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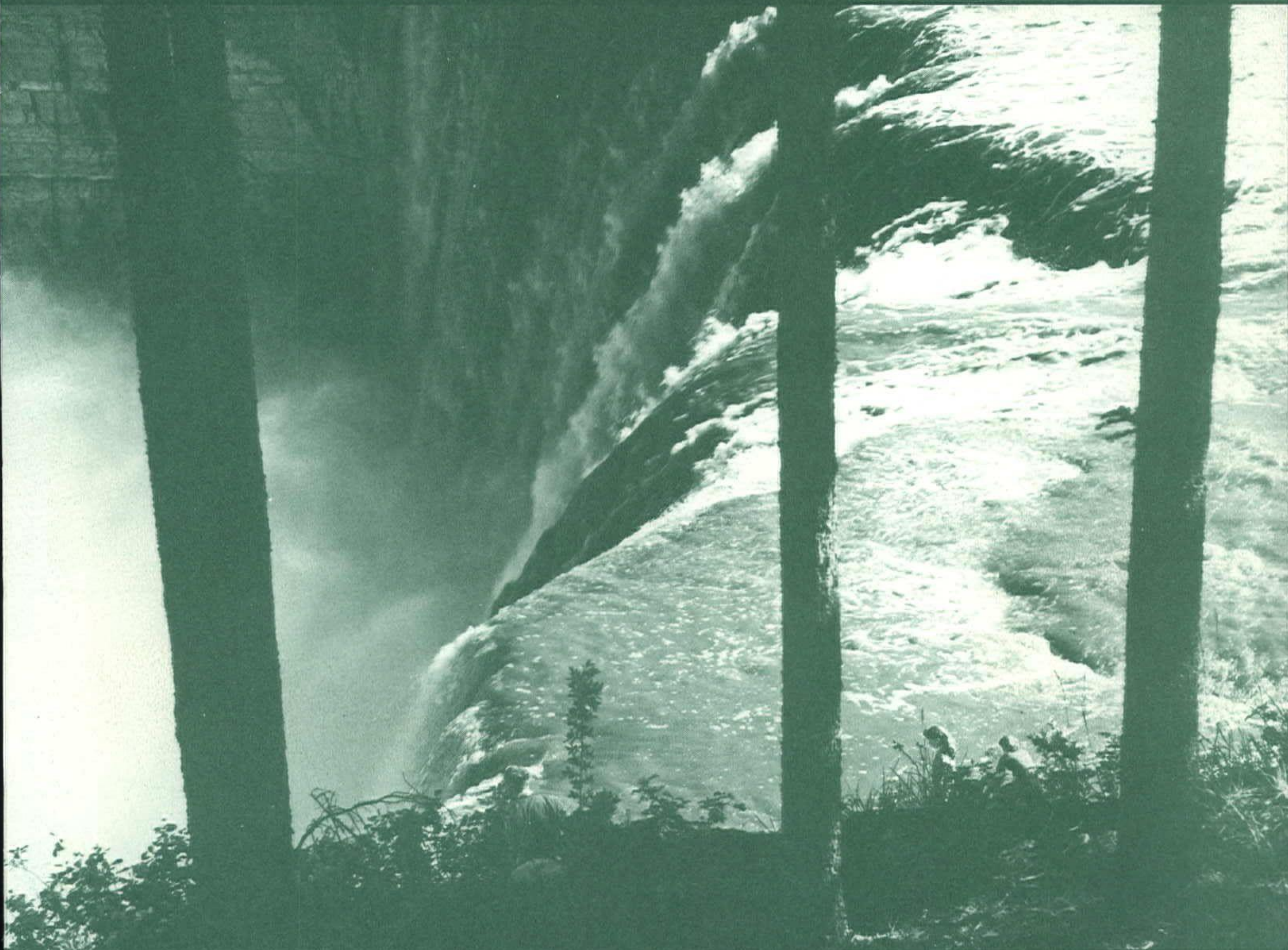

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INLAND WATERS DIRECTORATE,
WATER RESOURCES BRANCH,
OTTAWA, CANADA, 1973

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Introduction

On August 17, 1971, an Exactel Hydrogauge was placed in service at the Kitimat River hydrometric station below Hirsch Creek. Some difficulties were experienced in making the instrument operate correctly. These difficulties are described herein because it is felt that these operational problems should be made known to all personnel who will be operating this type of instrument. In this way the problems that have already been overcome should not cause any delays when this type of instrument is put into operation at other locations. *When other types of problems in the operation of the Exactel Hydrogauge occur, it is hoped that the technician responsible for the Exactel Hydrogauge operation will prepare and distribute a newsletter on the problems encountered and how they were overcome.*

For the benefit of those not familiar with the Exactel Hydrogauge, a description is given of the operating principle, the measurement technique, the accuracy and errors of measurement, the method of installing the piezometer lines, and the problems associated with the operation of the instrument. The methods of correcting these problems are also included.

Description of the Exactel Hydrogauge

OPERATING PRINCIPLE

Pascal's Principle (1623) states: "If a fluid (or a gas) at rest, completely fills a closed container, a pressure increment applied at one point on the fluid is transmitted undiminished to every other point in the fluid". The hydrogauge operates on this principle by measuring pressure or weight of water on top of an orifice or outlet of a tube that carries a gas. This gas is released into the fluid being measured or weighed.

The pressure on the gas is transmitted back through the line to an air pocket or bellows, which in turn exerts a force on a balance arm (Fig. 1). The balance arm or beam is kept level by the movement of a weight, called a poise, which rolls along the beam. When the beam is not in balance, its end touches an electrical contact, which, in turn, by means of a motor and chain, moves the poise bringing the beam back into balance, thus breaking the electrical circuit. As the poise is moved along the beam, the recorder is activated through the output drive gear.

MEASUREMENT TECHNIQUE

The measurement technique is based on the purge-bubble principle. A bubbler tube called a piezometer line, usually 1/4" to 3/8" in diameter, is run to the bottom or other suitable reference point in the river or lake that is being gauged (Fig. 2). The upper end of the line is connected to a source of compressed gas, usually bottled nitrogen, which is allowed to pass into the line at a low rate restricted by a throttling or metering valve (Fig. 3). The gas passes along the tube and bubbles up through the water. The pressure of the gas in the line is equal to the hydrostatic pressure of the water above the orifice, the place where the bubble line terminates. The pressure is then manifolded or "T'd" to a suitable pressure-responsive instrument calibrated to operate a recorder.

The bubble rate is adjusted to a suitably slow rate to conserve the gas supply. For bodies of water subject to rapid rise, the gas flow or bubble rate must be great enough to maintain the bubble rate coming out of the orifice against the rising hydrostatic back pressure. The typical bubble range at the sight glass is between 10 and 200 bubbles per minute. A pressure regulator is used to reduce the nitrogen tank pressure to a point slightly higher than the maximum pressure required to overcome the hydrostatic pressure of the water that is being gauged.

The oil-filled sight glass is provided solely for visual inspection of the bubble rate. The metering valve is also combined in the sight feed glass assembly for easy adjustment of the bubble rate.

A constant flow regulator is used to keep the flow relatively uniform and to stop variations that would be caused by wide fluctuations in the hydrostatic pressure of the gauged water body. If the back pressure or weight of water over the orifice in the piezometer line was reduced by 50%, the bubble rate would be doubled without a constant flow regulator. This would waste gas but would not introduce any error. According to the manufacturers of the Exactel Hydrogauge, the use of a constant flow regulator for ranges of less than eighty feet is not recommended because the internal diaphragm can be ruptured or made inoperative by oil from the sight glass leaking back into the regulator. Thus the sight feed glass is only half filled to prevent the oil from leaking back into the regulator. The rupturing of the diaphragm and the oil working back into the regulator is usually caused by an improper sequence of operations in changing the nitrogen cylinders. The manufacturers of Exactel Hydrogauge state: "Below 80 feet of range, the change of bubble rate that occurs with omission of the regulator is usually insignificant."

ACCURACY AND ERRORS

The purge-bubble system, under favourable conditions, is stated to be useful for sensing variations in depths of 0.001 foot. Two theoretical sources of measuring errors exist in the purge-bubble system but they are negligible for practical application.

(1) The pressure drop caused by the flow of gas in the bubbler line. At a bubble rate of 8 bubbles per minute, the error amounts to 0.003 foot of water per 1000 feet of 3/16" I.D. piezometer line. This is a figure quoted by the manufacturer. As the bubble rate gets higher, it can be assumed that there would

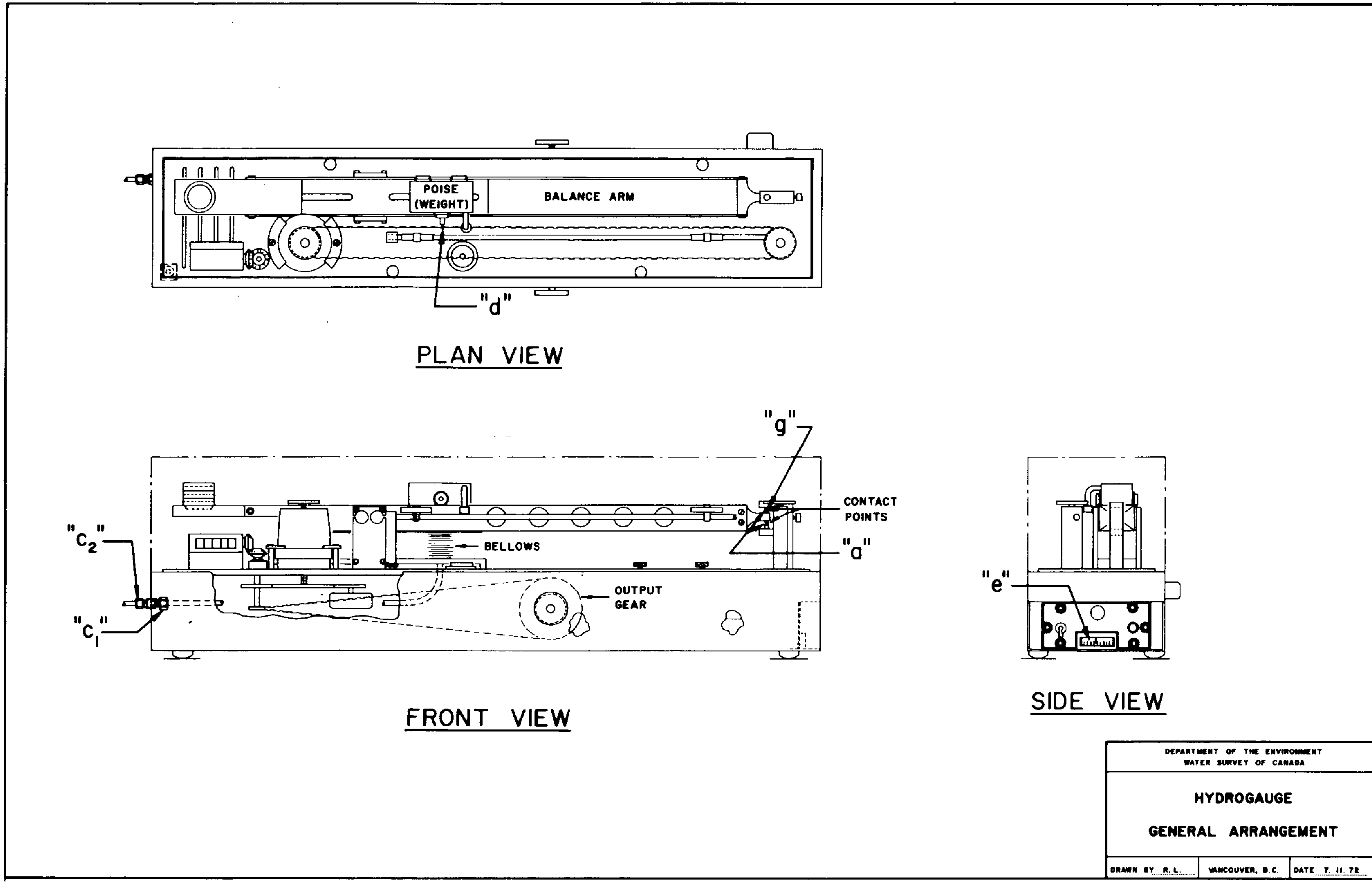


Figure 1. Plan and elevation views showing general arrangement of the Exactel Hydrogauge.

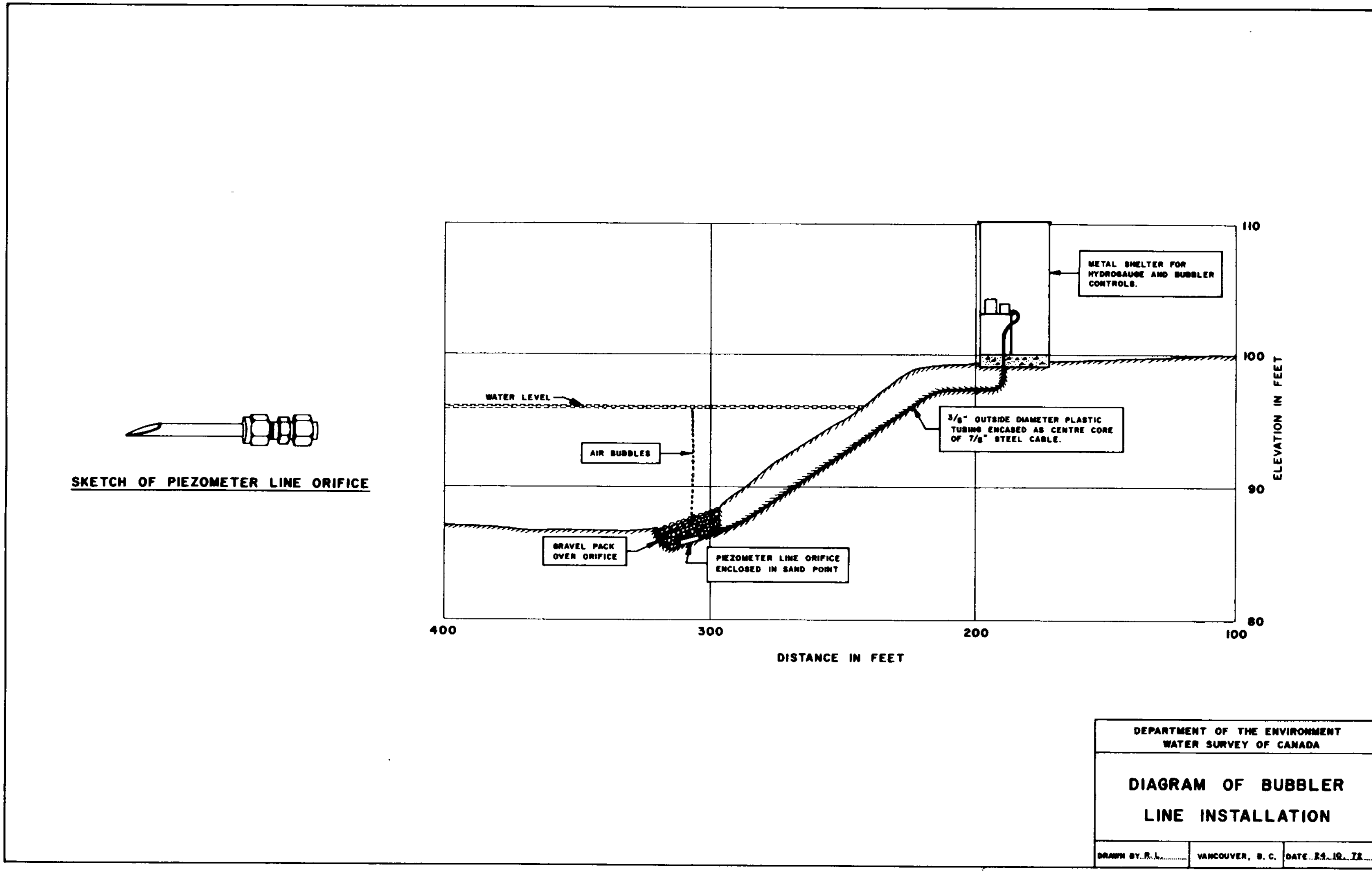


Figure 2. Cross-section showing typical bubbler line installation.

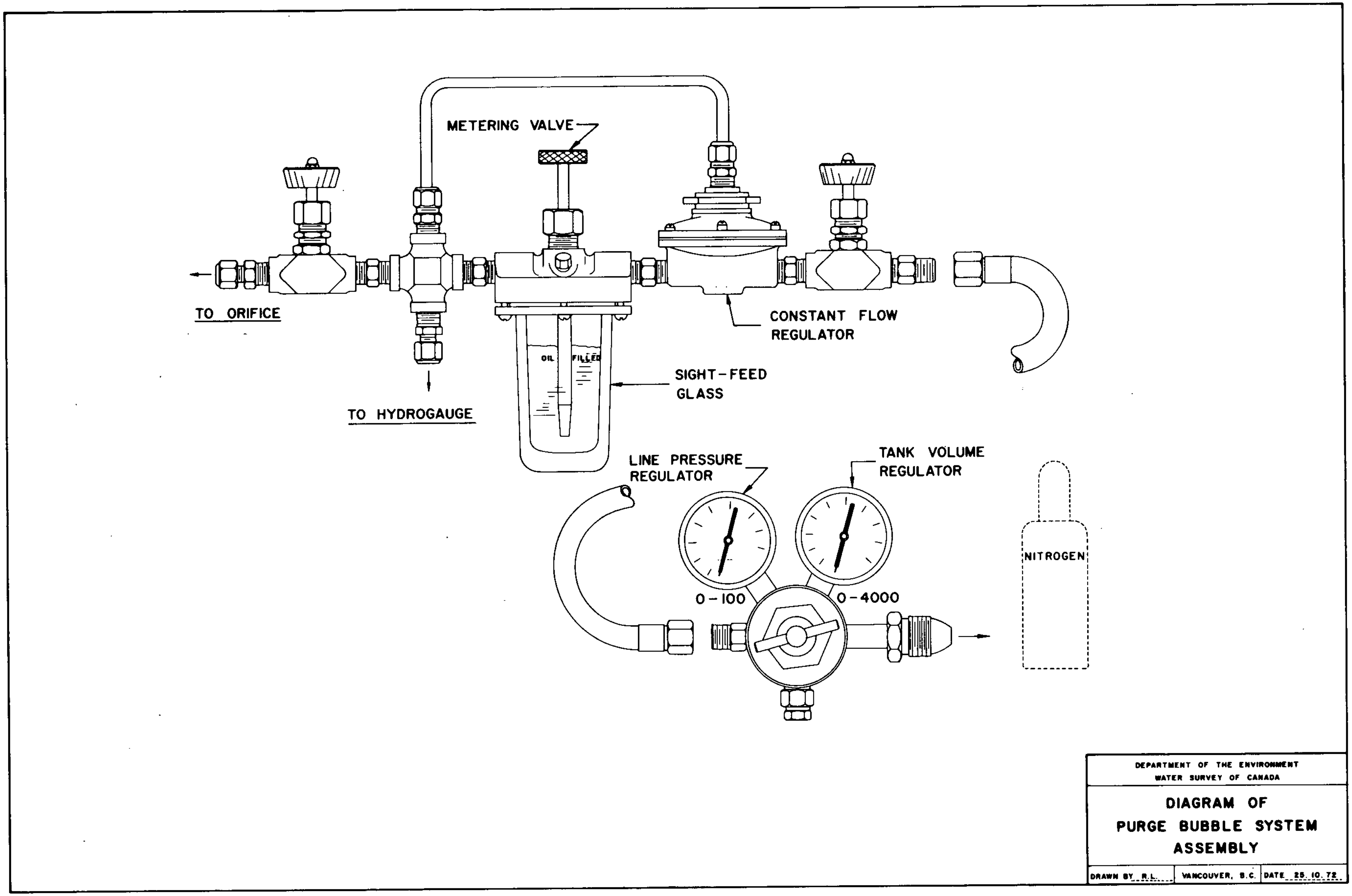


Figure 3. Typical Purge Bubble Assembly.

be less error caused by the flow of gas in the bubble line.

(2) The vertical component of the weight of gas in the bubbler line. The manufacturer does not quote any figures so that this source of error is assumed to be considerably less than that caused by the pressure drop.

In addition to the two measuring system errors above, errors may also develop due to wave action. The bubble principle is responsive substantially to the depth of water at the wave trough when wave action is present. This is due to pressurized gas in the bubbler line being released suddenly when the hydrostatic pressure is reduced, as when the trough of a wave passes over the orifice. The gas pressure then rebuilds slowly at a speed determined by the bubble rate.

The Exactel Hydrogauges employ restrictive filters to damp out wave action and prevent chart "painting". These filters are located at the pressure inlet ports of the instrument.

At the hydrogauge location on the Kitimat River, the water has a surge effect most of the time of ± 0.10 foot, with greater variations at higher stages. Figure 4A shows that no surge or painting effect has occurred on the recorder chart. Figure 4B shows the painting effect of a recorder activated by a mercury manometer gauge (Iskut River above Snippaker Creek) that does not have restrictive filters.

INSTALLATION OF PIEZOMETER LINES

The following is quoted from the Exactel Hydrogauge Application Note No. 1:

Some General Guidelines for Installation of Piezometer Lines. These guidelines should be observed rather carefully, as deviations from these principles have caused occasional difficulty with such systems.

(1) It is essential that all plumbing be leak-tight.

(2) Care must be taken to avoid dips or valleys in the piezometer line where water can accumulate. This is best accomplished by having a continuous descent of the piezometer line between the pressure instrument and the lower orifice. The slope need not be uniform but it should be free of valleys.

(3) The piezometer line should be buried a short distance beneath the ground surface or otherwise protected from the direct sun, which tends to introduce small perturbations due to expansion and contraction of the gas, producing variations in density of the gas in the line. In severe climates, sudden cooling of the line, as at dusk, can cause contraction of the gas to the point where water backs up the line, resulting in substantial error. (Ed. note: this would seem possible only with an extremely low bubble rate).

(4) The lower tip of the piezometer line should be well secured and located to prevent the orifice tip being buried in silt. (An instrument using the purge-bubble principle is able to purge itself of silt except under severa silting conditions such as in flooding streams.)

(5) The last few inches of the piezometer line should be run vertically downward and terminated with approximately 3/16 inch ID tubing cut diagonally at an angle of approximately 15°. This practice eliminates 'blurping' and produces bubbles of small, uniform diameter. (Fig. 2).

(6) Keep the piezometer internal volume of the pneumatic system to a practical minimum.

Table 1. Hydrogauge specifications

Standard ranges	0 – 12 1/2, 25, 50, 100 ft of water
Accuracy: including linearity and hysteresis	0.2% FS
Repeatability	0.1% FS or 0.01 ft of water
Resolution	Less than 0.03% or 0.01 ft of water (whichever is greater)
Operable temperature range	-40°F to +140°F
Rated temperature range	0°F to +120°F
Thermal zero shift, less than	0.005%/°F
Thermal sensitivity shift, less than	0.005%FS/°F
Least count	0.01 ft of water
Instrument reference calibration temperature	68°F
Optional output shaft torque (minimum)	25 OZ-in
Power	40 MA at 6 VDC
Batteries: ten standard alkaline 1.5 VDC cells recommended	Optional
Output shaft ratio: revolutions for full scale	100
Response time: nominal for full-scale travel	4 minutes
Weight	35 lbs

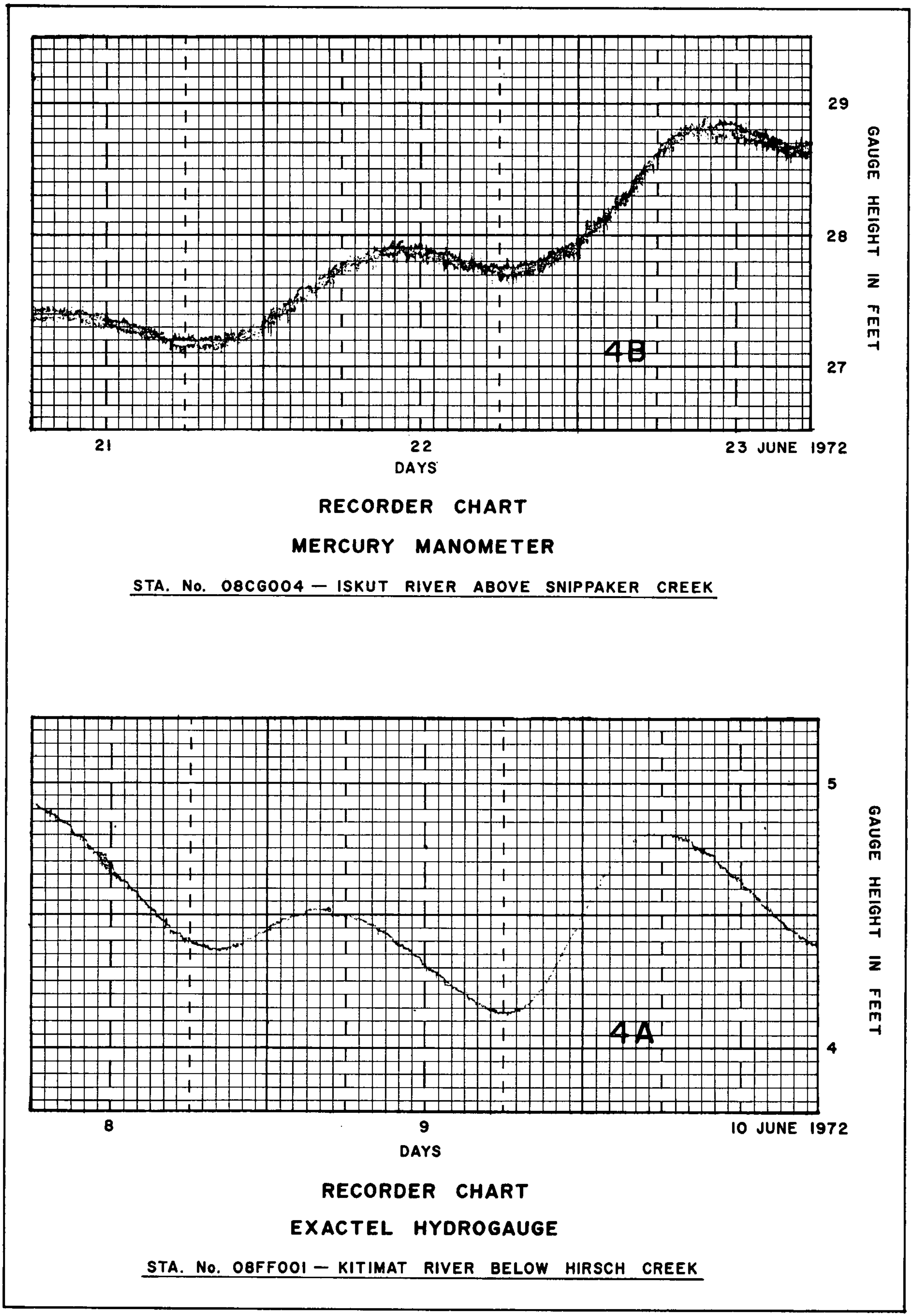


Figure 4. (A) Exactel Hydrogauge activated recorder chart, Kitimat River below Hirsch Creek. (B) Mercury Manometer activated recorder chart, Iskut River above Snippaker Creek.

Only guideline number 5 is different from the procedure presently followed for bubbler lines installed to activate mercury manometers. In the Kitimat River installation of the Exactel Hydrogauge, the orifice was put in the centre of a sandpoint that sloped gently downward (not vertically) and placed approximately one foot below the streambed. The specifications of the Exactel Hydrogauge are listed in Table I.

Operational Problems and Methods of Correction

FUSES WERE CONTINUALLY BURNING OUT WHEN THE INSTRUMENT WAS FIRST ASSEMBLED

(1) The gap between the electrical points and the beam balance arm was too small. It caused the electric current to flow to the beam balance from both directions, thus causing a short circuit and blowing the fuse.

(2) The problem was corrected by adjusting the gap spacing. This spacing should be 0.002" as per specifications, but this was found to be too small. The opening has now been adjusted to 0.005", which appears to be adequate.

(3) Point "a" on Figure 1 shows the location of the problem. The fuses are located behind the voltage indicator which comes out when the battery pack is removed.

ATTACHMENT FROM THE HYDROGAUGE LADDER CHAIN TO THE A-35 RECORDER WAS NOT OPERATING SATISFACTORILY

(1) The attachment would not allow slippage for the pen and margin settings of the pen attachment.

(2) The attachment was improved by the means of a sleeve made up in the machine shop.

(3) Point "b" on Figure 5 shows the location of the attachment.

RECORDER TRACE PRODUCED FALSE SURGES AND ALSO PAINTING OF THE CHART

(1) The painting of the recorder chart and the false surges were caused by leaks in the nitrogen gas system.

(2) The leaks were found at various points. The hardest one to locate was at bulkhead fitting "c_1" (Fig. 1). Any connection inside the instrument was assumed to be factory sealed and thus this connection was not tightened for a considerable length of time. Leaks at both ends of the plastic 1/4" O.D. tubing were corrected by inserting metal interior sleeves so that the Swagelok fitting tightened against the sleeve.

(3) Points "c_1" and "c_2" on Figure 1 show the location of the problem. Figure 5 shows the other end of the 1/4" O.D. tubing connection.

POISE DRIVE PIN SLIPPED OUT OF THE DRIVE CHAIN

(1) When the problem was reported to the manufacturer, his statement was: "The poise can only come out of the chain by misalignment of the flexures. The pin should literally float in the chain from end to end of the beam. Accuracy will be degraded if there is any binding in the chain or by the poise binding on the beam."

(2) The problem was corrected by bending the drive pin with an upturn after it went through the chain. This still allows the pin to float in the chain.

(3) Point "d" on Figure 1 shows the location of the drive pin.

VOLTAGE INDICATOR NEEDLE WAS STICKING IN COLD WEATHER

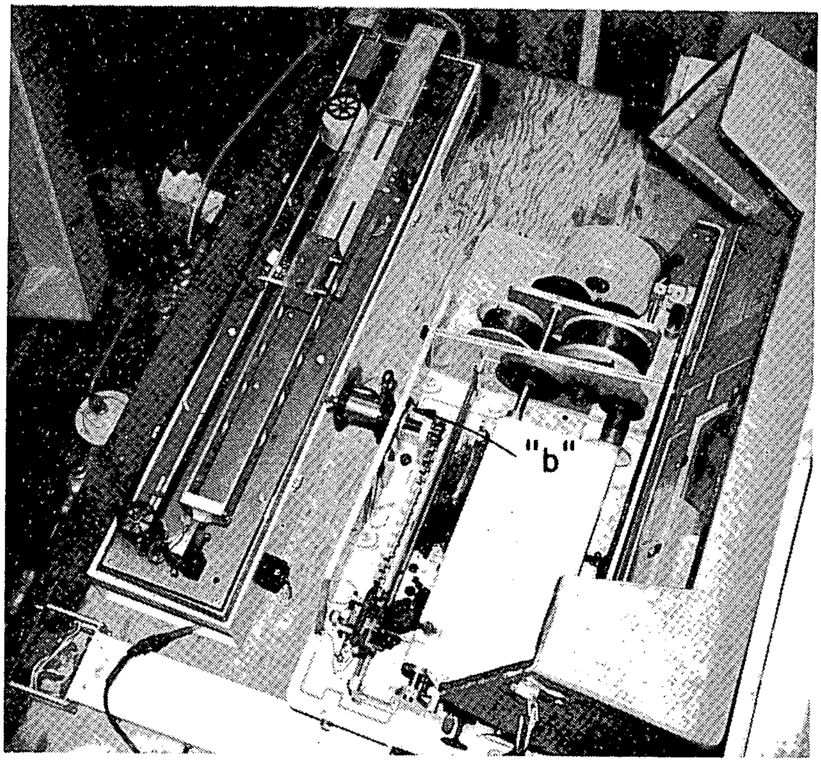
(1) The voltage indicator needle must have been jarred.

(2) The problem was solved by using an independent voltage meter (alternatively a heavy duty meter could be installed).

(3) Point "e" on Figure 1 shows the location of the problem.

NITROGEN BUBBLE LINE BECAME PLUGGED IN COLD WEATHER – CAUSE WAS ASSUMED TO BE ICE

(1) The bubble rate was set too low at 13 bubbles per minute.



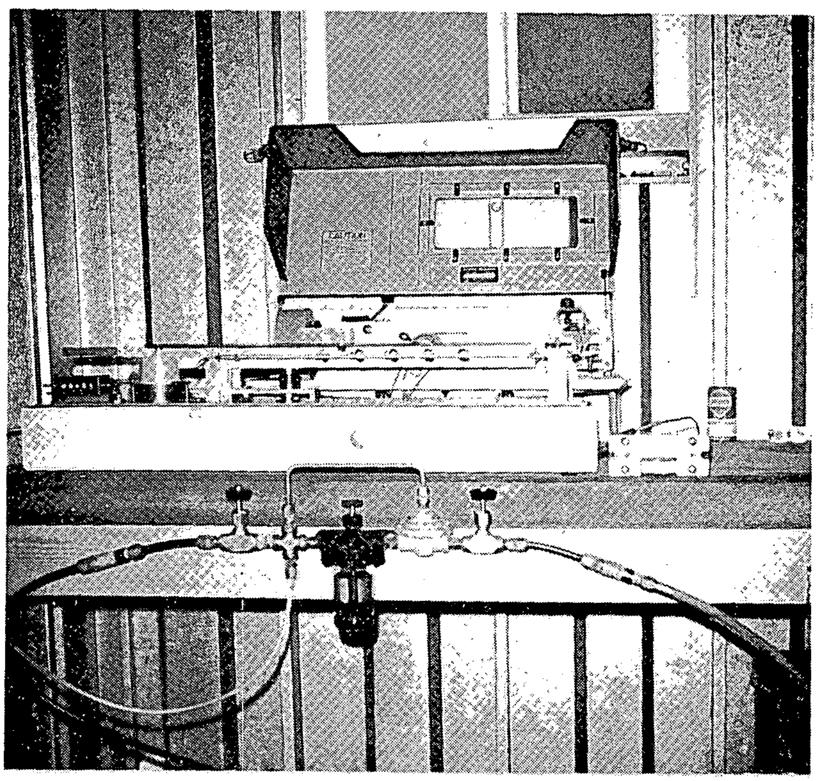


Figure 5. Bench installation of Hydrogauge.

(2) The line was cleaned out by applying full pressure from the tank at 1700 lbs. per square inch. The bubble rate was adjusted to 55 bubbles per minute and the instrument appeared to operate better at this rate. When the manufacturer was informed of this situation, he stated: "Accuracy is degraded with the high bubble rate. We would suggest that a rate of 15 bubbles per minute be used in warm weather and that the rate be increased to 25 bubbles per minute under ice conditions." After receipt of the manufacturer's instructions the bubble rate was dropped to 12 bubbles per minute. The record for the next segment of chart was considered poor in comparison with the previous segment so the rate was raised to 52 bubbles per minute, where a better record developed. More experimentation is really needed to find the lowest bubble rate at which the instrument gives the best results.

UP-FUSE SHORTED OUT PERIODICALLY

(1) The centre pin became unsoldered and periodically dropped from the contact holder. When the contact pin dropped, the electric current entered the beam from both sides causing a short circuit and burning out the up-fuse.

(2) The problem was solved by re-soldering the contact pin to the contact holder. The manufacturer claimed that in the future, all contact pins would be press-fitted rather than soldered.

(3) Point "g" on Figure 1 shows the location of the problem.

FLASHLIGHT BATTERIES TESTED LOW DURING COLD TEMPERATURES

The length of life was approximately one and a half months.

(1) The short battery life could have been due to a bad set of batteries whose shelf life had just about expired.

(2) Heavy duty batteries may be required for cold weather operation. Possibly two 7.5-volt batteries could be used, similar to those on manometers (Ray-O-Vac No. 903).

Summary and Conclusions

The purpose of this report has been to present the operational problems encountered with the Exactel Hydrogauge and the solutions to those problems. Many of the problems have been the result of mechanical deficiencies in the manufacture of this instrument. Most of the problems have been reported to the manufacturer and he has given his assurance that future models will be improved.

A comparison of the Exactel Hydrogauge to a mercury activated manometer revealed these attractive features of the Exactel Hydrogauge.

1. Minimization of moving parts.
2. Air bellows to record the difference in the weight of water over the orifice.
3. The speed with which the instrument can follow a sudden rise or fall in a body of water (4 minutes to cover a 25-foot change of stage).
4. The restrictive filter that effectively eliminates painting of the chart caused by minor surge action.

More of these gauges should be installed at various locations in order to test them under different weather conditions. The life of a battery pack should be tested for this instrument in the Department's Cold Chamber; temperatures should be varied and the motor activated at least once every two minutes.

A reporting system should be established whereby other technicians will report their operating problems and solutions. These reports should be passed along by the District Offices to all Water Survey personnel operating Exactel gauges. This procedure would surely promote more effective and efficient operation of these instruments.

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