	5	24.695	42	32	18	44	8.2	17	2.0
14	5	24.650	45	34	19	41	8.5	03	2.9
17	5	24.670	38	31	20	55	7.2	07	2.5
20	5	24.690	32	28	20	65	8.0	18	0.9
23	4	24.700	29	25	19	70	6.9	14	1.9

OBSERVATIONS AT 3-HOUR INTERVALS

AUG 1993
DENVER, CO
23062

Columns: HOUR L S T; SKY COVER (TENTHS); CEILING IN HUNDREDS OF FEET; VISIBILITY: WHOLE MILES, 16THS MILE; WEATHER; TEMPERATURE: AIR °F, WET BULB °F, DEW POINT °F; REL HUMIDITY %; WIND: DIRECTION, SPEED (KNOTS)

AUG 19th

HOUR L S T	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	9	230	20			62	57	53	73	15	4
05	9	240	35			59	55	52	78	32	3
08	10	170	30			63	57	53	70	32	6
11	10	230	12			72	61	54	53	29	3
14	7	230	15			84	63	50	31	16	6
17	9	85	50			75	64	57	54	20	10
20	4	UNL	20			70	58	49	47	18	9
23	3	UNL	20			62	56	51	67	18	5

AUG 20th

HOUR L S T	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	6	UNL	20			60	55	52	75	20	5
05	6	UNL	30			58	54	51	78	21	[illegible]
08	10	12	12			64	60	58	81	31	[illegible]
11	8	UNL	8			72	63	58	62	02	[illegible]
14	10	230	6		H	82	65	56	41	32	[illegible]
17	10	200	12			77	63	55	47	33	[illegible]
20	10	110	20			69	60	55	61	14	[illegible]
23	6	250	20			66	58	53	63	18	[illegible]

AUG 21st

HOUR L S T	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	7	UNL	20			63	59	56	78	21	5
05	5	UNL	30			59	56	54	84	31	4
08	3	UNL	50			68	61	57	68	35	4
11	7	230	50			80	64	54	41	32	4
14	7	230	50			85	64	52	32	32	5
17	10	120	50			72	60	53	51	16	11
20	4	UNL	30			65	60	56	73	18	6
23	6	UNL	20			62	58	55	78	13	3

AUG 22nd

HOUR L S T	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	10	250	20			59	57	55	87	16	3
05	9	120	20			60	56	53	78	15	5
08	8	160	70			65	55	48	54	17	4
11	7	UNL	70			81	57	39	22	25	5
14	5	UNL	60			84	58	37	19	33	8
17	3	UNL	60			78	56	38	24	29	9
20	0	UNL	30			69	54	42	38	27	5
23	0	UNL	20			61	51	42	50	00	0

AUG 23rd

HOUR L S T	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	0	UNL	20			59	50	42	54	21	[illegible]
05	0	UNL	20			55	49	43	64	29	[illegible]
08	0	UNL	60			65	54	45	49	24	[illegible]
11	0	UNL	60			80	58	41	25	21	[illegible]
14	0	UNL	60			87	59	37	17	16	[illegible]
17	0	UNL	50			88	59	37	16	11	[illegible]
20	0	UNL	30			71	56	44	38	13	4
23	0	UNL	20			65	55	47	52	21	[illegible]

AUG 24th

HOUR L S T	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	0	UNL	20			61	52	44	54	18	5
05	0	UNL	30			59	50	41	52	19	8
08	0	UNL	70			73	56	43	34	21	8
11	0	UNL	70			89	59	35	15	18	5
14	0	UNL	70			92	61	39	16	12	7
17	0	UNL	70			90	61	42	19	12	12
20	[illegible]	UNL	30			79	59	44	29	13	12
23	2	UNL	20			76	58	44	32	16	11

AUG 25th

HOUR L S T	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	1	UNL	20			71	57	46	41	15	8
05	7	130	30			66	55	47	51	22	7
08	3	UNL	50			75	59	48	39	31	7
11	2	UNL	60			88	62	46	23	01	10
14	3	UNL	20			91	67	54	29	34	10
17	7	230	30			82	65	55	40	34	13
20	3	UNL	20			72	58	49	44	35	14
23	2	UNL	20			64	55	48	56	36	8

AUG 26th

HOUR L S T	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	2	UNL	20			61	56	52	72	32	[illegible]
05	6	250	30			58	55	52	81	33	[illegible]
08	10	120	40			65	57	52	63	34	[illegible]
11	10	75	50			69	59	52	55	23	[illegible]
14	10	85	25		RW	70	59	51	51	25	[illegible]
17	9	100	60			69	60	55	61	19	[illegible]
20	10	UNL	25			62	56	51	67	16	[illegible]
23	10	UNL	20			56	54	52	87	13	[illegible]

AUG 27th

HOUR L S T	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	8	230	20			56	54	52	87	16	6
05	6	230	40			54	52	51	90	34	8
08	10	10	10			56	53	51	83	01	9
11	10	16	10			62	56	51	67	00	0
14	10	60	7		RW	64	58	53	68	13	5
17	10	140	8			69	59	53	57	11	6
20	10	140	15			66	56	48	53	17	9
23	10	150	15			62	57	53	73	13	3

AUG 28th

HOUR L S T	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	6	130	15			56	54	52	87	00	0
05	10	150	7			57	55	53	87	00	0
08	10	250	20			62	56	52	70	13	6
11	9	180	70			76	58	46	35	19	11
14	10	UNL	60			82	58	39	22	08	8
17	7	UNL	60			81	57	38	22	12	9
20	3	UNL	25			71	56	44	38	12	9
23	4	UNL	25			64	54	47	54	16	5

AUG 29th

HOUR L S T	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	4	UNL	30			60	53	48	65	17	[illegible]
05	4	UNL	30			55	51	47	75	22	[illegible]
08	8	250	60			71	55	43	37	31	4
11	10	180	60			79	57	40	25	00	[illegible]
14	8	UNL	60			84	58	39	20	17	[illegible]
17	10	UNL	40			81	57	38	22	13	[illegible]
20	10	120	20			73	57	45	37	20	[illegible]
23	10	90	15		RW	63	56	51	65	02	[illegible]

AUG 30th

HOUR L S T	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	10	26	10			55	50	46	72	01	13
05	10	29	15			52	48	44	74	36	11
08	10	60	40			52	47	43	72	34	8
11	10	120	40			54	47	41	62	06	5
14	9	55	30			59	48	37	44	05	6
17	6	140	30			60	48	37	43	22	6
20	2	UNL	15			53	46	39	59	27	3
23	10	140	20			51	46	42	72	12	5

AUG 31st

HOUR L S T	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	8	49	25			52	47	42	69	11	6
05	9	42	30			52	47	43	72	12	6
08	8	38	35			59	51	45	60	14	3
11	5	UNL	40			68	55	45	44	33	4
14	9	150	30			72	57	46	40	15	6
17	6	150	40			73	59	50	45	18	12
20	3	UNL	20			67	55	46	47	16	12
23	1	UNL	20			61	54	48	63	16	8

WEATHER CODES

*	TORNADO	SW	SNOW SHOWERS	GF	GROUND FOG
T	THUNDERSTORM	SG	SNOW GRAINS	BD	BLOWING DUST
Q	SQUALL	SP	SNOW PELLETS	BN	BLOWING SAND
R	RAIN	IC	ICE CRYSTALS	BS	BLOWING SNOW
RW	RAIN SHOWERS	IP	ICE PELLETS	BY	BLOWING SPRAY
ZR	FREEZING RAIN	IPW	ICE PELLET SHOWERS	K	SMOKE
L	DRIZZLE	A	HAIL	H	HAZE
ZL	FREEZING DRIZZLE	F	FOG	D	DUST
S	SNOW	IF	ICE FOG		

CEILING: UNL INDICATES UNLIMITED
WIND DIRECTION: DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH 27 FOR WEST. AN ENTRY OF 00 INDICATES CALM.
SPEED: THE OBSERVED AVERAGE ONE-MINUTE VALUE, EXP RESSED IN KNOTS (MPH=KNOTS X 1.151).

SUMMARY BY HOURS

HOUR L S T	AVERAGES: SKY COVER (TENTHS)	STATION PRESSURE (INCHES)	TEMPERATURE: AIR TEMP °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND SPEED (MPH)	RESULTANT WIND: DIRECTION	SPEED (MPH)
02	4	24.790	61	55	51	70	7.0	16	2.8
05	6	24.800	58	54	50	75	6.5	22	1.8
08	6	24.820	67	57	50	57	7.4	32	2.4
11	6	24.810	77	59	47	39	6.6	03	1.0
14	7	24.770	81	60	46	32	9.1	08	3.1
17	7	24.760	77	60	47	39	10.2	14	3.0
20	6	24.780	69	57	49	52	9.8	17	5.4
23	5	24.790	65	56	50	61	8.3	16	3.3

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OBSERVATIONS AT 3-HOUR INTERVALS

JAN 1994
MILWAUKEE, WI
14839

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY: WHOLE MILES	VISIBILITY: 16THS MILE	WEATHER	TEMPERATURE: AIR °F	TEMPERATURE: WET BULB °F	TEMPERATURE: DEW POINT °F	REL HUMIDITY %	WIND: DIRECTION	WIND: SPEED (KNOTS)
JAN 19th											
03	0	UNL	15			-19	-20	-27	66	24	7
06	0	UNL	12			-21	-21	-29	65	23	11
09	10	140	10			-14	-15	-23	63	24	10
12	10	100	4		S	-6	-7	-15	64	23	11
15	10	29	2	8	S	0	-1	-7	72	23	10
18	4	UNL	9			0	-1	-6	75	24	5
21	7	30	10		IC	-2	-3	-7	79	26	6
24	0	UNL	15			-4	-5	-8	83	24	6
JAN 20th											
03	0	UNL	10			-5	-6	-9	83	27	6
06	0	UNL	10			-7	-8	-13	75	28	5
09	7	UNL	7			-3	-4	-12	65	27	7
12	10	220	7			7	5	-9	47	27	12
15	2	UNL	10			9	6	-10	41	26	9
18	0	UNL	12			3	1	-11	52	25	7
21	0	UNL	15			-2	-3	-12	62	23	9
24	0	UNL	12			-3	-4	-13	62	26	7
JAN 21st											
03	10	130	10			0	-1	-11	59	23	13
06	10	100	10			6	4	-8	52	24	15
09	9	95	10			9	7	0	67	23	18
12	5	UNL	7			18	15	7	62	23	16
15	5	UNL	7			20	17	10	65	25	15
18	5	UNL	7			19	17	11	71	25	14
21	10	UNL	7			21	19	13	71	25	11
24	10	130	7			22	20	15	74	27	12
JAN 22nd											
03	10	130	7			22	20	16	78	29	10
06	10	140	7			21	20	16	81	31	5
09	10	140	6		H	24	22	17	75	27	4
12	10	200	7			31	28	22	69	08	7
15	10	200	7			31	28	23	72	11	7
18	10	10	7			27	26	24	89	17	4
21	10	19	3		F	26	25	24	92	18	3
24	10	3	0	10	ZLF	27	27	26	96	19	7
JAN 23rd											
03	10	0	0	1	ZLF	30	30	30	100	19	7
06	10	2	1		F	35	35	35	100	24	9
09	10	5	1	8	F	35	35	34	96	24	10
12	7	150	3		F	37	35	33	86	24	14
15	6	UNL	6		H	42	37	31	65	26	12
18	1	UNL	6		H	36	33	29	76	25	8
21	0	UNL	7			35	32	28	76	26	10
24	0	UNL	5		F	31	30	27	85	25	5
JAN 24th											
03	0	UNL	4		F	26	25	24	92	26	3
06	0	UNL	3		F	24	23	22	92	21	4
09	2	UNL	3		F	29	27	24	82	27	4
12	0	UNL	6		H	38	32	20	48	00	0
15	7	13	7			31	29	25	79	01	12
18	10	15	7			31	30	27	85	02	13
21	6	19	8			30	28	24	78	03	12
24	10	14	8			31	30	27	85	05	12
JAN 25th											
03	10	13	7			32	31	28	85	06	14
06	10	5	4		ZLSF	31	31	30	96	05	14
09	10	6	4		SF	30	29	28	92	05	13
12	10	5	2	8	ZLSF	28	27	26	92	05	17
15	10	5	2	8	ZRIPF	28	28	27	96	04	18
18	10	7	1	8	IPSF	28	28	27	96	04	17
21	10	10	2	8	IPSF	28	27	24	85	04	16
24	10	14	10		S	23	22	18	81	04	18
JAN 26th											
03	10	16	10		S	21	19	14	74	05	18
06	10	15	10		S	20	18	14	78	08	15
09	10	10	2	8	SF	19	18	15	84	07	17
12	10	15	10			21	19	15	78	06	15
15	10	20	10			23	21	15	71	08	15
18	10	200	10			23	21	15	71	08	17
21	10	11	9			21	20	16	81	07	18
24	10	8	1		SF	20	19	17	88	07	18
JAN 27th											
03	10	9	3		ZRIPSF	22	21	19	88	09	16
06	10	8	1	8	ZRIPSF	26	26	25	96	08	16
09	10	10	3		ZLF	30	29	28	92	12	13
12	10	4	2	8	ZRZLF	30	30	29	96	12	10
15	10	5	7			32	32	31	96	08	7
18	10	4	5		F	31	31	31	100	07	8
21	10	1	0	6	LF	32	32	32	100	03	10
24	10	2	2	8	ZRF	32	32	32	100	03	4
JAN 28th											
03	10	2	1	8	F	31	31	31	100	36	10
06	10	4	4		ZLF	29	29	28	96	33	10
09	10	17	1	8	SF	23	22	21	92	32	10
12	10	38	3		SF	25	24	21	85	32	9
15	10	23	1		SF	26	25	24	92	28	12
18	10	40	2		SF	25	25	23	88	31	11
21	10	46	6		SF	26	25	22	85	29	10
24	10	34	6		SF	24	22	17	75	32	8
JAN 29th											
03	4	UNL	9			20	19	16	84	31	5
06	10	55	9		S	21	20	17	85	33	6
09	10	43	7		S	20	18	14	78	35	6
12	10	29	1		S	23	21	18	81	35	6
15	10	65	4		SF	22	21	17	81	35	10
18	10	65	4		SF	17	16	13	84	35	13
21	10	23	1	8	SWF	15	14	11	84	34	11
24	10	18	3		SWF	16	15	13	88	35	9
JAN 30th											
03	10	14	2		SWF	14	13	11	88	35	11
06	10	16	3		SWF	12	11	9	88	33	8
09	10	14	1	8	SWF	14	13	11	88	32	6
12	10	17	2		SWF	19	18	14	81	35	9
15	10	31	3		SWF	18	17	14	84	01	9
18	3	UNL	10			13	12	8	80	31	7
21	2	UNL	8			8	7	3	80	31	9
24	5	UNL	10			6	5	-1	73	30	9
JAN 31st											
03	6	UNL	10			2	1	-3	79	29	8
06	3	UNL	10			-1	-2	-6	79	29	8
09	2	UNL	10			1	0	-7	69	28	10
12	0	UNL	12			8	6	-3	60	28	14
15	0	UNL	12			11	9	-2	55	27	9
18	2	UNL	10			4	2	-6	63	25	8
21	3	UNL	8			-1	-2	-8	72	25	8
24	0	UNL	8			-3	-4	-10	72	26	7

WEATHER CODES

*	TORNADO	SW	SNOW SHOWERS	GF	GROUND FOG
T	THUNDERSTORM	SG	SNOW GRAINS	BD	BLOWING DUST
Q	SQUALL	SP	SNOW PELLETS	BN	BLOWING SAND
R	RAIN	IC	ICE CRYSTALS	BS	BLOWING SNOW
RW	RAIN SHOWERS	IP	ICE PELLETS	BY	BLOWING SPRAY
ZR	FREEZING RAIN	IPW	ICE PELLET SHOWERS	K	SMOKE
L	DRIZZLE	A	HAIL	H	HAZE
ZL	FREEZING DRIZZLE	F	FOG	D	DUST
S	SNOW	IF	ICE FOG		

CEILING: UNL INDICATES UNLIMITED
WIND DIRECTION: DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH 27 FOR WEST. AN ENTRY OF 00 INDICATES CALM.
SPEED: THE OBSERVED AVERAGE ONE-MINUTE VALUE, EXP RESSED IN KNOTS (MPH=KNOTS X 1.15).

SUMMARY BY HOURS

HOUR L.S.T.	AVERAGES: SKY COVER (TENTHS)	STATION PRESSURE (INCHES)	TEMPERATURE: AIR TEMP °F	TEMPERATURE: WET BULB °F	TEMPERATURE: DEW POINT °F	REL HUMIDITY %	WIND SPEED (MPH)	RESULTANT WIND: DIRECTION	RESULTANT WIND: SPEED (MPH)
03	7	29.400	14	12	8	78	11.8	30	4.3
06	7	29.390	13	12	7	78	11.1	29	4.4
09	7	29.410	14	13	8	75	11.8	28	4.8
12	7	29.395	19	17	10	69	12.7	29	5.0
15	7	29.380	19	17	11	71	12.9	30	4.8
18	6	29.400	16	15	10	75	12.2	30	3.7
21	6	29.415	14	13	8	76	12.1	30	4.7
24	6	29.415	13	12	7	77	11.2	30	4.3

OBSERVATIONS AT 3-HOUR INTERVALS

OCT 1993 PHOENIX, AZ 23183

Date	Hour L.S.T.	Sky Cover (Tenths)	Ceiling in Hundreds of Feet	Visibility Whole Miles	Visibility 16ths Mile	Weather	Temperature Air °F	Temperature Wet Bulb °F	Temperature Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed (Knots)
OCT 19th	02	0	UNL	35			59	51	44	58	28	3
	05	0	UNL	35			57	50	44	62	27	3
	08	0	UNL	50			59	51	44	58	00	0
	11	0	UNL	50			73	56	41	32	00	0
	14	0	UNL	40			78	57	38	24	32	3
	17	0	UNL	60			79	57	38	23	26	6
	20	0	UNL	35			73	55	38	28	26	4
	23	0	UNL	35			68	54	42	39	03	3
OCT 20th	02	0	UNL	35			63	53	43	48	11	6
	05	0	UNL	35			60	51	42	52	10	6
	08	0	UNL	45			62	53	45	54	07	3
	11	0	UNL	45			76	56	39	26	10	3
	14	0	UNL	55			82	58	38	21	27	3
	17	0	UNL	60			83	59	38	20	35	4
	20	0	UNL	35			75	56	38	26	33	3
	23	0	UNL	35			69	54	41	36	02	3
OCT 21st	02	0	UNL	35			71	53	36	28	06	8
	05	0	UNL	35			60	51	42	52	00	0
	08	4	UNL	45			70	53	37	30	09	10
	11	10	UNL	45			79	58	39	24	09	12
	14	10	UNL	45			85	59	37	18	12	7
	17	10	250	50			85	58	34	16	11	6
	20	8	UNL	35			78	57	37	23	07	7
	23	10	250	35			75	54	33	22	06	6
OCT 22nd	02	10	250	35			72	52	32	23	12	3
	05	10	UNL	35			70	52	33	26	10	4
	08	8	250	45			70	52	33	26	09	4
	11	10	250	45			78	55	31	18	06	7
	14	8	250	45			84	57	31	15	06	5
	17	10	250	45			83	57	32	16	06	5
	20	10	250	35			77	55	34	21	06	3
	23	10	250	35			73	53	36	28	00	0
OCT 23rd	02	8	UNL	35			68	52	37	32	22	3
	05	2	UNL	35			63	51	40	43	13	3
	08	0	UNL	50			65	52	40	40	27	3
	11	0	UNL	50			81	56	33	18	09	6
	14	0	UNL	50			88	58	30	12	09	5
	17	0	UNL	60			87	58	30	13	02	3
	20	0	UNL	35			77	56	36	23	00	0
	23	0	UNL	35			70	54	39	32	13	3
OCT 24th	02	0	UNL	35			64	51	38	38	00	0
	05	0	UNL	35			62	51	40	45	10	4
	08	0	UNL	50			64	50	36	36	11	5
	11	0	UNL	60			77	56	38	25	09	6
	14	1	UNL	60			88	59	33	14	24	4
	17	5	UNL	45			85	57	30	14	32	3
	20	7	250	35			77	57	39	26	36	3
	23	4	UNL	35			73	55	39	29	12	4
OCT 25th	02	8	250	35			67	53	40	37	23	3
	05	10	140	35			68	54	42	39	10	6
	08	9	130	45			69	52	35	29	11	7
	11	2	UNL	40			78	56	34	20	09	5
	14	1	UNL	40			86	59	35	16	05	3
	17	2	UNL	50			88	59	32	13	18	4
	20	1	UNL	35			78	57	38	24	01	3
	23	1	UNL	35			72	57	44	37	12	3
OCT 26th	02	0	UNL	35			66	54	43	43	13	3
	05	0	UNL	35			65	52	40	40	10	6
	08	0	UNL	50			65	53	41	42	01	3
	11	0	UNL	45			79	58	40	25	02	3
	14	0	UNL	45			86	59	35	16	28	6
	17	1	UNL	45			87	58	32	14	23	7
	20	2	UNL	25			71	54	39	31	04	14
	23	8	120	35			69	53	37	31	04	10
OCT 27th	02	4	UNL	35			69	54	40	35	04	12
	05	2	UNL	35			69	54	41	36	06	14
	08	5	UNL	45			69	54	40	35	06	17
	11	3	UNL	45			73	56	40	30	07	20
	14	1	UNL	40			78	58	40	26	07	13
	17	0	UNL	60			79	58	41	26	07	12
	20	0	UNL	35			74	57	43	33	08	7
	23	0	UNL	35			68	54	42	39	00	0
OCT 28th	02	0	UNL	35			66	54	42	42	12	4
	05	0	UNL	35			63	52	41	45	11	6
	08	0	UNL	50			64	52	41	43	09	4
	11	1	UNL	50			73	56	42	33	10	6
	14	7	UNL	50			80	59	41	25	27	3
	17	5	UNL	50			80	58	39	23	31	7
	20	6	UNL	35			73	56	40	30	26	5
	23	10	220	35			70	54	39	32	33	3
OCT 29th	02	10	250	35			66	53	42	42	11	8
	05	0	UNL	35			62	54	46	56	09	6
	08	0	UNL	50			62	54	47	58	10	9
	11	0	UNL	50			74	59	47	38	23	5
	14	0	UNL	40			78	57	39	25	23	5
	17	0	UNL	45			79	57	36	21	28	7
	20	0	UNL	35			73	55	38	28	10	5
	23	0	UNL	35			67	52	38	35	08	4
OCT 30th	02	0	UNL	35			62	51	39	43	12	4
	05	0	UNL	35			60	49	38	44	00	0
	08	0	UNL	50			63	47	29	28	34	3
	11	0	UNL	50			70	47	14	12	08	10
	14	0	UNL	50			76	49	10	8	09	6
	17	0	UNL	70			77	50	11	8	09	7
	20	0	UNL	35			69	47	14	12	13	5
	23	0	UNL	35			62	45	22	22	09	3
OCT 31st	02	0	UNL	35			59	44	24	26	13	3
	05	5	UNL	35			57	42	22	26	08	3
	08	10	UNL	45			59	44	23	25	11	4
	11	10	250	45			68	48	24	19	10	10
	14	10	250	45			73	51	24	16	05	5
	17	10	180	60			73	51	26	17	00	0
	20	9	140	35			66	49	31	27	33	3
	23	6	UNL	35			62	47	30	30	00	0

WEATHER CODES

*	TORNADO	SW	SNOW SHOWERS	GF	GROUND FOG
T	THUNDERSTORM	SG	SNOW GRAINS	BD	BLOWING DUST
Q	SQUALL	SP	SNOW PELLETS	BN	BLOWING SAND
R	RAIN	IC	ICE CRYSTALS	BS	BLOWING SNOW
RW	RAIN SHOWERS	IP	ICE PELLETS	BY	BLOWING SPRAY
ZR	FREEZING RAIN	IPW	ICE PELLET SHOWERS	K	SMOKE
L	DRIZZLE	A	HAIL	H	HAZE
ZL	FREEZING DRIZZLE	F	FOG	D	DUST
S	SNOW	IF	ICE FOG		

CEILING: UNL INDICATES UNLIMITED
WIND DIRECTION: DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH 27 FOR WEST. AN ENTRY OF 00 INDICATES CALM.
SPEED: THE OBSERVED AVERAGE ONE-MINUTE VALUE, EXP RESSED IN KNOTS (MPH=KNOTS X 1.15).

SUMMARY BY HOURS

Hour L.S.T.	Averages: Sky Cover (Tenths)	Averages: Station Pressure (Inches)	Temperature: Air Temp °F	Temperature: Wet Bulb °F	Temperature: Dew Point °F	Rel Humidity %	Wind Speed (MPH)	Resultant Wind: Direction	Resultant Wind: Speed (MPH)
02	4	28.760	70	57	46	45	5.2	11	3.6
05	3	28.765	67	56	46	49	6.0	09	5.5
08	3	28.805	69	57	46	46	6.8	09	5.8
11	3	28.820	79	60	44	31	6.6	10	4.8
14	3	28.750	85	61	42	26	6.2	16	0.5
17	4	28.710	85	60	40	24	6.2	30	2.1
20	3	28.730	78	59	43	32	4.6	04	1.4
23	3	28.750	73	58	45	39	3.6	10	1.6

OBSERVATIONS AT 3-HOUR INTERVALS

NOV 1993 23183
PHOENIX, AZ

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY: WHOLE MILES	VISIBILITY: 16THS MILE	WEATHER	TEMPERATURE: AIR °F	TEMPERATURE: WET BULB °F	TEMPERATURE: DEW POINT °F	REL HUMIDITY %	WIND: DIRECTION	WIND: SPEED (KNOTS)
NOV 1st											
02	4	UNL	35			59	47	34	39	13	3
05	3	UNL	35			55	45	33	44	11	3
08	6	250	50			56	45	33	42	13	4
11	2	UNL	45			68	51	32	26	08	3
14	7	UNL	45			76	52	25	15	32	5
17	6	250	45			75	51	23	14	30	7
20	2	UNL	35			67	49	29	24	00	0
23	0	UNL	35			62	49	35	37	00	0
NOV 2nd											
02	0	UNL	35			57	47	35	44	13	3
05	0	UNL	35			52	44	35	53	00	0
08	0	UNL	45			57	46	34	42	23	3
11	0	UNL	60			73	50	20	13	05	7
14	0	UNL	60			78	51	15	9	02	6
17	0	UNL	60			78	50	12	8	36	4
20	0	UNL	35			72	47	8	8	06	6
23	0	UNL	35			63	44	15	15	34	3
NOV 3rd											
02	0	UNL	35			57	41	16	20	27	3
05	0	UNL	35			53	41	23	31	00	0
08	0	UNL	60			58	42	20	23	00	0
11	0	UNL	60			75	50	19	12	13	3
14	0	UNL	60			82	54	23	11	11	3
17	0	UNL	60			80	53	23	12	33	3
20	0	UNL	35			70	50	27	20	00	0
23	0	UNL	35			63	48	30	29	10	3
NOV 4th											
02	0	UNL	35			59	46	29	32	00	0
05	0	UNL	35			55	43	28	36	07	5
08	0	UNL	45			57	45	30	36	10	4
11	0	UNL	45			68	50	31	25	12	5
14	0	UNL	40			79	53	22	12	25	3
17	0	UNL	40			79	52	20	11	27	3
20	0	UNL	35			70	50	27	20	09	3
23	0	UNL	35			63	46	25	24	13	3
NOV 5th											
02	0	UNL	35			58	45	30	35	14	3
05	0	UNL	35			55	43	27	34	10	4
08	0	UNL	45			56	44	28	34	08	3
11	0	UNL	40			69	50	29	23	14	3
14	0	UNL	40			77	58	41	28	14	3
17	0	UNL	40			77	56	36	23	27	9
20	0	UNL	35			71	54	39	31	00	0
23	0	UNL	35			64	52	41	43	00	0
NOV 6th											
02	0	UNL	35			58	46	31	36	14	3
05	0	UNL	35			60	43	20	21	10	5
08	0	UNL	50			57	44	28	33	00	0
11	0	UNL	50			69	48	22	17	35	5
14	0	UNL	50			77	52	22	13	09	3
17	0	UNL	50			76	51	21	13	10	3
20	0	UNL	35			66	48	27	23	00	0
23	0	UNL	35			60	46	30	32	00	0
NOV 7th											
02	3	UNL	35			57	41	16	20	13	3
05	0	UNL	35			53	43	29	40	05	3
08	0	UNL	45			54	42	26	34	07	3
11	0	UNL	35			68	49	26	21	09	6
14	0	UNL	35			77	53	28	16	00	0
17	0	UNL	40			77	52	25	15	32	4
20	0	UNL	35			66	49	29	25	00	0
23	0	UNL	35			61	47	31	32	11	4
NOV 8th											
02	0	UNL	35			57	45	30	36	09	4
05	0	UNL	35			54	43	29	38	09	6
08	0	UNL	40			55	44	30	39	12	4
11	0	UNL	40			68	50	29	23	13	4
14	0	UNL	40			76	53	28	17	11	3
17	0	UNL	40			77	52	24	14	26	3
20	0	UNL	35			67	49	28	23	00	0
23	0	UNL	35			62	47	33	30	11	3
NOV 9th											
02	0	UNL	35			56	44	30	37	11	4
05	0	UNL	35			54	43	29	38	06	3
08	0	UNL	40			55	44	30	39	07	4
11	0	UNL	40			69	50	28	22	09	5
14	1	UNL	40			79	53	24	13	25	3
17	1	UNL	35			78	53	24	13	29	3
20	0	UNL	35			68	50	29	23	00	0
23	0	UNL	35			62	48	32	33	00	0
NOV 10th											
02	2	UNL	35			56	45	32	40	00	0
05	5	UNL	35			54	43	28	37	09	4
08	10	UNL	40			56	44	29	36	08	4
11	10	UNL	40			70	50	26	19	08	4
14	10	UNL	40			82	55	27	13	12	3
17	10	250	35			78	53	27	15	26	5
20	10	250	35			71	51	30	22	00	0
23	10	250	35			67	50	32	27	09	3
NOV 11th											
02	10	35	35			62	47	30	30	06	5
05	10	80	35			60	47	32	35	05	3
08	10	55	20		RW	62	48	32	33	10	6
11	7	35	25			58	56	54	87	10	8
14	8	65	35			69	55	32	38	27	21
17	2	UNL	30			68	52	37	32	26	15
20	0	UNL	35			62	50	37	40	28	8
23	0	UNL	35			57	48	33	51	30	4
NOV 12th											
02	0	UNL	35			53	47	41	64	08	6
05	0	UNL	35			52	47	41	66	11	6
08	10	75	35			52	48	43	72	07	7
11	10	75	20		RW	58	53	48	70	17	6
14	10	85	15		RW	58	55	52	81	14	4
17	5	UNL	25			61	55	50	67	11	7
20	4	UNL	35			56	54	53	90	08	6
23	10	45	15		RW	54	49	45	72	33	6
NOV 13th											
02	10	75	15		RW	51	51	50	96	06	4
05	10	44	15		RW	49	48	46	90	11	6
08	9	100	35			49	47	45	86	23	7
11	9	110	40		R	49	47	45	86	24	5
14	6	100	45			59	50	41	52	24	7
17	6	80	40			53	48	43	69	01	7
20	0	UNL	35			51	47	42	72	12	8
23	6	100	35			49	46	42	77	10	8
NOV 14th											
02	8	110	35			49	46	42	77	10	7
05	7	100	35			49	45	41	74	11	7
08	10	70	20		R	49	47	44	83	13	10
11	10	43	15		R	50	48	46	86	07	8
14	10	33	4		RF	50	49	47	90	05	10
17	10	50	5		RF	49	48	47	93	04	9
20	10	35	8		R	49	48	46	90	06	11
23	10	23	7		R	50	49	47	90	06	10
NOV 15th											
02	10	49	20		R	50	49	47	90	09	15
05	10	12	5		R	49	48	46	90	10	5
08	10	40	10		R	47	46	45	93	11	10
11	10	110	50			50	46	42	74	11	8
14	9	100	70			54	47	40	59	07	4
17	3	UNL	70			55	47	39	55	05	5
20	0	UNL	35			51	46	41	69	00	0
23	0	UNL	35			48	46	43	83	00	0
NOV 16th											
02	0	UNL	35			47	45	42	83	09	5
05	0	UNL	35			44	43	42	93	11	3
08	0	UNL	50			45	43	41	86	11	6
11	4	UNL	50			55	49	42	62	09	7
14	6	UNL	50			63	52	42	46	13	3
17	9	150	45			64	53	42	45	00	0
20	2	UNL	35			57	52	47	69	27	3
23	6	UNL	35			54	50	46	75	00	0
NOV 17th											
02	9	UNL	35			51	48	45	80	12	3
05	9	150	35			52	48	44	74	00	0
08	10	130	50			56	49	41	57	13	6
11	10	UNL	45			64	52	40	42	08	6
14	10	UNL	50			70	53	37	30	12	8
17	9	UNL	50			70	54	39	32	00	0
20	8	UNL	35			62	53	45	54	00	0
23	5	UNL	35			58	51	45	62	10	6
NOV 18th											
02	6	UNL	35			53	49	46	77	00	0
05	6	250	35			51	49	46	83	00	0
08	7	UNL	35			54	48	42	64	09	3
11	5	UNL	45			66	54	44	45	08	5
14	7	UNL	45			72	56	41	33	24	4
17	4	UNL	35			69	55	43	39	23	7
20	7	UNL	35			62	54	46	56	00	0
23	8	UNL	35			59	52	46	62	00	0

MAXIMUM SHORT DURATION PRECIPITATION

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	0.05	0.09	0.12	0.15	0.19	0.24	0.28	0.34	0.40	0.44	0.51	0.59
ENDED: DATE	14	14	14	14	14	14	14	14	14	14	14	14
ENDED: TIME	1314	1312	1317	1317	1317	1325	1340	1408	1420	1432	1821	1844

THE PRECIPITATION AMOUNTS FOR THE INDICATED TIME INTERVALS MAY OCCUR AT ANY TIME DURING THE MONTH. THE TIME INDICATED IS THE ENDING TIME OF THE INTERVAL. DATE AND TIME ARE NOT ENTERED FOR TRACE AMOUNTS.

OBSERVATIONS AT 3-HOUR INTERVALS

JAN 1994 PHOENIX, AZ 23183

Columns: HOUR L.S.T. | SKY COVER (TENTHS) | CEILING IN HUNDREDS OF FEET | VISIBILITY: WHOLE MILES | VISIBILITY: 16THS MILE | WEATHER | TEMPERATURE: AIR °F | TEMPERATURE: WET BULB °F | TEMPERATURE: DEW POINT °F | REL HUMIDITY % | WIND: DIRECTION | WIND: SPEED (KNOTS)

JAN 1st

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	0	UNL	35			50	45	40	69	12	4
05	6	UNL	35			48	44	39	71	11	5
08	8	250	40			48	43	38	69	11	7
11	4	UNL	45			58	49	39	49	13	6
14	8	UNL	45			67	53	40	37	12	3
17	9	250	50			67	53	39	36	00	0
20	1	UNL	35			58	50	42	56	00	0
23	8	UNL	35			54	48	42	64	00	0

JAN 2nd

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	7	UNL	35			49	45	41	74	13	3
05	9	250	35			49	44	39	69	12	4
08	2	UNL	50			45	42	39	80	11	3
11	6	UNL	50			59	50	40	50	13	3
14	2	UNL	50			67	53	39	36	30	6
17	5	UNL	45			69	53	38	32	31	4
20	0	UNL	35			60	50	39	46	00	0
23	3	UNL	35			54	47	40	59	00	0

JAN 3rd

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	4	UNL	35			51	45	37	59	00	0
05	6	UNL	35			47	42	35	63	11	5
08	1	UNL	45			45	41	35	68	11	7
11	0	UNL	45			58	47	35	42	10	7
14	0	UNL	40			69	50	30	23	32	3
17	0	UNL	40			71	51	28	20	28	3
20	0	UNL	35			60	48	35	39	00	0
23	0	UNL	35			54	44	32	43	09	6

JAN 4th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	0	UNL	35			50	42	33	52	10	5
05	0	UNL	35			45	39	32	61	07	5
08	0	UNL	45			45	39	30	56	09	7
11	3	UNL	45			60	45	27	29	09	8
14	7	UNL	50			72	52	30	21	01	3
17	7	UNL	50			74	52	29	19	27	3
20	6	UNL	35			62	48	33	34	00	0
23	6	UNL	35			57	47	35	44	09	3

JAN 5th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	6	250	35			53	44	34	49	09	8
05	5	UNL	35			50	42	33	52	12	3
08	9	160	45			51	43	33	50	07	8
11	10	250	45			57	45	31	37	11	6
14	10	160	45			64	48	30	28	11	3
17	7	250	45			66	49	30	26	13	3
20	5	UNL	35			59	47	34	39	09	6
23	5	UNL	35			51	45	39	64	10	6

JAN 6th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	1	UNL	35			48	42	34	59	08	4
05	3	UNL	35			44	40	35	71	31	4
08	7	UNL	35			45	39	31	58	27	5
11	1	UNL	35			58	42	20	23	30	10
14	0	UNL	35			64	44	11	12	33	12
17	0	UNL	70			62	43	14	15	29	14
20	0	UNL	35			54	39	15	21	23	9
23	0	UNL	35			48	36	14	25	22	5

JAN 7th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	0	UNL	35			42	32	13	31	27	7
05	0	UNL	35			39	31	14	36	13	3
08	0	UNL	50			39	30	13	34	00	0
11	0	UNL	50			57	40	11	16	06	12
14	1	UNL	70			61	42	9	13	08	10
17	9	UNL	70			62	43	14	15	05	3
20	9	UNL	35			53	39	16	23	23	4
23	6	UNL	35			49	37	17	28	00	0

JAN 8th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	0	UNL	35			43	34	20	40	00	0
05	0	UNL	35			44	34	18	35	10	4
08	7	UNL	70			41	33	17	38	12	3
11	7	UNL	70			54	40	18	24	08	3
14	10	UNL	70			65	45	14	14	20	3
17	10	UNL	70			65	45	15	14	31	5
20	10	UNL	35			55	41	21	27	00	0
23	10	250	35			50	40	26	39	00	0

JAN 9th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	9	250	35			46	37	24	42	10	7
05	2	UNL	35			44	35	20	38	09	6
08	6	UNL	45			40	33	22	49	12	4
11	5	UNL	45			53	40	20	27	11	4
14	0	UNL	35			63	44	16	16	00	0
17	1	UNL	35			64	44	16	16	29	5
20	3	UNL	35			54	40	18	24	00	0
23	0	UNL	35			48	38	22	36	13	4

JAN 10th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	0	UNL	35			44	36	23	44	10	6
05	0	UNL	35			41	34	22	47	09	6
08	0	UNL	40			39	32	21	49	12	7
11	0	UNL	25			52	40	22	31	12	5
14	0	UNL	25			62	44	20	20	27	3
17	0	UNL	25			62	44	19	19	29	4
20	0	UNL	20			54	41	22	29	00	0
23	0	UNL	30			49	39	24	38	08	3

JAN 11th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	0	UNL	35			44	37	27	51	24	3
05	0	UNL	35			42	36	27	55	12	4
08	0	UNL	45			40	34	23	51	10	5
11	0	UNL	45			55	42	22	28	22	3
14	0	UNL	40			66	47	21	18	28	3
17	0	UNL	40			67	47	20	17	28	6
20	0	UNL	30			57	43	23	27	00	0
23	0	UNL	35			51	40	23	34	23	6

JAN 12th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	0	UNL	35			46	37	23	40	12	3
05	0	UNL	35			41	35	25	53	10	4
08	0	UNL	35			41	35	25	53	00	0
11	0	UNL	35			57	43	23	27	00	0
14	0	UNL	35			65	46	21	19	31	8
17	0	UNL	50			66	46	20	17	29	8
20	0	UNL	35			57	43	23	27	02	3
23	0	UNL	35			52	40	23	32	00	0

JAN 13th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	0	UNL	35			45	37	26	47	36	4
05	0	UNL	35			42	35	24	49	09	5
08	7	UNL	60			42	35	24	49	00	0
11	7	UNL	50			59	43	21	23	11	4
14	8	UNL	40			68	48	22	17	22	4
17	9	UNL	45			68	49	25	20	30	5
20	8	UNL	35			59	45	28	31	00	0
23	2	UNL	35			53	43	30	42	13	3

JAN 14th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	1	UNL	35			48	42	34	59	00	0
05	8	UNL	35			47	41	32	56	14	3
08	10	UNL	60			48	41	31	52	00	0
11	9	UNL	60			68	49	25	20	08	9
14	7	250	60			73	50	23	15	00	0
17	8	UNL	45			73	52	29	20	24	4
20	9	250	35			63	47	29	28	00	0
23	7	UNL	35			59	46	29	32	11	4

JAN 15th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	10	UNL	35			55	44	31	40	10	4
05	10	UNL	35			52	42	28	40	11	6
08	9	160	40			52	42	29	41	10	6
11	6	170	40			67	49	28	23	13	4
14	6	UNL	35			70	49	25	18	28	4
17	7	UNL	30			70	50	28	21	28	6
20	0	UNL	35			60	47	31	34	00	0
23	0	UNL	35			54	43	30	40	11	5

JAN 16th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	0	UNL	35			50	42	31	48	08	5
05	0	UNL	35			47	39	29	50	11	7
08	0	UNL	30			45	38	28	52	11	4
11	0	UNL	25			57	45	30	36	12	5
14	0	UNL	20			67	49	29	24	27	5
17	0	UNL	30			69	50	30	23	34	3
20	0	UNL	35			60	47	32	35	13	3
23	0	UNL	35			53	44	34	49	11	5

JAN 17th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	0	UNL	35			50	42	33	52	11	5
05	0	UNL	35			45	40	33	63	00	0
08	0	UNL	50			44	39	32	63	05	3
11	0	UNL	50			59	44	22	24	10	3
14	0	UNL	55			70	47	15	12	35	4
17	0	UNL	50			72	48	13	10	26	5
20	0	UNL	35			61	44	19	20	35	3
23	0	UNL	35			54	42	25	33	13	3

JAN 18th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
02	0	UNL	35			48	39	27	44	00	0
05	0	UNL	35			46	37	24	42	11	5
08	0	UNL	60			47	38	24	41	11	5
11	0	UNL	50			60	45	24	25	10	6
14	0	UNL	45			73	50	23	15	27	3
17	0	UNL	45			76	52	25	15	29	5
20	0	UNL	35			63	47	28	27	00	0
23	0	UNL	35			58	45	30	35	23	3

MAXIMUM SHORT DURATION PRECIPITATION

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	0.05	0.05	0.06	0.07	0.09	0.11	0.12	0.12	0.12	0.13	0.13	0.13
ENDED: DATE	25	25	25	25	25	25	25	25	25	25	25	25
ENDED: TIME	1049	1049	1058	1105	1111	1124	1132	1132	1132	1159	1159	1159

THE PRECIPITATION AMOUNTS FOR THE INDICATED TIME INTERVALS MAY OCCUR AT ANY TIME DURING THE MONTH. THE TIME INDICATED IS THE ENDING TIME OF THE INTERVAL. DATE AND TIME ARE NOT ENTERED FOR TRACE AMOUNTS.

OBSERVATIONS AT 3-HOUR INTERVALS

JUL 1993 24233
SEATTLE SEA-TAC AP, WA

Date	Hour L.S.T.	Sky Cover (Tenths)	Ceiling in Hundreds of Feet	Visibility: Whole Miles	Visibility: 16ths Mile	Weather	Temperature: Air °F	Temperature: Wet Bulb °F	Temperature: Dew Point °F	Rel Humidity %	Wind: Direction	Wind: Speed (Knots)
JUL 19th	01	8	UNL	15			60	55	51	72	03	8
	04	8	110	20			58	55	52	81	02	4
	07	10	130	10			58	56	54	87	25	5
	10	10	5	6		RW	57	56	56	97	25	5
	13	10	17	10			62	59	57	84	20	6
	16	10	80	5		RFW	60	59	59	97	18	6
	19	10	75	6		RF	57	56	56	97	20	7
	22	10	60	7		R	55	55	54	97	19	7
JUL 20th	01	10	9	10		R	55	55	55	100	19	6
	04	10	11	10		R	55	55	54	97	17	8
	07	10	6	10			56	55	55	97	20	8
	10	10	10	15			57	56	55	93	20	8
	13	10	15	15		RW	57	56	56	97	22	14
	16	10	20	10		R	58	56	55	90	19	10
	19	10	27	15			59	56	53	81	22	8
	22	10	40	10			58	55	52	81	21	12
JUL 21st	01	10	18	15			56	55	54	93	15	5
	04	10	36	15			55	53	52	90	17	7
	07	10	41	15			57	54	52	84	17	6
	10	9	41	30			62	55	49	63	23	6
	13	10	200	30			65	57	51	61	20	10
	16	8	200	30			66	57	49	55	25	6
	19	10	45	30			63	56	50	63	24	5
	22	10	85	15		RW	60	56	52	75	00	0
JUL 22nd	01	10	27	7			57	56	55	93	13	3
	04	10	31	5		RF	57	56	56	97	13	7
	07	10	3	1	8	LF	58	57	57	97	16	7
	10	10	14	10			64	62	60	87	20	8
	13	9	40	15			64	62	60	87	21	7
	16	9	250	20			69	62	58	68	22	13
	19	8	45	20			63	58	55	75	23	10
	22	7	55	15			57	55	54	90	22	9
JUL 23rd	01	10	60	15			59	57	55	87	20	6
	04	10	15	15			58	56	55	90	21	6
	07	10	35	10			58	56	55	90	05	7
	10	10	20	15			60	58	56	87	28	7
	13	10	40	30			65	58	52	63	35	5
	16	10	48	20			66	58	51	59	03	10
	19	10	35	15			62	57	52	70	03	10
	22	10	50	10			59	56	54	84	06	8
JUL 24th	01	10	45	10			58	55	53	84	03	6
	04	10	24	10			57	54	52	84	04	6
	07	10	42	15			57	55	53	87	11	3
	10	10	12	12			58	55	53	84	19	5
	13	10	29	15			64	58	54	70	23	4
	16	10	49	15			64	57	52	65	35	3
	19	10	40	15			63	57	53	70	21	4
	22	10	27	10			58	56	54	87	22	5
JUL 25th	01	10	40	10			56	54	53	90	22	5
	04	10	9	10			55	54	53	93	20	4
	07	10	30	10			56	54	53	90	19	5
	10	10	17	6		LF	57	56	55	93	19	4
	13	8	33	15			66	60	56	70	26	5
	16	5	UNL	15			69	61	55	61	29	9
	19	1	UNL	15			68	60	54	61	22	8
	22	4	UNL	10			62	58	55	78	26	5
JUL 26th	01	0	UNL	15			56	55	54	93	00	0
	04	0	UNL	7			53	53	52	96	00	0
	07	10	3	1	8	F	54	54	53	96	00	0
	10	10	8	3		F	58	56	54	87	20	7
	13	1	UNL	10			66	60	56	70	20	7
	16	5	UNL	15			73	63	57	57	26	7
	19	2	UNL	25			70	62	56	61	24	4
	22	0	UNL	15			66	60	55	68	00	0
JUL 27th	01	4	UNL	15			58	57	56	93	19	5
	04	4	UNL	10			54	54	53	96	18	5
	07	8	160	10			57	56	55	93	19	5
	10	7	UNL	10			64	60	57	78	17	5
	13	10	100	20			68	59	53	59	25	6
	16	10	100	10			67	61	56	68	25	6
	19	10	95	15			66	61	57	73	16	5
	22	10	95	10		RW	63	61	60	90	22	3
JUL 28th	01	10	75	20			62	61	60	93	20	3
	04	10	70	20		R	61	60	60	97	23	4
	07	10	17	6		RF	60	60	60	100	23	5
	10	10	9	4		RF	59	59	59	100	22	10
	13	10	33	20			59	58	57	93	14	8
	16	9	40	15			60	59	58	93	15	9
	19	10	80	10			60	58	56	87	15	10
	22	10	45	15		R	57	55	54	90	19	9
JUL 29th	01	8	85	20			55	54	53	93	18	7
	04	7	80	20			54	53	52	93	16	7
	07	7	80	30			58	54	51	78	16	6
	10	9	50	30			61	56	51	70	20	12
	13	9	39	30			65	57	50	59	23	10
	16	10	36	10		TRW	54	53	52	93	17	5
	19	6	25	20			56	55	54	93	16	10
	22	1	UNL	15			53	53	52	96	15	10
JUL 30th	01	4	UNL	15			53	52	51	93	19	7
	04	7	100	20			53	51	50	90	19	6
	07	8	150	40			54	52	50	86	14	5
	10	9	170	40			61	55	49	65	16	6
	13	3	UNL	40			68	58	50	53	23	8
	16	9	80	40			70	59	50	49	20	5
	19	1	UNL	40			69	59	51	53	31	3
	22	4	UNL	15			63	57	52	68	29	4
JUL 31st	01	7	110	15			59	56	54	84	00	0
	04	0	UNL	20			55	54	53	93	13	4
	07	0	UNL	40			62	58	55	78	00	0
	10	2	UNL	40			70	61	54	57	35	4
	13	0	UNL	40			76	64	55	48	03	5
	16	2	UNL	50			78	64	55	45	34	10
	19	0	UNL	50			73	62	54	52	34	11
	22	0	UNL	10			65	59	55	70	01	9

WEATHER CODES

*	TORNADO	SW	SNOW SHOWERS	GF	GROUND FOG
T	THUNDERSTORM	SG	SNOW GRAINS	BD	BLOWING DUST
Q	SQUALL	SP	SNOW PELLETS	BN	BLOWING SAND
R	RAIN	IC	ICE CRYSTALS	BS	BLOWING SNOW
RW	RAIN SHOWERS	IP	ICE PELLETS	BY	BLOWING SPRAY
ZR	FREEZING RAIN	IPW	ICE PELLET SHOWERS	K	SMOKE
L	DRIZZLE	A	HAIL	H	HAZE
ZL	FREEZING DRIZZLE	F	FOG	D	DUST
S	SNOW	IF	ICE FOG		

CEILING: UNL INDICATES UNLIMITED
WIND DIRECTION: DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH 27 FOR WEST. AN ENTRY OF 00 INDICATES CALM.
SPEED: THE OBSERVED AVERAGE ONE-MINUTE VALUE, EXP RESSED IN KNOTS (MPH=KNOTS X 1.15).

SUMMARY BY HOURS

Hour L.S.T.	Averages: Sky Cover (Tenths)	Averages: Station Pressure (Inches)	Temperature: Air Temp °F	Temperature: Wet Bulb °F	Temperature: Dew Point °F	Rel Humidity %	Wind Speed (MPH)	Resultant Wind: Direction	Resultant Wind: Speed (MPH)
01	7	29.570	56	54	53	89	6.3	18	3.8
04	7	29.575	55	53	52	91	6.7	18	4.9
07	9	29.590	56	54	53	88	6.3	18	4.0
10	8	29.600	60	56	53	79	7.5	22	5.6
13	7	29.590	65	58	53	66	8.9	22	6.6
16	8	29.580	67	59	53	63	9.6	24	4.8
19	7	29.570	64	58	53	68	8.6	23	2.9
22	7	29.580	59	56	53	91	7.6	22	4.1

OBSERVATIONS AT 3-HOUR INTERVALS

AUG 1993 24233
SEATTLE SEA-TAC AP, WA

Date	HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY: WHOLE MILES	VISIBILITY: 16THS MILE	WEATHER	TEMPERATURE: AIR °F	TEMPERATURE: WET BULB °F	TEMPERATURE: DEW POINT °F	REL HUMIDITY %	WIND: DIRECTION	WIND: SPEED (KNOTS)
AUG 1st	01	0	UNL	15			64	58	54	70	01	9
	04	0	UNL	20			60	57	54	81	03	7
	07	0	UNL	50			64	59	55	73	02	9
	10	0	UNL	50			73	63	57	57	36	9
	13	0	UNL	50			79	65	56	45	36	11
	16	0	UNL	50			80	64	53	39	34	15
	19	0	UNL	50			75	63	55	50	36	11
	22	0	UNL	10			70	61	54	57	03	9
AUG 2nd	01	0	UNL	15			65	59	55	70	04	6
	04	0	UNL	20			62	59	56	81	01	6
	07	0	UNL	50			66	61	57	73	01	8
	10	0	UNL	50			74	65	60	62	36	12
	13	0	UNL	30			82	69	61	49	34	10
	16	0	UNL	30			85	70	62	46	36	10
	19	0	UNL	30			78	67	60	54	36	11
	22	0	UNL	10			74	64	57	56	02	7
AUG 3rd	01	0	UNL	15			70	61	55	59	01	8
	04	0	UNL	20			65	61	58	78	03	8
	07	0	UNL	50			70	65	61	73	35	7
	10	0	UNL	50			80	69	62	54	36	11
	13	0	UNL	50			87	71	62	43	33	8
	16	0	UNL	50			89	69	58	35	35	14
	19	0	UNL	50			81	67	59	47	34	12
	22	0	UNL	15			78	63	53	42	02	12
AUG 4th	01	0	UNL	15			73	62	54	52	03	9
	04	5	UNL	20			69	62	57	66	31	4
	07	1	UNL	50			74	65	59	60	35	4
	10	0	UNL	30			83	69	61	48	32	6
	13	0	UNL	30			89	69	58	35	32	8
	16	1	UNL	30			95	68	50	22	33	8
	19	1	UNL	30			86	68	57	37	36	9
	22	1	UNL	10			74	65	60	62	27	3
AUG 5th	01	4	UNL	15			66	62	59	78	19	5
	04	0	UNL	20			60	59	59	97	18	7
	07	10	2	0	8	F	60	60	60	100	22	8
	10	0	UNL	7			66	63	61	84	19	7
	13	0	UNL	15			80	69	62	54	32	7
	16	1	UNL	15			86	68	57	37	26	8
	19	1	UNL	15			81	69	63	54	27	5
	22	0	UNL	15			68	63	60	78	28	5
AUG 6th	01	10	2	1		F	60	60	60	100	21	9
	04	10	1	0	8	F	59	59	59	100	21	8
	07	10	2	0	12	LF	59	59	59	100	21	8
	10	10	5	7			61	60	59	93	23	8
	13	10	14	10			65	61	59	81	26	5
	16	0	UNL	10			74	65	60	62	21	8
	19	2	UNL	10			65	60	57	76	25	10
	22	10	23	7			61	58	56	84	18	7
AUG 7th	01	10	22	15			59	56	54	84	22	9
	04	10	21	15			57	55	53	87	16	7
	07	7	37	10			59	57	55	87	22	7
	10	6	37	15			62	58	54	75	22	13
	13	10	32	15			65	58	53	65	22	6
	16	5	UNL	20			67	59	52	59	24	10
	19	8	35	15			65	58	53	65	23	9
	22	10	39	15			60	57	55	84	19	4
AUG 8th	01	10	42	15			61	58	56	84	20	7
	04	10	45	15			60	57	55	84	19	4
	07	10	48	30			62	58	54	75	18	5
	10	7	50	30			67	59	52	59	20	9
	13	8	50	30			68	59	52	57	23	9
	16	6	55	35			73	61	53	50	23	10
	19	8	60	30			66	60	56	70	25	7
	22	10	60	20			63	58	55	75	22	7
AUG 9th	01	9	42	15			60	57	55	84	21	8
	04	10	55	15			60	57	55	84	13	7
	07	10	65	15			60	58	56	87	21	7
	10	9	65	30			65	59	55	70	22	10
	13	9	65	30			68	60	54	61	24	10
	16	8	80	20			69	61	55	61	26	10
	19	10	80	15			64	59	56	75	29	4
	22	10	55	10			60	58	57	90	29	5
AUG 10th	01	9	50	15			58	57	57	97	24	3
	04	10	70	10			57	57	57	100	31	3
	07	10	65	7			58	57	57	97	00	0
	10	10	37	10			64	60	57	78	24	5
	13	6	90	15			71	61	54	55	25	9
	16	3	UNL	15			74	61	51	45	32	11
	19	3	UNL	15			67	60	54	63	35	12
	22	1	UNL	10			63	58	54	73	04	10
AUG 11th	01	0	UNL	15			59	56	54	84	03	8
	04	0	UNL	15			57	55	53	87	03	5
	07	9	35	40			59	56	53	81	03	8
	10	6	45	20			66	60	55	68	04	4
	13	6	30	30			70	61	55	59	34	7
	16	3	UNL	30			74	63	55	52	32	10
	19	2	UNL	30			68	58	51	55	34	10
	22	0	UNL	10			60	57	54	81	32	3
AUG 12th	01	3	UNL	15			60	57	54	81	03	6
	04	2	UNL	7			53	53	53	100	20	3
	07	10	1	0	4	F	55	55	55	100	00	0
	10	10	8	4		F	58	56	55	90	23	5
	13	9	19	10			66	60	55	68	23	15
	16	2	UNL	15			69	61	56	63	20	8
	19	1	UNL	15			65	60	57	76	23	8
	22	0	UNL	15			58	56	55	90	24	6
AUG 13th	01	9	11	15			56	54	53	90	22	6
	04	10	13	15			56	55	54	93	19	5
	07	10	21	15			57	55	53	87	18	7
	10	10	29	15			62	57	53	73	20	8
	13	10	27	15			63	57	52	68	23	10
	16	10	39	15			64	58	53	68	18	8
	19	10	44	10			63	57	52	68	16	6
	22	10	40	10			60	56	53	78	19	5
AUG 14th	01	10	47	15			58	56	54	87	22	4
	04	10	41	15			57	55	53	87	19	6
	07	10	48	15			57	55	53	87	18	5
	10	10	45	15			59	56	53	81	22	5
	13	10	31	15			59	55	52	78	21	9
	16	10	48	20			63	56	51	65	14	4
	19	9	41	20			60	56	53	78	29	4
	22	9	36	15			58	56	54	87	29	4
AUG 15th	01	10	28	15			59	57	55	87	03	7
	04	10	55	10			58	56	54	87	04	7
	07	9	55	10			59	56	54	84	01	5
	10	8	55	10			66	60	55	68	33	7
	13	8	40	15			67	59	53	61	34	9
	16	10	80	12		R	64	59	55	73	35	5
	19	10	36	12			62	59	56	81	26	4
	22	10	32	10			60	57	55	84	27	4
AUG 16th	01	10	8	15			60	58	57	90	21	7
	04	10	8	6		RF	58	57	57	97	20	8
	07	10	8	10			58	57	57	97	23	8
	10	10	14	7			59	58	57	93	23	8
	13	10	11	10		R	59	58	57	93	21	7
	16	10	23	15			62	60	58	87	18	8
	19	10	32	10		RW	61	59	58	90	15	8
	22	10	36	15			60	57	54	81	21	8
AUG 17th	01	10	19	15			57	55	54	90	17	6
	04	10	9	15			57	56	56	97	16	6
	07	10	5	1	4	LF	58	57	57	97	18	4
	10	10	8	6		F	61	59	58	90	15	5
	13	5	UNL	15			68	62	57	66	28	7
	16	2	UNL	10			71	62	56	59	28	8
	19	1	UNL	10			67	60	54	63	34	8
	22	0	UNL	10			61	57	54	78	01	8
AUG 18th	01	0	UNL	15			60	57	55	84	01	8
	04	2	UNL	15			58	56	54	87	36	10
	07	0	UNL	30			60	57	54	81	03	7
	10	0	UNL	30			70	62	57	64	03	8
	13	1	UNL	30			77	65	57	50	35	9
	16	4	UNL	30			78	66	58	50	36	10
	19	4	UNL	30			71	63	57	61	35	10
	22	0	UNL	10			67	61	57	70	02	10

MAXIMUM SHORT DURATION PRECIPITATION

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	0.02	0.03	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06
ENDED: DATE	22	22	22	22	22	22	22	22	22	22	22	22
ENDED: TIME	1955	1955	1955	1955	1955	1955	1955	1955	1955	1955	1955	1955

THE PRECIPITATION AMOUNTS FOR THE INDICATED TIME INTERVALS MAY OCCUR AT ANY TIME DURING THE MONTH. THE TIME INDICATED IS THE ENDING TIME OF THE INTERVAL. DATE AND TIME ARE NOT ENTERED FOR TRACE AMOUNTS.

OBSERVATIONS AT 3-HOUR INTERVALS

AUG 1993 24233
SEATTLE SEA-TAC AP, WA

Date	Hour L.S.T.	Sky Cover (Tenths)	Ceiling in Hundreds of Feet	Visibility: Whole Miles	Visibility: 16ths Mile	Weather	Temperature: Air °F	Temperature: Wet Bulb °F	Temperature: Dew Point °F	Rel Humidity %	Wind: Direction	Wind: Speed (Knots)
AUG 19th	01	0	UNL	15			63	59	56	78	02	11
	04	0	UNL	15			62	58	55	78	04	6
	07	1	UNL	20			65	61	58	78	36	4
	10	1	UNL	20			73	64	58	60	35	4
	13	4	UNL	20			78	67	60	54	29	9
	16	4	UNL	20			82	69	61	49	01	10
	19	4	UNL	20			76	66	60	58	34	8
	22	0	UNL	10			70	63	59	68	03	6
AUG 20th	01	1	UNL	15			68	64	61	78	11	5
	04	4	UNL	15			59	58	57	93	18	3
	07	10	2	1		F	57	57	57	100	23	8
	10	10	5	3		F	61	59	58	90	19	6
	13	3	UNL	15			70	63	59	68	17	7
	16	4	UNL	15			73	65	59	62	23	11
	19	5	UNL	15			65	60	57	76	22	10
	22	6	36	10			59	56	53	81	22	11
AUG 21st	01	10	41	15			58	54	51	78	18	9
	04	10	16	15			57	54	51	81	17	8
	07	10	16	12		R	58	55	52	81	19	7
	10	10	110	15			63	57	53	70	18	8
	13	8	110	25			67	59	52	59	26	7
	16	10	65	15			69	59	51	53	23	8
	19	10	48	15			67	59	53	61	16	5
	22	4	UNL	10			61	56	52	72	24	5
AUG 22nd	01	0	UNL	15			58	55	53	84	15	5
	04	4	UNL	15			57	55	54	90	11	7
	07	5	UNL	45			59	56	53	81	18	5
	10	7	130	45			70	61	55	59	14	6
	13	8	120	40			74	62	54	50	24	7
	16	10	120	20		R	73	63	57	57	21	6
	19	10	80	10		R	63	61	59	87	24	11
	22	10	45	7			63	62	61	93	17	10
AUG 23rd	01	7	26	15			63	61	59	87	20	9
	04	3	UNL	15			58	56	54	87	20	18
	07	7	24	15			58	55	52	81	20	12
	10	8	25	15			62	57	53	73	20	13
	13	2	UNL	30			67	58	50	55	21	10
	16	8	55	30			64	57	52	65	01	14
	19	7	32	25			59	53	47	65	04	12
	22	7	45	15			56	51	46	69	11	8
AUG 24th	01	9	85	15			52	50	47	83	18	6
	04	10	8	15			52	51	49	90	21	6
	07	6	85	15			52	50	48	86	20	5
	10	2	UNL	15			58	53	48	70	20	6
	13	6	UNL	30			64	54	44	48	23	8
	16	6	85	35			67	55	44	44	25	7
	19	9	50	20		RW	56	52	49	78	11	9
	22	5	UNL	15			54	52	50	86	12	7
AUG 25th	01	9	60	15			52	51	50	93	24	3
	04	9	17	15			53	51	49	86	11	3
	07	7	80	10			53	51	50	90	00	0
	10	10	15	10			58	54	51	78	05	7
	13	6	UNL	30			65	55	47	52	36	9
	16	3	UNL	30			67	54	43	42	31	10
	19	0	UNL	30			60	52	44	56	32	7
	22	0	UNL	10			56	51	46	69	01	6
AUG 26th	01	0	UNL	15			53	51	49	86	00	0
	04	0	UNL	15			52	51	49	90	27	3
	07	0	UNL	25			53	51	50	90	30	4
	10	9	UNL	25			63	57	52	68	28	7
	13	9	UNL	30			68	59	51	55	28	8
	16	3	UNL	20			74	60	50	43	36	9
	19	8	220	15			65	57	50	59	01	8
	22	8	220	10			58	53	48	70	33	7
AUG 27th	01	7	250	15			58	52	47	67	03	5
	04	6	250	15			56	52	48	75	03	5
	07	9	UNL	25			55	53	51	87	15	6
	10	10	UNL	15			63	55	49	61	12	6
	13	7	UNL	20			70	59	50	49	31	8
	16	9	UNL	20			71	59	49	46	04	10
	19	8	75	15			64	57	51	63	35	9
	22	10	65	10			62	57	53	73	04	11
AUG 28th	01	8	90	15			59	54	50	72	03	7
	04	9	60	15			56	52	49	78	02	8
	07	6	90	20			56	53	51	83	05	7
	10	9	19	20			63	56	51	65	30	6
	13	4	UNL	25			68	59	51	55	01	5
	16	2	UNL	15			70	58	49	47	01	10
	19	3	UNL	15			62	55	49	63	32	7
	22	0	UNL	15			59	55	51	75	36	4
AUG 29th	01	0	UNL	15			58	55	52	81	05	4
	04	0	UNL	15			51	50	49	93	14	3
	07	0	UNL	45			55	52	50	83	26	2
	10	0	UNL	45			66	58	52	61	01	11
	13	2	UNL	50			73	61	53	50	35	10
	16	0	UNL	50			75	62	53	46	35	11
	19	0	UNL	50			66	57	49	55	35	9
	22	0	UNL	15			64	58	54	70	02	10
AUG 30th	01	0	UNL	15			62	55	49	63	02	11
	04	0	UNL	15			59	56	54	84	03	12
	07	0	UNL	50			60	57	54	81	02	10
	10	1	UNL	50			71	61	54	55	01	14
	13	1	UNL	50			79	64	54	42	36	10
	16	5	UNL	20			79	62	50	36	35	13
	19	5	UNL	20			68	59	52	57	35	9
	22	0	UNL	10			65	57	50	59	36	9
AUG 31st	01	0	UNL	15			63	56	50	63	04	6
	04	8	UNL	15			58	55	53	84	02	6
	07	10	250	40			56	55	54	93	23	4
	10	10	UNL	40			69	60	53	57	36	5
	13	10	UNL	40			75	63	54	48	32	5
	16	8	UNL	40			78	60	46	32	00	0
	19	10	UNL	40			72	60	50	46	00	0
	22	7	UNL	15			65	57	51	61	19	5

SUMMARY BY HOURS

Hour L.S.T.	Averages: Sky Cover (Tenths)	Averages: Station Pressure (Inches)	Temperature: Air Temp °F	Temperature: Wet Bulb °F	Temperature: Dew Point °F	Rel Humidity %	Wind Speed (MPH)	Resultant Wind: Direction	Resultant Wind: Speed (MPH)
01	5	29.560	60	57	54	80	7.6	06	0.7
04	6	29.560	58	56	54	87	7.4	14	1.1
07	6	29.580	59	56	54	85	6.7	22	1.3
10	6	29.580	66	60	55	70	8.9	26	1.7
13	6	29.565	71	61	54	57	9.6	29	5.4
16	5	29.540	74	62	53	51	10.5	31	4.9
19	5	29.530	67	60	54	64	9.3	33	4.3
22	4	29.540	63	58	54	74	8.0	36	1.5

WEATHER CODES

*	TORNADO	SW	SNOW SHOWERS	GF	GROUND FOG
T	THUNDERSTORM	SG	SNOW GRAINS	BD	BLOWING DUST
Q	SQUALL	SP	SNOW PELLETS	BN	BLOWING SAND
R	RAIN	IC	ICE CRYSTALS	BS	BLOWING SNOW
RW	RAIN SHOWERS	IP	ICE PELLETS	BY	BLOWING SPRAY
ZR	FREEZING RAIN	IPW	ICE PELLET SHOWERS	K	SMOKE
L	DRIZZLE	A	HAIL	H	HAZE
ZL	FREEZING DRIZZLE	F	FOG	D	DUST
S	SNOW	IF	ICE FOG		

CEILING: UNL INDICATES UNLIMITED
WIND DIRECTION: DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH 27 FOR WEST. AN ENTRY OF 00 INDICATES CALM.
SPEED: THE OBSERVED AVERAGE ONE-MINUTE VALUE, EXP RESSED IN KNOTS (MPH=KNOTS X 1.15).

OBSERVATIONS AT 3-HOUR INTERVALS

OCT 1993 24233
SEATTLE SEA-TAC AP, WA

OCT 1st

Hour L.S.T.	Sky Cover (Tenths)	Ceiling in Hundreds of Feet	Visibility Whole Miles	Visibility 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed (Knots)
01	0	UNL	15			53	51	50	90	02	4
04	2	UNL	7			51	51	50	96	35	5
07	0	UNL	5		F	51	51	50	96	00	0
10	0	UNL	7			62	57	53	73	03	7
13	0	UNL	20			71	60	52	51	32	7
16	2	UNL	15			73	59	48	41	35	8
19	1	UNL	10			62	55	49	63	35	9
22	0	UNL	10			58	54	51	78	01	5

OCT 2nd

Hour L.S.T.	Sky Cover (Tenths)	Ceiling in Hundreds of Feet	Visibility Whole Miles	Visibility 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed (Knots)
01	[illegible]	UNL	15			55	54	53	93	30	3
04	0	UNL	10			52	51	50	93	01	4
07	3	UNL	5		F	53	53	53	96	01	3
10	0	UNL	10			66	59	54	65	36	6
13	0	UNL	30			74	62	54	50	01	5
16	0	UNL	35			76	64	55	48	33	5
19	0	UNL	20			65	59	54	68	31	3
22	0	UNL	15			63	58	55	75	01	6

OCT 3rd

Hour L.S.T.	Sky Cover (Tenths)	Ceiling in Hundreds of Feet	Visibility Whole Miles	Visibility 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed (Knots)
01	0	UNL	15			56	54	53	90	35	5
04	0	UNL	15			53	53	52	96	17	3
07	0	UNL	5		F	52	52	52	100	17	4
10	0	UNL	7			64	59	55	73	23	5
13	0	UNL	10			74	62	53	48	27	5
16	0	UNL	15			77	63	54	45	25	6
19	0	UNL	15			66	60	55	68	22	3
22	0	UNL	12			56	54	53	90	22	3

OCT 4th

Hour L.S.T.	Sky Cover (Tenths)	Ceiling in Hundreds of Feet	Visibility Whole Miles	Visibility 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed (Knots)
01	7	2	5		F	51	51	51	100	21	5
04	10	1	0	1	F	51	51	51	100	27	4
07	10	2	0	1	F	50	50	50	100	24	3
10	10	4	0	8	F	52	52	52	100	30	4
13	10	4	1	8	F	54	54	54	100	30	4
16	10	4	1		F	54	53	52	93	30	6
19	10	[illegible]	0	3	F	53	53	53	100	04	4
22	10	1	0	3	F	53	53	53	100	29	5

OCT 5th

Hour L.S.T.	Sky Cover (Tenths)	Ceiling in Hundreds of Feet	Visibility Whole Miles	Visibility 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed (Knots)
01	10	1	0	3	F	52	52	52	100	25	3
04	10	2	0	12	F	51	51	51	100	19	4
07	10	2	0	12	F	51	51	51	100	20	5
10	10	2	0	12	LF	51	51	51	100	22	6
13	10	4	1	4	F	51	51	50	96	25	5
16	10	6	3		LF	52	51	50	93	21	3
19	10	14	6		F	53	51	50	90	15	6
22	10	13	7			54	52	52	86	16	6

OCT 6th

Hour L.S.T.	Sky Cover (Tenths)	Ceiling in Hundreds of Feet	Visibility Whole Miles	Visibility 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed (Knots)
01	10	4	1		3 LF	[illegible]	54	53	96	18	7
04	10	2	1		8 LF	[illegible]	54	54	100	22	10
07	10	15	15			[illegible]	54	53	96	21	6
10	10	17	15			[illegible]	55	54	93	20	7
13	10	27	20			[illegible]	55	51	75	22	10
16	10	21	7			[illegible]	55	53	84	25	8
19	10	65	10			[illegible]	54	53	93	07	7
22	10	4	5		F	53	53	52	96	20	3

OCT 7th

Hour L.S.T.	Sky Cover (Tenths)	Ceiling in Hundreds of Feet	Visibility Whole Miles	Visibility 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed (Knots)
01	10	2	5		RF	52	52	52	100	24	5
04	10	6	2	3	F	52	52	52	96	16	4
07	10	19	10			51	51	51	100	00	0
10	10	19	7			53	53	52	96	00	0
13	10	16	15			56	53	51	83	05	9
16	4	UNL	15			61	54	47	60	35	10
19	1	UNL	15			53	50	48	83	31	4
22	0	UNL	10			52	51	49	90	04	7

OCT 8th

Hour L.S.T.	Sky Cover (Tenths)	Ceiling in Hundreds of Feet	Visibility Whole Miles	Visibility 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed (Knots)
01	0	UNL	7			47	47	46	96	35	3
04	9	2	0	2	F	47	47	47	100	36	4
07	10	1	0		F	49	49	49	100	03	5
10	8	UNL	3		F	54	52	51	90	36	8
13	10	200	20			61	54	48	63	36	11
16	9	200	15			59	54	49	70	02	9
19	2	UNL	15			55	52	49	80	02	11
22	6	UNL	10			54	52	50	86	01	12

OCT 9th

Hour L.S.T.	Sky Cover (Tenths)	Ceiling in Hundreds of Feet	Visibility Whole Miles	Visibility 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed (Knots)
01	2	UNL	10			[illegible]	50	49	96	01	10
04	0	UNL	7			[illegible]	50	50	100	03	9
07	4	UNL	0	4	F	[illegible]	49	49	100	04	10
10	1	UNL	45			[illegible]	53	48	67	04	11
13	0	UNL	60			[illegible]	58	48	44	31	10
16	0	UNL	60			[illegible]	57	44	38	35	8
19	0	UNL	15			[illegible]	55	47	54	03	10
22	0	UNL	15			[illegible]	50	[illegible]	52	14	4

OCT 10th

Hour L.S.T.	Sky Cover (Tenths)	Ceiling in Hundreds of Feet	Visibility Whole Miles	Visibility 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed (Knots)
01	0	UNL	15			52	48	43	72	05	3
04	0	UNL	15			49	48	47	93	01	6
07	0	UNL	45			49	49	48	96	35	4
10	4	UNL	45			63	55	49	61	31	3
13	9	230	40			65	55	47	52	31	4
16	9	150	20			65	55	46	50	18	3
19	10	95	10			60	54	48	65	19	3
22	6	110	10			59	54	50	72	05	3

OCT 11th

Hour L.S.T.	Sky Cover (Tenths)	Ceiling in Hundreds of Feet	Visibility Whole Miles	Visibility 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed (Knots)
01	2	UNL	15			53	52	51	93	02	3
04	0	UNL	7			50	50	50	100	32	3
07	0	UNL	6		F	49	49	49	100	35	3
10	0	UNL	7			60	54	49	67	10	3
13	9	150	10			63	55	48	58	19	7
16	10	140	10			63	56	50	63	18	6
19	10	70	15			61	56	51	70	19	4
22	10	60	15			58	57	[illegible]	93	18	5

OCT 12th

Hour L.S.T.	Sky Cover (Tenths)	Ceiling in Hundreds of Feet	Visibility Whole Miles	Visibility 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed (Knots)
01	9	75	15			56	55	54	93	24	4
04	8	70	15			[illegible]	54	53	90	12	4
07	10	65	15			[illegible]	54	53	96	21	4
10	10	65	10			[illegible]	57	56	90	20	5
13	10	65	10		RW	[illegible]	58	56	87	20	8
16	10	75	10			[illegible]	58	57	90	20	5
19	10	250	10			[illegible]	55	54	93	16	5
22	8	80	10			[illegible]	56	56	97	13	4

OCT 13th

Hour L.S.T.	Sky Cover (Tenths)	Ceiling in Hundreds of Feet	Visibility Whole Miles	Visibility 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed (Knots)
01	8	90	4		F	56	56	56	100	12	4
04	10	80	4		F	55	55	54	97	13	5
07	9	85	4		F	55	54	53	93	16	5
10	8	UNL	6		F	60	57	55	84	20	3
13	8	UNL	7			65	58	52	63	20	5
16	9	120	7			64	57	52	65	25	5
19	10	65	7			58	55	53	84	21	4
22	10	65	7			55	55	54	97	22	5

OCT 14th

Hour L.S.T.	Sky Cover (Tenths)	Ceiling in Hundreds of Feet	Visibility Whole Miles	Visibility 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed (Knots)
01	10	9	7			55	55	54	97	18	4
04	10	15	5		F	55	55	54	97	19	5
07	10	9	4		F	55	55	54	97	00	0
10	10	8	7			57	55	53	87	19	5
13	9	50	15			62	57	53	73	22	9
16	10	75	10			60	57	54	81	23	8
19	10	33	7			55	55	54	97	18	5
22	10	20	7			56	55	54	93	19	7

OCT 15th

Hour L.S.T.	Sky Cover (Tenths)	Ceiling in Hundreds of Feet	Visibility Whole Miles	Visibility 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed (Knots)
01	10	75	7			[illegible]	55	54	97	15	5
04	10	32	7			54	54	54	100	00	0
07	10	5	2		RF	54	54	54	100	32	5
10	10	11	2		F	56	55	54	93	01	7
13	10	24	10		RW	54	52	51	90	02	7
16	10	23	10			55	53	51	83	34	7
19	10	28	7			54	52	51	90	30	7
22	10	[illegible]	[illegible]	2	3 LF	52	52	51	96	20	8

OCT 16th

Hour L.S.T.	Sky Cover (Tenths)	Ceiling in Hundreds of Feet	Visibility Whole Miles	Visibility 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed (Knots)
01	10	1	2	8	RF	51	51	51	100	21	6
04	10	55	5		F	51	51	51	100	14	5
07	10	55	10			50	50	49	96	19	3
10	7	50	15			53	51	49	86	21	5
13	9	55	25			57	52	48	72	26	4
16	4	UNL	15			59	53	47	65	30	4
19	6	75	10			50	50	49	96	22	3
22	10	75	10			52	50	48	86	13	4

OCT 17th

Hour L.S.T.	Sky Cover (Tenths)	Ceiling in Hundreds of Feet	Visibility Whole Miles	Visibility 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed (Knots)
01	10	75	7			51	50	48	90	15	7
04	10	75	7			49	48	46	90	12	4
07	8	6	7			48	47	46	93	17	4
10	10	7	4		F	52	50	49	90	22	6
13	8	28	10			55	51	47	75	24	5
16	6	UNL	10			56	51	47	72	24	6
19	3	UNL	10			50	49	48	93	26	3
22	3	UNL	7			49	48	47	93	14	5

OCT 18th

Hour L.S.T.	Sky Cover (Tenths)	Ceiling in Hundreds of Feet	Visibility Whole Miles	Visibility 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed (Knots)
01	2	UNL	6		F	46	46	46	100	15	5
04	8	19	5		F	44	44	44	100	13	5
07	9	21	6		F	47	46	44	89	13	10
10	10	21	7			52	49	46	80	18	5
13	10	16	10			57	53	50	78	22	8
16	7	100	15			55	54	49	70	21	11
19	10	85	10			54	52	50	86	19	11
22	10	22	15			53	51	50	90	18	11

MAXIMUM SHORT DURATION PRECIPITATION

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	0.05	0.08	0.11	0.12	0.14	0.15	0.15	0.15	0.15	0.19	0.19	0.22
ENDED: DATE	06	06	06	06	06	06	06	06	22	06	22	22
ENDED: TIME	1712	1712	1714	1719	1719	1719	1719	1719	1524	1759	1554	1553

THE PRECIPITATION AMOUNTS FOR THE INDICATED TIME INTERVALS MAY OCCUR AT ANY TIME DURING THE MONTH. THE TIME INDICATED IS THE ENDING TIME OF THE INTERVAL. DATE AND TIME ARE NOT ENTERED FOR TRACE AMOUNTS.

OBSERVATIONS AT 3-HOUR INTERVALS

SEP 1993 — SEATTLE SEA-TAC AP, WA — 24233

Columns: HOUR L.S.T. | SKY COVER (TENTHS) | CEILING IN HUNDREDS OF FEET | VISIBILITY: WHOLE MILES | VISIBILITY: 16THS MILE | WEATHER | TEMPERATURE: AIR °F | TEMPERATURE: WET BULB °F | TEMPERATURE: DEW POINT °F | REL HUMIDITY % | WIND: DIRECTION | WIND: SPEED (KNOTS)

SEP 1st

Hour	Sky Cover	Ceiling	Vis Whole Miles	Vis 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed
01	6	UNL	15			58	56	54	87	22	8
04	4	UNL	15			54	54	53	96	17	7
07	0	UNL	10			57	55	53	87	14	8
10	0	UNL	15			65	58	53	65	23	8
13	0	UNL	30			72	61	53	51	21	3
16	0	UNL	30			76	63	53	45	30	5
19	0	UNL	30			68	60	55	63	30	5
22	0	UNL	15			65	59	54	68	35	5

SEP 2nd

Hour	Sky Cover	Ceiling	Vis Whole Miles	Vis 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed
01	0	UNL	15			58	56	54	87	35	5
04	0	UNL	15			58	56	55	90	02	6
07	0	UNL	10			60	57	55	84	01	6
10	0	UNL	30			72	63	57	59	01	9
13	0	UNL	40			78	66	59	52	30	8
16	0	UNL	15			84	68	58	41	01	7
19	0	UNL	15			72	63	57	59	35	8
22	0	UNL	10			70	62	57	64	03	8

SEP 3rd

Hour	Sky Cover	Ceiling	Vis Whole Miles	Vis 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed
01	0	UNL	15			60	59	58	93	20	5
04	0	UNL	15			57	56	56	97	18	5
07	2	UNL	7			57	57	57	100	22	5
10	3	UNL	2		F	62	59	57	84	24	7
13	0	UNL	15			75	65	58	56	23	6
16	0	UNL	10			82	67	58	44	25	6
19	0	UNL	10			71	64	59	66	25	4
22	0	UNL	7			62	59	57	84	25	5

SEP 4th

Hour	Sky Cover	Ceiling	Vis Whole Miles	Vis 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed
01	0	UNL	7			55	55	55	100	18	5
04	10	2	2		F	55	55	55	100	22	7
07	10	2	0	8	F	55	55	55	100	21	7
10	10	4	2		F	57	56	55	93	21	5
13	10	11	6		FH	62	58	55	78	20	6
16	0	UNL	10			69	61	56	63	20	6
19	0	UNL	15			65	60	57	76	12	3
22	0	UNL	7			56	55	55	97	25	5

SEP 5th

Hour	Sky Cover	Ceiling	Vis Whole Miles	Vis 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed
01	1	UNL	0	8	F	52	52	52	100	32	3
04	10	3	0	2	F	55	55	55	100	33	3
07	10	3	0	2	F	56	56	56	100	29	4
10	10	3	1		F	57	57	57	100	34	4
13	9	15	6		F	65	60	57	76	30	7
16	5	UNL	7			70	62	57	64	03	8
19	0	UNL	7			62	59	56	81	35	8
22	0	UNL	7			59	57	56	90	01	7

SEP 6th

Hour	Sky Cover	Ceiling	Vis Whole Miles	Vis 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed
01	0	UNL	7			54	54	54	100	29	3
04	10	5	2	8	F	53	53	53	100	31	3
07	10	3	0	10	F	57	56	56	97	36	5
10	2	UNL	3		F	65	60	57	76	30	6
13	0	UNL	12			76	66	59	56	02	10
16	0	UNL	7			81	67	59	47	35	10
19	0	UNL	7			70	62	57	64	35	8
22	0	UNL	7			68	62	57	68	05	4

SEP 7th

Hour	Sky Cover	Ceiling	Vis Whole Miles	Vis 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed
01	0	UNL	15			62	59	57	84	10	3
04	0	UNL	10			59	58	58	97	14	3
07	0	UNL	7			60	59	58	93	23	4
10	0	UNL	7			73	65	59	62	29	4
13	1	UNL	7			80	68	61	52	24	8
16	4	UNL	7			82	69	61	49	29	7
19	2	UNL	7			76	64	55	48	01	8
22	0	UNL	7			69	61	55	61	36	6

SEP 8th

Hour	Sky Cover	Ceiling	Vis Whole Miles	Vis 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed
01	0	UNL	10			64	60	57	78	02	3
04	0	UNL	10			60	59	59	97	00	0
07	0	UNL	4		F	63	61	60	90	00	0
10	0	UNL	12			75	65	58	56	01	7
13	0	UNL	20			82	65	54	38	35	8
16	0	UNL	20			85	66	53	33	35	10
19	0	UNL	20			73	63	56	55	35	5
22	0	UNL	15			69	62	57	66	03	6

SEP 9th

Hour	Sky Cover	Ceiling	Vis Whole Miles	Vis 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed
01	0	UNL	15			60	58	57	90	26	3
04	0	UNL	7			58	57	56	93	19	3
07	0	UNL	7			59	58	57	93	11	3
10	0	UNL	10			71	62	56	59	29	3
13	0	UNL	15			79	65	56	45	29	6
16	0	UNL	15			83	65	54	37	30	6
19	0	UNL	15			73	62	55	53	24	4
22	0	UNL	15			66	59	54	65	00	0

SEP 10th

Hour	Sky Cover	Ceiling	Vis Whole Miles	Vis 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed
01	0	UNL	15			59	57	55	87	18	3
04	0	UNL	15			60	58	56	87	13	5
07	2	UNL	7			57	56	56	97	00	0
10	2	UNL	8			70	62	57	64	19	6
13	1	UNL	12			80	65	56	44	22	6
16	4	UNL	10			83	63	49	34	25	8
19	2	UNL	15			64	59	55	73	20	8
22	2	UNL	12			55	54	53	93	20	10

SEP 11th

Hour	Sky Cover	Ceiling	Vis Whole Miles	Vis 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed
01	10	14	10			56	53	51	83	17	6
04	10	17	10			55	53	51	87	17	10
07	10	11	8		L	54	53	52	93	15	7
10	10	18	25			58	54	51	78	20	11
13	10	27	35			61	56	51	70	21	13
16	4	UNL	15			66	57	50	57	20	15
19	8	32	10			59	56	53	81	29	8
22	1	UNL	12			55	51	48	77	22	9

SEP 12th

Hour	Sky Cover	Ceiling	Vis Whole Miles	Vis 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed
01	1	UNL	12			51	49	47	86	14	6
04	0	UNL	7			48	47	46	93	16	5
07	0	UNL	10			50	49	48	93	20	4
10	2	UNL	12			58	54	50	75	26	7
13	1	UNL	20			66	55	46	49	04	8
16	1	UNL	20			69	56	45	42	02	10
19	0	UNL	15			58	52	46	65	35	9
22	0	UNL	10			59	53	47	65	05	9

SEP 13th

Hour	Sky Cover	Ceiling	Vis Whole Miles	Vis 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed
01	0	UNL	12			52	50	48	86	14	4
04	0	UNL	10			50	48	46	86	34	3
07	0	UNL	20			51	50	48	90	14	6
10	0	UNL	20			64	56	49	58	01	5
13	0	UNL	20			71	59	50	48	32	6
16	5	UNL	20			73	57	43	34	35	10
19	8	220	15			63	54	45	52	36	8
22	8	UNL	7			62	53	45	54	01	8

SEP 14th

Hour	Sky Cover	Ceiling	Vis Whole Miles	Vis 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed
01	3	UNL	15			56	52	49	78	36	6
04	3	UNL	15			53	50	47	80	36	4
07	10	140	20			55	52	50	83	02	5
10	10	110	20			58	54	51	78	32	4
13	10	95	10		RW	59	54	50	72	24	7
16	8	65	15			65	56	49	56	17	5
19	9	55	7			63	57	52	68	07	7
22	10	65	7			55	54	53	93	23	8

SEP 15th

Hour	Sky Cover	Ceiling	Vis Whole Miles	Vis 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed
01	10	20	15			54	52	51	90	19	5
04	8	25	15			53	52	51	93	17	5
07	9	50	15			54	53	52	93	23	5
10	8	250	15			61	54	48	63	23	5
13	8	UNL	20			67	57	48	51	29	7
16	3	UNL	15			67	58	50	55	02	10
19	1	UNL	10			59	54	50	72	35	9
22	4	UNL	10			58	55	52	81	02	8

SEP 16th

Hour	Sky Cover	Ceiling	Vis Whole Miles	Vis 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed
01	0	UNL	15			55	52	50	83	03	6
04	6	95	15			54	52	51	90	03	8
07	3	UNL	4		F	53	53	52	96	05	6
10	0	UNL	15			65	58	52	63	36	10
13	0	UNL	25			72	60	50	46	34	10
16	0	UNL	25			72	57	44	37	34	13
19	4	UNL	15			62	53	45	54	34	8
22	2	UNL	15			62	55	48	60	04	7

SEP 17th

Hour	Sky Cover	Ceiling	Vis Whole Miles	Vis 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed
01	8	UNL	15			57	53	49	75	13	5
04	2	UNL	15			52	50	49	90	14	3
07	7	UNL	20			53	51	50	90	16	3
10	1	UNL	20			65	55	47	52	08	6
13	1	UNL	20			72	57	44	37	32	6
16	1	UNL	25			74	56	39	28	03	7
19	0	UNL	15			63	52	41	45	34	5
22	0	UNL	15			54	52	50	86	27	4

SEP 18th

Hour	Sky Cover	Ceiling	Vis Whole Miles	Vis 16ths Mile	Weather	Air °F	Wet Bulb °F	Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed
01	0	UNL	15			50	50	49	96	19	4
04	7	12	15			46	46	45	96	18	6
07	10	14	15			49	48	46	90	14	7
10	10	15	15			53	50	47	80	19	8
13	3	UNL	25			61	54	47	60	29	5
16	9	55	15			64	54	45	50	24	9
19	7	95	10			55	51	47	75	26	4
22	6	70	15			51	50	48	90	23	3

MAXIMUM SHORT DURATION PRECIPITATION

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
ENDED: DATE	14	14	14	14	14	14	14	14	14	14	14	14
ENDED: TIME	2125	2125	2125	2125	2125	2125	2125	2125	2125	2125	2125	2125

THE PRECIPITATION AMOUNTS FOR THE INDICATED TIME INTERVALS MAY OCCUR AT ANY TIME DURING THE MONTH. THE TIME INDICATED IS THE ENDING TIME OF THE INTERVAL. DATE AND TIME ARE NOT ENTERED FOR TRACE AMOUNTS.

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AUG 1993
SEATTLE C.O., WA
NAT'L WEA SER MET OBS
2725 MONTLAKE BLVD. E

INQUIRIES/COMMENTS CALL
(704) 271-4800

WSMO (EMSU)

ISSN 0198-5477

LOCAL CLIMATOLOGICAL DATA

Monthly Summary

AUG 1993 SEATTLE C.O., WA

LATITUDE 47° 39´N LONGITUDE 122° 18´W ELEVATION (GROUND) 22 FEET TIME ZONE PACIFIC 24281

Weather types (column 8): 1 FOG; 2 HEAVY FOG; 3 THUNDERSTORM; 4 ICE PELLETS; 5 HAIL; 6 GLAZE; 7 DUSTSTORM; 8 SMOKE, HAZE; 9 BLOWING SNOW

DATE 1	TEMPERATURE °F MAXIMUM 2	MINIMUM 3	AVERAGE 4	DEPARTURE FROM NORMAL 5	AVERAGE DEW POINT 6	DEGREE DAYS BASE 65°F HEATING (SEASON BEGINS WITH JUL) 7A	COOLING (SEASON BEGINS WITH JAN) 7B	WEATHER TYPES 8	SNOW ICE PELLETS OR ICE ON GROUND AT 0400 INCHES 9	PRECIPITATION WATER EQUIVALENT (INCHES) 10	SNOW, ICE PELLETS (INCHES) 11	AVERAGE STATION PRESSURE IN INCHES ELEV. 2761 FEET ABOVE M.S.L. 12	WIND IN M.P.H. RESULTANT DIR. 13	RESULTANT SPEED 14	AVERAGE SPEED 15	PEAK GUST SPEED 16	PEAK GUST DIRECTION 17	FASTEST SPEED 18	FASTEST DIRECTION 19	SUNSHINE MINUTES 20	PERCENT OF TOTAL POSSIBLE 21	SKY COVER (TENTHS) SUNRISE TO SUNSET 22	MIDNIGHT TO MIDNIGHT 23
01	83	57	70	4		0	5		0	0.00	0.0					22	NNW						
02	86	60	73	7		0	8		0	0.00	0.0					15	N						
03	87	63	75	8		0	10		0	0.00	0.0					17	N						
04	94*	64	79*	12		0	14		0	0.00	0.0					10	NW						
05	89	64	77	10		0	12		0	0.00	0.0					13	W						
06	75	62	69	2		0	4		0	0.00	0.0					18	SW						
07	70	57	64	-3		1	0		0	0.00	0.0					21	WSW						
08	73	62	68	1		0	3		0	0.00	0.0					20	W						
09	74	60	67	1		0	2		0	0.00	0.0					18	SSW						
10	76	59	68	2		0	3		0	0.00	0.0					16	NW						
11	75	55	65	-1		0	0		0	0.00	0.0					18	WNW						
12	72	56	64	-2		1	0		0	0.00	0.0					13	W						
13	67	58	63	-3		2	0		0	0.00	0.0					17	SSW						
14	65	57	61	-5		4	0		0	0.04	0.0					10	ESE						
15	67	58	63	-3		2	0		0	T	0.0					14	WNW						
16	64	59	62	-4		3	0		0	0.04	0.0					12	SW						
17	74	58	66	0		0	1		0	T	0.0					15	WNW						
18	79	56	68	2		0	3		0	0.00	0.0					16	WNW						
19	81	59	70	4		0	5		0	0.00	0.0					16	WNW						
20	74	59	67	1		0	2		0	0.00	0.0					22	WSW						
21	73	57	65	0		0	0		0	T	0.0					15	W						
22	77	56	67	2		0	2		0	0.02	0.0					21	S						
23	67	55	61	-4		4	0		0	0.36	0.0					24	SSW						
24	68	51	60	-5		5	0		0	0.12	0.0					14	ENE						
25	68	50	59*	-6		6	0		0	0.00	0.0					17	NW						
26	74	50*	62	-3		3	0		0	0.00	0.0					14	W						
27	72	55	64	-1		1	0		0	0.00	0.0					21	NW						
28	71	55	63	-1		2	0		0	0.00	0.0					16	WNW						
29	75	52	64	0		1	0		0	0.00	0.0					17	WNW						
30	79	55	67	3		0	2		0	0.00	0.0					16	NNW						
31	80	55	68	4		0	3		0	0.00	0.0					10	W						
	SUM 2329	SUM 1774				TOTAL 35	TOTAL 79			TOTAL 0.58	TOTAL 0.0	FOR THE MONTH:				24	SSW			TOTAL	% FOR MONTH	SUM	SUM
	AVG. 75.1	AVG. 57.2	AVG. 66.2	DEP. 0.5	AVG.	DEP. -23	DEP. -1			DEP -0.64						DATE: 23		DATE:		POSSIBLE		AVG.	AVG.

NUMBER OF DAYS

MAXIMUM TEMP. ≥ 90°	MAXIMUM TEMP. ≤ 32°	MINIMUM TEMP. ≤ 32°	MINIMUM TEMP. ≤ 0°
1	0	0	0

DEGREE DAYS SEASON TO DATE	HEATING	COOLING
TOTAL	99	116
DEP.	-3	-33

NUMBER OF DAYS	
PRECIPITATION ≥ .01 INCH	5
SNOW, ICE PELLETS ≥ 1.0 INCH	0
THUNDERSTORMS	0
HEAVY FOG	0
CLEAR	
PARTLY CLOUDY	
CLOUDY	

GREATEST IN 24 HOURS AND DATES: PRECIPITATION 0.45 23-24; SNOW, ICE PELLETS 0.0

GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE: 0

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT.
\+ ALSO ON EARLIER DATE(S).
HEAVY FOG: VISIBILITY 1/4 MILE OR LESS.
BLANK ENTRIES DENOTE MISSING OR UNREPORTED DATA.
LESS THAN 24-HOUR WEATHER WATCH FOR DATA IN COLUMN 8.

DATA IN COLS 6 AND 12-15 ARE BASED ON 21 OR MORE OBSERVATIONS AT HOURLY INTERVALS. RESULTANT WIND IS THE VECTOR SUM OF WIND SPEEDS AND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS. COLS 16 & 17: PEAK GUST - HIGHEST INSTANTANEOUS WIND SPEED. ONE OF TWO WIND SPEEDS IS GIVEN UNDER COLS 18 & 19: FASTEST MILE - HIGHEST RECORDED SPEED FOR WHICH A MILE OF WIND PASSES STATION (DIRECTION IN COMPASS POINTS). FASTEST OBSERVED ONE MINUTE WIND - HIGHEST ONE MINUTE SPEED (DIRECTION IN TENS OF DEGREES). ERRORS WILL BE CORRECTED IN SUBSEQUENT PUBLICATIONS.

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATIC DATA CENTER

Kenneth D. Hadeen
DIRECTOR
NATIONAL CLIMATIC DATA CENTER

noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION · NATIONAL ENVIRONMENTAL SATELLITE, DATA AND INFORMATION SERVICE · NATIONAL CLIMATIC DATA CENTER ASHEVILLE NORTH CAROLINA

SEP 1993
SEATTLE C.O., WA
NAT'L WEA SER MET OBS
2725 MONTLAKE BLVD. E

INQUIRIES/COMMENTS CALL
(704) 271-4800

WSMO (EMSU)

LOCAL CLIMATOLOGICAL DATA

Monthly Summary

ISSN 0198-5477

U.S. Department of Commerce ... 1993

SEP 1993
SEATTLE C.O., WA

LATITUDE 47° 39'N LONGITUDE 122° 18'W ELEVATION (GROUND) 22 FEET TIME ZONE PACIFIC 24281

DATE	TEMPERATURE °F: MAXIMUM	MINIMUM	AVERAGE	DEPARTURE FROM NORMAL	AVERAGE DEW POINT	DEGREE DAYS BASE 65°F: HEATING (SEASON BEGINS WITH JUL)	COOLING (SEASON BEGINS WITH JAN)	WEATHER TYPES (1 FOG, 2 HEAVY FOG, 3 THUNDERSTORM, 4 ICE PELLETS, 5 HAIL, 6 GLAZE, 7 DUSTSTORM, 8 SMOKE, HAZE, 9 BLOWING SNOW)	SNOW ICE PELLETS OR ICE ON GROUND AT 0400 INCHES	PRECIPITATION: WATER EQUIVALENT (INCHES)	SNOW, ICE PELLETS (INCHES)	AVERAGE STATION PRESSURE IN INCHES ELEV 2761 FEET ABOVE M.S.L.	WIND (M.P.H.): RESULTANT DIR.	RESULTANT SPEED	AVERAGE SPEED	PEAK GUST SPEED	PEAK GUST DIRECTION	FASTEST SPEED	FASTEST DIRECTION	SUNSHINE: MINUTES	PERCENT OF TOTAL POSSIBLE	SKY COVER (TENTHS): SUNRISE TO SUNSET	MIDNIGHT TO MIDNIGHT
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
01	79	57	68	4		0	3		0	0.00	0.0					12	W						
02	82	56	69	5		0	4		0	0.00	0.0					13	WNW						
03	82	59	71	8		0	6		0	0.00	0.0					18	N						
04	71	57	64	1		1	0		0	0.00	0.0					12	N						
05	69	56	63	0		2	0		0	0.00	0.0					12	N						
06	80	56	68	5		0	3		0	0.00	0.0					15	WNW						
07	84	58	71	8		0	6		0	0.00	0.0					12	WNW						
08	83	58	71	9		0	6		0	0.00	0.0					16	WNW						
09	84*	57	71+	9		0	6		0	0.00	0.0					15	WSW						
10	83	57	70	8		0	5		0	0.00	0.0					14	SSW						
11	69	54	62	0		3	0		0	0.00	0.0					21	SSW						
12	70	49	60	-2		5	0		0	0.00	0.0					17	WNW						
13	74	49	62	0		3	0		0	0.00	0.0					15	WNW						
14	66	51	59	-2		6	0		0	0.00	0.0					15	WSW						
15	68	55	62	1		3	0		0	0.00	0.0					17	NW						
16	73	51	62	1		3	0		0	0.00	0.0					18	NW						
17	75	50	63	3		2	0		0	0.00	0.0												
18	64	50	57	-3		8	0		0	0.00	0.0												
19	65	50	58	-2		7	0		0	T	0.0												
20	60	47	54	-6		11	0		0	T	0.0												
21	66	43*	55	-5		10	0		0	0.00	0.0					17	NW						
22	69	45	57	-2		8	0		0	0.00	0.0					15	NW						
23	72	46	59	0		6	0		0	0.00	0.0					13	WNW						
24	61	47	54+	-5		11	0		0	0.00	0.0					14	WNW						
25	68	51	60	1		5	0		0	0.00	0.0					20	NW						
26	73	48	61	3		4	0		0	0.00	0.0					14	WNW						
27	77	50	64	6		1	0		0	0.00	0.0					10	W						
28	76	52	64	6		1	0		0	0.00	0.0					13	WNW						
29	81	53	67	9		0	2		0	0.00	0.0					17	N						
30	74	52	63	5		2	0		0	0.00	0.0					12	W						
	SUM 2198	SUM 1564				TOTAL 102	TOTAL 41	NUMBER OF DAYS		TOTAL trace	TOTAL 0.0	FOR THE MONTH:				21	SSW			TOTAL	% FOR MONTH	SUM	SUM
	AVG. 73.3	AVG. 52.1	AVG. 62.7	DEP 1.3	AVG.	DEP -42	DEP 23	PRECIPITATION ≥ .01 INCH 0		DEP. -1.94						DATE: 11		DATE		POSSIBLE		AVG.	AVG.

NUMBER OF DAYS				SEASON TO DATE				GREATEST IN 24 HOURS AND DATES			GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE
MAXIMUM TEMP.		MINIMUM TEMP		TOTAL	TOTAL	SNOW, ICE PELLETS ≥ 1.0 INCH	0	PRECIPITATION		SNOW, ICE PELLETS	
≥ 90°	≤ 32°	≤ 32°	≤ 0°	201	157	THUNDERSTORMS	0	trace	20+	0.0	0
0	0	0	0	DEP -45	DEP -10	HEAVY FOG	0				
						CLEAR	PARTLY CLOUDY	CLOUDY			

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT.
+ ALSO ON EARLIER DATE(S).
HEAVY FOG: VISIBILITY 1/4 MILE OR LESS.
BLANK ENTRIES DENOTE MISSING OR UNREPORTED DATA.
LESS THAN 24-HOUR WEATHER WATCH FOR DATA IN COLUMN 8.

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Kenneth D. Hadeen
DIRECTOR
NATIONAL CLIMATIC DATA CENTER

noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION — NATIONAL ENVIRONMENTAL SATELLITE, DATA AND INFORMATION SERVICE — NATIONAL CLIMATIC DATA CENTER ASHEVILLE NORTH CAROLINA

JAN 1994
SEATTLE C.O., WA
NAT'L WEA SER MET OBS
2725 MONTLAKE BLVD. E

INQUIRIES/COMMENTS CALL
(704) 271-4800

NSMO (EMSU)

LOCAL CLIMATOLOGICAL DATA
Monthly Summary

ISSN 0198-5477

SEATTLE C.O., WA JAN 1994

LATITUDE 47° 39'N LONGITUDE 122° 18'W ELEVATION (GROUND) 22 FEET TIME ZONE PACIFIC 24281

DATE	TEMPERATURE °F MAXIMUM	MINIMUM	AVERAGE	DEPARTURE FROM NORMAL	AVERAGE DEW POINT	DEGREE DAYS BASE 65°F HEATING (SEASON BEGINS WITH JUL)	COOLING (SEASON BEGINS WITH JAN)	WEATHER TYPES 1 FOG 2 HEAVY FOG 3 THUNDERSTORM 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW	SNOW ICE PELLETS OR ICE ON GROUND AT 0400 INCHES	PRECIPITATION WATER EQUIVALENT (INCHES)	SNOW, ICE PELLETS (INCHES)	AVERAGE STATION PRESSURE IN INCHES ELEV 2761 FEET ABOVE M.S.L.	WIND (M.P.H.) RESULTANT DIR.	RESULTANT SPEED	AVERAGE SPEED	PEAK GUST SPEED	PEAK GUST DIRECTION	FASTEST SPEED	FASTEST DIRECTION	SUNSHINE MINUTES	PERCENT OF TOTAL POSSIBLE	SKY COVER (TENTHS) SUNRISE TO SUNSET	MIDNIGHT TO MIDNIGHT
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
01	52	45	49	8		16	0		0	0.05	0.0					21	SSE						
02	54	44	49	8		16	0		0	0.18	0.0					31	SW						
03	53	43	48	7		17	0		0	0.20	0.0					13	SE						
04	53	45	49	8		16	0		0	0.13	0.0					40	SW						
05	51	40	46	5		19	0		0	0.07	0.0					23	SSW						
06	47	35	41	0		24	0		0	0.00	0.0					12	SSE						
07	47	41	44	3		21	0		0	T	0.0					17	S						
08	51	43	47	6		18	0		0	T	0.0					14	SSE						
09	51	47	49	8		16	0		0	0.23	0.0					23	SSW						
10	51	46	49	8		16	0		0	0.13	0.0					18	SSE						
11	51	46	49	8		16	0		0	0.00	0.0					20	SSW						
12	52	49	51	10		14	0		0	0.06	0.0					24	S						
13	54	43	49	8		16	0		0	0.03	0.0					14	SSE						
14	47	42	45	4		20	0		0	T	0.0					14	ESE						
15	51	45	48	7		17	0		0	T	0.0					16	SW						
16	50	43	47	6		18	0		0	0.05	0.0					12	SW						
17	50	36	43	2		22	0		0	0.00	0.0					7	SE						
18	44	36	40	-1		25	0		0	0.00	0.0					7	E						
19	43	36	40	-1		• 25	0		0	0.00	0.0					9	NNE						
20	43	37	40	-1		25	0		0	0.00	0.0					9	E						
21	49	39	44	3		21	0		0	0.17	0.0					14	SW						
22	55*	46	51*	10		14	0		0	0.40	0.0					14	S						
23	52	45	49	7		16	0		0	0.38	0.0					13	SE						
24	50	43	47	5		18	0		0	0.08	0.0					16	WSW						
25	51	42	47	5		18	0		0	0.10	0.0					8	SE						
26	49	43	46	4		19	0		0	T	0.0					9	SSE						
27	49	38	44	2		21	0		0	0.00	0.0					18	ENE						
28	52	36	44	2		21	0		0	0.00	0.0					12	NNE						
29	50	33	42	0		23	0		0	0.00	0.0					8	ESE						
30	54	33	44	2		21	0		0	0.00	0.0					9	N						
31	49	30*	40*	-2		25	0		0	0.00	0.0					12	NW						
	SUM 1555	SUM 1270				TOTAL 594	TOTAL 0			TOTAL 2.20	TOTAL 0.0	FOR THE MONTH:				40	SW			TOTAL	% FOR MONTH	SUM	SUM
	AVG. 50.2	AVG. 41.0	AVG 45.6	DEP. 4.3	AVG.	DEP. -141	DEP 0			DEP -3.15						DATE: 4		DATE:		POSSIBLE		AVG.	AVG.
						SEASON TO DATE TOTAL 2424	TOTAL 0																
						DEP -200	DEP 0																

NUMBER OF DAYS			
MAXIMUM TEMP ≥ 90°	MAXIMUM TEMP ≤ 32°	MINIMUM TEMP ≤ 32°	MINIMUM TEMP ≤ 0°
0	0	1	0

NUMBER OF DAYS	
PRECIPITATION ≥ .01 INCH	15
SNOW, ICE PELLETS ≥ 1.0 INCH	0
THUNDERSTORMS	0
HEAVY FOG	0
CLEAR	
PARTLY CLOUDY	
CLOUDY	

GREATEST IN 24 HOURS AND DATES			
PRECIPITATION		SNOW, ICE PELLETS	
0.54	31-01	0.0	

GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE	
0	

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT.
• ALSO ON EARLIER DATE(S).
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Kenneth D. Hadeen
DIRECTOR
NATIONAL CLIMATIC DATA CENTER

OBSERVATIONS AT 3-HOUR INTERVALS

AUG 1993
TAMPA, FL
12842

AUG 1st

HOUR (LST)	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
01	5	UNL	12			78	74	72	82	00	0
04	5	UNL	10			77	72	70	79	00	0
07	0	UNL	15			81	74	71	72	00	0
10	7	UNL	15			90	76	70	52	24	6
13	5	UNL	15			93	76	68	44	31	7
16	5	UNL	15			93	75	66	41	29	9
19	1	UNL	15			87	73	66	50	25	8
22	0	UNL	12			81	71	65	58	00	0

AUG 2nd

HOUR (LST)	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
01	1	UNL	15			76	70	67	74	00	0
04	2	UNL	15			74	70	67	79	10	3
07	8	UNL	10			79	74	71	77	00	0
10	5	UNL	15			90	76	69	50	22	6
13	8	UNL	15			92	74	65	41	18	9
16	4	UNL	15			92	77	70	49	26	9
19	6	250	10		TRW	84	78	75	75	25	15
22	4	UNL	10			78	73	71	79	00	0

AUG 3rd

HOUR (LST)	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
01	0	UNL	15			80	77	76	88	16	3
04	0	UNL	15			78	76	75	91	00	0
07	4	UNL	10			79	76	75	88	11	3
10	4	UNL	12			89	80	76	66	14	5
13	6	40	12			91	80	76	62	23	5
16	5	UNL	12			93	79	73	52	30	7
19	10	250	10			76	73	72	88	01	8
22	8	UNL	12			78	73	71	79	00	0

AUG 4th

HOUR (LST)	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
01	2	UNL	15			76	73	71	85	00	0
04	2	UNL	12			76	73	72	88	00	0
07	0	UNL	7			79	77	76	91	12	3
10	2	UNL	10			88	79	76	68	17	5
13	4	UNL	9			92	77	71	50	13	7
16	1	UNL	7			94	78	71	47	27	7
19	1	UNL	7			87	79	75	68	31	6
22	6	40	7			84	77	74	72	00	0

AUG 5th

HOUR (LST)	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
01	0	UNL	8			81	77	75	82	00	0
04	0	UNL	7			81	74	71	72	00	0
07	0	UNL	8			81	77	75	82	14	4
10	0	UNL	8			88	79	75	66	23	4
13	1	UNL	7			93	78	71	49	13	4
16	1	UNL	7			95	77	69	43	13	5
19	6	50	7			88	78	74	63	05	6
22	2	UNL	7			82	76	74	77	00	0

AUG 6th

HOUR (LST)	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
01	3	UNL	7			80	75	72	77	00	0
04	3	UNL	7			81	76	74	79	22	7
07	7	UNL	10			80	75	72	77	00	0
10	6	UNL	10			89	78	74	61	15	7
13	4	UNL	10			92	77	70	49	14	6
16	2	UNL	9			94	77	70	46	14	5
19	6	UNL	10			88	77	72	59	07	6
22	3	UNL	9			82	76	74	77	00	0

AUG 7th

HOUR (LST)	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
01	2	UNL	8			80	77	75	85	00	0
04	0	UNL	8			80	76	74	82	00	0
07	0	UNL	12			80	75	73	79	00	0
10	0	UNL	12			87	78	74	65	23	4
13	2	UNL	10			93	76	69	46	26	3
16	1	UNL	8			96	74	63	34	22	4
19	3	UNL	8			89	78	73	59	05	7
22	1	UNL	10			84	76	73	70	31	3

AUG 8th

HOUR (LST)	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
01	2	UNL	10			81	74	71	72	26	6
04	0	UNL	10			77	74	72	85	25	3
07	6	UNL	8			77	74	73	88	00	0
10	6	UNL	10			86	77	73	65	22	3
13	4	UNL	12			94	76	68	43	09	4
16	2	UNL	12			95	74	64	36	30	7
19	6	UNL	15			89	74	66	47	31	3
22	3	UNL	10			85	76	72	65	29	6

AUG 9th

HOUR (LST)	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
01	0	UNL	10			80	75	72	77	25	5
04	0	UNL	10			75	74	73	94	00	0
07	6	UNL	9			76	74	73	91	30	3
10	7	23	15			89	78	74	61	24	7
13	8	45	15			92	79	74	56	03	4
16	1	UNL	15			96	73	62	33	32	3
19	10	100	12			81	75	72	74	17	9
22	8	250	15			81	74	71	72	00	0

AUG 10th

HOUR (LST)	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
01	8	UNL	12			80	75	73	79	28	4
04	5	UNL	7			76	74	73	91	00	0
07	1	UNL	8			77	75	74	91	30	3
10	5	UNL	15			86	76	72	63	00	0
13	8	43	15			89	76	70	54	00	0
16	9	100	10		T	80	74	71	74	00	0
19	7	250	15			82	75	71	69	12	7
22	2	UNL	15			78	74	72	82	00	0

AUG 11th

HOUR (LST)	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
01	5	UNL	12			77	74	73	88	15	4
04	4	UNL	7			74	73	72	94	00	0
07	1	UNL	20			74	73	72	94	00	0
10	5	UNL	20			86	77	73	65	05	3
13	7	44	20			90	78	73	58	21	8
16	5	UNL	15			91	78	73	56	20	10
19	2	UNL	15			88	73	66	48	05	4
22	1	UNL	15			84	75	71	65	03	8

AUG 12th

HOUR (LST)	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
01	2	UNL	10			79	74	71	77	36	5
04	4	UNL	8			77	74	72	85	00	0
07	1	UNL	20			76	74	73	91	00	0
10	0	UNL	15			88	78	73	61	04	3
13	4	UNL	15			93	78	72	51	24	7
16	2	UNL	12			92	79	73	54	22	10
19	8	100	12			83	74	70	65	35	4
22	4	UNL	12			81	74	70	69	36	4

AUG 13th

HOUR (LST)	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
01	4	UNL	10			77	74	72	85	00	0
04	3	UNL	10			75	72	71	87	00	0
07	2	UNL	20			80	75	72	77	33	3
10	3	UNL	15			89	78	74	61	27	3
13	7	90	15			90	78	73	58	23	9
16	8	UNL	15			91	78	73	56	20	10
19	4	UNL	15			86	77	73	65	20	5
22	2	UNL	15			83	77	74	74	00	0

AUG 14th

HOUR (LST)	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
01	2	UNL	12			82	78	76	82	00	0
04	5	UNL	12			79	77	76	91	00	0
07	3	UNL	15			81	78	76	85	00	0
10	7	30	7		TRW	79	76	74	85	30	4
13	10	25	8		TRW	81	77	75	82	26	9
16	9	250	15			85	78	75	72	23	7
19	9	UNL	20			84	76	73	70	26	3
22	8	UNL	12			82	78	76	82	26	3

AUG 15th

HOUR (LST)	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
01	7	UNL	12			82	78	76	82	00	0
04	10	250	12			83	78	76	80	25	4
07	8	250	15			84	78	76	77	24	5
10	10	90	7		TR	76	74	73	91	00	0
13	10	100	7		R	78	75	74	88	22	7
16	10	130	20			85	77	74	70	18	7
19	10	110	20			84	77	74	72	19	9
22	5	UNL	12			81	78	76	85	00	0

AUG 16th

HOUR (LST)	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
01	6	UNL	12			80	77	76	88	00	0
04	8	250	10			79	77	76	91	00	0
07	8	UNL	10			82	78	77	85	00	0
10	9	35	12			82	76	73	74	22	10
13	10	130	10			89	80	77	68	21	10
16	10	120	7		T	89	80	76	66	20	11
19	10	250	6		H	84	79	77	80	18	3
22	10	250	5		FH	80	78	77	91	00	0

AUG 17th

HOUR (LST)	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
01	9	UNL	5		F	74	73	72	94	00	0
04	6	UNL	5		F	73	72	71	94	00	0
07	0	UNL	4		F	73	72	72	97	00	0
10	1	UNL	12			85	76	72	65	05	6
13	5	UNL	15			91	76	69	49	06	4
16	8	250	12			90	75	68	48	25	7
19	8	90	12			84	76	72	67	17	7
22	3	UNL	12			79	74	72	79	00	0

AUG 18th

HOUR (LST)	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
01	2	UNL	10			77	74	72	85	00	0
04	2	UNL	8			74	72	71	90	00	0
07	0	UNL	7			75	74	73	94	00	0
10	0	UNL	8			88	77	72	59	00	0
13	2	UNL	9			92	77	70	49	23	8
16	7	48	6		RWH	87	77	73	63	00	0
19	5	UNL	7			85	77	73	67	00	0
22	0	UNL	7			81	77	75	82	00	0

MAXIMUM SHORT DURATION PRECIPITATION

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	0.29	0.48	0.58	0.70	0.91	1.03	1.11	1.16	1.22	1.28	1.31	1.31
ENDED: DATE	25	25	25	25	25	25	25	25	25	25	25	25
ENDED: TIME	1513	1513	1514	1515	1516	1533	1539	1545	1614	1645	1649	1649

THE PRECIPITATION AMOUNTS FOR THE INDICATED TIME INTERVALS MAY OCCUR AT ANY TIME DURING THE MONTH. THE TIME INDICATED IS THE ENDING TIME OF THE INTERVAL. DATE AND TIME ARE NOT ENTERED FOR TRACE AMOUNTS.

OBSERVATIONS AT 3-HOUR INTERVALS

SEP 1993 TAMPA, FL 12842

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY: WHOLE MILES	VISIBILITY: 16THS MILE	WEATHER	TEMPERATURE: AIR °F	TEMPERATURE: WET BULB °F	TEMPERATURE: DEW POINT °F	REL HUMIDITY %	WIND: DIRECTION	WIND: SPEED (KNOTS)
SEP 1st											
01	4	UNL	10			78	75	74	88	00	0
04	0	UNL	9			77	75	74	91	12	3
07	4	UNL	15			77	74	73	88	12	4
10	6	UNL	20			86	78	75	70	15	9
13	7	35	15			91	78	73	56	13	11
16	3	UNL	20			91	81	77	64	21	7
19	10	45	8		TRW	85	76	72	65	17	4
22	6	250	15			75	73	72	90	08	3
SEP 2nd											
01	3	UNL	15			74	73	72	94	00	0
04	3	UNL	6		F	74	73	72	94	08	3
07	4	UNL	20			76	73	72	88	12	4
10	5	UNL	20			84	78	75	75	14	7
13	7	UNL	20			89	79	75	63	19	5
16	8	250	15		RW	81	77	75	82	12	9
19	5	UNL	15			79	74	72	79	33	3
22	2	UNL	15			77	74	72	85	07	3
SEP 3rd											
01	0	UNL	15			74	72	71	90	00	0
04	0	UNL	15			75	72	71	87	00	0
07	1	UNL	20			77	75	74	91	11	3
10	1	UNL	20			86	75	69	57	15	7
13	2	UNL	20			90	77	71	54	26	7
16	3	UNL	15			92	75	67	44	24	6
19	4	UNL	15			84	75	71	65	29	7
22	3	UNL	15			80	76	74	82	05	3
SEP 4th											
01	1	UNL	15			76	75	74	94	00	0
04	0	UNL	15			74	73	73	97	00	0
07	1	UNL	12			75	74	74	97	00	0
10	2	UNL	15			86	78	75	70	20	4
13	2	UNL	15			90	78	73	58	23	4
16	4	UNL	15			90	77	72	56	26	7
19	10	UNL	15			83	75	72	70	28	5
22	3	UNL	15			79	75	73	82	00	0
SEP 5th											
01	0	UNL	12			76	74	73	91	00	0
04	0	UNL	8			77	75	74	91	00	0
07	1	UNL	12			77	75	74	91	00	0
10	1	UNL	12			88	77	73	61	00	0
13	1	UNL	15			91	78	72	54	26	7
16	8	UNL	15			89	78	73	59	26	10
19	9	150	12		T	83	76	73	72	12	7
22	10	250	10			75	74	73	94	00	0
SEP 6th											
01	5	UNL	12			75	72	71	87	00	0
04	1	UNL	10			74	73	72	94	09	3
07	3	UNL	8			74	73	72	94	00	0
10	6	UNL	12			84	78	75	75	11	6
13	5	UNL	15			89	79	75	63	27	6
16	5	UNL	15			91	78	73	56	24	6
19	10	55	4		TRW	74	73	73	97	12	7
22	10	120	8			74	73	72	94	00	0
SEP 7th											
01	5	UNL	15			72	71	70	94	00	0
04	5	UNL	15			73	72	71	94	00	0
07	1	UNL	8			74	73	72	94	00	0
10	1	UNL	15			86	79	76	72	13	4
13	4	UNL	15			90	79	75	61	21	6
16	5	UNL	15			90	79	75	61	30	8
19	7	250	15			84	76	73	70	30	6
22	8	110	9			75	73	72	90	12	6
SEP 8th											
01	10	140	7		R	75	74	74	97	18	3
04	8	UNL	15			75	74	73	94	00	0
07	2	UNL	15			75	74	73	94	00	0
10	6	250	15			85	79	76	75	12	3
13	9	250	12			76	74	73	91	11	3
16	10	250	12			80	76	74	82	00	0
19	8	250	12			79	76	74	85	00	0
22	5	UNL	12			77	75	74	91	00	0
SEP 9th											
01	1	UNL	10			78	75	74	88	00	0
04	0	UNL	15			78	75	73	85	00	0
07	2	UNL	15			78	75	74	88	14	3
10	7	UNL	15			86	80	78	77	21	7
13	4	UNL	15			89	80	77	68	23	9
16	6	UNL	20			89	78	74	61	27	9
19	7	250	15			76	75	74	94	00	0
22	6	250	15			81	78	77	88	00	0
SEP 10th											
01	8	250	12			80	77	76	88	00	0
04	5	UNL	10			80	77	76	88	00	0
07	5	UNL	15			81	78	77	88	00	0
10	3	UNL	15			88	79	76	68	23	9
13	7	250	12			80	77	75	85	25	3
16	8	250	15			87	79	75	68	25	10
19	7	250	15			83	78	76	80	25	5
22	4	UNL	15			81	77	75	82	27	3
SEP 11th											
01	2	UNL	12			81	78	76	85	25	3
04	3	UNL	12			78	76	75	91	00	0
07	9	250	12			77	76	75	94	00	0
10	9	120	15			86	79	76	72	27	3
13	6	250	8			89	80	76	66	33	7
16	6	250	15			87	78	74	65	23	5
19	1	UNL	12			77	73	71	82	08	5
22	7	UNL	10			76	73	71	85	09	3
SEP 12th											
01	4	UNL	10			76	74	73	91	00	0
04	0	UNL	6		F	73	72	72	97	00	0
07	2	UNL	2	8	F	73	72	72	97	00	0
10	1	UNL	8			84	76	73	70	12	3
13	9	30	12			88	77	72	59	12	4
16	9	250	8		TRW	79	76	74	85	05	11
19	3	UNL	15			81	75	72	74	00	0
22	1	UNL	15			75	72	70	85	10	3
SEP 13th											
01	3	UNL	12			73	71	70	90	00	0
04	0	UNL	7			73	72	71	94	00	0
07	0	UNL	7			75	74	73	94	00	0
10	3	UNL	12			86	78	75	70	07	5
13	6	40	12			90	77	72	56	12	6
16	5	UNL	15		T	88	77	72	59	00	0
19	10	35	7		TR	74	73	72	94	24	5
22	10	100	12			75	74	73	94	07	5
SEP 14th											
01	5	UNL	10			75	74	73	94	00	0
04	4	UNL	7			74	73	73	97	00	0
07	5	UNL	12			74	73	72	94	07	4
10	1	UNL	12			86	78	74	68	11	8
13	8	37	15		T	89	78	73	59	11	6
16	10	250	12			82	76	73	74	00	0
19	7	250	12			80	76	74	82	06	3
22	3	UNL	12			76	73	72	88	00	0
SEP 15th											
01	3	UNL	10			74	72	71	90	00	0
04	2	UNL	9			73	72	72	97	00	0
07	7	UNL	7			74	73	73	97	00	0
10	6	UNL	12			85	77	74	70	08	9
13	8	250	12			91	78	73	56	12	8
16	9	48	12			86	78	75	70	24	7
19	9	80	12			75	72	71	87	00	0
22	9	100	12			75	73	72	90	00	0
SEP 16th											
01	8	150	10			75	73	72	90	00	0
04	0	UNL	7			74	73	73	97	00	0
07	2	UNL	15			76	75	74	94	00	0
10	9	UNL	20			86	79	76	72	11	6
13	9	35	15			90	79	74	59	12	6
16	5	UNL	15			92	79	73	54	05	4
19	10	35	10			76	74	73	91	36	7
22	3	UNL	15			77	74	73	88	00	0
SEP 17th											
01	3	UNL	10			76	75	74	94	00	0
04	5	UNL	7			75	74	74	97	00	0
07	10	UNL	7			76	75	75	97	00	0
10	9	UNL	12			86	79	76	72	10	3
13	8	33	15			89	78	73	59	12	5
16	9	250	15			90	77	72	56	13	5
19	9	250	15		T	85	77	73	67	12	8
22	8	100	15			83	77	74	74	08	6
SEP 18th											
01	8	250	15			79	75	73	82	11	4
04	10	100	15			77	75	74	91	09	3
07	10	130	10			76	75	74	94	00	0
10	8	250	12			86	78	75	70	12	5
13	7	250	15			91	76	69	49	06	3
16	3	UNL	15			91	79	74	58	27	6
19	0	UNL	15			83	77	75	77	33	6
22	7	250	15		RW	82	77	75	79	09	3

MAXIMUM SHORT DURATION PRECIPITATION

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	0.42	0.63	0.73	0.76	0.81	1.03	1.32	1.42	1.44	1.45	1.45	1.45
ENDED: DATE	16	16	16	16	13	13	13	13	13	13	13	13
ENDED: TIME	1806	1806	1810	1812	1748	1759	1814	1833	1841	1906	1906	1906

THE PRECIPITATION AMOUNTS FOR THE INDICATED TIME INTERVALS MAY OCCUR AT ANY TIME DURING THE MONTH. THE TIME INDICATED IS THE ENDING TIME OF THE INTERVAL. DATE AND TIME ARE NOT ENTERED FOR TRACE AMOUNTS.

OBSERVATIONS AT 3-HOUR INTERVALS

AUG 1993
TAMPA, FL
12842

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
AUG 19th											
01	0	UNL	7			80	76	74	82	00	0
04	0	UNL	6		H	78	76	75	91	00	0
07	0	UNL	6		H	80	77	75	85	00	0
10	0	UNL	8			89	79	75	63	26	5
13	2	UNL	8			92	79	74	56	25	7
16	2	UNL	7			91	78	73	56	22	10
19	3	UNL	7			85	78	75	72	20	7
22	3	UNL	7			84	78	75	75	20	8
AUG 20th											
01	1	UNL	7			82	77	75	79	21	4
04	1	UNL	7			80	77	75	85	00	0
07	0	UNL	7			81	77	75	82	00	0
10	2	UNL	8			89	78	74	61	24	6
13	1	UNL	8			92	78	72	52	23	10
16	1	UNL	9			91	79	74	58	22	11
19	3	UNL	10			86	78	75	70	20	8
22	2	UNL	12			83	77	74	74	20	5
AUG 21st											
01	0	UNL	12			80	76	74	82	00	0
04	0	UNL	10			81	76	74	79	00	0
07	7	UNL	12			83	78	76	80	00	0
10	6	250	12			84	77	74	72	24	3
13	4	UNL	10			91	80	76	62	22	13
16	8	UNL	10			90	78	73	58	20	13
19	9	UNL	10			85	77	73	67	22	9
22	7	UNL	10			84	76	73	70	23	4
AUG 22nd											
01	4	UNL	10			83	77	75	77	18	3
04	3	UNL	9			80	77	75	85	00	0
07	3	UNL	9			82	77	75	79	00	0
10	3	UNL	12			88	79	75	66	21	8
13	7	UNL	12			92	79	74	56	19	12
16	2	UNL	12			90	79	75	61	35	12
19	6	UNL	12			86	77	73	65	33	9
22	8	UNL	12			82	77	75	79	00	0
AUG 23rd											
01	8	UNL	12			81	77	75	82	00	0
04	5	UNL	10			80	77	75	85	00	0
07	7	UNL	20			81	76	74	79	00	0
10	4	UNL	15			91	78	73	56	29	7
13	6	UNL	10			93	81	76	58	26	13
16	10	250	10			90	79	74	59	27	10
19	10	250	8			84	78	75	75	00	0
22	7	250	7			80	76	74	82	00	0
AUG 24th											
01	7	UNL	8			77	74	73	88	00	0
04	3	UNL	6		F	75	74	73	94	00	0
07	2	UNL	5		F	77	74	73	88	00	0
10	3	UNL	5		H	87	79	75	68	10	3
13	8	UNL	7			92	78	72	52	12	5
16	9	UNL	9			93	78	71	49	12	4
19	9	250	9		T	84	76	73	70	09	6
22	3	UNL	8			80	76	74	82	04	3
AUG 25th											
01	3	UNL	7			78	76	75	91	09	4
04	3	UNL	6		F	76	75	75	97	00	0
07	10	4	2		F	77	76	75	94	06	3
10	3	UNL	4		H	87	79	75	68	00	0
13	6	250	7			88	79	75	66	24	4
16	10	60	2		TRW	76	75	74	94	25	8
19	8	250	3		F	75	74	73	94	12	3
22	8	250	6		F	74	73	73	97	00	0
AUG 26th											
01	9	140	6		F	74	73	73	97	00	0
04	2	UNL	7			73	72	72	97	00	0
07	1	UNL	7			75	73	72	90	10	4
10	4	UNL	15			83	76	73	72	13	5
13	7	140	15			90	78	73	58	23	6
16	6	250	15			88	79	75	66	25	12
19	10	50	2	8	RWF	73	71	70	90	06	8
22	10	90	8		R	73	72	71	94	00	0
AUG 27th											
01	10	150	12			73	72	72	97	00	0
04	9	150	8			72	71	71	97	07	3
07	9	150	2		F	73	72	72	97	00	0
10	7	UNL	9			84	76	73	70	13	3
13	4	UNL	15			89	78	73	59	23	6
16	8	250	15			85	76	72	65	27	6
19	8	250	15			82	76	73	74	35	3
22	7	250	15			80	76	74	82	11	5
AUG 28th											
01	8	250	15			77	74	73	88	23	3
04	5	UNL	15			77	74	73	88	00	0
07	7	130	15			79	75	73	82	00	0
10	6	90	15			84	77	74	72	24	4
13	8	100	12		RW	79	76	75	88	24	7
16	9	140	15			81	77	75	82	17	3
19	9	140	12		R	76	75	74	94	00	0
22	5	UNL	15			76	75	74	94	00	0
AUG 29th											
01	6	250	12			76	75	74	94	00	0
04	10	100	7		R	76	75	74	94	12	4
07	7	100	15			77	75	74	91	13	3
10	8	50	12		T	84	78	75	77	14	5
13	10	250	9			80	77	76	88	18	5
16	10	130	20			82	77	75	79	15	3
19	10	35	8		RW	77	75	74	91	14	5
22	10	70	5		TRWF	76	75	74	94	13	4
AUG 30th											
01	10	85	4		RWF	75	74	73	94	16	3
04	9	60	7			75	74	73	94	00	0
07	9	250	2	8	F	74	73	72	94	13	4
10	10	13	15			80	77	75	85	15	4
13	10	19	15			81	77	75	82	14	5
16	10	30	7			77	74	72	85	00	0
19	10	50	7		R	75	74	74	97	00	0
22	8	120	7			75	74	74	97	00	0
AUG 31st											
01	5	UNL	6		F	74	73	73	97	00	0
04	9	5	4		F	74	73	73	97	11	4
07	10	5	1	8	F	75	74	73	94	07	4
10	10	9	7			80	77	75	85	12	7
13	9	27	12			84	77	74	72	19	6
16	9	100	12			86	78	75	70	19	8
19	8	45	12			82	76	74	77	12	4
22	10	65	10			79	76	75	88	00	0

WEATHER CODES

*	TORNADO	SW	SNOW SHOWERS	GF	GROUND FOG
T	THUNDERSTORM	SG	SNOW GRAINS	BD	BLOWING DUST
Q	SQUALL	SP	SNOW PELLETS	BN	BLOWING SAND
R	RAIN	IC	ICE CRYSTALS	BS	BLOWING SNOW
RW	RAIN SHOWERS	IP	ICE PELLETS	BY	BLOWING SPRAY
ZR	FREEZING RAIN	IPW	ICE PELLET SHOWERS	K	SMOKE
L	DRIZZLE	A	HAIL	H	HAZE
ZL	FREEZING DRIZZLE	F	FOG	D	DUST
S	SNOW	IF	ICE FOG		

CEILING: UNL INDICATES UNLIMITED
WIND DIRECTION: DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH 27 FOR WEST. AN ENTRY OF 00 INDICATES CALM.
SPEED: THE OBSERVED AVERAGE ONE-MINUTE VALUE, EXPRESSED IN KNOTS (MPH=KNOTS X 1.151).

SUMMARY BY HOURS

HOUR L.S.T.	AVERAGES: SKY COVER (TENTHS)	STATION PRESSURE (INCHES)	TEMPERATURE: AIR TEMP °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND SPEED (MPH)	RESULTANT WIND: DIRECTION	SPEED (MPH)
01	4	30.020	78	75	73	85	1.6	22	0.7
04	4	30.000	77	74	73	88	1.0	17	0.4
07	4	30.030	78	75	74	86	1.6	11	0.5
10	5	30.060	86	77	74	67	5.0	20	2.4
13	6	30.040	89	78	73	59	7.8	22	5.2
16	6	29.990	89	77	72	59	8.1	23	5.3
19	7	30.000	83	76	73	72	6.4	18	1.0
22	5	30.035	80	75	73	79	2.0	24	0.2

Appendix C. Tabulation of Field Observation Data by Climatic Area

Site: **Boulder, Colorado**

Date	Time	Underlayment Condition Index	Underlayment Moisture Reading	Reported Temp. (F)	Reported Humidity
Felt Product: A30 (Non-Classified, Type II) Orientation Unknown					
8/23/93	–	Installation	0%	84°	16%
8/25/93	10:30 a.m.	1	1%	-	-
Felt Product: B15 (ASTM D 226, Type I) Northeastern & Southwestern Orientation					
12/13/93	3:00 p.m.	Installation	0%	36°	24%
2/14/93	10:30 a.m.	1	-	-	-
Felt Product: C15 (Non-Classified, Glass-Fiber-Reinforced) Orientation Unknown					
9/3/93	–	Installation	0%	79°	36%
9/8/93	9:15 a.m.	3/4	5%	55°	89%
Felt Product: D15 (ASTM D 4869, Type I) Southern Orientation					
11/18/93	2:00 p.m.	Installation	0%	45°	-
Felt Product: E30 (ASTM D 4869, Type II) Northern Orientation					
11/18/93	2:00 p.m.	Installation	0%	45°	-
11/21/93	2:00 p.m.	1	-	48°	-
Felt Product: F15 (Non-Classified, Type I) Eastern & Western Orientations					
8/25/93	–	Installation	0%	90°	32%
8/30/93	11:30 a.m.	3	0%	60°	44%
8/31/93	3:30 p.m.	-	0%	69°	39%
Felt Product: G30 (ASTM D 226, Type II) Orientation Unknown					
8/19/93	–	Installation	0%	80°	20%
8/20/93	4:15 p.m.	1	4%	76°	50%
8/23/93	11:00 a.m.	1	7.5%	86°	30%

Site: **Neenah, Wisconsin**					
Date	**Time**	**Underlayment Condition Index**	**Underlayment Moisture Reading**	**Reported Temp. (F)**	**Reported Humidity**
Felt Product: A30 (Non-Classified, Type II) Eastern & Western Orientations					
1/21/94	12:00 p.m.	Installation	1%	12°	55%
1/22/94	10:00 a.m.	1	4%	20°	-
1/24/94	1:00 p.m.	2	3%	22°	80%
Felt Product: B15 (ASTM D 226, Type I) Eastern & Western Orientations					
1/21/94	12:00 p.m.	Installation	1%	12°	55%
1/22/94	10:00 a.m.	2	5%	20°	-
1/24/94	12:50 p.m.	2	4%	22°	80%
Felt Product: C15 (Non-Classified, Glass-Fiber-Reinforced) Eastern & Western Orientations					
1/21/94	12:15 p.m.	Installation	2%	12°	55%
1/22/94	10:00 a.m.	2	-	20°	-
1/24/94	12:40 p.m.	3	3%	22°	80%
Felt Product: D15 (ASTM D 4869, Type I) Eastern Orientation					
1/21/94	12:40 p.m.	Installation	1%	12°	55%
1/22/94	10:05 a.m.	2	6%	20°	-
1/24/94	12:40 p.m.	3	4%	22°	80%
Felt Product: E30 (ASTM D 4869, Type II) Northern and Southern Orientations					
1/22/94	9:30 a.m.	Installation	1%	20°	68%
1/24/94	10:00 a.m.	2	4%	22°	80%
1/25/94	11:00 a.m.	3	3%	18°	-
Felt Product: F15 (Non-Classified, Type I) Northern & Southern Orientations					
1/21/94	10:00 a.m.	Installation	1%	20°	68%
1/24/94	10:00 a.m.	2	4%	22°	88%
1/25/94	11:00 a.m.	3	3%	18°	-
Felt Product: G30 (ASTM D 226, Type II) Northern & Southern Orientations					
1/22/94	10:00 a.m.	Installation	1%	20°	68%
1/24/94	10:00 a.m.	3	3%	22°	88%
1/25/94	11:00 a.m.	3	3%	18°	-

Site: **Phoenix, Arizona**

Date	Time	Underlayment Condition Index	Underlayment Moisture Reading	Reported Temp. (F)	Reported Humidity
Felt Product: A30 (Non-Classified, Type II) Northern & Southern Orientation					
1/3/94	8:00 a.m.	Installation	5%	44°	47%
1/4/94	10:00 a.m.	1	7%	-	-
1/6/94	10:00 a.m.	2	-	-	-
Felt Product: B15 (ASTM D 226, Type I) No Data, Not Evaluated					
Felt Product: C15 (Non-Classified, Glass-Fiber-Reinforced) Northern, Southern, Eastern, and Western Orientations					
9/23/93	12:00 p.m.	Installation	5%	95°	13%
9/24/93	11:30 a.m.	1	7%	85°	57%
9/25/93	9:15 a.m.	2	5%	-	-
9/27/93	7:30 a.m.	3	-	77°	18%
Felt Product: D15 (ASTM D 4869, Type I) Northern, Southern, Eastern, and Western Orientations					
9/23/93	11:00 a.m.	Installation	5%	95°	13%
9/24/93	10:50 a.m.	1	5%	85°	57%
9/25/93	9:40 a.m.	2	-	-	-
9/27/93	9:30 a.m.	1	7%	82°	18%
Felt Product: E30 (ASTM D 4869, Type II) Northern, Southern, Eastern, and Western Orientations					
9/23/93	9:30 a.m.	Installation	5%	95°	13%
9/24/93	10:15 a.m.	1	5%	85°	57%
9/25/93	8:50 a.m.	2	5%	-	-
9/27/93	6:50 a.m.	3/4	2%	77°	18%
Felt Product: F15 (Non-Classified, Type I) Northern Orientation					
11/10/93	2:30 p.m.	Installation	5%	78°	-
11/11/93	11:00 a.m.	2	100%	56°	80%
11/13/93	9:00 a.m.	2	40%	-	-
Felt Product: G30 (ASTM D 226, Type II) Northern, Southern, and Eastern Orientations					
10/26/93	10:00 a.m.	Installation	5%	80°	16%
10/27/93	8:40 a.m.	2	4%	69°	-
10/28/93	10:00 a.m.	2	5%	-	-
10/30/93	10:00 a.m	1	5%	-	-

Site: Seattle, Washington					
Date	**Time**	**Underlayment Condition Index**	**Underlayment Moisture Reading**	**Reported Temp. (F)**	**Reported Humidity**
Felt Product: A30 (Non-Classified, Type II)					
Eastern Orientation					
8/12/93	2:30 p.m.	Installation	0%	65°	-
8/13/93	4:35 p.m.	1	2%	63°	-
8/14/93	10:35 a.m.	2	5%	60°	60%
Western Orientation					
8/17/93	8:00 a.m.	Installation	11%	65°	-
8/18/93	10:30 a.m.	1	-	70°	-
Felt Product: B15 (ASTM D 226, Type I) Western Orientation					
9/24/93	9:55 a.m.	Installation	5%	50°	-
9/25/93	9:30 a.m.	1	29%	55°	-
9/26/93	9:50 a.m.	1	20%	60°	-
9/27/93	10:00 a.m.	2	8%	55°	-
Felt Product: C15 (Non-Classified, Glass-Fiber-Reinforced)					
Northern Orientation					
9/25/93	9:30 a.m.	Installation	29%	55°	-
9/26/93	9:50 a.m.	1	20%	61°	-
Southern Orientation					
9/30/93	8:30 a.m.	Installation	40%	53°	-
10/1/93	8:30 a.m.	-	100%	53°	-
10/2/93	10:35 a.m.	1	2%	56°	-
10/4/93	11:00 a.m.	3	62%	52°	-
Felt Product: D15 (ASTM D 4869, Type I)					
No Data, Not Evaluated					
Felt Product: E30 (ASTM D 4869, Type II) Western Orientation					
7/30/93	11:30 a.m.	Installation	10%	60°	-
7/31/93	10:15 a.m.	2	9%	70°	-
8/2/93	8:20 a.m.	3	-	-	-
Felt Product: F15 (Non-Classified, Type I)					
No Data, Not Evaluated					
Felt Product: G30 (ASTM D 226, Type II)					
Northern Orientation					
8/2/93	11:00 a.m.	Installation	0%	65°	-
8/3/93	9:45 a.m.	1	-	-	-
8/4/93	8:05 a.m.	1	-	68°	-
Southern Orientation					
8/9/93	8:00 a.m.	Installation	-	66°	-
8/10/93	11:00 a.m.	2	2%	-	-

Site: **Tampa, Florida**

Date	Time	Underlayment Condition Index	Underlayment Moisture Reading	Reported Temp. (F)	Reported Humidity
Felt Product: A30 (Non-Classified, Type II)					
Eastern Orientation					
8/6/93	9:30 a.m.	Installation	11%	95°	85%
8/9/93	9:30 a.m.	2	12%	90°	65%
8/11/93	3:15 p.m.	2	11%	96°	84%
8/17/93	3:45 p.m.	2	11%	92°	75%
8/27/93	2:45 p.m.	2	11%	95°	78%
Western Orientation					
8/5/93	10:00 a.m.	Installation	11%	95°	85%
8/9/93	9:30 a.m.	1	13%	90°	65%
8/11/93	3:15 p.m.	2	11%	96°	84%
8/17/93	3:45 p.m.	2	11%	92°	75%
8/27/93	2:45 p.m.	2	11%	95°	78%
Felt Product: B15 (ASTM D 226, Type I)					
Eastern Orientation					
8/9/93	9:00 a.m.	Installation	11%	90°	65%
8/11/93	3:15 p.m.	1	11.5%	96°	84%
8/17/93	3:45 p.m.	2	11%	92°	75%
8/27/93	2:45 p.m.	2	11.5%	95°	78%
Western Orientation					
8/5/93	10:00 a.m.	Installation	11%	95°	85%
8/9/93	9:30 a.m.	1	14.5%	90°	65%
8/11/93	3:14 p.m.	1	11%	96°	84%
8/17/93	3:45 p.m.	2	11%	92°	75%
8/27/93	2:45 p.m.	2	11.5%	95°	78%
Felt Product: C15 (Non-Classified, Glass-Fiber-Reinforced)					
Eastern Orientation					
8/9/93	10:00 a.m.	Installation	11%	90°	65%
8/9/93	2:00 p.m.	-	11%	95°	80%
8/11/93	3:15 p.m.	1	11%	96°	84%
8/17/94	3:45 p.m.	1	11%	92°	75%
8/27/94	2:45 p.m.	1	11%	95°	78%
Western Orientation					
8/9/93	9:30 a.m.	Installation	11%	90°	65%
8/9/93	2:00 p.m.	1	11%	95°	80%
8/11/93	3:15 p.m.	1	11%	96°	84%
8/17/93	3:45 p.m.	1	11%	92°	75%
8/27/93	2:45 p.m.	1	11%	95°	78%
Felt Product: D15 (ASTM D 4869, Type I)					
Eastern Orientation					
8/6/93	10:00 a.m.	Installation	11%	95°	85%
8/9/93	9:30 a.m.	1	12%	90°	65%
8/10/93	10:30 a.m.	2	11%	90°	68%
8/11/93	3:15 p.m.	2	11%	96°	84%
8/27/93	2:45 p.m.	2	11%	95°	78%
Western Orientation					
8/5/93	10:00 a.m.	Installation	11%	95°	85%
8/6/93	4:00 p.m.	1	11%	95°	85%
8/9/93	9:30 a.m.	3	15%	90°	65%
8/11/93	3:15 p.m.	2	11%	96°	84%
8/27/93	2:45 p.m.	2	12%	95°	78%

Site: **Tampa, Florida** (continued)

Date	Time	Underlayment Condition Index	Underlayment Moisture Reading	Reported Temp. (F)	Reported Humidity
Felt Product: E30 (ASTM D 4869, Type II)					
Eastern Orientation					
8/6/93	10:00 a.m.	Installation	11%	-	-
8/9/93	9:30 a.m.	2	11%	90°	65%
8/11/93	3:15 p.m.	2	11%	96°	84%
8/17/93	3:45 p.m.	2	11%	92°	75%
8/27/93	9:30 a.m.	2	11%	82°	85%
Western Orientation					
8/6/93	10:00 a.m.	Installation	11%	95°	85%
8/9/93	9:30 a.m.	2	11%	90°	65%
8/11/93	3:15 p.m.	2	-	96°	84%
8/17/93	3:45 p.m.	2	-	92°	75%
8/27/93	2:45 p.m.	2	11%	95°	78%
Felt Product: F15 (Non-Classified, Type I)					
Eastern Orientation					
8/6/93	10:00 a.m.	Installation	11%	95°	85%
8/9/93	9:30 a.m.	2	13%	90°	65%
8/11/93	3:15 p.m.	2	11%	96°	84%
8/17/93	3:45 p.m.	2	-	92°	75%
8/27/93	2:45 p.m.	2	11.5%	95°	78%
Western Orientation					
8/6/93	10:00 a.m.	Installation	11%	95°	85%
8/9/93	9:30 a.m.	2	15%	90°	65%
8/11/93	3:15 p.m.	2	11%	96°	84%
8/17/93	3:45 p.m.	2	12%	-	-
8/27/93	2:45 p.m.	2	11.5%	95°	78%
Felt Product: G30 (ASTM D 226, Type II)					
Eastern Orientation					
8/5/93	9:00 a.m.	Installation	11%	95°	85%
8/9/93	2:00 p.m.	1	11%	95°	80%
8/11/93	3:15 p.m.	2	11.5%	96°	84%
8/17/93	3:45 p.m.	2	11.5%	-	-
8/27/93	2:45 p.m.	2	11.5%	95°	78%
Western Orientation					
8/5/93	9:00 a.m.	Installation	11%	95°	85%
8/9/93	9:30 a.m.	1	14%	90°	65%
8/11/93	3:15 p.m.	2	11%	96°	84%
8/17/93	3:45 p.m.	2	11.5%	92°	75%
8/27/93	2:45 p.m.	2	11.5%	95°	78%

Notes regarding the tabulation of field data:

A. Moisture readings were taken with an electronic capacitance meter designed to locate moisture in roofing systems.†

B. The Underlayment Condition Index used was described in Section 5.5.

C. Information on the size of wrinkles and/or buckles, the direction of wrinkles and/or buckles, and foot traffic on the roof also was listed on the form but is not included here.

D. Information on the structure's ventilation and deck construction also was listed on the form but is not included here. Ventilation and deck construction were judged to have no significant impact on the products at all five sites.

† The capacitance meter used for this research project was the "Moisture Encounter" model manufactured by Tramex and distributed by David White, Germantown, WI.

Appendix D. Literature Survey

D.1 Research of the 1920s and 1930s

An investigation into the use of various fiber compositions in the production of organic felts for use in the manufacturing of asphalt-saturated and asphalt-coated felts was conducted by the National Bureau of Standards (NBS)† through the research associate of the Manufacturing and Industrial Research Committee of the Asphalt Shingle and Roofing Institute††, in the 1920s and 1930s. The first report, RP No. 67, "Experimental Production of Roofing Felts," was published in June 1929.[15] In this research, the researchers manufactured experimental felts containing various paper making materials, including No. 2 roofing rags, old jute and manila bagging, old newspapers, and finely ground wood sawdust. The experimental felts were made from various combinations of these materials. The total content of the individual material was a variable (expressed as a percentage). The experimental felts were compared to commercially used felts (available at that time), which were included in the research. The researchers reported that the contents of the materials used to make the felts could be varied without causing difficulty in the manufacturing process. These experimental felts were then saturated and coated for an exposure durability test, the results of which were reported in another research paper years later. The purpose of this research was to determine if performance of the asphalt roofing felts would be affected by the substitution of these various materials for the traditional rag stock. The economics of producing felts from these less expensive substitutes was a primary consideration.

The second part of the NBS research into experimental felts was reported by O. G. Strieter in RP No. 888, "A Study of the Weathering Quality of Roofing Felts made from Various Fibers."[17] The 19 different felt combinations manufactured in 1926 were exposed for seven years. Both saturated and coated felts were included in this stage of the research. The physical properties of the felts were measured at the outset, at intervals during the exposure, and at the conclusion of the exposure period. Strieter concluded, "There was no significant difference in the resistance to weathering of asphalt roofing which may be attributed to the kind of fiber or combination of fibers employed."

D.2 Research of the 1940s, 1950s, and 1960s on Absorption, Temperature, and Moisture-Induced Deformation

For reinforcing felts, groundbreaking research came from the Commonwealth Scientific and Industrial Research Organization, Australia (CSIRO) in 1959, when researcher K.G. Martin published the Division of Building Research *Technical Paper No. 8*, "Changes in Bituminous Roofing Felts Associated with Changes in Moisture Content."[2] Martin reported on dimensional changes in organic and other roofing felts. Martin concluded, "Shrinkage is associated with repeated wetting and drying of the bonded felt, and is accentuated by the usual condition of high surface temperatures during drying and low surface temperatures during wetting." Martin proposed a laboratory shrinkage test for use in material standards, which he found to correlate with observed performance.

Martin stated, "The most common defects of the materials [felts] (shrinkage, folding, blistering), not covered by specification tests, are due to change in moisture content." When moisture penetrates a felt, Martin reported, "they tend to swell and subsequently shrink upon drying out." Martin referenced work performed by G.S. son Frey (Takpappen och de plana taken, *Byggmastaren*, 1952)[12], which stated: "Organic fiber felts with all voids full of bitumen will still absorb water and swell, and poorly saturated felts are therefore likely to swell to a greater extent. The degree of saturation is consequently a factor which may influence the moisture movement of the material."

In Martin's research, various type of felts were exposed outdoors on a low-pitched roof for a period of time. Raw felts, saturated felts, and coated felts were exposed. The felt samples were adhered to the roof's surface with various adhesives, as well as being loose laid in a retainer box for the exposure. In addition to the weathering exposure, laboratory analysis of the physical properties of the felts was conducted. The reported properties for the organic felts used in the test by Martin were as follows: (Note: Only the organic *saturated felts* are listed below. Martin also reported on other types of material.)

Material Designation (lb/100 ft²)	Actual Weight per Unit Area Base Felt (% w/w)	Bitumen Capacity of Bitumen (% w/w)	Actual Saturant (%)	Saturation Efficiency
PS1	16.9	212	154	73
PS2	10.1	142	91	65
PS3	21.3	194	136	70
PS4	11.7	149	109	70

Source: CSIRO, Division of Building Research Technical Paper No. 8, *page 8.*

† The National Bureau of Standards (NBS) is now known as the National Institute of Standards and Technology (NIST).

†† The work was conducted through a research associate program established in 1926 by the Asphalt Shingle and Roofing Institute (ASRI) at the National Bureau of Standards (NBS). ASRI was the predecessor of the Asphalt Roofing Industry Bureau (ARIB), which later became the Asphalt Roofing Manufacturers Association (ARMA) of today. This research associate program of the asphalt roofing industry was continued through the 1960s, during which time several research reports were issued on various topics relating to asphalt roofing.[16]

Martin reported that during the weathering exposure, the saturated organic felts began to pucker after four weeks and apparently reached a stable condition after exposure for about 250 days. Martin noted, "The low capacity felts moved most and it is interesting to note that the *lower saturation efficiency* for PS2 may explain its *inferior behavior* compared with PS4."

Martin also referenced work performed by H.F. Rance (*The Mechanical Properties of Wood and Papers*, 1953)[9], which stated: "Organic felts had a higher moisture movement in the cross direction than in the machine direction, for the organic fibers tend to orientate to the machine direction during formulation of the felt, and part of the tension which is applied in the machine direction as the felt dried is retained. This prestressed condition reduces the swelling strain in the machine direction when the felt is rewetted, and most of the strain which occurs after rewetting occurs in the cross direction."

A couple of the conclusions Martin provided are as follows:

- The moisture movement of certain bitumen-saturated organic fiber felts when fixed with a bonding bitumen and exposed outdoors is surprisingly large, being as great in the saturated felts as in the raw felts from which they are made.
- Shrinkage is greater when the bituminous felts are fixed with bitumen instead of being loose laid, as the swelling is then restrained when the felts are wetted under cool conditions but the shrinkage under warm conditions is not restrained.

In October 1961, research at the University of Illinois, Small Homes Council—Building Research Council by D. E. Brotherson was published in *Research Report 61-2*, "An Investigation into the Causes of Built-Up Roofing Failures."[3] Brotherson was investigating the causes of wrinkle-cracking in built-up roofs with the use of a conditioned laboratory exposure of test panels of built-up roof construction. During the exposure of the test panels under the conditions the researchers assumed would create the phenomena, Brotherson theorized "that the ridge or wrinkle was formed by the *expansion* of the roofing felts *due to the absorption of moisture.*" And from the observations of a test panel, Brotherson concluded "that when the felts became saturated [with water] they will tend to expand, and, if the temperature is such that the roof surface is flexible, wrinkling will occur."

In September 1963, research at the Pennsylvania State University College of Engineering, Building Research by F.A. Joy was published in *Better Building Report No. 5*, "Premature Failure of Built-Up Roofing."[5] Joy referenced the earlier work of K.G. Martin, C.E. Lund, and D.E. Brotherson. Joy also referred to the work of N.G. Brown (*The Analysis of Bituminous Felts*, 1960)[11], who stated, "saturated felts are not truly saturated, however, since they contain small voids." Brown reported, "The saturating process does not eliminate air, the bitumen filling 75% of the volume of voids in organic felts." Joy further stated, "Asphalt felt will act somewhat like a sponge when wetted, and they swell much more across the sheet than along its length." Joy stated that wrinkles in built-up roofing are caused by the presence of moisture within the roof system that then enters the organic felts and causes swelling. Joy also stated, "Saturated felt, as it is furnished, is not protected from moisture entrance and swelling."

In June 1966, at the ASTM Symposium "Engineering Properties of Roofing Systems" (later published in *ASTM Special Technical Publication No. 409*), E.G. Long presented a paper titled "Effects of Temperature and Humidity on Linear Dimensions of Roofing Felt Laminates."[6] In his discussion of test results, Long stated: "The organic felt roofing laminates move in response to both temperature and humidity variations, but the movement due to humidity changes is so great relative to that due to temperature changes that it predominates and often obscures the thermal effect. In this case the movement between the normal conditions and the wet conditions is an order of magnitude larger than any of the other measured movements. It is also seen that the response of organic felt to humidity change is sharply directional, with the transverse or cross-machine movement being much the greater." Long further stated: "It is not surprising that a fair correlation between moisture absorption and movement caused by moisture was found. However, it may be surprising that the data indicate that complete equilibrium is approached very slowly." Long concluded this discussion by stating, "Since a roof never receives three or four days of constant conditions of humidity and temperature, it is unlikely that it is ever in a state of equilibrium."

Also in June 1966, at the ASTM Symposium "Engineering Properties of Roofing Systems" (later published in *ASTM Special Technical Publication No. 409*), E.C. Shuman presented a paper titled "Moisture-Thermal Effects Produce Erratic Motions in Built-Up Roofing."[7] As part of this work, Shuman conducted tests where strips of felt and built-up roofing were exposed to relative humidity variation at constant temperature. Shuman stated: "The data reveal a rapid response to changes in relative humidity, even for BUR, although the expected lesser degree of motion was found for the BUR. That a prompt length change with reversed relative humidity change occurs was demonstrated at the extremes." Shuman further stated: "While the BUR changed length substantially less than the single felts, the cumulative effect from not losing all absorbed moisture is clear. Not only did the BUR indicate this incremental effect, but also the coated base sheet." In further describing the erratic behavior of the moisture-thermal motions, Shuman noted, "While exposure to moisture is a factor, duration of exposure is often the most significant factor which affects performance." In his conclusions, Shuman, like others, stated: "Roofings respond promptly to changes in relative humidity regardless of temperature between -20° and 160°F (-29°C and 71°C), but the motion depends upon the moisture history and the duration of changed environment. The moisture effect frequently overrides the thermal effect."

The National Bureau of Standards published a report in June 1969, *Building Science Series 19*, "A Study of the Variables Involved in the Saturating of Roofing Felts."[8] Researcher Sidney H. Greenfeld (research associate for the Asphalt Roofing Manufacturers Association) reported on his investigation of the saturating process for roofing felts. Greenfeld described the difficulties in achieving complete saturation commercially because of the operating speed of felt production equipment. He also described that if a felt was saturated as much as possible, problems then would develop with adhesion of coatings applied to the felt (e.g., in roll roofing and shingles), incompatibility or slippage of coatings, or sticking of the saturated felt within a roll. Greenfeld stated, "Thus, when specifications are written, compromise saturations are required."

Greenfeld listed common minimum saturation percentages at that time for the following products: *asphalt shingles*—170 percent saturation; *roll roofing*—160 percent saturation; *saturated felts*—140 percent saturation. Greenfeld describes *percent saturation* as "the ratio of the weight of the saturant to that of the dry felt, expressed as a percentage." For example, this means that the amount of saturant used for asphalt shingle felt must weigh 1.7 times as much as the felt itself. (Today, according to ASTM D 226, for Type I [i.e., No. 15] saturated felts, the mass of the saturant only has to weigh 1.2 times the mass of the dry felt, with a saturation efficiency of 70 percent. This is a 14 percent reduction in saturant mass from the 140 percent minimum saturation that Greenfeld listed as being common.) Greenfeld stated: "These figures are the compromises made to accommodate production, storage, and application requirements. Theoretically, completely impregnated felt can hold more than 235 percent of its weight in saturant." He further stated that commercially, a saturation of 195 is more realistic.

Greenfeld conducted saturation tests with two felts designated by their felt number: No. 27 and No. 55 (weight of 480 square feet of dry felt), which are the felts used for manufacturing No. 15 and No. 30 saturated felts, respectively. These saturation tests were conducted under the conditions of ambient pressure, under vacuum, and at above atmospheric pressure. Greenfeld commented on the volumes of gases and vapors that release from organic felts when saturated. To achieve the minimum specification of 140 percent, contact time for the lighter felt in excess of a quarter-minute was sufficient. For the heavier felt, a two-minute submersion achieved the desired results.

Greenfeld also reported that the moisture content for felts had to be at least 3 percent in order for the felts to function in the equipment. Greenfeld stated: "Moisture tends to lubricate the fibers or fiber bundles to permit their movement over each other and swells the fibers to permit the saturant to penetrate more easily. However, when the moisture content is too high, the felts again become weak and breaks occur."

Greenfeld also performed tests designed to show how well saturation protects felts. The heavier felt was saturated to eight different percentages between 64 percent and 185 percent. These saturated felts then were exposed to relative humidities of 30 percent and 50 percent at 73°F (23°C) and 75 percent at 79°F (26°C). The lighter felt was saturated at six different percentages between 72 percent and 169 percent and exposed to a relative humidity of 50 percent. Greenfeld reported: "At all relative humidities moisture absorption proceeded rapidly at first and then at progressively lower rates until some constant moisture content was attained. The rate of absorption, rate of attaining 'equilibrium,' and 'equilibrium' moisture content decreased as the saturation of the felt was increased." He continued, "For any particular saturation, the 'equilibrium' moisture content increased with the relative humidity to which the felts were exposed."

Greenfeld concluded: "Even the most highly saturated felts in this study absorbed moisture to some extent. It is, therefore, necessary to front- and back-coat roofing products to isolate and protect the felts from moist environments." For the lighter weight felt, Greenfeld emphasized that the "vulnerability to moisture absorption is very significant" and because saturated felts do not receive the higher levels of saturant by design, this susceptibility to "moisture absorption, if accomplished nonuniformly throughout a roll of felt, can also lead to temporary or permanent distortions of the felt.".

Greenfeld also submerged saturated felts in water and found that "felts meeting ASTM specifications will absorb about 10 percent water in a week." He stated, "These data further emphasize the necessity for protecting saturated felts by impermeable surface coatings as rapidly as possible."

Greenfeld noted, "Even under the most favorable conditions, only 82 percent of the theoretically possible saturation was attained." Greenfeld offered the following technical conclusions at the end of his report. They are listed here in their entirety.

(1) At 400°F (204°C) with the saturants normally used, it was immaterial whether the No. 27 felt was saturated from either one or both sides if more than 15 seconds of submersion time was used. The No. 55 felt required a minimum of 1½ minutes of complete submersion to meet minimum specification requirements.

(2) Felts containing about 4 percent moisture were saturated more easily and more completely than dry felts. As the moisture content increased, the level of saturation attainable also increased, but beyond 7 percent moisture content, excessive foaming and cooling of the saturant were observed. The moisture seemed to "open up" the felt.

(3) Under normal conditions, felts saturated best in the viscosity range of 50 to 150 Hz. At higher viscosities, the penetration was hindered; at lower viscosities, the sheet could not "carry" sufficient saturation to meet specifications.

(4) Spacers on the press rolls increased the quantity of saturant carried on the sheet, but the viscosity range in which surface-dry saturated felts could be produced was greatly shortened. The beneficial effects were more noticeable with the softer saturants.

(5) Small increments of pressure in the saturator produced marked increases in saturation, especially with the harder saturants. Higher pressures produced further improvements in saturation with the shingle saturant, but not with the softer saturant.

(6) Vacuum saturation produced the highest saturations.

(7) Rate of moisture and liquid water sorption of saturated felt decreased with increasing saturation. A large fraction of the total sorption occurred in the first few hours of exposure.

(8) Air permeability decreased rapidly with increasing saturation.

This work was sponsored by the Asphalt Roofing Manufacturers Association (formerly the Asphalt Roofing Industry Bureau).

D.3 Research of the 1970s and early 1980s on Product Characteristics and Performance

Work conducted by E. Rissmiller was reported on in National Bureau of Standards *Technical Note 965*, "Effects of Moisture in Built-Up Roofing—A State-of-the-Art Literature Survey," published in July 1978.[18] "Rissmiller noted from laboratory experiments that moisture is absorbed rapidly in roofing felts and that significant quantities of moisture are absorbed in a few hours. For absorption tests of at least 100 days' duration, the following order of increasing absorption was observed: coated organic roofing felt, impregnated glass mat, perforated asphalt-saturated asbestos felt, perforated asphalt-saturated organic felt, tar-saturated organic felt. Approximately 30-90 percent of the total moisture was absorbed during the first 5 days of water immersion."

Research work conducted by NRCA and the Chicago Roofing Contractors Association (CRCA) from 1976 to 1979 found that some felts being manufactured and labeled as ASTM D 226 felts were not meeting the requirement for saturant levels. Information on this testing was reported in an article that appeared in *The Roofing Spec* in May 1979.[19] Conway Burton of Chicago Testing Laboratory (who conducted the tests) reported, "Manufacturers who use lower softening point asphalt as a saturant might be producing roofing felts with poorer resistance to water absorption."

In response to this article, D. C. Portfolio responded with an article that was presented in *The Roofing Spec* in November 1979.[20] Portfolio presented information from research conducted by Jim Walter Research Corporation (JWRC) and reported to ARMA.[21] The property of the felt that controls moisture absorption was reported to be "the percent moisture that a saturated felt would absorb, based on the weight of the fiber in the felt is proportional to the percent saturation efficiency." Additional points made include:

- The amount of saturant that the felt retained was controlled by the amount of time that the sample was allowed to remain in the saturant and the amount of time excess surface saturant was allowed to remain in contact with the felt before the saturant was removed by a set of heated rollers.
- The type of fiber and the kerosene value of the felt had a profound effect on the amount of asphalt that was absorbed by the felt.
- Any time the moisture condition to which the felt is exposed changes substantially, the equilibrium moisture content of the felt will respond rapidly during the first 24 hours. Experiments were conducted on pieces of felt, not rolls of felt. The edges and outer layers of felt are probably more apt to respond quickly to changes in humidity than the inner portions of the rolls.

The information presented by this JWRC research was used as part of the basis for making changes to ASTM D 226, resulting in the standard in use today.

Appendix E. Acknowledgments

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10.0 REFERENCES

[1] Eastman, Martin. "Underlayment: Contractors say yes, homebuilders say no," *Professional Roofing*, National Roofing Contractors Association, March 1990, p. 30.

[2] Martin, K. G. "Changes in Bituminous Roofing Felts Associated with Changes in Moisture Content," *Technical Paper No. 8*, Division of Building Research, Commonwealth Scientific and Industrial Research Organization, Australia, 1959, 20 pages.

[3] Brotherson, D. E. "An Investigation into the Causes of Built-Up Roofing Failures," *Research Report 61-2*, Small Homes Council—Building Research Council, University of Illinois, October 1961, 26 pages.

[4] Cullen, W. C. "The evolution of asphalt shingles: Survival of the fittest?" *Professional Roofing*, National Roofing Contractors Association, June 1992, pp. R4-R8.

[5] Joy, F. A. "Premature Failure of Built-Up Roofing," *Better Building Report No. 5*, College of Engineering, Pennsylvania State University, September 1963, 20 pages.

[6] Long, E. G. "Effects of Temperature and Humidity on Linear Dimensions of Roofing Felt Laminates," *Engineering Properties of Roofing Systems*, ASTM STP 409, 1967, pp. 71-77.

[7] Shuman, E. C. "Moisture-Thermal Effects Produce Erratic Motions in Built-Up Roofing," *Engineering Properties of Roofing Systems*, ASTM STP 409, 1967, pp. 41-70.

[8] Greenfeld, S. H. "A Study of the Variables Involved in the Saturating of Roofing Felts," *Building Science Series 19*, National Bureau of Standards, June 1969, 16 pages.

[9] Rance, H.F. *The Mechanical Properties of Wood and Papers*, 1953. Quoted in K.G. Martin, "Changes in Bituminous Roofing Felts Associated with Changes in Moisture Content," *Technical Paper No. 8*, Division of Building Research, Commonwealth Scientific and Industrial Research Organization, Australia, 1959.

[10] Cullen, W. C. "Effects of Thermal Shrinkage on Built-up Roofing," *Monograph 89*, National Bureau of Standards, March 4, 1965, 6 pages.

[11] Brown, N.G. *The Analysis of Bituminous Felts*, 1960. Quoted in F.A. Joy, "Premature Failure of Built-Up Roofing," *Better Building Report No. 5*, College of Engineering, Pennsylvania State University, September 1963, 20 pages.

[12] son Frey, G.S. "Takpappen och deplana taken," *Byggmastaren*, 1952. Quoted in K.G. Martin, "Changes in Bituminous Roofing Felts Associated with Changes in Moisture Content," *Technical Paper No. 8*, Division of Building Research, Commonwealth Scientific and Industrial Research Organization, Australia, 1959.

[13] American Society for Testing and Materials. "Roofing, Waterproofing, and Bituminous Materials," *Annual Book ASTM Standards, Volume 04.04*, April 1994.

[14] Maugul, T. "Proposed Standard Method of Test for Moisture Conditioning and Related Testing of Roofing Felts and Membranes," ASTM D 08 Committee, August 15, 1990, 4 pages.

[15] Shaw, M. B., G.W. Bicking, and O.G. Strieter. "Experimental Production of Roofing Felts," RP No. 67, *Journal of Research 2*, National Bureau of Standards, 1929, 1001-1016.

[16] Cullen, W.C. "Research and Performance Experience of Asphalt Shingles," *Proceedings of the 10th Conference on Roofing Technology*, National Roofing Contractors Association, April 1993, pp. 6-12.

[17] Strieter, O. G. "A Study of the Weathering Quality of Roofing Felts Made from Various Fibers," RP No. 888, *Journal of Research 16*, National Bureau of Standards, 1936, 511-523.

[18] Busching, H. W., W.C. Cullen, R.G. Mathey, and W.J. Rossiter, Jr. "Effects of Moisture in Built-Up Roofing A State-of-the-Art Literature Survey," *Technical Note 965*, National Bureau of Standards, July 1978, 78 pages.

[19] Burton, C. "Early Tests Show 'Certified' Felts Not Meeting ASTM Specifications," *The Roofing Spec*, May 1979, pp. 23-26.

[20] Portfolio, D.C. "Asphalt-Saturated Felt—A New Look," *The Roofing Spec*, November 1979, pp. 29-31.

[21] Portfolio, D. C. "A Study of Saturation Efficiency in Type 15 Asphalt-Saturated Organic Felt," *Project No. 03-02-44-20*, Jim Walter Research Corporation, 1978, 81 pages.

Additional Reading

Asphalt Roofing Manufacturers Association. *Manufacture, Selection, and Application of Asphalt Roofing and Siding Products—Seventh Revised Edition*, Asphalt Roofing Industry Bureau, August 1959.

Asphalt Roofing Manufacturers Association. *Residential Asphalt Roofing Manual*, Asphalt Roofing Manufacturers Association, 1988.

Asphalt Roofing Manufacturers Association. *Residential Asphalt Roofing Manual*, Asphalt Roofing Manufacturers Association, 1993.

Burton, C. C. "Laboratory Study of Asphalt-Saturated Roofing Felt," *Technical Report No. 73499*, Chicago Testing Laboratory, April 22, 1980, 70 pages. {Restricted}

Greenfeld, S. H. "The Performance of Roofing Made with Asplund Felts," *Technical Note 477*, National Bureau of Standards, March 1969, 25 pages.

Greenfeld, S. H. "Natural Weathering of Mineral Stabilized Asphalt Coatings on Organic Felt," *Building Science Series 24*, National Bureau of Standards, October 1969, 15 pages.

Laaly, H. O. "Effects of Moisture on the Strength Characteristics of Built-Up Roofing Felts," *Roofing Systems*, ASTM STP 603, 1967, pp. 104-113.

LaCosse, R. A. "Bituminous saturation and moisture relationship in organic felts," *Roofs and Roofing 1981*, 1981, 11 pages.

National Roofing Contractors Association. *The NRCA Steep Roofing Manual*, National Roofing Contractors Association, 1990.

Underwriters Laboratories. "Standard for Class C Asphalt Organic-Felt Sheet Roofing and Shingles," *UL 55B*, Underwriters Laboratories, October 30, 1974, 27 pages.

Underwriters Laboratories. "Standard for Materials for Built-Up Roof Coverings," *UL 55A*, Underwriters Laboratories, August 15, 1978, 17 pages.

Notes

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