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1986 FIELD TRIAL
FRAZIL ICE RECORDER SYSTEM
NASHWAAK RIVER, N.B.

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by
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MANAGEMENT PERSPECTIVE

The development of a Frazil Ice Recording System was undertaken by the National Water Research Institute at the instigation of the Sub-Committee on River Ice, Environment New Brunswick. This report summarizes the system development to-date. The results here demonstrate the difficulties inherent in getting a time-series record of frazil ice events; and in interpreting the signals obtained from the sensor system. These initial efforts show that considerabl, more effort must be expended before fully satisfactory results can be obtained on a routine basis.

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ABSTRACT

Results are given from the second operational deployment of the NWRI Frazil Ice Recorder System. Described are modifications and tests resulting from earlier field trials, the selection of the deployment site in the Nashwaak River, New Brunswick, and the records obtained. Recommendations are made for future operations.

PERSPECTIVE DE GESTION

La mise au point d'un Système enregistreur de frasil a été entreprise à l'Institut national de recherche sur les eaux à l'instigation du Sous-comité sur la glace de cours d'eau d'Environnement Nouveau-Brunswick. Le présent rapport résume les travaux de mise au point accomplis jusqu'à maintenant. Les résultats présentés démontrent les difficultés que pose l'obtention d'une succession chronologique d'enregistrements des épisodes de formation de frasil ainsi que l'interprétation des signaux reçus du système capteur. Ces efforts initiaux montrent que de futurs efforts considérables seront nécessaires avant que puissent être obtenus régulièrement des résultats parfaitement satisfaisants.

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RÉSUMÉ

Les résultats de la deuxième installation opérationnelle du Système enregistreur de frasil de l'INRE sont présentés. Les modifications et les essais découlant d'antérieures mises à l'épreuve sur le terrain, le choix d'un emplacement d'installation dans la rivière Nashwaak (Nouveau-Brunswick) et les enregistrements obtenus sont décrits. Des recommandations concernant les travaux futurs sont présentées.

1.0 BACKGROUND

The formation of frazil ice appears to be one of the most troublesome of the various processes involved in the freeze up of rivers. Large quantities of frazil ice can be rapidly produced in fast flowing, turbulent sections of the channel and eventually reduce channel conveyance significantly. Frazil ice accumulation can cause flooding of river channels, and reduced flow or blockage at intakes for hydroelectric generating stations, industrial cooling water systems and city water supply systems. Studies of the dynamics of frazil ice events are in progress and it is clear that improvements in the instrumentation available to investigators in this field are needed.

Ford (1986) describes the NWRI Frazil Ice Recorder System, and the results of a field trial in December 1985 at the Sills Island Generating Station on the Trent-Severn Waterway near Frankford, Ontario. This field experience revealed some deficiencies which required modification to the sensor body prior to the present deployment.

The present report describes these modifications and reviews the results of a second field trial from 20 October through 27 November 1986, in the Naskwaak River, by Durham Bridge, New Brunswick.

The Frazil Ice Recorder System is designed to produce a continuous time series record of the concentration by mass of frazil ice at a fixed point in flowing water. It operates by measuring the change in temperature of a water/ice sample from the flow pumped through a heated pipe. By holding the sample flow rate and the rate of heating constant, the change in temperature of the sample will be reduced in proportion to the concentration of frazil ice in the water.

The System consists of a sensor body which is deployed in the river channel, and a control and recorder cabinet which is set up on the river bank. These two units are inter-connected by power and signal cables which are partially buried in the channel bottom for protection.

The sensor body is bullet shaped and contains a pump, a heater, and three electronic thermometers. Water is drawn into the intake, through the heater and pump, and ejected downstream of the body. One thermometer is at the intake, one at the heater outlet, and one at the downstream outlet from the body. The two temperature differentials measured provide a redundancy of data for checking. The inlet cone of the body is swept by a rotating agitator to prevent ice from plugging the inlet to the heater.

2.0 MODIFICATIONS

Based on the Sills Island deployment, some modifications were made to the sensor body.

It was suspected that ice might plug the inlet cone of the sensor body regardless of the agitator. Further tests were done in an ice flume, and it was found that frazil did adhere to the agitator but only at the tip end of its helix, where an ice ball formed. The agitator was modified by bending the tip end back on the helix to form a ring with no free end.

The progressive cavity type pump displayed poor flow stability over long periods of operation. At the suggestion of the manufacturer, extra plating was added to the rotor to tighten the seal with the stator. Further tests showed this improved stability to a satisfactory level.

Test data showed that the final water temperature at the downstream outlet was partially dependent on the internal temperature of the sensor body. This tended to mask very low ice concentration readings. Thermal insulation of the water piping through the sensor body was improved. After this, a change of 0.1 C in the pump water per degree C change of body temperature was still found. Further improvement of insulation is required.

3.0 OPTIMUM POSITIONING

Results from the Sills Island deployment of the System, with the sensor body at a depth of about 4 m, indicated very low frazil ice concentration (0.13 % by mass), even though adjacent hydro inlets were affected by icing conditions. Other observations by Tsang (1985) indicated that in shallow, relatively tranquil flows, the vertical distribution of frazil concentration is very skewed to the top 15 to 30 cm of the water column. These data are reproduced here in Figure 1. The proposed installation in the Naskwaak River at Durham Bridge, N.B. was reviewed (Roy, 1986) in order to choose an optimum location for the sensor body deployment. To achieve the desired result, the power and signal cables between the sensor body and the shore cabinet were lengthened. In addition, the field installation crew took care to place the sensor as close as possible to fast water in as shallow a depth as possible while still avoiding the risk of having the sensor body frozen into a developing ice cover.

4.0 FIELD INSTALLATION

With diver assistance, the System was installed in the Nashwaak River at Durham Bridge on 20 October, 1986. This site is also the location of a Water Survey of Canada stream gauging station. River surface level was 18.1 m relative to datum. It was estimated by Water Survey of Canada that the mean level for the winter would be 18 m, and that an ice cover thickness of about 1 m maximum could be expected at this site. Data from the gauging station subsequently confirmed that the water level stayed around 18 m between the 6th and the 24th of November.

The divers found that the main channel was fairly shallow but deepened into a basin of 1.5 m or more. The current was sufficiently swift so the sensing body was placed there. The intake was about 15 m upstream from the bridge, about 5 m from the right bank (looking downstream), and about 1.5 m below the water surface.

The sensor body on its weighted base was secured to rocks on the river bottom with quarter inch stainless steel cable. The electrical cables were trailed downstream then curved into the bank near the gauging house. The cables were laid between and under rocks in the river bed after being ballasted with weights from divers belts. Where the cables left the river, they were buried in the mud and sand to a depth of about 10 cm. The total cable run was estimated to be 150 m. The excess cable was cut off to minimize the wire losses of power to the pump motor.

4.0 RESULTS

The System operated normally from 20 October through 27 November, 1987. Events recorded during this period are summarized in Table 1. The estimated daily mean of air temperature at Royal Road (10 km west of Durham Bridge) and the estimated daily mean of river water temperature (at sensor body intake) over the period are shown in Figure 2.

The general correlation between water and air temperatures is evident from Figure 2. Based on this cursory data, it appears that conditions required to produce frazil ice did not occur until about 14 November.

Significant data records from this operating period are cross referenced in Table 1 to Figures 3 through 9. These chart records are to be read as follows:

(i) Time runs from the bottom of the page to the top;

and (ii) Each division in the time axis is 20 minutes.

For temperatures, the left margin is set at - 1 C and the right margin is 5 C. Minor divisions in the temperature axis are 0.10 C and major divisions are 0.50 C. Temperatures are recorded for intake to the sensor (typically around 0.0 C), the output of the heater (typically around 1.6 C), and the exit from the body (typically around 3.6 C).

The amperage records for the heater and pump motor circuits are taken to confirm the stability of energy inputs. Otherwise, they may be ignored.

The term "baseline" is actually the zero frazil signal. Each minor division to the right is equal to 0.1 % frazil concentration by mass.

The day - time records are days in the Julian calendar and local standard time at Durham Bridge.

Examples of the events recorded are shown in Figures 3 to 8 as follows:

Figure 3.
The first signs of supercooling in the river were recorded at 06:00, 5 November, when the intake temperature went below 0 C for approximately 30 minutes. Maximum supercooling was -0.05 C. There was no record of frazil ice on the chart.

Figure 4.
Following on the same day, after the intake temperature had risen to + 0.35 C, a further 45 minute period of supercooling occurred with a maximum supercooling of - 0.07 C. Approximately 1.5 hr after the onset of this period, a very small frazil signal was recorded for about 2 minutes, indicating the sampling of a small frazil cluster.

Figure 5.
The record of 8 November shown here, and that of 19 November are unusual. They display a cyclic variation of output temperature of up to 1 C without significant variation in heater current or pump motor current. This indicates that the flow through the system decreased quickly and then

restored gradually during several cycles, with each cycle of flow variation being less severe. This suggests that the intake passage was plugged with something, possibly a leaf or other debris. The agitator and pump were designed to ingest materials like this, and the design appears to be successful. Earlier field trials showed that leaves in the flow are not uncommon. After the sensing body was recovered from the present deployment, one leaf was found in the intake but was not in a position to block through flow of water or ice.

Figure 6.
The first evidence of continuous frazil ice generation appeared in the records between 22:00 on 13 and 03:00 on 14 November, as shown in Figure 6. The frazil content was about 0.06 % and 0.1 % . Three clusters were recorded as well on 14 November. This record is consistent with the record of daily average air and water temperatures shown in Figure 2.

Figure 7.
An unexpected event recorded on 15 November is shown in Figure 7. For three hours between approximately 13:00 and 16:00, the intake temperature rose about 0.02 C above zero while the output temperature remained constant.

The lack of noise on the output temperature signal indicates normal operation. The noisiness of the intake temperature signal is quite characteristic of above zero signals. The record is time averaged over 30 seconds by the chart recorder.

One possible (but unlikely) cause of this could be that warm water backed up the intake pipe from the heater to the intake thermometer. This problem had occurred during development, but was fixed earlier. Further more, if this was a likely cause, it should also have appeared when the intake pipe and pump were partially blocked (Figure 5), aggravating the tendency for warm water to backup in the pipe.

Another possibility is that small drifting ice particles were injected and then detected by the system.

Figure 8.
As shown in Figure 2, between 19 and 23 November, the daily average air temperature was well below 0 C, and the daily average water temperature was at 0 C. One cluster of frazil was recorded on 19 November. Figure 8 shows the record of a

second frazil event of five hours duration on 21 November, beginning at about 11:40 and running through to about 16:40. Maximum concentration recorded during this run was between 0.06 and 0.1 % Although the temperature of both the air and water remained cold enough through to 26 November, there were no further records of frazil ice. This suggests that an ice cover developing over the sensor body inhibited vertical mixing in the water column, so no frazil was intercepted by the sensor intake.

Figure 9.
On 27 November, two ice events were recorded. The first occurred at 07:50 and lasted for an hour. The peak concentration was 0.1 %. The second occurred at 10:50 and lasted forty minutes. Peak concentration for this event was 0.2 % by mass. These were likely clusters of trash ice, since both water and air temperatures were above 0 C at the time. As explained below, it is possible that the ice cover shifted during this afternoon. Such signals of trash ice might be useful indicators of impending ice cover break up.

5.0 SYSTEM FAILURE

The System stopped operating at 15:53, 27 November, 1986; that is five hours after the last recorded ice event. There was 53 mm of rain measured at Royal Road and the daily average air temperature was + 3 C. Discussions with Mr Don McIntosh, of the Water Survey of Canada, indicated that due to the warmer weather and rainfall, the ice cover on the river may have shifted resulting in damage to the Frazil Ice Recording System.

The sensor body installation was inspected by divers a few weeks later. It was still in place as originally installed. Changes observed were that the cables in the river bed had been disturbed, and the outer portion of the agitator had broken off the intake. The latter was found lying nearby on the bottom.

By the time of this inspection, new shore ice had formed and the cables entered this ice half way up from the bottom. To retrieve the sensor body, the cables were cut where they entered the ice from the river. Once on shore, the cables were examined and found to be sound. The sensor body was also found to be in operating condition. It appeared that the cables had been damaged at the shore line, and the damaged portions remained buried in the new shore ice.

The agitator was found to be broken off at a weld joint. Inspection of the break indicated that the failure was due to fatigue rather than excessive loading.

6.0 CONCLUSIONS

The sensing body was too deep below the river surface to produce consistent records of frazil ice events. Some of the records are interesting, but the readings are so close to the resolving power of the System that it is difficult to have confidence in them.

The System proved to be reliable in operation, except that an improved method of protecting the cables on installation is required.

The agitator appears to prevent ice from clogging the intake. Improved manufacturing technique is required to avoid the observed fatigue failure.

The trash ice signals observed prior to the movement of the ice cover at the end of the trial may be useful to some river monitoring applications.

The thermal insulation in the body is still not sufficient to ensure a very stable baseline for the ice record. The pump body must be insulated as well.

7.0 RECOMMENDATIONS

It appears that frazil events in rivers cannot be effectively monitored by sampling at a fixed point below the surface as initially assumed. The sensor head and its mounting must be designed in such a way that it can be profiled from the water surface to some depth and yet be robust enough to avoid damage from larger ice flows or becoming trapped in developing ice cover.

One expedient would be to place the sensor body in shallow rapidly flowing reaches of the river where observation from previous years shows that the surface remains open and flow depth is relatively unaffected by the formation of downstream ice cover. The risk of such an installation is that ice pans running through the rapid may strike the body with sufficient force to upset or damage it.

A second approach might be to suspend the sensor body from an existing bridge deck by cables and a winch which would allow the sensor to be profiled in the water column. Such an installation could not be left unattended for long periods, since there would be greater risk of the whole set up being iced up or trapped by a developing ice cover.

A third more elaborate approach would be to install the sensor body on a stand which incorporates an hydraulic jack to raise and lower the sensor in the water column. This type of installation could be automated by installing a pressure sensor in the body and driving the system between selected pressure limits from a shore pump. This approach also has a high risk of damage from floating ice and of being trapped in a developing ice cover.

Finally, some organization dedicated to the study of frazil ice in rivers should be found to continue the work of operating and developing this System from its present baseline configuration. Each year's experience will produce further information about the characteristics of System and more importantly the long term characteristics of frazil and trash ice.

ACKNOWLEDGEMENTS

The encouragement and assistance provided by Roy Lane and Don McIntosh of the Water Survey of Canada and Brian Burrell of the Water Resources Planning Branch of the Province of New Brunswick were essential to this work. Thanks are due to Frank Roy, Engineering Services, NWRI, for his contributions, especially the work on the pump. Wilfred Waite was very helpful in retrieving the meteorological data used in Figure 2. Many others contributed to the good record of reliability and have set the standard for future work.

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Roy, F. E. (1986), A Review of the Proposed Application of the NWRI Frazil Ice Recorder near Durham Bridge, N. B., Winter 1986-7., Engineering Services Section, National Water Research Institute, Burlington, Ont., August,1986.

TABLE 1

Summary of Events with the Frazil Ice Recorder.

DATE	EVENT	REF. FIG.
86-11-05	Two supercooling events. One frazil cluster signal.	3,4
86-11-06	Freezing conditions but no frazil signals.	
86-11-08	Probable plugging by a leaf.	5
86-11-13	Frazil signals of 0.06% for two hours.	6
86-11-14	Frazil signals of 0.1% max. for nine hours.	6
86-11-15	Frazil signals of 0.01% with an odd intake temperature.	7
86-11-18	Freezing weather but no frazil signals.	
86-11-19	Freezing weather but only cluster recorded. Partial plugging.	
86-11-21	Plugging effects cleared.	8
86-11-22	Freezing weather but no frazil.	
86-11-27	Trash ice recorded. System fails.	9

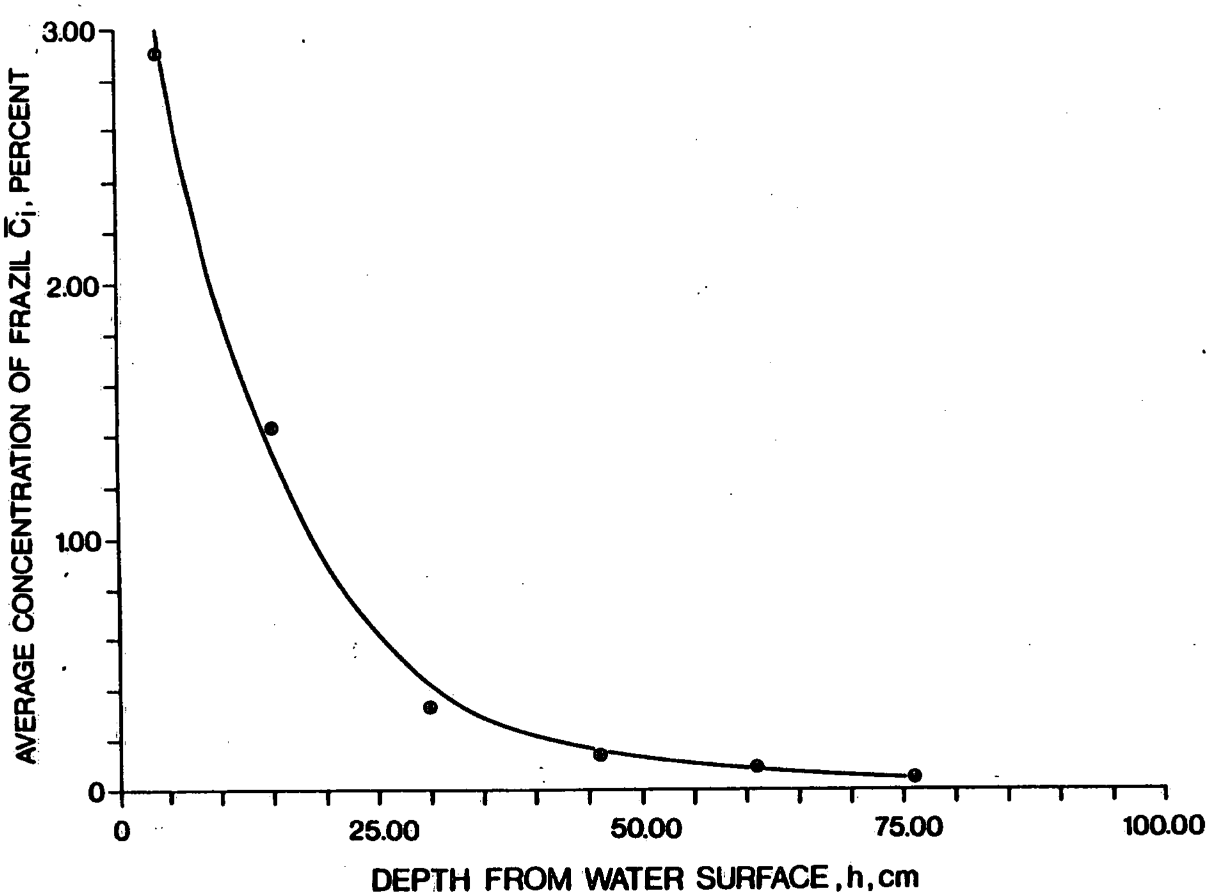

FIGURE 1 Distribution of frazil as a function of depth. (from Tsang, 1986)

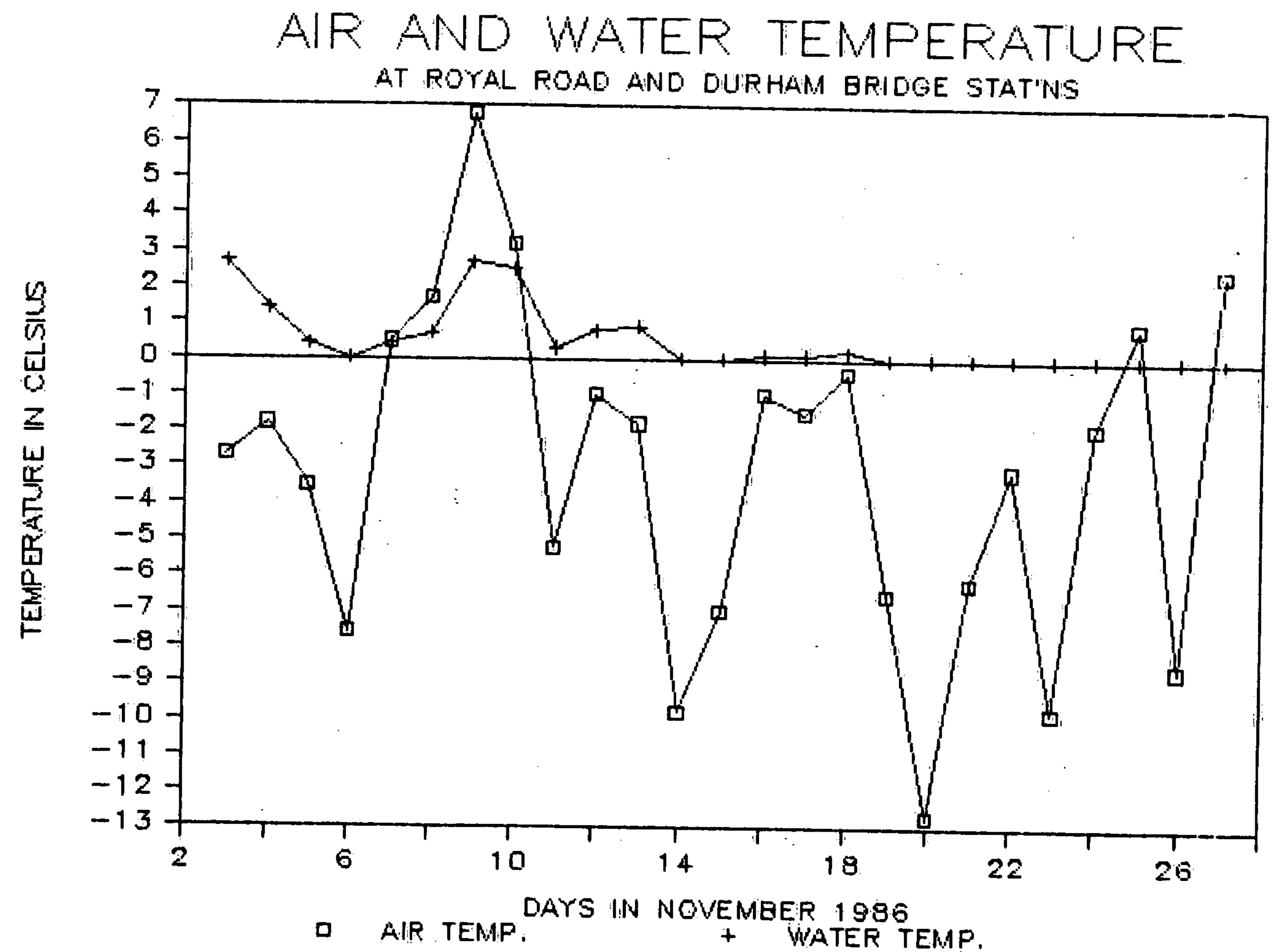

FIGURE 2 TEMPERATURE RECORDS

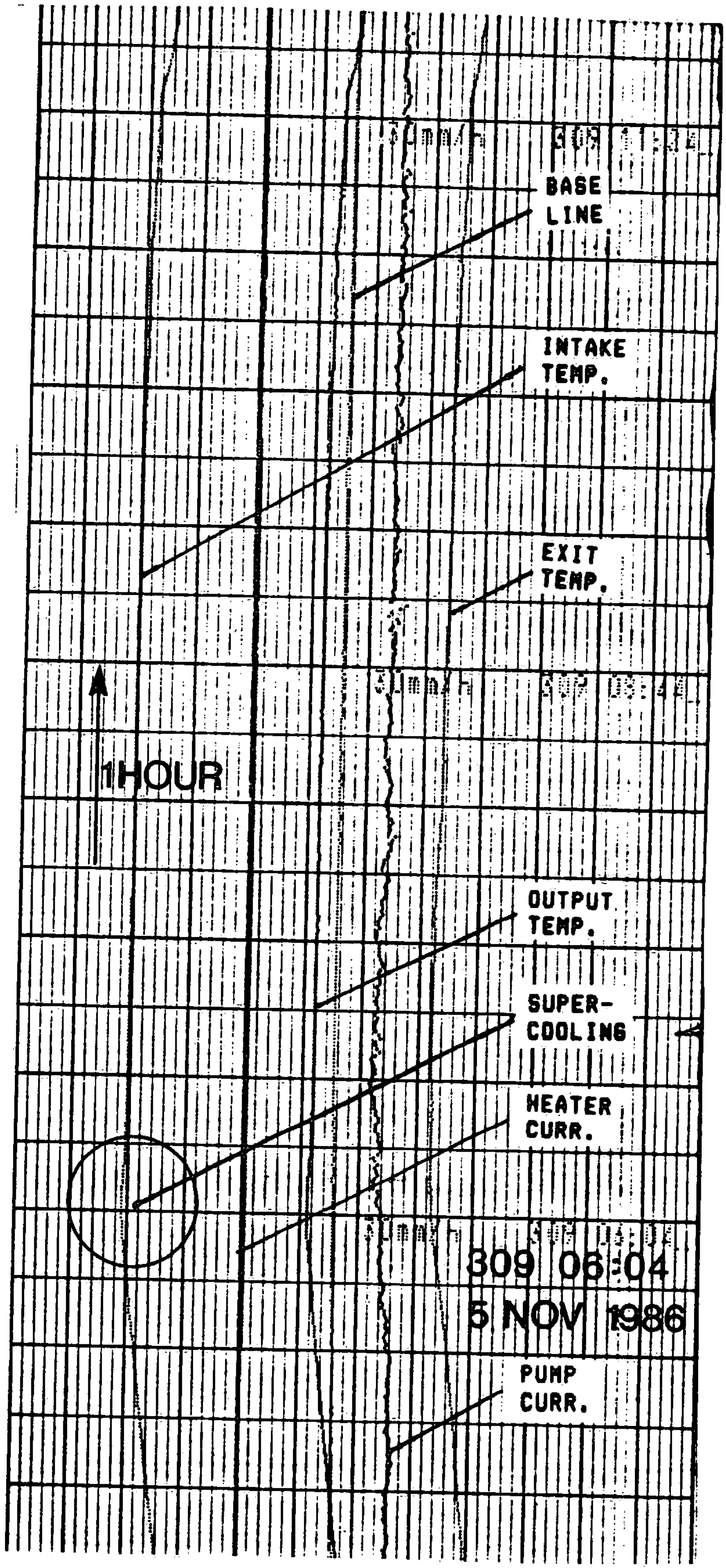

FIGURE 3 SUPERCOOLING EVENT

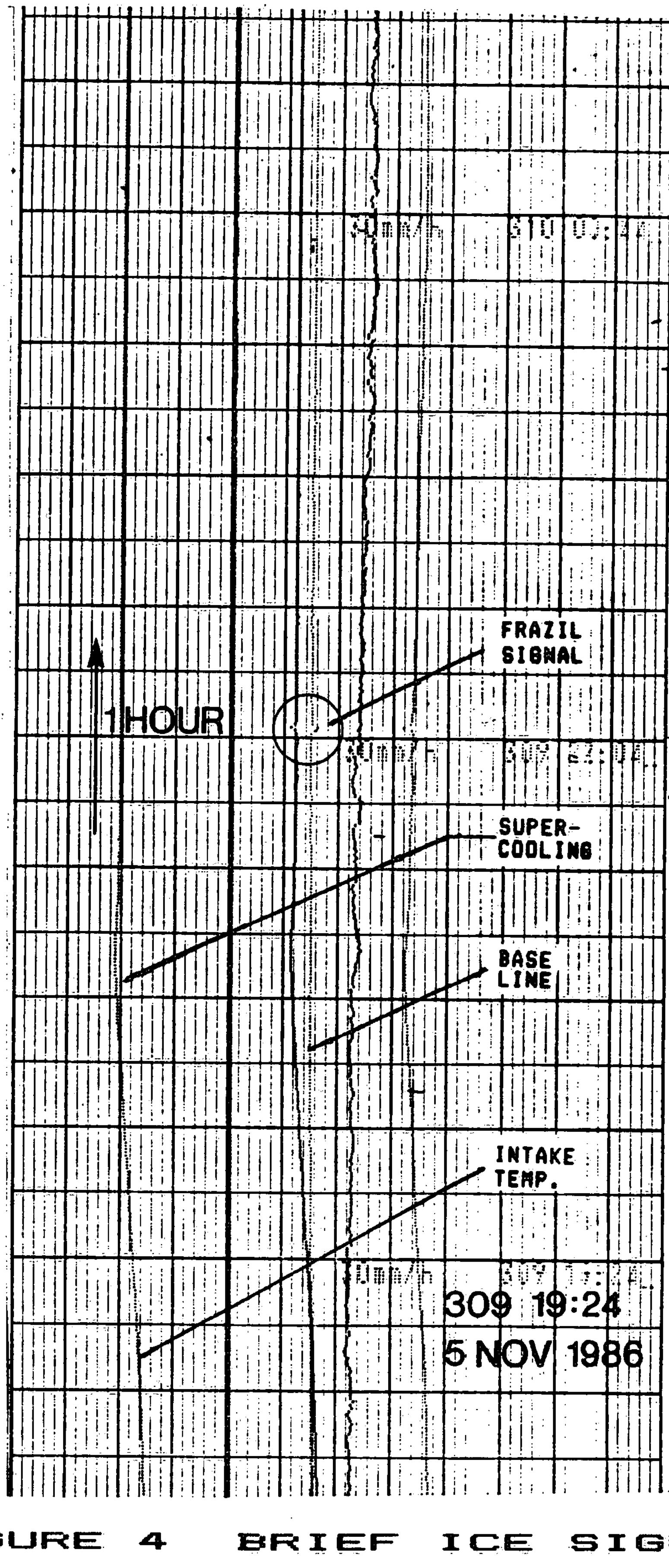

FIGURE 4 BRIEF ICE SIGNAL

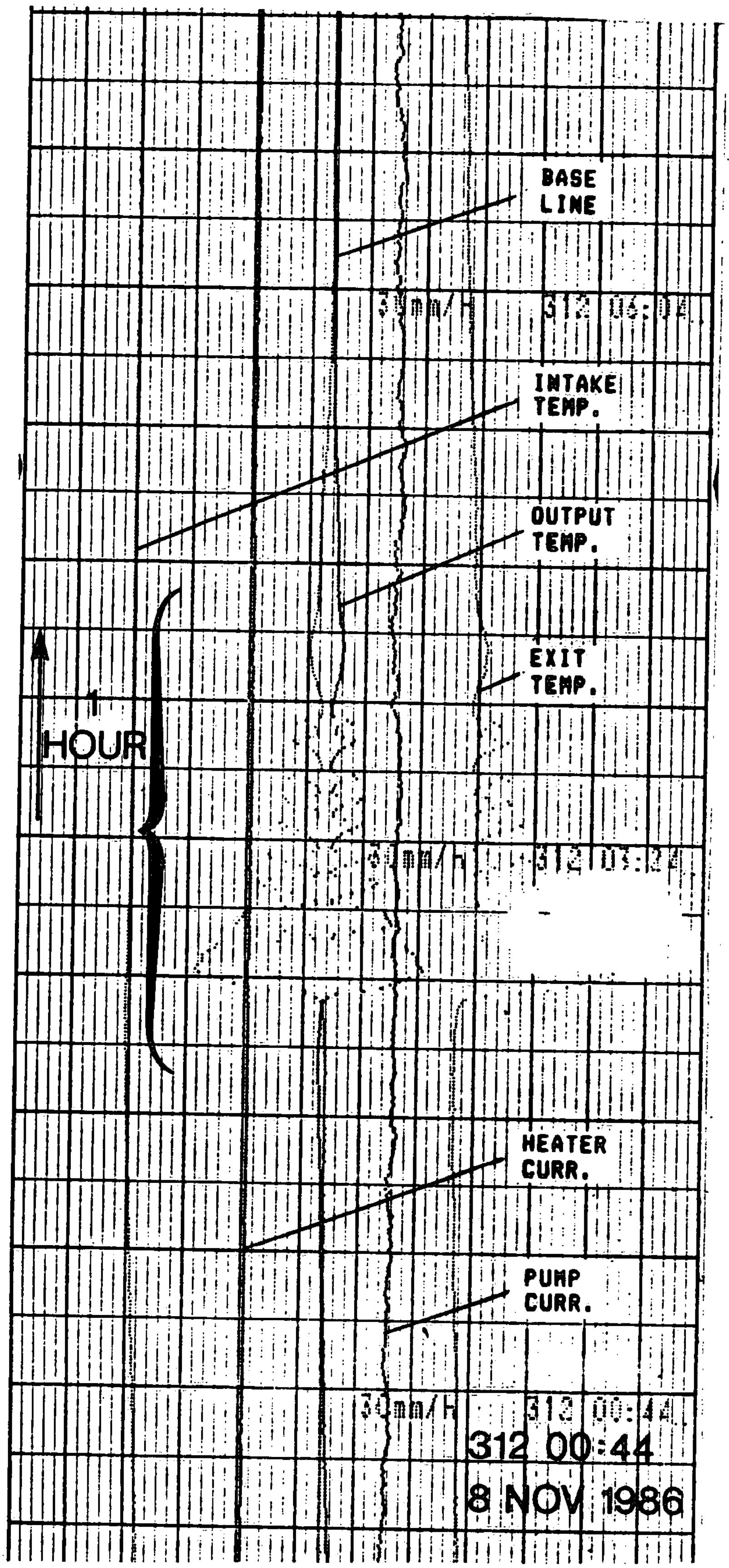

FIGURE 5 PLUGGING SIGNAL

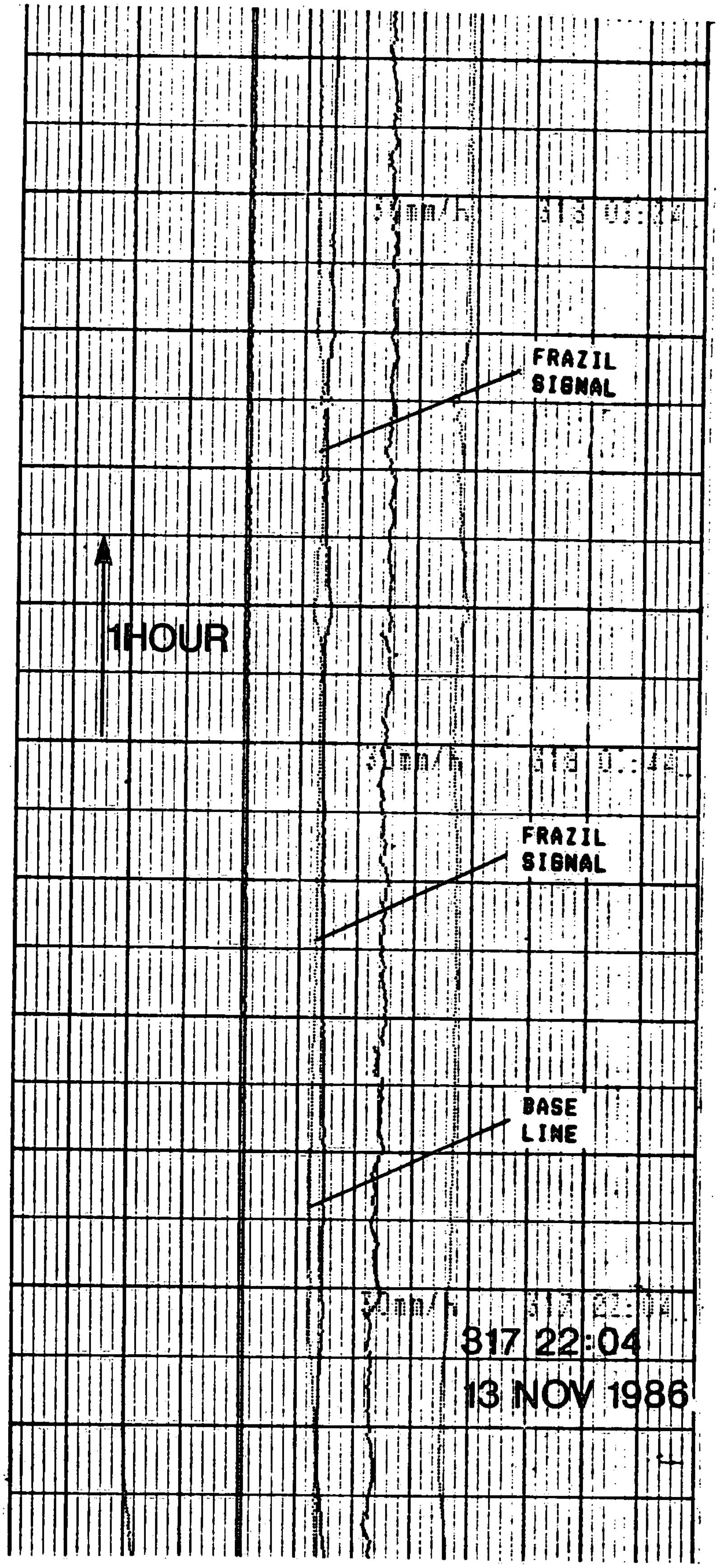

FIGURE 6 CONTINUOUS FRAZIL

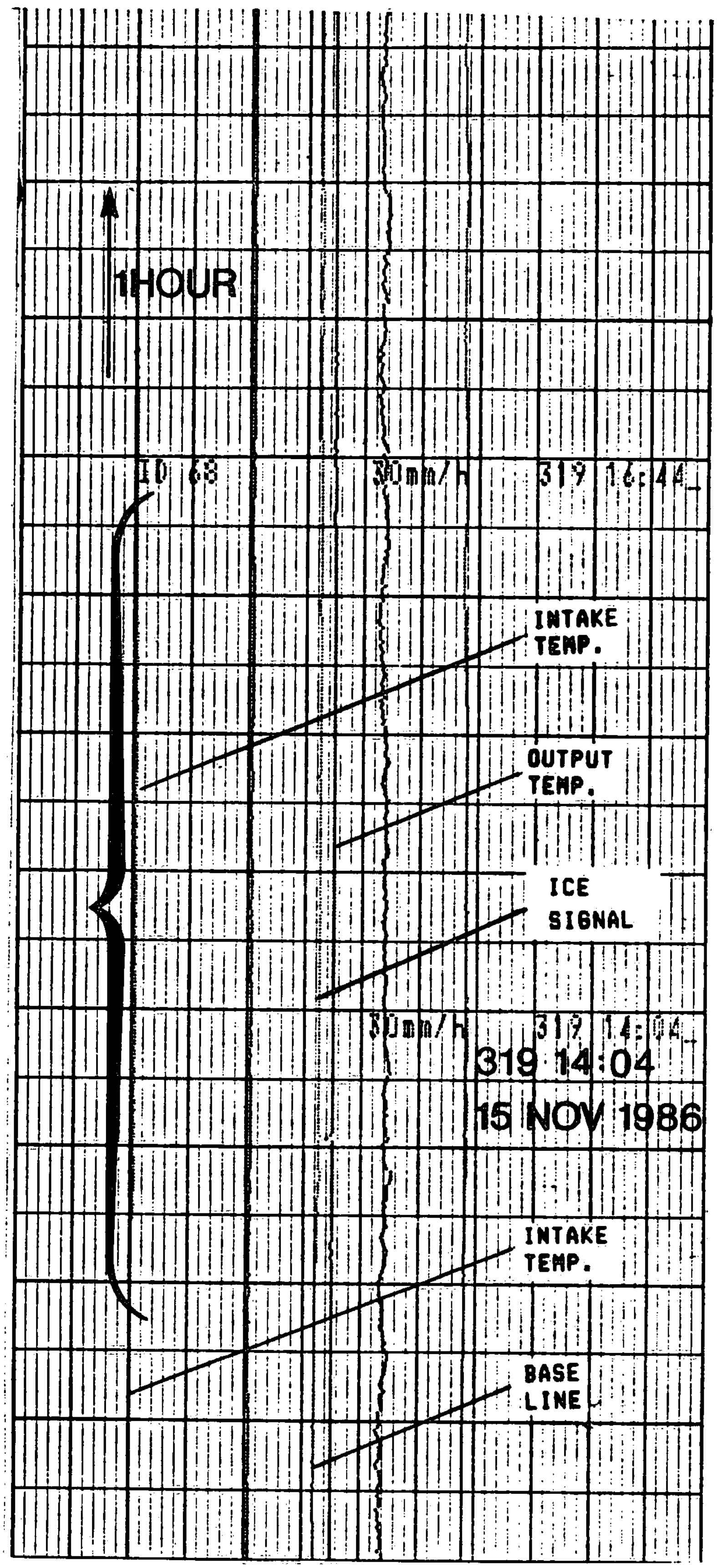

FIGURE 7 UNEXPECTED RECORD

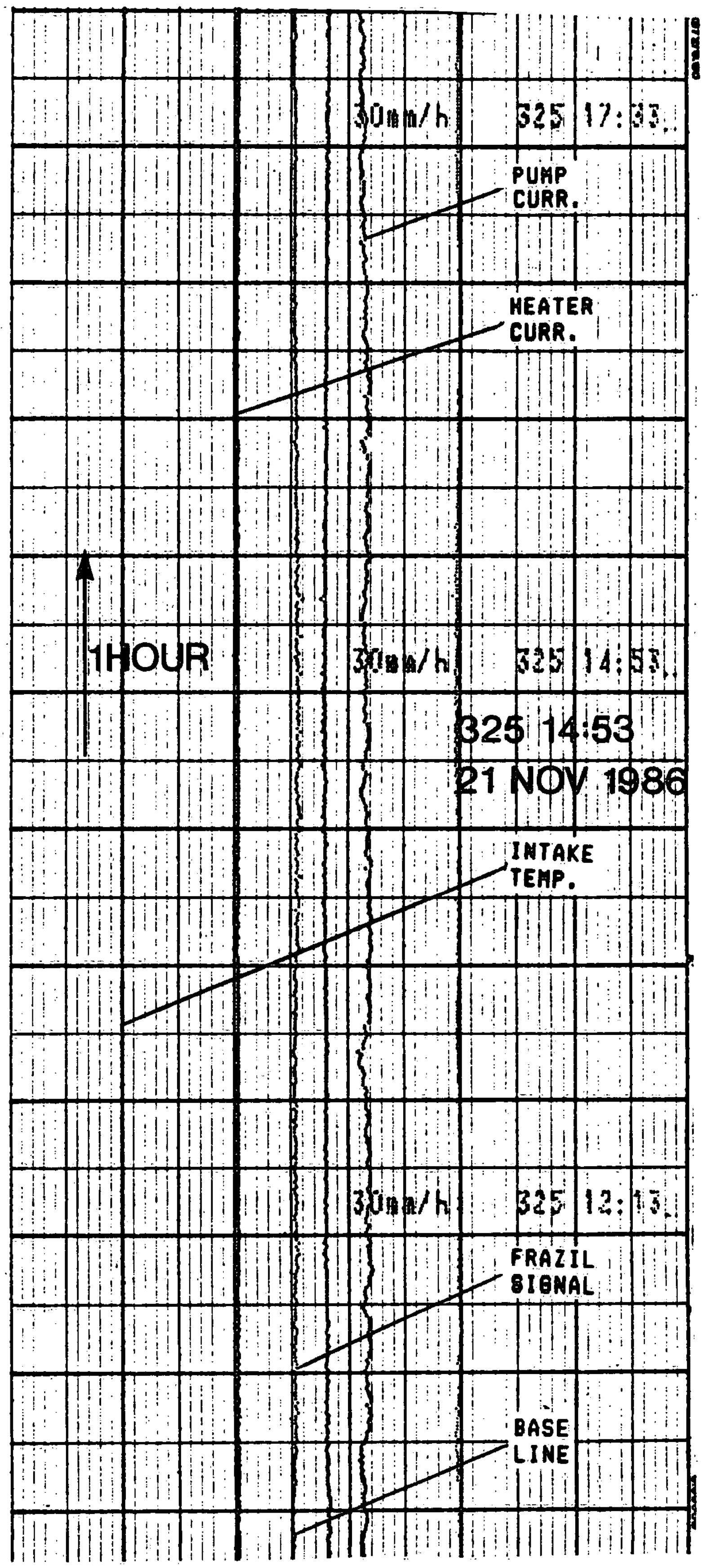

FIGURE 8 FRAZIL ICE READINGS

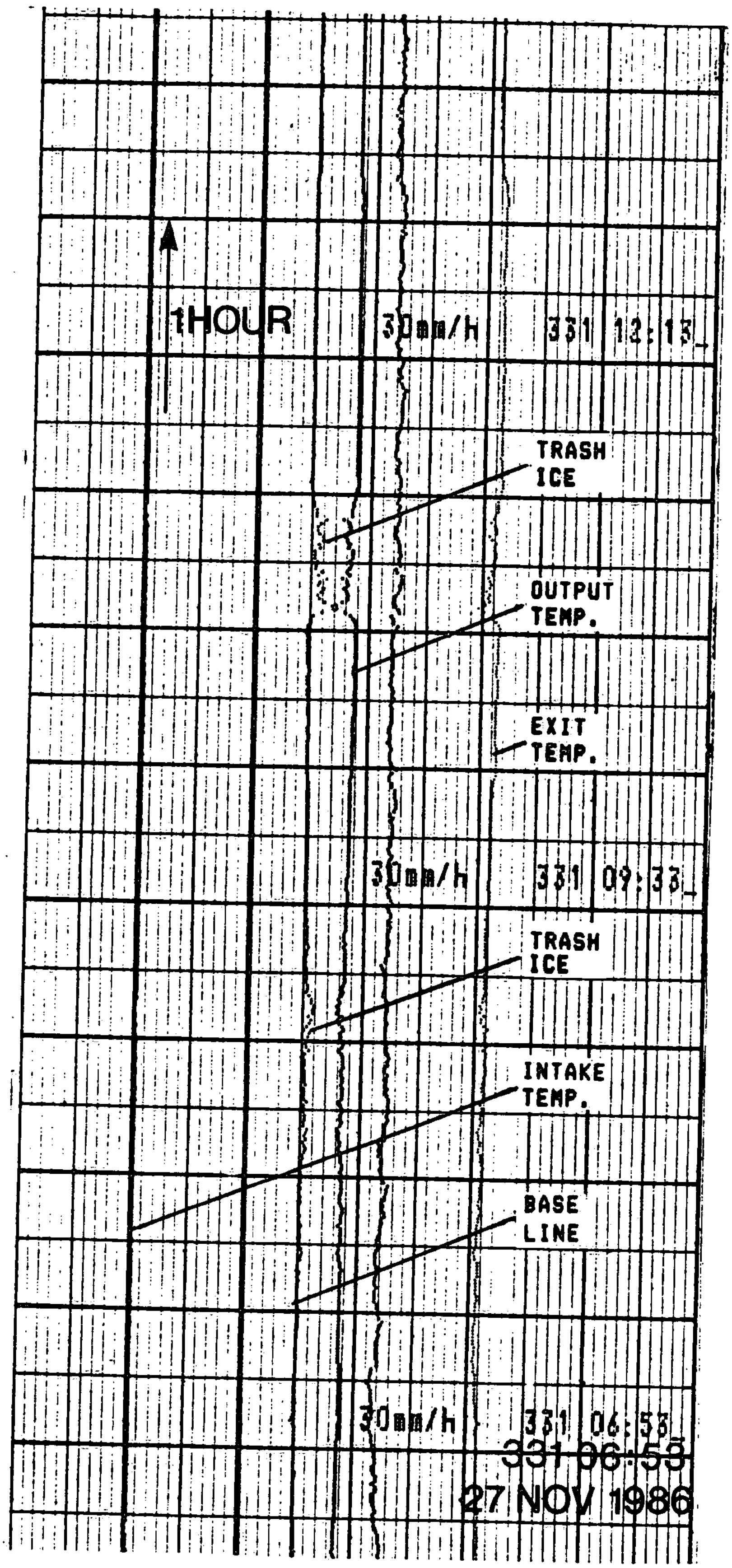

FIGURE 9 TRASH ICE READINGS

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