A Study of Dew and Frost Formation On Retro-Reflectors

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•THE formation of dew and, at subfreezing temperatures, frost, may occur on a solid body if proper atmospheric conditions prevail. The condensation of atmospheric moisture occurs when the temperature of the solid body is lowered by radiation of heat below the dew point of the surrounding air. Because of the high surface tension of water, its condensation occurs as minute spherical droplets having distinct optical properties. Their formation on retro-reflective materials, which depend on collimated incident light for efficient reflection, refracts and scatters the light beam, rendering them less bright. Certain environmental conditions must be met for dew formation:

1. Relatively clear sky. The solid body must lose sufficient heat by radiation to fall below the dew point of the surrounding air. A relatively clear path to open sky must be available because trees, buildings and cloud cover will effectively reflect radiation back to earth, inhibiting heat loss by radiation. Open sky acts as a radiant source at absolute zero temperature, therefore no radiation is received from the sky. Under this condition, heat loss occurs at all surfaces of the object (both front and rear) with access to open sky. Portions of the supporting sign structure may shadow radiation or provide sufficient heat mass to inhibit it otherwise. Thus on rare occasions, the image of structural members has been observed from the face, caused wholly by a differential in radiation rate.
2. Still air. Unless fog is present, the air temperature is above the dew point and heat loss by radiation must proceed at a greater rate than heat input to the object by convection currents. Thus, if air currents are present the object is maintained at air temperature and no dew can form.
3. Moisture. Adequate moisture must be available in the air. When high humidity is present less heat loss is required for dew formation.

SCOPE OF STUDY

The purpose of this study was to find means of relief; the study was not for the purpose of correlation with weather observations or for the exploration of the precise heat loss and temperature relationships. Prior tests revealed practical difficulties in the laboratory testing of this natural phenomenon and indicated that conventional reflex-reflectors of all types, mounted on conventional and experimental backings, would require testing out-of-doors at night. Yearly incidence of dew and frost was desired together with hourly progress, under circumstances that would permit simultaneous direct comparison of all materials whenever dew occurred.

DATA COLLECTION SITE

The test site is located in the southwest corner of Washington County, Minn., approximately 2,000 ft from the Mississippi River. It is 119 ft above river level; the site elevation is 806 ft. Dew formation has been observed to be extremely random within a given locality and the site was selected for its relatively low elevation, proximity to the river and unobstructed sky view. It was felt that these circumstances would provide a relatively humid environment with maximum radiation opportunity. The

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findings at this site can likely be compared only to localities having similar average climatological data, relative elevation and exposure.

EQUIPMENT

The experimental sign structures (Figs. 1 and 2) are arranged on a scaffold 80 ft in front of a small building housing photographic monitoring equipment. Signs face northwest. Flood lamps adjacent to the camera permit signs to be observed by reflex-reflection. A 16-mm movie camera within the building is operated automatically a single frame at a time throughout the night (Fig. 3). A panel showing the date and a clock are within camera view to provide the time sequence. A simple wind indicator consisting of a suspended, lightweight plastic sphere establishes the presence of air currents. If the sphere is observed to move, little or no dew occurs.

RESULTS

The data reported were obtained over a 16-month period (through November 1963) during which 234 nights were recorded. Recording was on a regular weekly basis with occasional omissions due to minor difficulty with the recording apparatus. For the period spanned, this represents an extensive 50 percent sample under all prevailing weather conditions. Dew or frost was observed on a minimum of one test panel on 86 of the nights for an occurrence of 37 percent. The total hours for which dew was observed was 413.

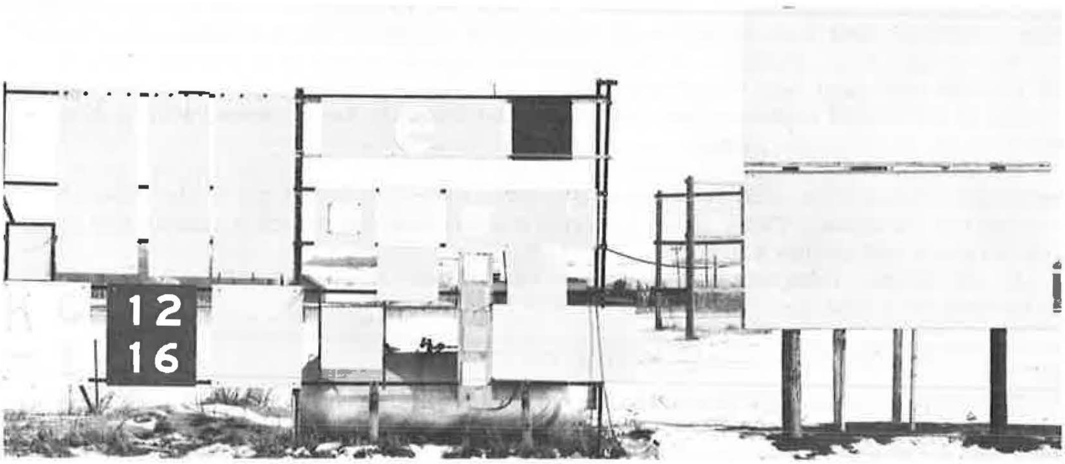

Figure 1. Experimental sign structures, day view.

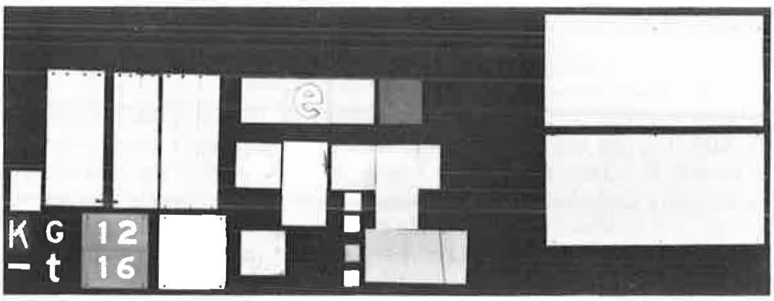

Figure 2. Experimental sign structures, night view.

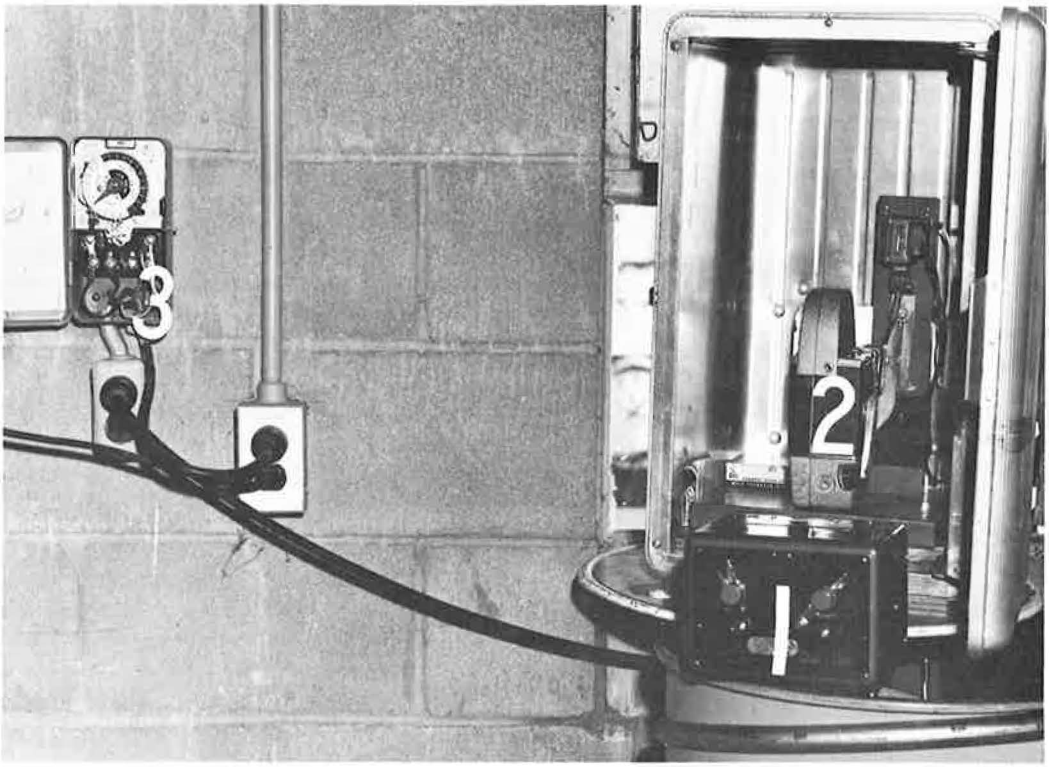

Figure 3. Photographic monitoring equipment: Intervolometer (1) actuates camera's (2) single frame shutter; sequence is started at dusk by astronomical timer (3).

The results are shown for average time after sunset to the formation of dew, average duration of dew, and percent of total dew time. Total dew time was recorded whenever dew appeared on any test panel.

The test materials for which results are shown are type of backing (Table 1) and type of background reflector and reflectorized demountable letter (Table 2).

The data illustrate the value of a heat-conductive backing material. Daytime heat storage is provided to some degree by any backing material. Superficial heat losses are, however, not readily replaceable if insulated from the heat mass of the backing. Therefore, thermally insulated surfaces are observed to have a somewhat earlier dew period and greater duration. Comparison of conductive backings (aluminum) may be made with an insulated backing (plywood) in Table 1. Although the differences appear to be slight, they have been consistent throughout the observation period.

The more massive of the heat conductive backings provides the utility of greater daytime heat storage. In this respect, comparison may be made of aluminum sheet 0.081 in. thick, aluminum extrusion 0.125 in. thick and the $1\frac{1}{4}$ in. thick water or paraffin filled tanks. The percent of dew time, an important indicator, is 64 percent, 56 percent and 23 percent, respectively.

By comparing actual hours of darkness observed, 2,574 (234 nights at 11 hours per night) against the average dew time for the typical backing material of 256 hours (62 percent of the 413 hours observed for dew), it is apparent that the average backing was free of dew formation 90.4 percent of the time.

SUMMARY

Tests in the natural environment indicate that the typical sign backing was free of

TABLE 1

SIGN BACKING MATERIAL

Sign Backing Material	Avg. Time[a]	Avg. Duration	Total Dew Time (%)
	Hr:Min	Hr:Min	
Aluminum extrusions	6:18	2:28	56
Aluminum sheet	6:16	2:39	64
Plywood (5/8-in. high density)	5:27	2:57	67
Average	6 hr	2½ hr	62
Experimental[b]:			
Tank (1¼-in. thick, water or paraffin filled)			23
Honeycomb (aluminum faces bonded to fiber core, 1¼-in. thickness)			62

[a]From sunset to dew formation.
[b]Reflectorized with enclosed lens sheeting.

TABLE 2

REFLECTOR TYPE

Reflector Type	Total Dew Time (%)[a]
Background reflector (on 0.081-in. aluminum panel):	
Enclosed lens	64
Exposed lens	71
Demountable letter type:	
Enclosed lens (on 0.040-in. aluminum)	43
Plastic reflector button	68
Film overlaid reflective sheeting (on 0.040-in. aluminum)	23

[a]Percent of total dew time is the total time dew appeared on any test panel compared to samples shown.

dew formation on the average of 90.4 percent of the nighttime hours. When dew was recorded it occurred on the average 6 hr after sunset and was of 2½-hr duration. Results would be expected to differ under other climatic conditions.

There are two general approaches of inhibiting dew formation. The first is to change the dew particle from a spherical droplet to a film. A relatively smooth film of water will not materially alter the light path of reflectors made with a smooth, flat outer surface. Alteration of the droplet by a chemical surfactant has been accomplished experimentally. Much more work will be necessary before a weatherable surfactant is possible. The second suggests the replacement of heat lost by radiation. The massive heat conductive backings illustrate (Table 2) that internal heat storage is quite possible. External heating by simple fan to transfer the heat energy of the air to the sign has not provided completely adequate results. However, external heating by portable radiant heaters had been tested and has proved to be effective. If factors of maintenance and vandalism are not excessive, this may be a practical consideration.

Extensive testing of dew formation on typical reflector media and sign backings has yielded useful performance relationships and contributed basic understanding. Its incidence does not appear to be severe on the basis of yearly average for the natural climatic conditions tested. Means sought to inhibit dew formation offer promise for its reduction or ultimate elimination.