A Present Weather Detector for Highways

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Abstract

A new precipitation detector has been developed specifically for highway use. The detector is based on a patented technology using in combination optical and electronic sensing of precipitation particles. Integrating these two sensing methods in one instrument allows distinguishing between frozen and liquid precipitation. The intensity and accumulation are determined from the optical signal. The detector is also capable of measuring visibility up to 2 km. Field tests with prototypes imply an estimated accuracy of about 20 % in accumulated snow.

Introduction

Accurate precipitation information is very valuable for highway maintenance personnel. Especially knowledge of intensity and accumulation of snow fall would help in managing snow removal operations. In some rural areas snow removal may be the only winter maintenance operation. Precipitation data can be used also to determine water layer thickness on the highway (Blaauboer et.al., 1991). This information is vital in estimating the risks of aquaplaning and reduced visibility due to vehicle induced spray of water. In Germany, for instance, there are systems which adjust the speed limit according to the water layer thickness.

A new instrument based on commercial present weather technology has been developed. The technology and an instrument (FD12P) have been described in more detail by Haavasoja et.al. (1994) and field tests by Andersson et.al. (1994). Essential in this technology is to use an optical forward scatter principle together with capacitive sensing of precipitation particles. The optical signal provides information mainly on the size of the particles whereas the capacitive signal is more sensitive to the water content. Ambient temperature measurement is used to confirm the type during certain precipitation events.

The new instrument is called Present Weather Detector PWD11. The most obvious difference to the predecessor FD12P is in overall size and in some specifications. PWD11 is only 0.7 m wide and weighs under 3 kg, while FD12P is 1.5 m and 20 kg, correspondingly. This massive reduction in dimensions will allow easy installation of PWD11 almost to any existing mast by the side of a highway. The unit may be regarded as an optional sensor to a typical road weather station. The precipitation type, intensity, and amount as well as visibility information provided by PWD11 will allow a more specific determination of current weather phenomena in comparison to a standard road weather station equipped with a precipitation "yes/no" detector. Low cost will make it also feasible as a standard instrument in road weather stations. PWD11 will be commercially available by the fall of 1996.

Reduced visibility in foggy driving conditions is sometimes very local. Consequently, a relatively dense network of fog detectors may be needed to fully cover a given area. In these cases special emphasis has to be given to installation, maintenance and life time cost of the warning system. Naturally it is a great advantage if the same detector may provide precipitation information to estimate water layer thickness to warn about aquaplaning or reduced visibility due to vehicle induced spray of water.

Technical Specifications

Fig. 1. shows a general view of PWD11. The optical transmitter is located in the left side and the receiver-controller on the right side in the box. A microprocessor controls the measurement logic and communication. The capacitive precipitation detector is seen on the upper side of the controller box.

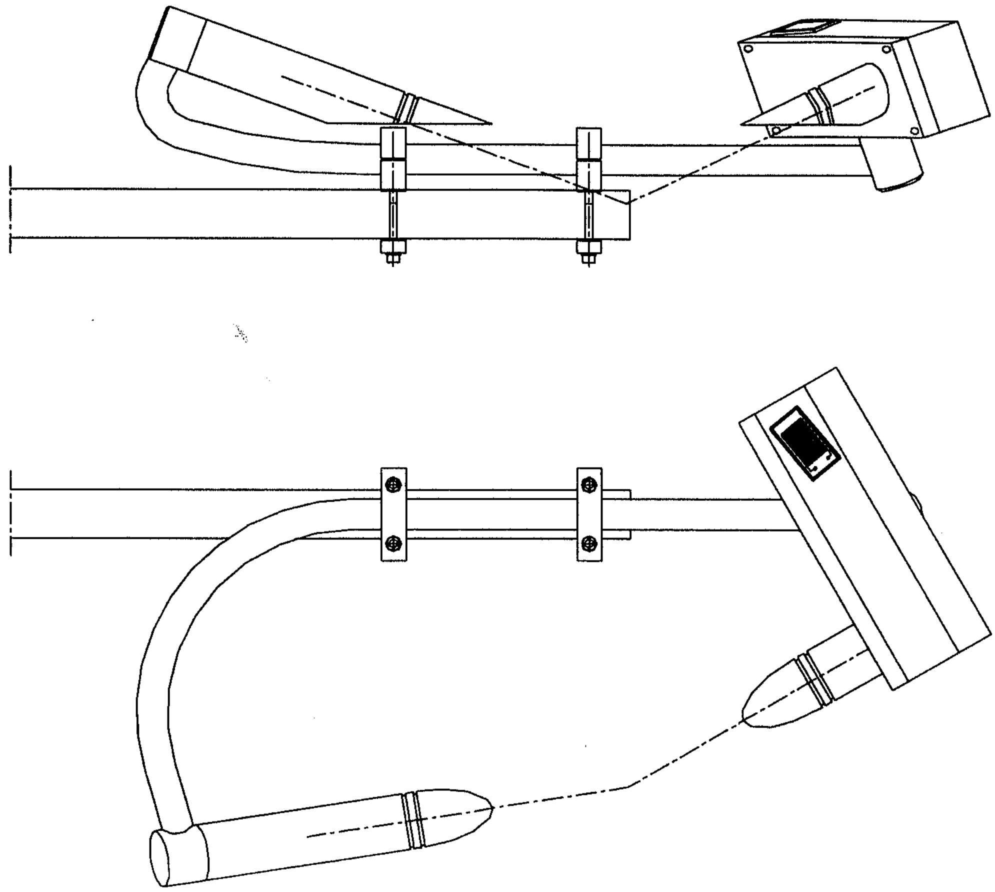

Fig.1. A side view and a top view of PWD11 installed in a horizontal support arm. The width of the unit is 0.7 m and weight less than 3 kg.

The optical transmission band is in near infra-red. Modulated transmission with a lock-in detection is used to reduce noise due to changes in background light level. The transmitter is equipped with transmission level monitoring and with a back reflection detector to watch contamination of the transmitter lens. The receiver has an additional LED to allow monitoring of contamination of the receiver lens. We want to remind that in a forward scatter principle the contamination of lenses has only a proportional effect on the measurement as compared to transmissometer principle where the lens contamination has a drastic effect in certain visibilities. We expect that cleaning interval of the lenses is longer than three months and annual calibration should be sufficient.

The detector is specified to report visibility from 10 m to 2000 m. This range is adequate for highway use, since typically 500 m is referred to as the distance where reduced visibility starts to have an impact on driving conditions.

The reported precipitation types are rain, sleet, and snow. The lowest measured intensity is 0.1 mm/h and the highest approximately 200 mm/h. Snow and rain accumulation are estimated by integrating the intensity values.

PWD11 requires a low voltage DC power supply (12 - 40 VDC). The communication is by serial RS-232 or RS-485 line. The detector can be used as a stand alone unit assuming power and a modem are provided. Power consumption is about 10 W and most of that power is needed for heating of the lenses and the capacitive precipitation detector. PWD11 is mainly intended to complement the sensor selection of a road weather station. Its small size allows for an easy installation even into existing weather stations.

Field Tests

A prototype series of 12 units have been made. Seven out of them are in operative use in field tests at the Finnish National Road Administration. Three units have been installed in a test yard in similar conditions to check conformity. Fig. 2. shows accumulation as a function of time in a snow fall episode during 1996-02-12 ...13. The snow accumulation is expressed as water content in millimeters. Typically the density of snow varies from 0.05 to 0.3 kg/m^3, i.e., 1 mm of water corresponds to 3 to 20 times in snow thickness depending on air temperature at the time of precipitation.

As can be seen in Fig.2. the consistency of the three different units in accumulated snow is fairly good. The maximum differences are about 12 % in accumulation. These differences originate mainly from the statistic nature of the measurement and a relatively small sample volume of about 1 dl. Increasing of the sample volume would increase the accuracy for low intensities, but with a larger sample volume there might be more than one precipitation particle at the same time, which would saturate the intensity measurement at a reasonably low intensity.

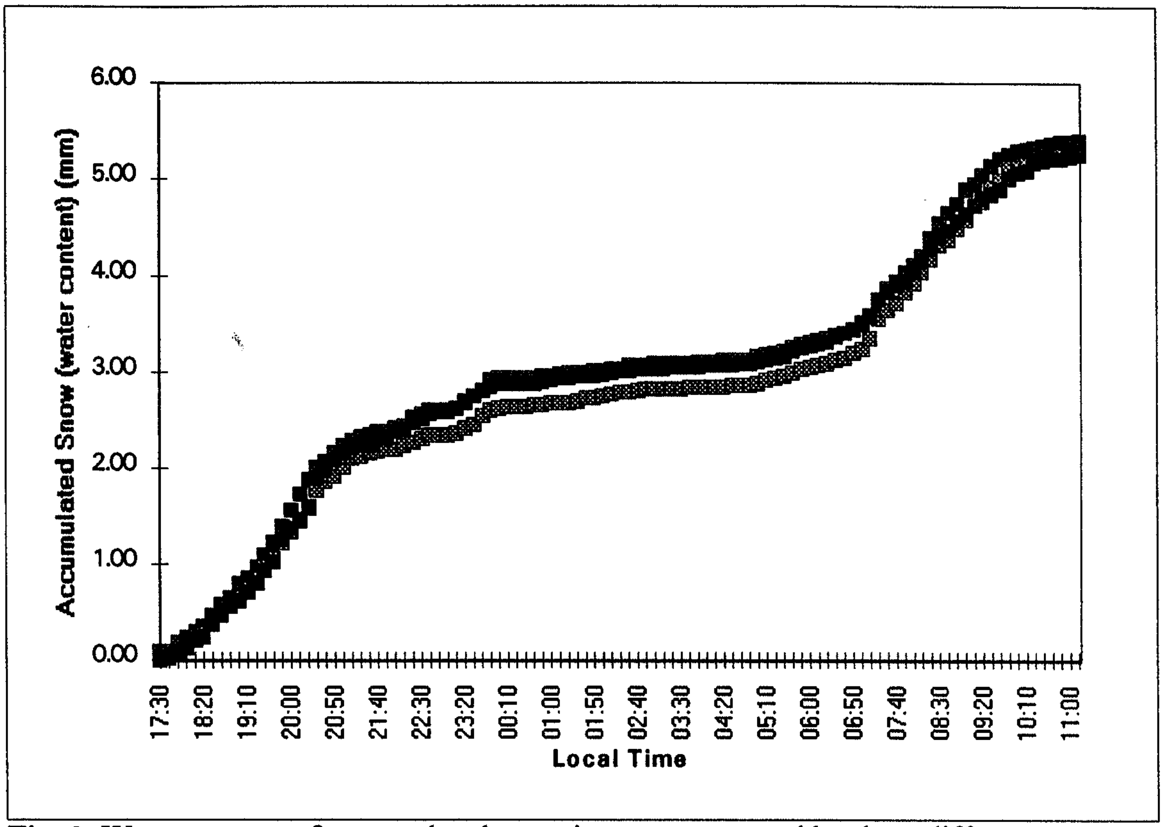

Fig. 2. Water content of accumulated snow in mm as reported by three different prototypes of PWD11 as a function of time in a snow episode in 1996-02-12...13.

There was a thin plate on the ground near the test area. The accumulated snow on this plate was weighed and that corresponded to 2.5 mm of water content. The amount reported by PWD11 is a little over twice as much, which can be explained by inaccurate calibration of the algorithm in these prototypes and obvious wind effects. The units were calibrated only to transmit the same amount of infra-red light and the receiver sensitivity was adjusted equal in all units. Interestingly enough a weighing Geonor T-200 reference gauge with a US standard wind shield around the gauge reported only 1.4 mm for the same episode.

The air temperature was about -10 °C and the wind was a few meters per second. At this low temperature the snow density is very small for about 5 mm flakes. Actually the measured value of accumulated snow was 48 mm, which corresponds to a density of 0.052 kg/m³. This powder snow is falling at a very low angle even in a wind of a few meters per second, which will explain the 44 % loss of the precipitation reference gauge.

Fig. 3. shows the average 10 minute intensity of the same three PWD11 units as a function of time. The data of the different units seem to agree within about a factor of two. As can be seen

from the data the differences between the units seem to be statistical in nature, which comes mainly from the finite sample volume.

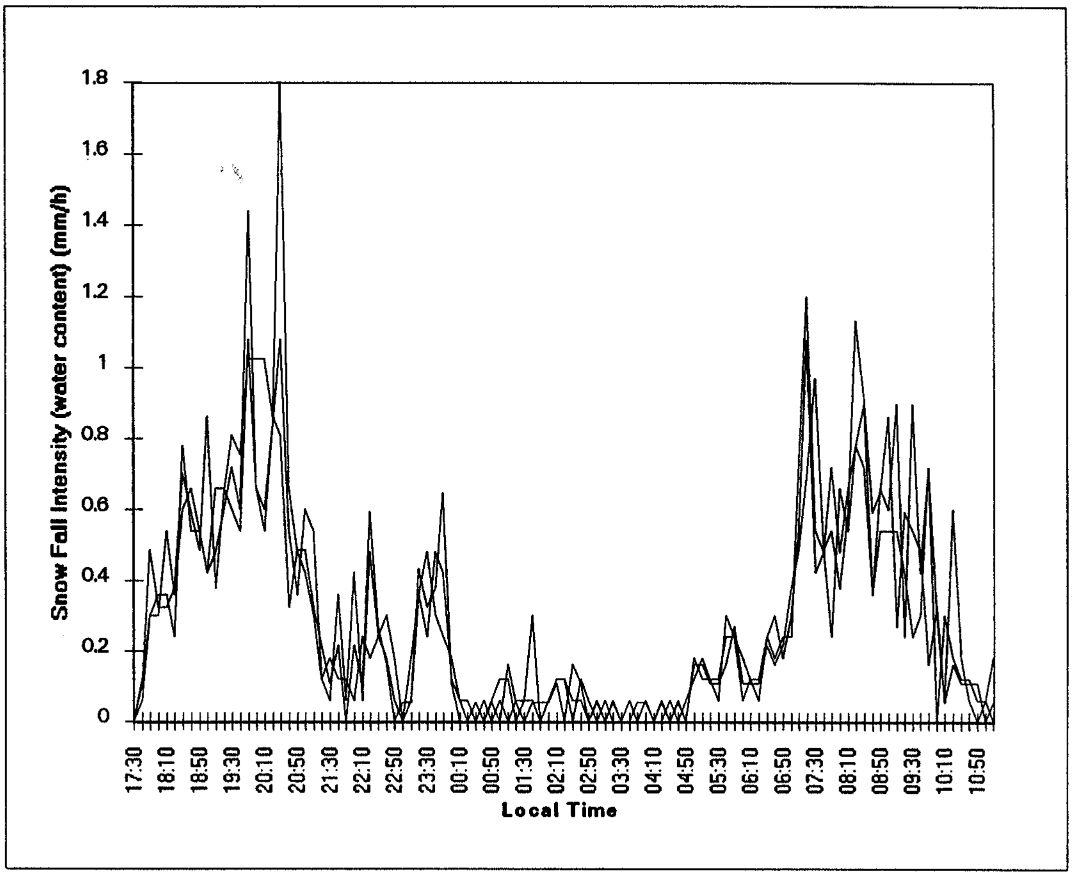

Fig. 3. A ten minute average of snow fall intensity in mm/h of water content versus time for three different PWD11 prototypes in the same episode as shown in Fig. 2.

Conclusion

The new present weather detector has the advantage of being fairly small in size allowing an easy installation to road weather stations as an optional sensor to report precipitation type and intensity as well as visibility. The field tests have so far shown that there is potential to reach very high accuracy, presumably better than 20 %, as compared to other automatic means of measuring snow fall.

Acknowledgment

This work is based on earlier work on the same technology and we would like to thank all who have participated and, especially, Jan Lönnqvist for his contributions.

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