INLAND WATERS BRANCH

DEPARTMENT OF THE ENVIRONMENT

Low Temperature Tests on Leupold & Stevens Type A-35 Recorders and Recorder Clocks

E.F. CHAPMAN

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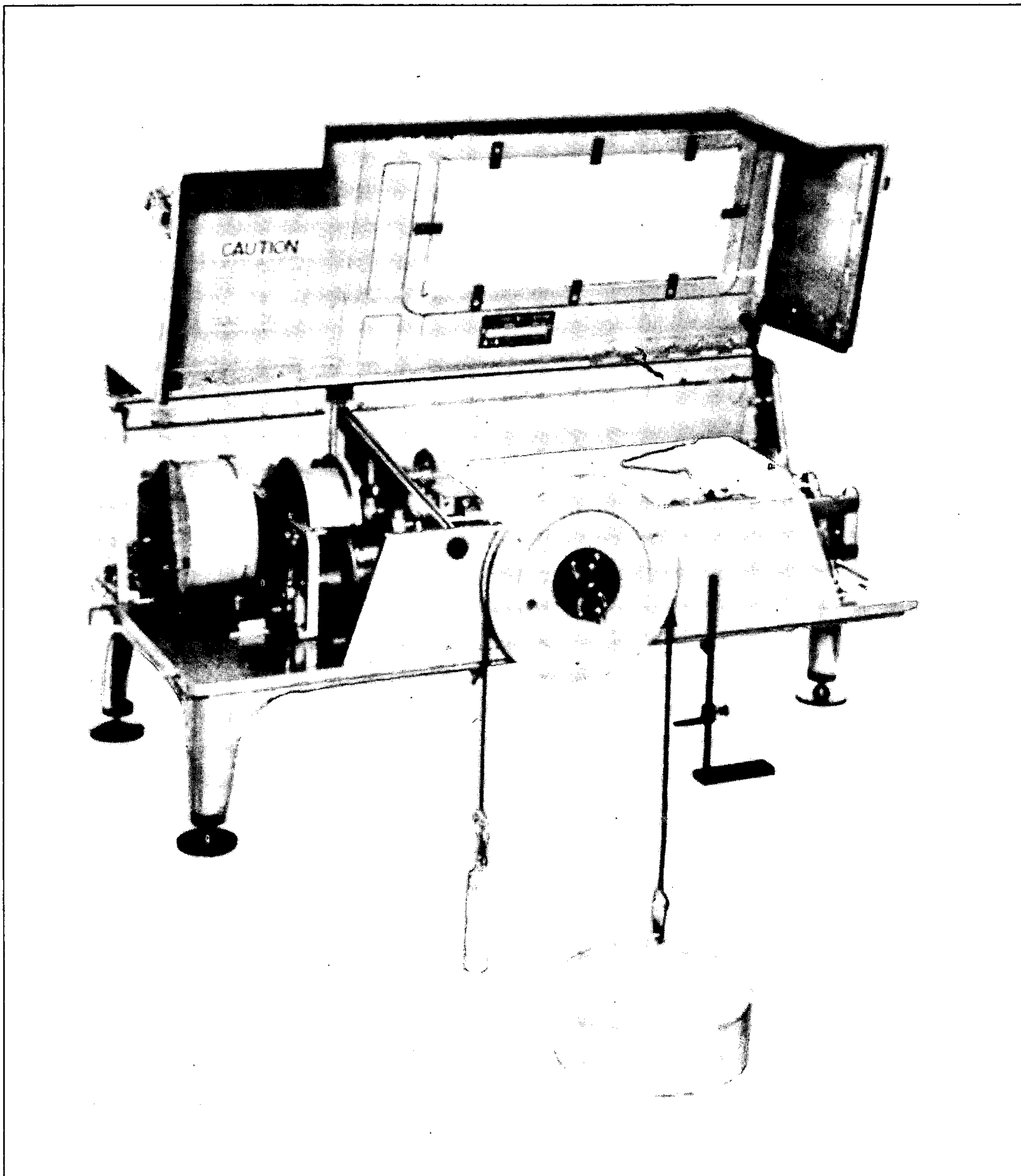

Water Level Recorder (Stevens Type A-35).

CANADA

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Contents

Illustrations

Preface

The Water Survey's Equipment Calibration and Development Unit in Calgary recently obtained a low temperature chamber for its laboratory. Using this cold chamber, it is now possible to simulate the extreme low temperatures which the equipment will encounter in the far north and, in this way, determine how best to service the equipment to provide satisfactory uninterrupted operation.

This report describes the methods and results of low temperature tests on automatic water storage recording equipment used by the Water Survey of Canada.

The recording equipment (see Frontispiece Photo) consists essentially of two mechanisms, a chart drive to move a strip chart at a constant speed and a pen movement to provide a trace on the strip chart to indicate water levels. The chart drive is powered by a negator spring and regulated by a clock mechanism; the pen movement can be actuated by a float, as shown, or by other methods.

In the first part of this report, the operation of the recorder clocks is variously described as slow or very slow, without any attempt being made to delineate these conditions more accurately. It would have been preferable to be able to accurately record the amount that the clock slowed at extremely low temperatures; however, the oscilloscope, which was to be used to record the magnitude of the balance-wheel sweep and the resulting change in timing, failed at the start of the tests and could not be readily repaired.

In the second part of this report, an electronic timer was available to measure the accuracy of clock operation at very low temperatures. This accuracy is reflected in the results of tests on clocks which were specially serviced by two different agencies.

LOW-TEMPERATURE TESTS
NEGATOR-SPRING DRIVEN A-35 RECORDERS

INTRODUCTION

The Water Survey of Canada utilizes a great number of Leupold & Stevens A-35 Water Level Recorders in its water survey networks. There has been evidence for many years that the reliability of this instrument suffers in the extremely cold environment of the far north. While many attempts have been made to isolate the causes of recorder failure and to improve the reliability of the instrument, no systematic study of the effects of sub-zero temperatures on the recorder clocks and the paper-drive mechanism has been possible prior to the study described herein.

It should be noted that there will be frequent references made in this report to times allotted for stabilizing temperatures in the cold chamber. These times are not significant in themselves, but are only an indication that there was consideration given to the requirement of good temperature stability in the recorder and clock mechanism. As the use of the cold chamber is new to the Division, such soaking times were established arbitrarily by the operator and were a function of his best judgment and the time that was available for the tests. Longer periods could have been allowed for stabilization of temperatures; in the opinion of the writer, however, sufficient time was allotted for all tests and the results should be indicative of actual operating conditions.

Of further concern at this point was the possibility that the recorder clocks, being in sealed cases, were not reaching the proper temperature even with the ample soaking periods which were allowed. The backs of several of the clocks were removed during the series of tests to allow all the clock components to reach chamber temperature. To further facilitate cooling, the recorder cases were left open so that the cold air, which was being moved rapidly through the chamber by the cooling fan, could circulate through the mechanism. It was noted, however, that the removal of the clock back did not improve the cooling operation substantially but that an extended soaking period was sufficient for a stable temperature condition.

EQUIPMENT

The Equipment Calibration and Development Unit acquired nineteen new Negator-Spring driven Leupold & Stevens Recorders on loan from the Water Survey's Calgary District Office. These instruments were manufactured during one production run so it was reasonable to assume that they were identical in construction and that the lubrication method was the same for each unit. Additional recorder clocks, specifically treated with a low temperature silicone lubricant, were also obtained from the Calgary District Office and these clocks were used in Test 4 with the above recorders.

The cold chamber is an insulated compartment with an inside dimension of six feet by six feet by seven feet high, and is equipped with shelves to accommodate several recorders.

An evaporator unit is suspended from the ceiling of the chamber and the cold air is circulated by means of a large fan behind the evaporator coils.

The compressor is a large, five horsepower, two-stage unit positioned outside the chamber and connected to the evaporator by insulated copper pipes. The compressor unit is air and water cooled and is controlled by a variable range thermostat mounted on the side of the chamber.

The combination of the large capacity compressor and the fan-driven air circulation on the evaporator unit resulted in an extremely rapid and efficient cooling system with a capability of changing from room temperature to -65°F in approximately eighty minutes. This rapid cooling rate can be very effective if many tests are to be conducted in a condensed time period, but as will be explained later, it can also cause problems and must be carefully controlled. Also, because of the rapid cooling rate of the freezing unit, the thermostat tends to over-control and difficulty is experienced in establishing and maintaining a truly stable temperature in the compartment. Therefore, it must be understood that although the temperatures in the accompanying tables are specific, they are in fact the mean of a temperature which will vary in either direction from one to two degrees depending on the ON or OFF condition of the compressor. The mean was established visually by the operator and therefore some slight latitude could be allowed.

The temperature of the units under test was noted on two remote reading thermometers, the sensor bulbs of which were taped together to ensure uniformity of temperature.

TEST NO. 1

Method

Ten Leupold & Stevens A-35 Recorders were placed in the cold chamber, set in operation, and then observed for several hours to ensure that the clocks were functioning properly. The freezer unit was then set in operation. The temperature was dropped rapidly to -28°F, and held at this temperature for twelve hours, following which it was then slowly stepped down during the next 32 hours and the condition of the instruments noted at the temperatures indicated in the accompanying table. At -62°F, the compressor was stopped, the chamber was allowed to warm to room temperature, and the instruments removed.

Observations

The condition of the clocks at some temperature stages is delineated as "slow" or "very slow". As already indicated, it could not be more exactly determined because the equipment with which the actual timing of each clock could be accurately appraised, was not available at the time of the tests. Therefore, the operation of the clock was described as "slow" if the balance wheel did not rotate in a lively manner through its proper arc. It would not necessarily mean that the clock was in fact running slow. Similarly, the "very slow" condition designated a very sluggish movement of the balance wheel through only a few degrees of arc. Again, it was not possible to state that the actual timing was slow.

Recorder	Temperature - Degrees Fahrenheit							
No.	-28°F	-36°F	-40°F	-47°F	-50°F	-54°F	-59°F	-62°F
69-43N	OK	OK	OK	STOP	STOP	STOP	STOP	STOP
69-42N	OK	OK	OK	OK	VERY SLOW	VERY SLOW	STOP	STOP
69-45N	OK	OK	OK	OK	SLOW	VERY SLOW	VERY SLOW	VERY SLOW
69-47N	OK	OK	SLOW	SLOW	STOP	STOP	STOP	STOP
69-46N	OK	OK	SLOW	SLOW	STOP	STOP	STOP	STOP
69-48N	OK	OK	OK	OK	OK	OK	VERY SLOW	VERY SLOW
69-44N	OK	OK	OK	OK	VERY SLOW	VERY SLOW	VERY SLOW	STOP
69-40N	OK	OK	OK	OK	VERY SLOW	VERY SLOW	VERY SLOW	STOP
69-39N	OK	OK	OK	OK	OK	OK	SLOW	SLOW
69-41N	OK	OK	OK	SLOW	SLOW	VERY SLOW	VERY SLOW	STOP

TEST NO. 2

Method

Seven new recorders were placed in the chamber at +70°F and set in operation. After a period of observation, the temperature was lowered to -58°F within seventy-five minutes. All of the recorders ceased operation. The temperature was then raised to -40°F and the clocks were re-started and allowed to stabilize for fifteen hours. After the restabilizing period, the temperature was very slowly stepped down to -59°F. The observations made are shown in the table below.

Observations

During the very rapid temperature drop, frequent visual inspections were made of the recorders. Due to the rapidly changing conditions, it was not possible to note the exact temperature at which the recorders stopped.

It was observed, however, that performance diminished very rapidly and that at approximately -40°F, all clocks were operating in a sluggish and erratic manner. At -58°F all clocks had stopped.

When the temperature was decreased slowly to -59°F, all recorders were functioning normally at -40°F but only two continued to operate at -59°F, only one of which was operating normally.

During this test, an interesting observation was made which was later confirmed in other tests. The recorder clock which stops due to extreme cold conditions will not normally restart when the temperature warms but must, in fact, be started manually by first removing the spring pressure from the clock mechanism.

Recorder No.	Rapid Drop -58°F		Temperatures Stepped Down Slowly -40°F	-47°F	-56°F	-59°F
69-29N	STOP	CLOCK RESTARTED	OK	STOP	STOP	STOP
69-30N	STOP	CLOCK RESTARTED	OK	VERY SLOW	STOP	STOP
69-31N	STOP	CLOCK RESTARTED	OK	VERY SLOW	STOP	STOP
69-32N	STOP	CLOCK RESTARTED	OK	VERY SLOW	STOP	STOP
69-33N	STOP	CLOCK RESTARTED	OK	OK	SLOW	SLOW
69-34N	STOP	CLOCK RESTARTED	OK	STOP	STOP	STOP
69-27N	STOP	CLOCK RESTARTED	OK	OK	OK	OK

TEST NO. 3

Method

Two A-35 recorders chosen at random were tested at room temperature with an accurate balance to determine the torque available at the clock connection for operating the paper drive and the recorder clock. The process was repeated at -59°F.

Observations

A slight problem developed in observing the available torque at cold temperatures. The recorder shaft, in a static condition, appeared to stick slightly and produce a lower torque rating. If the shaft was allowed to move very slowly in either direction, the torque reading showed an appreciably higher figure. This is the reason for the "static" and the "motion" figures in the following torque table. At room temperature this problem did not exist.

Recorder	Torque at +70°F	Torque at -59°F
69-41N	70 in. ounces	(static) 60 in. Ozs. (motion) 68 in. Ozs.
69-48N	70 in. ounces	(static) 57.5 in. Ozs. (motion) 65 in. Ozs.

TEST NO. 4

Method

Thirteen recorders were slowly cooled to -57°F and held at that temperature for 12 hours. Recorder clocks which stopped or which operated in a sluggish manner were replaced by clocks which had been especially prepared for cold weather operation by the proper application of "Moebius Syntalube Arctic" oil. After an extended period of operation with these specially lubricated clocks, the condition of each recorder was noted as in the table below.

Observations

Of the thirteen recorders tested, only one continued to operate in an acceptable manner using the clock received from the factory; the clocks on the other twelve instruments had to be replaced with the specially prepared clocks.

Operation of the recorders improved significantly with the specially prepared clocks and none of the recorders failed to operate; in fact, ten of the recorders with specially lubricated clocks operated normally at this extremely cold temperature.

Recorder	Temperature	Condition
69-46N	-57°F	GOOD
69-47N	-56°F	VERY SLOW
69-39N	-57°F	GOOD
69-40N	-57°F	GOOD
69-41N	-57°F	SLOW
69-42N	-57°F	GOOD
69-43N	-57°F	GOOD
69-44N	-58°F	GOOD
69-48N	-58°F	GOOD
69-45N	-58°F	GOOD
69-36N	-58°F	GOOD
69-35N	-58°F	GOOD
69-27N*	-58°F	GOOD

* Only this one recorder, No. 69-27N, using its original clock, operated in a normal manner (for a whole week) at temperatures of -50 to -60°F. No explanation is offered for the exceptional performance of this one recorder.

CONCLUSIONS

The results of these tests appear to contradict many established concepts of proper recorder operation. The results are discussed in the following:

1. New Leupold & Stevens, type A-35, negator-spring driven recorders are reliable to -40°F. The tables indicate that all of the seventeen recorders in Tests 1 and 2 continued to function at approximately -40°F, although two clocks operated in a sluggish manner. At -47°F, three recorders had stopped, with only eight of the remaining fourteen operating normally. At -59°F, all but five recorders had stopped, with only one functioning normally.

2. The tests appear to indicate that the major cause of recorder stoppage in cold weather is the congealing of oil in the clock escapement and balance wheel, rather than the increased friction of the paper-drive mechanism.

   It appears that there is no need to change the oiling techniques or the type of oil which is presently used in the paper-drive mechanism, as it has been demonstrated that there is ample torque available to drive the clock and the paper drive at -60°F.

3. Clocks which stop due to cold temperatures normally will not start when warmed but will remain with the escapement in a locked condition until the pressure is relieved manually. In almost every case of clock stoppage, an increase in torque to the clock would not keep it operating, nor would it restart a clock that had stopped. Increased pressure was applied to clocks which were operating in a sluggish manner, to the extent that gear failure was imminent, resulting only in the fact that the escapement would lock and the clock would cease to function.

4. When measured at the clock-drive point, torque of the negator spring at extremely cold temperatures is only slightly less than that at normal room temperatures. It is possible that the increased drag of the recorder mechanism is offset partially by the increased tension of the spring steel due to this low temperature.

5. Recorders which are chilled rapidly will cease to operate at a relatively higher temperature than those which are cooled slowly. This rapid cooling could result, for instance, from removing the instrument from a warm car and placing it in an extremely cold shelter.

6. The accuracy of the clock at low temperatures is of secondary importance. It has been demonstrated that a clock will not usually restart when it has been stopped by cold conditions. Therefore, it would seem of paramount importance that the clock keep operating, even if in a slow condition, so that it will resume normal operation when the weather warms. With the clocks specially conditioned for cold temperatures, the operation of the escapement becomes sluggish upon occasion, but the clocks normally do not stop.

RECOMMENDATIONS

1. It is recommended that when ordering new recorders, the clocks be specially serviced for cold-weather operation in accordance with exact specifications set down by the Water Survey of Canada. The oil and the preparation utilized in these tests is the "Moebius Syntalube Arctic" preparation. As yet, no superior substitute has been found.

2. Increasing the torque to the recorder clock for cold weather operation, by changing the size or the type of the driving mechanism, is not recommended since damage to the clock escapement could result from this type of modification.

3. If a recorder is cooled rapidly at the time of its installation, it should be checked within a period of one day; if the clock has stopped due to the rapid cooling, it should be restarted manually. If the clock has been properly oiled, it will, in most instances, continue to operate normally.

4. When recorders stop under extreme cold conditions, the clock should always be replaced with one which has been specially serviced for cold weather operation.

LOW-TEMPERATURE TESTS
A-35 RECORDER CLOCKS

INTRODUCTION

The following tests were made to determine the relative efficiencies of two clock repair agencies which were providing recorder maintenance service for the Calgary District Office of the Water Survey of Canada. The procedures for oiling the recorder clocks followed precisely the techniques and materials prescribed by the manufacturers of "Moebius Syntalube Arctic Oils" - the best combination of clock oiling material and technique which has yet been found for consistent clock operation under extremely cold conditions.

In tests previously conducted in the low temperature laboratory of the National Research Council in Ottawa, several clocks were tested using low temperature oils supplied by major oil companies and local clock repair agencies. "Moebius Syntalube Arctic" oil when used in conjunction with the manufacturers oiling technique, proved to be superior to other lubricants tested, particularly at temperatures below -40°F. Before carrying out these earlier tests, an accumulation of frost was observed on the clock gears of a field recorder. It was theorized that this could possibly be the cause of clock stoppage. During the tests, however, moist air was applied until the gears were heavy with frost without affecting the operation of the clock; it was established with reasonable certainty that frost build-up in the clock is not a serious condition.

Test Procedures

Each of the two clock repair agencies prepared three Leupold & Stevens A-35 recorder clocks for cold weather operation by the application of "Moebius Syntalube Arctic" oil. The agencies had been instructed to follow the manufacturers preparation procedures in order that the clocks would receive similar preparation.

The clocks were then placed in the cold chamber and were suitably weighted to simulate actual working conditions. After a period of operation to assure that all the clocks were running freely, they were accurately timed at room temperature by the use of an electronic clock timer. As the actual timing of the clocks at room temperature was not significant for these tests, this timing was only used as a base for comparison of timings later obtained at low temperatures as the tests progressed.

It should be noted also, that the date and time of each set of readings is indicated on the left of the table. These times are not significant in themselves, but are an indication that a considerable period of time was allotted between temperature changes in order to allow the components in the clock to stabilize. Although the times allotted were arbitrary, they were nevertheless considered to be sufficient for temperature stability. It should be noted also, that as the temperature in the chamber varies slightly as the compressor cycles, the temperatures indicated are a visual mean temperature as observed by the operator. Therefore, a latitude of one to two degrees is quite possible.

The temperature in the chamber was lowered to -10°F and the clocks were allowed to soak at this temperature for approximately 24 hours. The clocks were then timed electronically. The temperature was then stepped down in 10 degrees increments (over the next 36 hours) and timing was noted at each temperature interval.

Observations

In the table, the three clocks in Group I were serviced by one of the clock repair agencies and the three clocks in Group II by the other. All of the clocks in the first group maintained acceptable accuracy at all temperature ranges. In the second group, the operation of the clocks became erratic as the temperature was lowered; at -40°F, the three clocks had slowed perceptibly, and at -60°F, two of the clocks had stopped.

			GROUP I			GROUP II		
Date	Time	Temp	1	2	3	4	5	6
		+72°F	0.0	0.0	0.0	0.0	0.0	0.0
Oct. 21	07:15	-10°F	+15S	+ 5S	+ 5S	0	+ 5S	-15S
Oct. 22	07:15	-20°F	+15S	-30S	+ 5S	0	+ 40S	-15S
Oct. 22	10:07	-30°F	+30S	0	+ 5S	- 35S	+ 40S	-45S
Oct. 22	11:37	-40°F	+15S	-15S	+20S	- 85S	- 50S	-35S
Oct. 22	13:31	-50°F	0	-45S	+35S	-230S	-185S	STOP
Oct. 23	19:00	-60°F	0	-50S	-10S	STOP	-355S	STOP

Gain (+) or Loss (-) in seconds per 24-hour period.

Conclusions

From the test results, it is evident that an extremely cold environment is only one condition that must be reckoned with to achieve proper operation of the Water Survey's automatic recording equipment; it has become evident that improper servicing of the clocks intended for recorders in extreme cold conditions can also be a significant contributor to unsatisfactory operation.

The exact reason for the different performance of the clocks cannot be pinpointed. The material and technique for oiling and preparing the clocks for winter operation were specified by the Water Survey of Canada personnel. It can only be assumed that one agency prepared the clocks in a more proficient manner than the other.

This test has brought out the apparent need for occasional comparative testing of this type of equipment to ensure that the methods, as well as the materials used, conform to the best possible standards attainable.