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DEVELOPMENT OF A WEIGHING TYPE SNOW WATER EQUIVALENT SENSOR

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PREFACE

The beauty of snow as seen on the Himalayas is fascinating. Beyond its esthaetic and recreational appeal, snow plays a vital role in our lives as a primary source of the water supply in India. However, so far the country lacks a coordinated effort for obtaining accurate, reliable and timely information on the extent and water content of the snowpack. This not only requires specially trained people, but also suitable equipment for use in the difficult mountainous conditions. To a limited extent, manual snow surveys have been conducted to access this vital resource. Under a few bi-lateral or collaborative projects, some automated instruments were also deployed at a few selected sites. Due to various operational problems, these automated instruments could not sustain for longer durations.

For an integrated development of the snowpacks, an automated network of stations would be required for collecting information related to water supply forecasting such as streamflow, precipitation, snow depth and snow water equivalent. Since, in the Indian context, totally imported equipment cannot be generally relied upon, it is necessary that equipment with indigenous technology are developed within the country.

The National Institute of Hydrology has taken the initiative for the development of automated, yet simple, instruments for measurement of the snow water equivalent (SWE). The basic idea was to develop the sensors with indigenously available components and use readily available data logger alongwith the other required components (e.g. battery, solar panel) for in-situ SWE measurements. With about two years of efforts, the Institute has been able to develop a prototype of an automated instrument for SWE measurements. The report describes the development, and the laboratory as well as the field testing of the instrument carried out over two snow seasons. Dr V C Goyal, Scientist C of the Institute has been responsible for the development of the instrument and for preparation of this report.

(S M SETH)
DIRECTOR

ABSTRACT

The estimation of water resources from the snow bound regions requires continuous monitoring of several hydro-meteorological parameters at remote locations. Limited accessibility of these sites inhibits regular maintenance of such instruments, especially if these are of manual operating types (e.g. non-recording or daily/weekly recording types). Subzero temperatures, high precipitation and strong winds are additional factors which prevent continuous operation of such manual instruments. Under extreme conditions, therefore, robust instrumentation, with a fair degree of assured automated operation, is required.

Although snow plays a vital role in our lives as a primary source of the water supply in India, so far the country lacks a coordinated effort for obtaining accurate, reliable and timely information on the extent and water content of the mountain snowpack. To a limited extent, manual snow surveys have been conducted to access this vital resource. Under a few bi-lateral or collaborative projects, some automated instruments were also deployed at a few selected sites. Due to various operational problems, these automated instruments could not be sustained for long. Since, in the Indian context, maintenance problems are generally associated with imported equipment, it is necessary that equipment with indigenous expertise and technology are developed within the country.

In order to cater to this long felt need, the National Institute of Hydrology initiated the development of automated, yet simple, instruments for measurement of the snow water equivalent (SWE). The basic idea was to develop the sensors with indigenously available components and use a versatile, and readily available, data logger alongwith the other required components (e.g. battery, solar panel) for in-situ SWE measurements. With about two years of efforts, the Institute has been able to develop a prototype of an automated instrument for SWE measurements.

The SWE instrument comprise a weighing platform with strain gauge based load cell, a Campbell Scientific data logger (CR10), a PT107 thermistor temperature probe, SPV supported battery pack and suitable enclosure for housing the electronics. After conducting an extensive laboratory testing, the prototype instrument was first installed at a site near Chilla Top (Jammu & Kashmir) in the winter of 1993-94 and later at Kaddukhal (Garhwal Himalayas, U.P.) in the winter of 1994-95. After initial problems with the battery, the instrument was successfuly tested during the winter of 1995-96 near Dhanaulti in Garhwal Himalayas. In this report, development of the snow gauge and preliminary results of the testing are reported.

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1.0 INTRODUCTION

Snow is an important component of the hydrological cycle in mountainous and polar areas, and also in mid-latitude countries. The appearance and disappearance of snow is an important environmental factor too. Snow can be regarded as a convenient form of precipitation because it is a natural reservoir, storing water for extended periods which, if harnessed judiciously, can be used for a variety of essential purposes. Also, snow covered areas are recognized as extremely sensitive barometers of climate variability and change.

Although the earliest known rain gauge is reported to be described in Indian writings as back as fourth century BC, the designs of precipitation gauges have been improved upon a lot during the last two centuries. The development of new technology for precipitation measurements, in fact for any hydrological parameter, is essential in order to cater to the ever increasing demands, especially when measurements are required from remote and difficult areas under harsh conditions. However, the cost of the new technology must be contained so that the developing and underdeveloped countries can make use of these developments. New technologies should be preferred if they offer some advantages over the existing systems at comparable costs.

Since snow contributes a major amount to the available water, areal values of snow cover are required for estimation of the water resources. It has been established that a combination of remote sensing and ground measurements should be used for snow cover mapping. The important parameters for hydrological purposes are snow depth, density and snow water equivalent.

2.0 PRECIPITATION MEASUREMENT TECHNIQUES

Accumulated precipitation is one of the oldest meteorological measurements. The three methods most commonly used are- measuring the depth of accumulated liquid in a container, weighing an increment of liquid and counting the increments, and weighing the total accumulation in a container.

Precipitation (snowfall) is conventionally measured in collecting gauges in which the snow and ice are melted or which weigh the total in-falling water substance. The water equivalent of snowcover is measured with snow pillows which are circular, rectangular or octagonal membranes made of rubber or flexible metal and containing a liquid with a low freezing point. The weight of the snow on the pillow controls the pressure of the liquid, which is recorded or monitored via a manometer or pressure transducer. The diameter of snow pillows ranges from 2 to 4m.

A slightly roughened, white painted wooden board (Snow Board) is used on which snow is allowed to accumulate during the normal 24 hour observation period. In UK, an inverted gauge funnel is pushed into the accumulated snow cover and removed with collected snow which is melted and weighed. Elsewhere in the world snow depth on a snow board is simply measured by dipping a rule into the accumulated snow. In Canada, 40 cmx40 cm boards are used.

The Canadian Nipher Shielded Snow Gauge System has been designated as the standard AES instrument system for measuring snowfall amount in terms of water equivalent. The snow collector of the gauge is a hollow metal cylinder, 56 cm long and 12.7 cm in diameter. It is surrounded by a solid shield, made of spun alluminium or moulded fibreglass, having the shape of an inverted bell. It is non- recording and requires at least daily observation.

Belfort Universal weighing type recording gauges (Figure 1) and Belfort punched tape precipitation recorder (formerly known as the Fischer and Porter precipitation gauge) are also used at few places, both with shields and without shield. The Belfort gauges weigh the accumulated precipitation using a spring balance with a cable/pulley or lever arrangement to translate the linear motion of the catchment container into angular motion. In the latter punched type gauge, the angular motion is measured via a mechanical shaft encoder connected to a tape punch; the punched output is recorded in increments of 2.54mm. The Belfort Universal gauge uses a clock and drum assembly, with a drum rotation varying from 6 hours to 36 days; the time resolution is about 1 hour for an 8

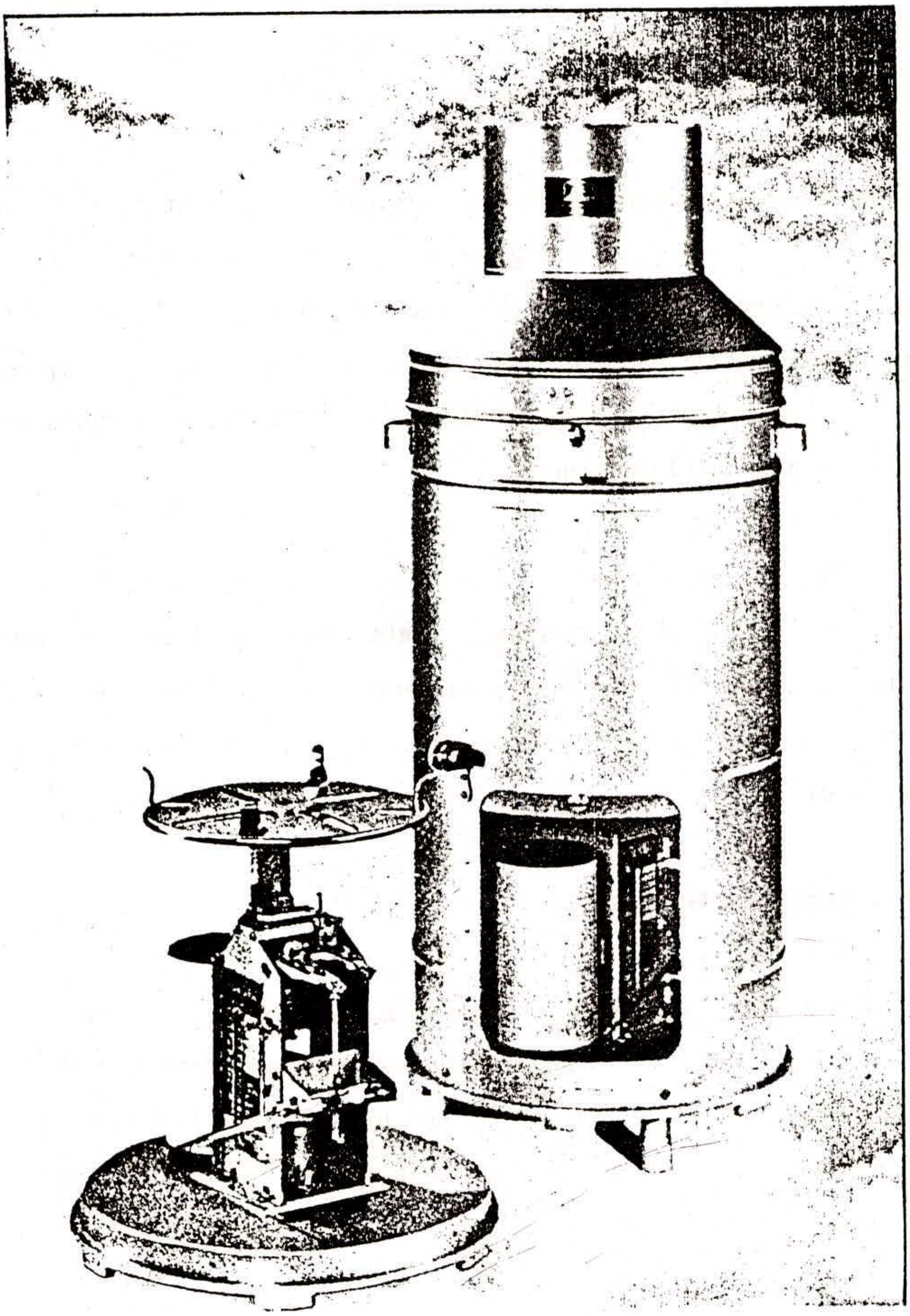

Figure 1. Belfort's Universal Weighing Type Precipitation Gauge

day rotation. When these types of weighing gauge are used with electronic data logger, the mechanical recording device is replaced by an optical shaft encoder or potentiometer which provides an electrical output allowing resolution of precipitation amounts to values of 0.1mm. Both these gauges are available with capacities upto 750mm.

Six basic types of precipitation measurement methods are reported : tipping bucket gauge, siphon gauge, weighing gauge, optical gauge and the radar and satellite methods. The heated tipping bucket and siphon type gauges report under catch (Hansson et al., 1983, Sevruk, 1983). The optical gauges are claimed to be able to determine both the type of precipitation and the intensity of precipitation but their ability to determine the intensity of precipitation is yet to be established (Lundberg and Johansson, 1994).

The present setup of snowfall measurement is considered to be inadequate, and improvement of conventional snow gauging networks is necessary. The snow measurements are time consuming, expensive and inadequate and, therefore, new techniques are sought after. For this, development of automatic sensors is essential for measurements especially from remote inaccessible areas.

2.1 Weighing Snow Gauges

Cox (1971) developed a 'universal surface precipitation gauge' that measures snowfall and snowpack water equivalent by weight and collects and measures water output. Waring and Jones (1978) modified his design to make it more suitable for shallow snowpacks. The snowfall water equivalent is measured by recording an increase in weight on the collector in the absence of near-simultaneous production of water output.

The weighing gauge is designed to provide accumulated totals of precipitation, with a manufacturer's stated measuring accuracy of approx. ±3.8mm. The addition of an optical encoder to a weighing gauge (e.g. Belfort 3000) now provides for resolution of precipitation totals to 0.1mm. Field tests have shown, however, that it is unreasonable to expect this type of gauge configuration to resolve precipitation totals to better than ±1.0mm (Metcalfe and Goodison, 1994). Electronic load cells for weight measurements have advantages for use in precipitation gauges (Seibert and Moren, 1995). They allow to measure weight (and consequently precipitation) with a high resolution, both in time and volume, and they can be easily connected to a data logger. Precipitation is then calculated from the weight measurements of the accumulated water, i.e. every increase in the weight correspond to a certain volume of precipitation.

An alternative method of in-situ snowfall measurement involves the weighing of the snow as it accumulates. The gauge is usuallly located above the worst wind eddies and normal levels to which snow may accumulate on the ground. This may provide a more realistic method of estimation of snow intensity (Summer, 1988). Commonly available weighing gauges contain buckets which accumulate the total precipitation until they are emptied. The buckets rest on spring loaded platforms and their position is sensed by linear potentiometers (Figure 2), LVDTs, etc. Although weighing gauges are two to three times more expensive than tipping bucket gauges, their accuracy is not intensity dependent and their resolution is limited only by the mechanical sensitivity of the platform mechanism (Tanner, 1990).

A variation on the weighing technique is the use of a 'snow pillow' (Figure 3), similar to a large mattress, filled with antifreeze solution, which responds to the weight of the accumulated snow. When the weight is recorded by means of a potentiometer, there is often electrical noise induced on the resistance values so that the accuracy of precipitation intensity and duration is insufficient. In order to overcome these limitations, strain gauge based precipitation gauges have also been tried (e.g. Bakkehol et al., 1985). However, in the USA these gauges have suffered from various inaccuracies due to freezing of load cell, etc. (Crook, 1995).

The Atmospheric Environment Service (AES) of the Environment Canada has extensive experience in the operation of two types of weighing recording precipitation gauges (Goodison, 1995). The Belfort Universal gauge and the Fisher & Porter gauge use a combination of springs, levers and pulleys to translate the accumulated weight of a catchment bucket to a recording

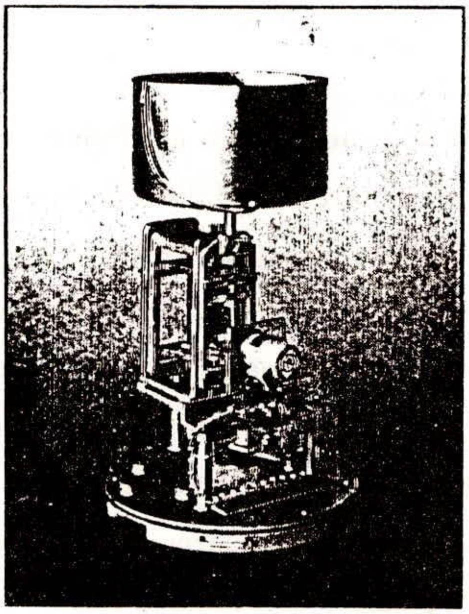

Figure 2. Weighing Bucket Gauge

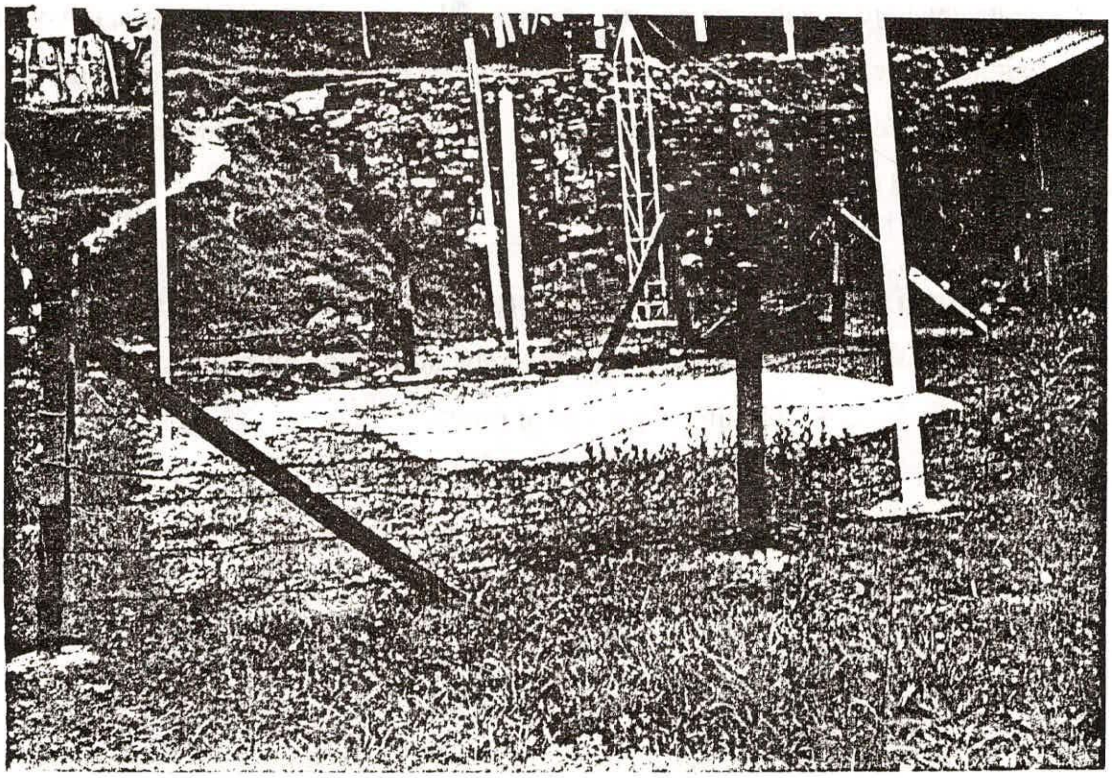

Figure 3. Snow Pillow

mechanism. Based on the national and international intercomparisons of solid precipitation measurements, Metcalfe and Goodison (1994) prepared recommendations on the use of weighing recording gauges with automatic weather stations.

With a view to justify the operational use of weighing precipitation gauges, it would be topical to reproduce the relevant recommendations by the Organising Committee of the WMO Solid Precipitation Measurement Intercomparison, and the suggested guidelines by the AES Canada (Metcalfe and Goodison, 1994) :

1. Use of heated tipping bucket gauges for winter precipitation measurement should be carefully assessed; their usefulness is severely limited in regions where temperatures fall below 0 deg C for prolonged periods of time,

2. Weighing recording gauges are presently the most practical method of measuring precipitation amount at auto-stations. Tipping bucket gauges should only be used for rainfall measurement,

3. The addition of the large Nipher-type shield on weighing gauges, particularly in exposed, cold, dry snow, windy environments, offers a viable method of minimizing systematic errors in gauge catch. Design changes in either the gauge or shield to make it easier to service and to reduce vibration in the recording mechanism is necessary,

4. In areas where the large Nipher-type shield is not suitable, Alter shields should be used on weighing gauges at exposed or partially sheltered sites. Additional wind speed measurements should be taken at the level of the gauge orifice in order to correct for the wind induced errors,

5. The use of an ultrasonic snow depth sensor in conjunction with precipitation gauge measurements has been found to be an effective tool in providing further information on type and timing of precipitation as well as snow accumulation.

2.2 Errors Associated with Snow Gauges

Assessment of the accuracy and performance of recording precipitation gauges involves consideration of several factors, including shielding and the associated catch efficiency of the gauge, accuracy and resolution of the measured output from the gauge, performance of the instrument during all types of precipitation events, and interpretation of gauge measurements with respect to timing and type of precipitation (Goodison and Metcalfe, 1989).

The major problem with solid precipitation measurement is that of the under-catch due to wind effects. In order to minimize this error, many different designs of wind shields have been tried (e.g. Tabler et al., 1990, Goodison et al., 1983, Goodison et al., 1989) and empirical relationships relating the true catch to the gauge catch and the wind speed were also presented.

One significant problem with recording weighing gauges is that wet snow or freezing rain can stick to the inside of the orifice of the gauge and not fall into the bucket to be weighed until some time later, often after an increase in ambient air temperature. For seasonal precipitation totals this timing problem may not be too severe for data analysis; however, for hourly and daily applications of precipitation data, this problem with recording gauge need to be acknowledged.

At automated stations where, normally, only one gauge is in operation, it becomes difficult to identify this type of problem and quality control of such measurements. Air temperature data will be one additional element which must be analysed to help assess the type and timing of precipitation. Operation of an acoustic snow depth sensor in conjunction with a recording precipitation gauge can provide additional information, both on the timing and type of precipitation. For example, an increase in accumulated precipitation accompanied by a decrease in snow depth, alongwith a mean temperature above freezing, will suggest occurence of rain. This kind of information, particularly on an hourly basis, is valuable in identifying changes in precipitation type during a storm, i.e. rain turning to snow or vice-versa.

Blowing snow is a problem that can affect all precipitation gauges if they are mounted too close to the ground. The more efficient a gauge is in catching and measuring snow passing over its orifice, the more likely a gauge is to overmeasure during blowing snow conditions. During the WMO Intercomparison in Canada, this problem has been significantly overcome by mounting the orifice at 2m above the ground, barring very high winds.

Another common error associated with weighing gauges is wind pumping. This usually occurs during high winds when turbulent air currents passing over and around the catchment container cause oscillations in the weighing mechanism. By using programmable data loggers, these errors can be minimized by averaging a number of short duration samples during a measurement interval. For example, samples at twenty seconds interval may be averaged over a fifteen minute period.

For non-recording gauges using volumetric method of measuring the liquid contents, a correction for moisture retained in the Nypher collector ("wetting loss") is necessary. Another concern is the determination of "trace amounts" of precipitation (<0.2mm) using the Nypher. Measurement of trace amounts are not a problem with the recording weighing type gauges, since even very small amounts will accumulate over time.

Use of a long duration recording precipitation gauge with proper shield is required for winter precipitation measurements at automated stations. An ultrasonic snow depth gauge in conjunction with a weighing type precipitation gauge can be an effective tool for determining precipitation totals, assessing the type of precipitation and providing an indication of the state of the snowpack (Goodison and Louie, 1985).

In order to improve the catch efficiency of recording gauges, it has been established during WMO's Solid Precipitation Measurement Intercomparison in Canada that a double fence or large Nypher type sheild designs considerably improve the catch efficiency of a recording gauge resulting in a more accurate measurement of total winter precipitation. The timing of individual storms or precipitation events, however, may still vary considerably for different types of gauges (Goodison and Metcalfe, 1989).

Use of recording weighing type precipitation gauges enables measurement of both rain and snow under extreme weather conditions and recording on a variety of electronic data loggers or data recording systems. The potential ability to measure precipitation over very short time intervals (e.g. minutes) offers a capability not previously available.

Improvements in designs and costs of commercial load cells and data logger systems have enabled the design of weighing type precipitation instrument which have no moving parts. The report presents development of a load cell based weighing sensor for in-situ measurement of snow water equivalent. The sensor alongwith a commercially available data logger and an ultrasonic sensor (both from Campbell Scientific Inc., USA) was tested under field conditions, and initial results are presented here.

3.0 DESCRIPTION OF THE SNOW WATER EQUIVALENT (SWE) INSTRUMENT

The reported snow gauge comprises a weighing platform with strain gauge based load cell, a data logger, a PT107 thermistor temperature probe, supporting electronics and a solar panel (SPV) backed battery pack. With this arrangement, precipitation is calculated from the weight measurements of the accumulated water, i.e. every increase in the weight correspond to a certain volume of precipitation.

3.1 Load Cell

The load cell used for the measurements was a 'S' type 500 Kg capacity with 3.0 mv/V rated output and a non-linearity of <0.03% FSO (model 20210 of ADI Artech, Baroda). The load cell was corrosion resistant (stainless steel) and hermetically sealed for use in outdoor environment. A four conductor shielded cable was available for excitation and output of the cell.

The load cell had the following error characteristics : rated output was 3mv/V of excitation; zero balance was ±1.0% FSO; maximum non-linearity was ±0.03% FSO; maximum hysteresis was 0.02% FSO; maximum non-repeatability was 0.01%FSO. The compensated temperature range was 0 to 150 deg F, with maximum effect on output as 0.0008% FSO/deg F and maximum effect on zero balance as 0.0011% FSO/deg F. With these specifications, the load cell was able to measure the snowfall at a resolution of 1mm SWE.

3.2 Platform

The snowfall is received on a MS platform of 50cmx50cm size. This area corresponded to 120 cm of SWE. The load cell was fixed between a bottom MS plate and a top MS plate, both of 4 mm thicknesses, through a separate fixing arrangement so that the load is uniformly transmitted to the centre of the load cell. Dimensions of the top plate were 490mm x 490mm whereas that of the bottom plate were 479mm x 479mm, thereby providing a 5 mm gap to facilitate a free vertical movement of the top plate during loading. The sides of the two plates were covered by welding 5" collar plates on the periphery of the bottom plate. Figures 4 show a plan view of the SWE sensor (i.e. the platform).

3.3 Data Logger

A Campbell Scientific Inc. data logger (model CR10) was selected to measure the weight using the load cell as well as to measure the other parameters, e.g. air temperature and snow depth using a PT-100 air temperature probe and an ultrasonic sensor UDG01, respectively, of Campbell Scientific Inc. The data logger supplied excitation voltage to the load cell and the height sensor,

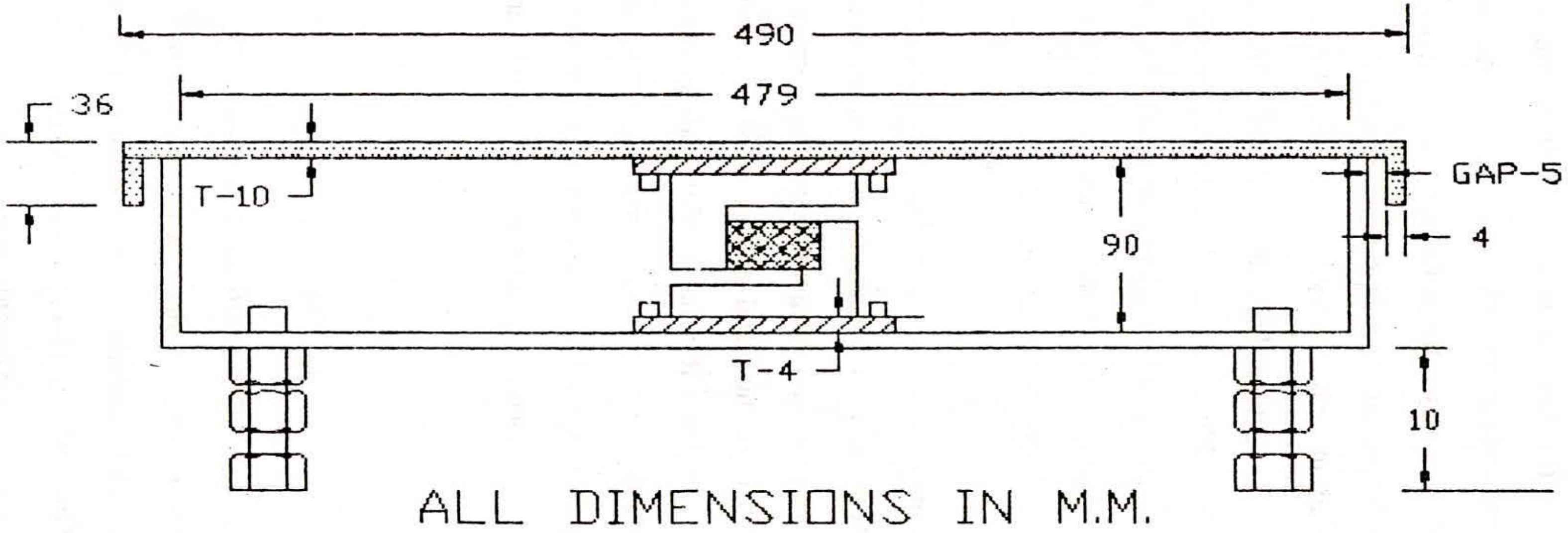

Figure 4. Plan View of the Snow Sensor (Weighing Platform)

measured incoming volatge signals, converted the analogue signals to digital values, and stored the values for later retrieval and analysis.

The CR10 data logger has the capacity to make multiple measurements during each measurement interval. This feature is useful to obtain average mass measurements with greater resolution. The CR10 uses 13 data bits during the A/D conversion so that each input channel has a range of 8192 possible values. Using the 2.5 mV range, the resolution or size of each of the 8192 values is 2.5 mV/8192 or about 0.000305 mV. The load cell used had an output signal strength of 3 mV/V of excitation with a full scale range of 500 Kg. Using an excitation of 2.5 V, the resolution of the load cell was 500 Kg/(3 mV/V x 2.5 V) or 66.67 Kg/mV. The final resolution of load cell measurements was 0.000305 mV/bit x 66.67 Kg/mV or about 0.02033 Kg/bit. Therefore, the data logger had sufficient resolution to detect changes in snow weight of less than 1 mm of SWE, which corresponded to 250 g.

Snow weight was determined every half-hour. Initial weight of the MS platform was removed from the measured value as offset to increase accuracy of the measurements. Height of the accumulated snow (using UDG01) and air temperature were also measured simultaneously. Measured data was stored on on-board memory and later retrieved on a Laptop PC by connecting the CR10 through a RS232 interface. The CR10 had sufficient on-board memory to store upto 39,000 values before overwriting the data in a cyclic manner. CR10 had a detachable type keyboard and LCD display which was used for various setups and display of data in field. Additionally, a Laptop computer was used for programming the CR10 and for retrieval of the stored data.

3.4 PVC Enclosure

Since the instrument is to be left unattended at remote field sites under severe environmental conditions, a double wall polyethylene box with rigid PUF (Polyurethane Foam) insulation, having 'K' value of 0.016 K cal/mhr deg C, was used for housing the data logger, batteries and other electronics. The field trials have shown that the box was able to maintain a difference of about 4 deg C in the inside and outside temperatures.

3.5 Battery

Initially the system was operated with a normal grade Hitachi make 12V, 24 Ah SMF battery, with charging through a SPV module. The battery failed during low temperature (about -5 deg C) operation at a site in J & K (Chilla Top) in winter of 1993-94. Then, a special grade Plus Oerlikon make SMF battery of 12V, 38 Ah (suitable for upto -30 deg C operation) was procured from Switzerland. Two such batteries were connected through an add on circuit for switching over to the second standby battery in case of emergencies, e.g. failure of the main battery. With this arrangement, the system can be operated upto 10 days even without charging of batteries.

3.6 Software Control

The data logger needs to be programmed before it will make any measurements. The program consists of a group of instructions entered into a program table. The program table is given an execution interval which determines how frequently that table is executed. When the table is executed, the instructions are executed from beginning to end.

The interval at which the table is executed generally determines the interval at which the sensors are measured. The interval at which data are stored is separate from how often the table is executed, and may range from samples for every execution interval to processed summaries output for hourly, daily, or for longer or irregular intervals. The final processed values are stored in the Final Storage memory area in the CR10. Approximately 29,900 locations are available in this memory area.

The CR10 data logger was programmed to perform a variety of operations including measurement of sensor outputs, some basic mathematical computations, control, and data storage. For IBM compatible computers, a telecommunication software package 'PC208' is available, which contains a terminal emulator programme 'TERM'. TERM was used to manually initiate several operations such as data review and/or retrieval, the uploading and downloading of logger programmes/data, setting the logger clock, etc. The program developed for this application was downloaded to the CR10 using a Laptop computer. Any in between changes in the execution/storage interval was carried out using a detachable keyboard/display (CR10KD) via a 9 pin serial I/O port available on the CR10.

All measurements were taken every 10 seconds and averaged over 30 minute periods. Measurement average interval must be long enough to provide a realistic mean, but short enough not to reflect the influence of diurnal cycles. For this reason, a 30 minute interval was considered adequate to provide representative values of the measured parameters. In order to monitor the health of the system, the battery voltage and the ambient temperature at the data logger were also recorded. Also, the Julian Day and the real time were recorded. The programme was developed using the editor EDLOG available in the PC208. Sample instructions used for the load cell, temperature probe and ultrasonic height sensor measurements are described below.

FULL BRIDGE WITH SINGLE DIFFERENTIAL MEASUREMENTS (P6)

This instruction was used to apply an excitation volatge to a full bridge and make a differential volatge measurement of the bridge output. The measurement is made with the polarity of the excitation voltage both positive and negative. The result is 1000 times the ratio of the measurement to the excitation voltage. The instruction is described as follows :

PARAM. #	DATA TYPE	DESCRIPTION
01 :	1	Repetitions
02 :	33	Range code
03 :	4	Input channel number for first measurement
04 :	2	Excitation channel number
05 :	2500	Excitation voltage (mV)
06 :	8	Input location number for first measurement
07 :	152.44 Multiplier	
08 :	-22.13 Offset	

107 TEMPERATURE PROBE (P11)

This instruction applies a 2V AC excitation voltage to Campbell Scientific's Model 107 Thermistor Probe, makes a fast, single-ended voltage measurement across a resistor in series with the thermistor and calculates the temperature in deg C with a polynomial. The instruction is described as follows :

PARAM. #	DATA TYPE	DESCRIPTION
01 :	1	Repetitions
02 :	1	Input channel number for first measurement
03 :	1	Excitation channel number
04 :	1	Input location number for first measurement
05 :	1	Multiplier
06 :	273.15	Offset

EXCITATION WITH DELAY (FOR ULTRASONIC MEASUREMENTS) (P22)

This instruction is used in conjunction with others for measuring a response to a timed excitation using the switched analogue outputs. It sets the selected excitation output to a specific value, waits for the specified time, then turns off the excitation and waits an additional specified time before continuing execution of the following instruction. The analogue circuitry is not powered up during the delay after excitation. This reduces the current consumption of the CR10 to about 3mA. The instruction is described as follows :

PARAM. #	DATA TYPE	DESCRIPTION
01 :	1	Excitation channel number
02 :	8	Delay time in hundredths of a second that excitation is on
03 :	0	Delay time in hundredths of a second that excitation is turned off
04 :	0	Excitation voltage (mV)

The data was stored in the ASCII format, and after offloading from the CR10, through a Laptop computer, was processed using the data split (SPLIT) software and stored into a report file. SPLIT allows the user to output the report file to disk, printer or both.

3.7 Operation

A data logger (CR10 of Campbell Scientific), two nos 12V, 36Ah SMF battery (Oerlikon Plus, Switzerland) and other electronic circuitary for SPV based charger were housed in a PUF insulated PVC box. The functional block-diagram of the SWE instrument is shown in Figure 5.

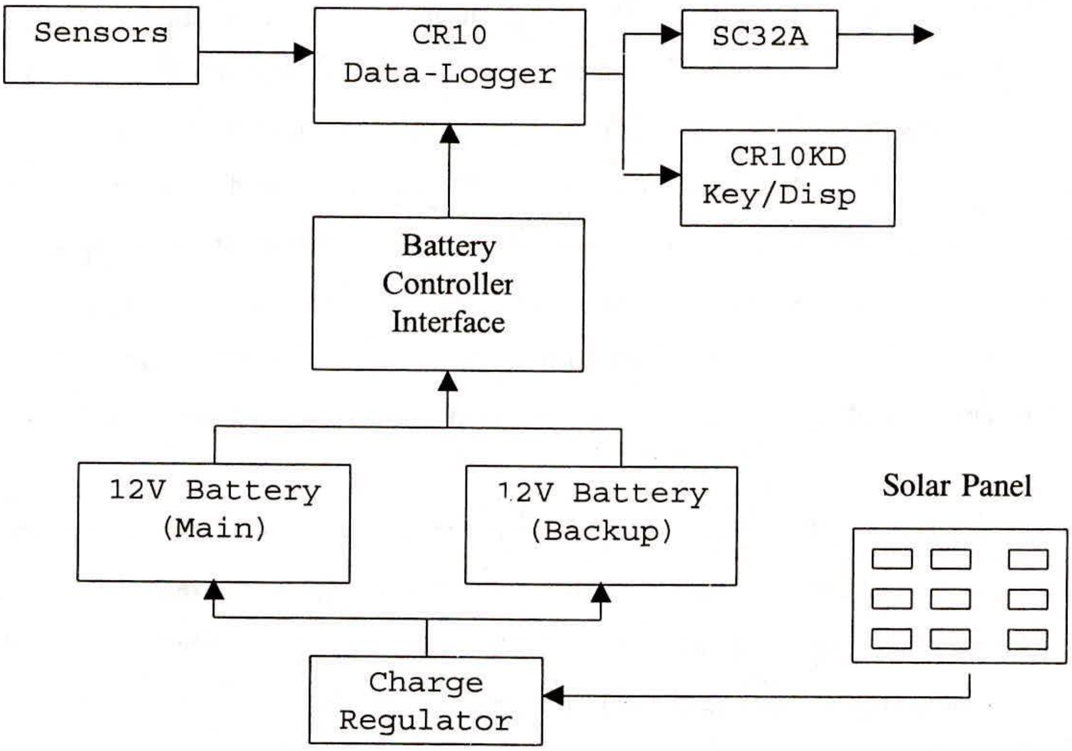

Figure 5. Functional Block-Diagram of WSG Data-Logger

The system operation was automatic with half-hourly averaged data stored on the on-board solid-state memory. The stored data included snow water equivalent using load cell sensor, snow height using ultrasonic sensor, air temperature using a Pt-100 probe, and the battery voltage. A sample printout of the data collected during Feb 11-March 4, 1995 at Kaddukhal is given in Appendix-1.

4.0 RESULTS

Although the field testing was carried out in absence of a standard snow gauge, future field trials would incorporate the use of a standard weighing snow gauge for comparision of the results. An ultrasonic snow depth sensor (model UDG01, from Campbell Scientific, Inc.) was used with the SWE instrument to have an idea on the functioning of the developed instrument. Snow weight was measured every half-hour. Initial weight of the MS platform was removed from the measured value as offset to increase accuracy of the measurements. Height of the accumulated snow (using UDG01) and air temperature were also measured simultaneously. Measured data was stored in an on-board solid-state memory and later retrieved on a Laptop PC.

Since the data logger, batteries and other electronic circuitary were to be left unattended at remote field sites under severe environmental conditions, a double wall polyethylene box with rigid PUF (Polyurethane Foam) insulation, having 'K' value of 0.016 K cal/mhr ^{0}C, was used for housing the data logger, batteries and other electronics. The field trials have shown that the box was able to maintain a difference of about 4^{0}C in the inside and outside temperatures.

A prototype of the SWE instrument was first installed at a site in Chilla Top, a hill station in the state of Jammu & Kashmir (India), in February, 1994. On a latter visit it was found that the SMF type battery failed due to very low temperature, and the stored data was lost. Due to operational difficulties, subsequently the field testing at that site was discontinued. The instrument was then tested at two sites in the hills of Western Uttar Pradesh (India) during February to March, 1995 and December, 1995 to February, 1996, respectively. Both these sites are located in the lesser Himalayas (Kaddukhal, 2600m amsl and Dhanaulti, 2400m amsl), and are only 7 kms apart. Due to relatively low elevation of both these sites, the precipitation recorded was generally a mix of rain and snow.

Figure 6 shows the installation of the instrument at the Dhanaulti site. The ultrasonic snow height sensor (UDG01) and the air temperature sensor are also shown in the figure. Figure 7 shows the snow water equivalent measured using the reported snow gauge during December 15 to February 27, 1996 at the Dhanaulti site. As seen in Figure 7, five snowfall events occured out of which only on three occasions (on December 22, 1995, on February 10 and February 26, 1996) SWE was recorded more than 10mm. Due to relatively low elevation and abundant sunshine at the site, the snow melted immediately after cessation of the storm. Since the snow gauge recorded cumulative weight of the precipitation (snowfall being the major contributor), numerous small peaks shown in the figure correspond to accumulation of dew, light rainfall, etc., and their melting during sunshine hours. A fine slit opening between the vertical collar and the horizontal weighing platform of the snow gauge passed off the rainwater while retaining the snow. A non-recording snow gauge was also installed at the site to measure the accumulated snow so as to have some kind of a check on the functioning of the weighing snow gauge (although results may not be truely comparable due to a small collector area).

Table 1 shows results from the field testing of the snow gauge at the Kaddukhal and Dhanaulti sites. As seen in Table 1(b) for the Dhanaulti site, SWE computed from the non-recording snow gauge is higher, mainly because the readings included the contribution of both the rainfall and the snowfall whereas the weighing gauge recorded only the solid precipitation. Rainfall contribution was especially significant in the two events recorded during February 10 (0400 hrs, LMT) to February 11 (1000 hrs, LMT) and during February 25 (2000 hrs, LMT) to February 27 (1500 hrs, LMT). This could be ascertained from a combined analysis of the snowfall (weight), snow depth and air temperature data. A careful scrutiny of the above mentioned three events revealed that in absence of a wind shield, drifting of freshly fallen snow resulted in loss of accumulated weight on the

Figure 6. Installation of the Snow Gauge Setup at Dhanaulti (India)

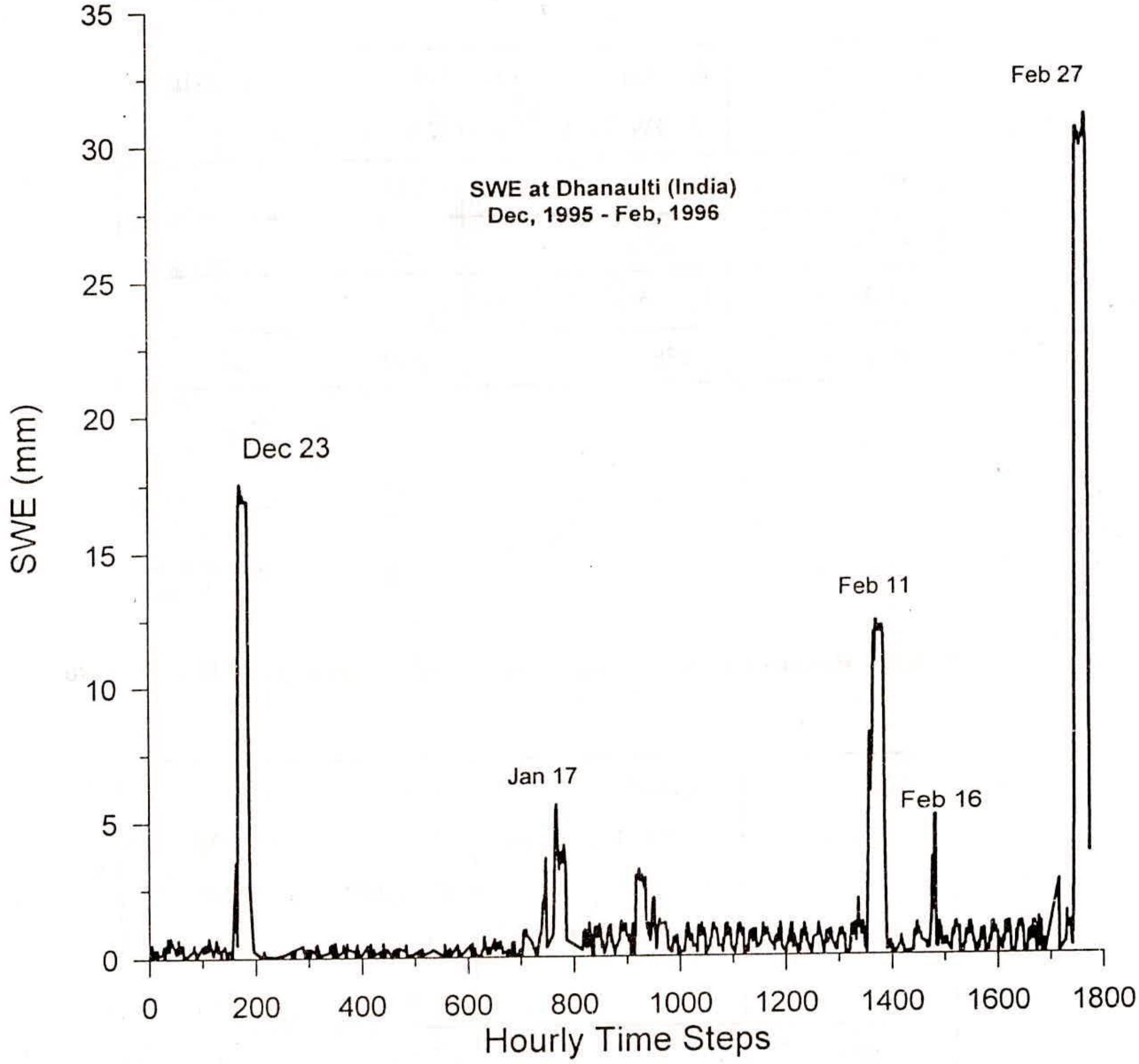

Figure 7. SWE Measurement from Dhanaulti Site (Dec, 1995- Feb, 1996)

Table 1(a). Results from Kaddukhal Site during February-March, 1995

DATE	WEIGHT OF SNOW (Kg)	SWE FROM WEIGHING GAUGE (mm)
15.02.95	4.206	17.52
23.02.95	4.415	18.39
24.02.95	5.0365	20.98
28.02.95	3.478	14.49

Table 1(b). Results from Dhanaulti Site during December, 1995-Feb, 1996

DATE	WEIGHT OF SNOW (Kg)	SWE FROM WEIGHING GAUGE (mm)	SWE FROM MANUAL GAUGE (mm)
22.12.95	4.212	17.54	22.28
10.02.96	2.963	12.34	38.2
27.02.96	7.428	30.94	100.27*

* Accumulated value of precipitation after Feb 11, 1996

platform in between the recording interval. This was ascertained from the snow depth data simultaneously recorded by the ultrasonic sensor.

5.0 CONCLUSION

The report describes the development, and the laboratory as well as the field testing, carried out over the last two snow seasons, of a weighing type instrument for in-situ measurement of snow water equivalent (SWE). The basic idea was to develop a sensor with indigenously available components and use off-the-shelf data logger alongwith the other required components (e.g. battery, solar panel) for in-situ SWE measurements.

The SWE instrument comprise a weighing platform with strain gauge based load cell, a Campbell Scientific data logger (CR10), a PT107 thermistor temperature probe, SPV supported battery pack and suitable enclosure for housing the electronics. After conducting an extensive laboratory testing, the prototype instrument was first installed at a site in J & K state (Chilla Top) in 1993-94, and later at two sites in Garhwal Himalayas (Kaddukhal in 1994-95 and Dhanaulti in 1995-96). After initial problems with the battery, the instrument was successfuly tetsted during 1995-96.

An ultrasonic snow height sensor (UDG01) from Campbell Scientific was also used with the SWE instrument to have some idea on the functioning of the developed instrument. Although the reported field testing was carried out in absence of a standard snow gauge (e.g. IMD type), future field trials would incorporate the use of standard snow gauges for comparision of the results.

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FEATURES OF SNOW WATER EQUIVALENT (SWE) INSTRUMENT

 # Based on weighing mechanism (load cell)

Catch is through a platform of 50cmx50cm

 # Battery operated (charging through SPV modules)

Operation upto 10 days even without charging of batteries

standby battery included for emergencies

 # Operating temperature : upto -15 deg C

 # Capacity : 120 cm ht of snowfall

 # Resolution : 1 mm ht of snowfall

 # Measurement interval : 1s to 1 hr (programmable)

 # Data storage (programmable) :

Interval : 1 s to 1 hr

Sufficient memory for more than 6 months data storage

 # Keyboard & display :

Detachable type, for setups and display of data in field

 # PC interface :

For data offloading and processing

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