AN ENHANCED TECHNIQUE FOR A MORE RELIABLE DAILY SNOW MEASUREMENTS WITH AN ANTIFREEZE-BASED TIPPING BUCKET GAUGE

By
Radu Carcoana[1] and John W. Enz[2]

ABSTRACT

The record snowfall during the 1996-1997 winter season and subsequent spring flood stressed the need for a suitable method to measure daily snowfall at all 52 North Dakota Agricultural Weather Network (NDAWN) stations. Our goal was to obtain accurate daily winter precipitation values from a remote automatic weather station. In November 1997, a system comprised of a Texas Electronics TE525[3] rain gauge with a Campbell Scientific CS705 antifreeze based snow adapter, suitable for obtaining a *"reasonable estimate of the total seasonal precipitation"* (McCaughey and Farnes, 1996), was installed at Fargo, North Dakota NDAWN station. Laboratory testing identified an antifreeze overflow restriction and a system support problem. We redesigned the shape of the overflow tube and added surfactant to the antifreeze mixture to diminish surface tension. We installed a weight support (tripod) and a side post to increase gauge stability in windy conditions and maintain a plumb position. The new system was tested during the second half of the 1997-98 winter, and the 1998-99 and 1999-2000 winter seasons. Comparative data for each snow precipitation event were recorded, collected and analyzed from three different sources: NWS Coop observer located about two miles E, a standard NWS universal Belfort weighing gauge, and the adjacent TE525/CS705 tipping bucket gauge/snow adapter at the Fargo, NDAWN station. The combination of the new overflow tube design, added surfactant and a reliable support system, enhanced the flow timing and provided more reliable "daily" totals.

INTRODUCTION

Generally in agriculture and especially for flood forecasting in North Dakota there is an important need for more accurate, timely winter precipitation information, especially snow water equivalent. The Fargo, ND Microclimate Research Station (MRS) is situated on NDSU campus and is a part of North Dakota Agricultural Weather Network (NDAWN). Our goal was to obtain accurate daily winter precipitation values from a remote automatic weather station. In November 1997, a system comprised of a Texas Electronics TE525 rain gauge with a Campbell Scientific CS705 antifreeze based snow adapter was installed at Fargo NDAWN station. For comparison, we installed a standard NWS universal Belfort weighing gauge adjacent to the CS705. The first two months of field tests (Dec '97 and Jan '98) showed unreliable and inconsistent daily records of precipitation from the CS705 in comparison with the Belfort and NWS observations. The tipping bucket continued recording precipitation 6 to 12 hours after the precipitation event ceased (Table 3). In other cases, the precipitation event commenced more than 2-3 hours before any precipitation was recorded on the CS 705. For NDAWN this situation was unacceptable because stations are equipped with voice synthesizer modems which, by a simple phone call, provide total precipitation recorded since midnight. It is confusing for a person to call a station on a sunny day and be informed that 0.02 inches of "rain" have been received since midnight, or to call in stormy weather and hear that no precipitation has been recorded.

OBJECTIVE

Our purpose was to find an appropriate and reliable method to measure daily snow water equivalent at all NDAWN stations, using the present TE525 rain gauges, and the CS 705 Precipitation Adapter, if suitable and reliable. We concentrated our laboratory tests on the antifreeze flow restrictions which we assumed was the cause of the slow reaction (*dam effect*) followed by a spontaneous spill (*burst effect*), due to the surface tension. We observed that three elements were influencing the antifreeze flow rate in the CS 705 (Figure 1):

---

[1] Research Specialist, North Dakota Agricultural Weather Network, ND State University, Fargo, North Dakota 58105
[2] Professor and North Dakota State Climatologist, ND State University, Fargo, North Dakota 58105
[3] The authors are not endorsing any of the commercial names mentioned in this paper.

Presented at the 68th Annual Western Snow Conference, Port Angeles, WA, April 18-20, 2000

1. Wrinkles on the arched area of the overflow tube,
2. Surface tension of the antifreeze solution which accumulates in overflow tube creating a "dam like" restriction until "bursting" down creating unreal (time wise) and/or delayed values,
3. Antifreeze expansion/contraction due to temperature variation.

The purpose of this paper is to find a solution to problem 1 and 2. The antifreeze increase/decrease in volume due to small variations in temperature will remain the subject of a future study.

METHODS:

Initial Field Test - Research Site and Instrumentation:. Winter precipitation was measured with an electronic tipping bucket TE525 with an eight inch diameter funnel to accommodate the Campbell Scientific CS705 precipitation adapter. Data were automatically downloaded every night providing hourly and daily data. A Belfort weighing gauge was installed twenty feet SE of the station. The charts were changed weekly and the recordings evaluated. Both instruments were surrounded by an Alter shield to maximize the snow catch (Alter J. C., 1934). Both instruments contained a 50-50 solution of ethylene glycol and methanol antifreeze (also called glycometh or EG) and water as per McCaughey and Farnes (1996) and McGurk (1992). We installed a supporting tripod with a collecting receptacle underneath, protected by a 0.25 inch wire mesh screen. Information obtained from both instruments installed at the Fargo site were compared to the official National Weather Service (NWS) data, recorded at Station #21-5586-1 (MORM5) by the NWS cooperative observer. The station is located about two miles ESE from the Fargo NDAWN station. For the purpose of this study we considered NWS data the official values and measured our instruments against it. Table 3 shows the inconsistency of the values recorded by TE525/CS 705 from Nov. '97 until Jan. '98.

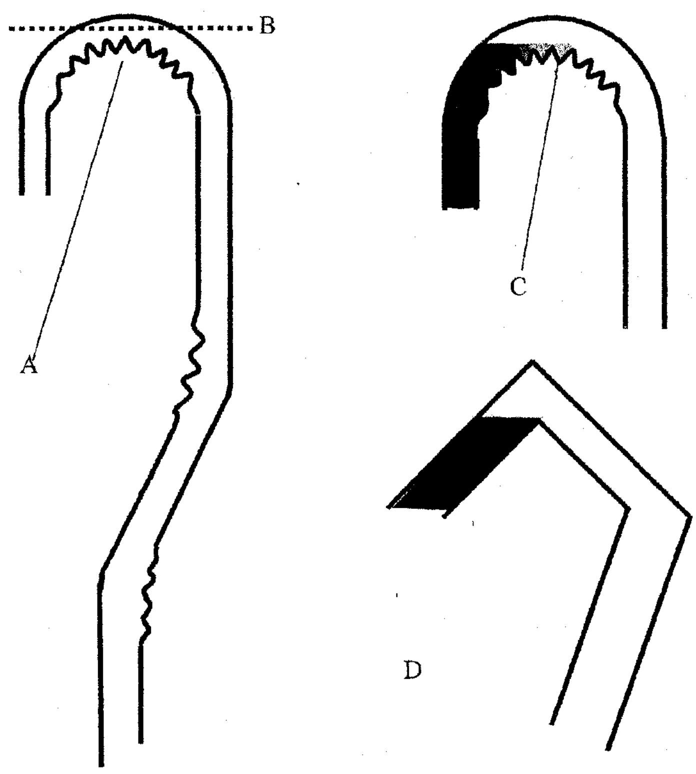

Figure 1- *CS 705 Overflow Tube*

A - Significant wrinkles on the inside part of the arched area that restrict the flow path;

B - Cut open the upper part of the tube creating a 1.5 inches window for monitoring the flow path;

C - How wrinkles delay the antifreeze solution free overflow and creates the "burst" effect (accumulates about 0.11 inches of solution until burst);

D - The new V-shaped tube design with no wrinkles.

Laboratory test (conducted in a relatively constant temperature room)[4]:

1) During manufacturing process, the overflow tube was bent and wrinkled in three places (Fig. 1A, C). For evaluating the influence of wrinkles in the overflow area and better monitoring of the liquid flow path we shaved open the upper part of the tube, creating a 1.5 inch long window (Fig. 1B) . After reinstalling the tube in the CS 705, we duplicated field conditions in the laboratory. Instead of the TE 525 tipping bucket gauge, we fabricated a tripod to support the CS 705 antifreeze reservoir with enough clearance underneath to accommodate a 100ml graduated glass cylinder as a catching reservoir. The precipitation was simulated with a 500 ml burette cylinder with a constant flow rate control, calibrated at 3 ml/min. The water dripped in the CS705 at the specified constant rate and overflow was measured in the collection tube every five minutes. We also measured the time elapsed from the first drop IN until the first drop OUT. The results represent the average of six replications for each of the three tube designs. We added surfactant to the most responsive of all and again run six replications. The most responsive time wise, and reliable (accurate) quantity wise, was the V- shaped, not wrinkled tube design (Fig. 2, Table 1, 2)

Table 1. Average time lapsed from the first drop IN until first drop OUT

Original Round, Wrinkled	*Design #1 Round Not Wrinkled*	*V-Shaped Design + Surfactant*
3 min 20 sec	**1 min 45 sec**	**1 min 20 sec**

2) The surface tension in the antifreeze solution was diminished by adding 10-12 ounces of surfactant[5] to the existing 50/50 mixture of antifreeze and water. The surfactant reduces the surface tension of nearly any aqueous solution. In this specific case the added surfactant decreased the overflow spill time and eliminated the delay from the first drop IN until the first drop OUT. It also improved the flow uniformity by eliminating the "burst" created by the accumulation (dam effect) due to the surface tension.

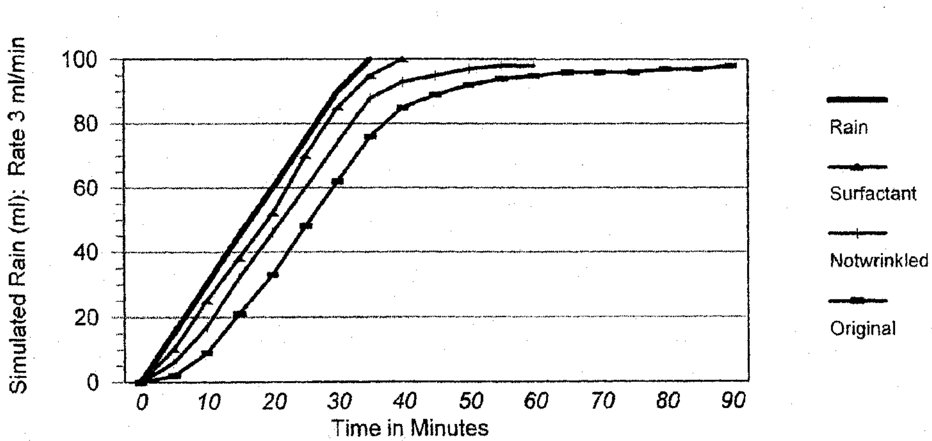

Figure 2 - *CS 705 Overflow Tube Analysis: Recuperation Time Comparison*

Final Field Test - Duration: three winter seasons in Fargo, ND

The new tube design has been recommended to the CS 705 manufacturer, Campbell Scientific, Inc.. The prototype was installed at our Fargo NDAWN station in Feb. 1998. We added 8 to 12 ounces of surfactant to the antifreeze solution. The CS 705 was installed in November and removed at the end of March each year since Nov. 1997 until March 2000. The Belfort gauge charts were replaced weekly. We also downloaded data from CS705 nightly with occasional checking by phone.

---

[4] The laboratory tests were done and expressed in milliliters, instead of inches of precipitation.

[5] SILWET L77 made by Loveland Industries, Inc.

DISCUSSION

The new V-shaped overflow tube design with added surfactant greatly improved the accuracy and timing of the CS 705 snow adapter to obtain more dependable daily recordings. They closely matched the NWS recordings. Table 3 shows the daily recordings for three winter seasons. Time wise, Table 3 shows compact blocks of precipitation recordings with a definite start and definite end by all three instruments (ex. Feb. 14 and 25, Mar. 1 and 5, 1998). The CS 705 overflow tube is more reactive, matching the other two methods of recording precipitation. We also compared the hourly values for certain precipitation events. Space concerns do not permit elaboration.

Quantity wise, the CS705 precipitation recordings were always in between the NWS observer and Belfort gauge. Table 2 gives a comparative look to the total precipitation for three winters, recorded by all three stations. However, the local variability should be taken in consideration due to the distance between NWS observer and MRS site. The expansion/contraction variable remains an important factor for consideration and should be correlated with the maximum and minimum daily temperature. A fluctuation of over 10^0 F in 24 hours (Table 3), creates specific situations that needs to be considered and specifically addressed.

Table 2. *Total Season Snow Water Equivalent, Comparative Table (inches)*

Winter Season (Dec - Mar)	NWS Coop	Belfort Gauge	TE 525 CS 705
1997 - 1998	3.92	3.07	3.66
1998 - 1999	3.49	2.90	3.43
1999 - 2000	1.97	1.71	2.07

CONCLUSIONS

We found solutions to problem 1 and 2 (Fig. 1 A). The only variable that we did not address (not the purpose of our study) was the antifreeze increase/decrease in volume due to temperature variability. Our research shows that the CS 705 Snow Adapter with a modified overflow tube and surfactant are suitable for North Dakota climate and geo/topographical conditions. It allows us to automatically and instantly have access to more accurate snow water equivalent data. The data are also more realistic time wise when called by phone via voice modem. Quantity wise, the data express the water equivalent of snow fall and is comparable with the other two NWS standard methods of measurement. The system can also be adjusted and adapted to suit other geographical areas with specific conditions like: more snow precipitation, milder temperatures in winter, mountain region, etc.

REFERENCES

Alter, J.C., "Shielded Storage Precipitation Gauges". Monthly Weather Review, July 1937

McCaughey, W. and Farnes, P.E., 1996. "Measuring Winter Precipitation with an Antifreeze-Based Tipping Bucket System". Proceedings 64th Western Snow Conference, Bent, OR.

McGurk, B. J., 1992. "Propylene Glycol and Ethanol as Replacement Antifreeze for Precipitation Gauges: Dilution, disposal and Safety". Proceedings 60th Western Snow Conference, Jackson Hole, WY.

Peck, E. L., 1997. "Improvement in Method to Adjust U. S. Solid Precipitation Records". Phase 1 Interim Report, August 1997.

	December 1997				*January 1998*				*February 1998*				*March 1998*			
Day	NWS Coop	Belfort Gauge	TE 525 CS 705	Max Temp F	NWS Coop	Belfort Gauge	TE 525 CS 705	Max Temp F	NWS Coop	Belfort Gauge	TE 525 CS 705	Max Temp F	NWS Coop	Belfort Gauge	TE 525 CS 705	Max Temp F
1				32			0.04	36	T			30	0.09	0.07	0.06	32
2	0.05			31	T		0.01	36	0.01			12	T		0.01	29
3				32				2				12	0.01			24
4	0.04			23	T			18	T			22	T			27
5	0.02	0.12		25	0.34	0.30	0.33	25	T			24	0.04	0.03	0.04	33
6	T		0.08	26	0.01		0.01	20				22	0.04	0.04	0.06	24
7	T			26	T			21	Replaced the original CS705 Overflow Tube with a V-shaped tube and Surfactant added.			34	T			25
8	T		0.09	28	T		0.01	27				38	T			14
9	0.01		0.04	30	0.13	0.05	0.01	13				29				6
10	T			29				-4				31				5
11	T			22	0.11	0.10	0.03	-2				29				11
12			0.02	34			0.02	-6	T			26	T			22
13				34	0.03		0.01	3				30	T			31
14				38	0.04	0.03	0.07	10	0.10	0.05	0.04	34	T			21
15				39	T			16	0.02	0.02	0.04	37	0.08	0.08	0.06	30
16				38	0.01		0.01	20	0.07	0.15	0.13	41	T			30
17				37				13	0.33	0.27	0.26	38			0.01	38
18			0.02	38				11	0.01	0.03	0.03	36			0.02	42
19	T			29	T			3	0.01	0.01	0.02	36				39
20				28	T			9				35			0.02	41
21			0.01	32	T			19	T			35	T			42
22				32	0.01		0.02	26	T	0.01	0.01	43	0.03	0.03		35
23				35	0.03	0.03	0.02	24		0.01	0.01	41			0.06	37
24				29	0.06			22	T		0.03	48	0.01			34
25	0.01			31	0.03	0.06	0.06	26	0.71	0.45	0.49	44			0.03	53
26				26	0.01		0.01	26		0.05	0.07	46	0.02		0.01	50
27				32			0.01	28	0.32	0.14	0.15	37			0.01	47
28	T			26				29	0.12	0.16	0.19	34			0.04	56
29	0.01		0.12	28				27					0.66	0.62	0.55	38
30	0.30	0.16	0.10	26				27							0.06	50
31				20	T			29								
Avg	**0.44**	**0.28**	**0.48**	**30**	**0.81**	**0.57**	**0.67**	**18**	**1.70**	**1.35**	**1.47**	**30**	**0.97**	**0.87**	**1.04**	33

Table 3. 1997 - 1998 Winter Season Comparative Table. Daily Snow Precipitation Recorded by NWS Observer, Belford Gauge and TE525/CS705 Snow Adapter