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A SOLID-STATE LOGGER FOR TEMPERATURE

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ABSTRACT

The design for a low cost single channel high accuracy temperature logger is described. Prototype test results are summarized in a demonstrated performance specification. Future development and potential applications are mentioned.

MANAGEMENT PERSPECTIVE

The acquisition of long time series of temperature measurements is a requirement for many studies in the aquatic environment.

This report describes the development at NWRI of a solid state temperature logger which may be employed either singly or in an array of several units to obtain this data. The unit is self-contained for convenient use in the field, and if procured in economic production quantities, promises to be of lower cost per data channel than presently available equipment of equal accuracy and capacity.

Similar technology to obtain pressure records could conceivably provide a method in many places to obtain water level records with or without ice cover.

A pressure sensor must also be able to operate in cold conditions but as there are no moving parts, serious difficulties should not occur.

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RÉSUMÉ

On décrit les caractéristiques d'un enregistreur de température à un seul canal, à la fois très précis et économique. Les résultats des essais menés sur le prototype sont résumés dans une fiche technique. On signale les progrès envisagés et les applications possibles.

PERSPECTIVE-GESTION

L'acquisition d'ensembles de données sur la température à longue échéance s'impose dans maintes études du milieu aquatique.

Le présent rapport décrit la mise au point, à l'INRE, d'un enregistreur à semiconducteur qui peut être utilisé seul ou avec une gamme d'appareils pour obtenir des mesures de température. Son format compact est tout désigné pour les études sur-le-terrain. S'il était fabriqué en grande quantité, il entraînerait des coûts moindres par canal que les appareils à capacité et à précision égales actuellement utilisés.

Une technique semblable pour obtenir des données sur la pression fournirait, selon toute vraisemblance, une méthode qui permettrait de recueillir à bien des endroits des données sur le niveau de l'eau, peu importe si cette dernière est recouverte de glace.

Il est nécessaire que l'appareil soit utilisable même par temps froid et, n'ayant pas de parties mobiles, il ne devrait pas poser de difficultés majeures.

Le Chef
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1.0 INTRODUCTION

A major part of research in the aquatic environment is the study of the thermal behaviour of lakes and rivers over time scales which are long compared to the time scale of various forcing events such as storms, seasonal change and so on. One instrumentation approach to the collection of this type of data is to mount an array of temperature sensors on a common cable, and record their readings on a multi-channel logger. An example of this approach is the NWRI Fixed Temperature Profile (FTP) system, for application in lake and deep river environments.

This approach has several disadvantages for general application. The integrated system, although providing 21 channels of measurement at a cost of about $1200 per channel, is not economically adaptable to different applications. For general application, it is desirable to be able to vary the size and orientation of the sensor array to suit the needs of a specific experiment. Damage to the common cable of the FTP generally means loss of data from all points in the array. The FTP logger stores the data on magnetic tape, and this requires the case to be opened and resealed each time it is necessary to change the tape.

Following consideration of these problems, and reflecting on recent advances in solid state technology. The NWRI Scientific Equipment Development Working Group (SEDWG) supported a proposal to design and develop a single channel temperature logger with a target cost of $1000 to $1500 per unit. Such a logger would become the building block of temperature measurement arrays of any desired size and configuration, with much wider application to Institute programs than was offered by existing equipment.

2.0 DESIGN

Major design criteria for this development were that the cost per channel of temperature data should not exceed $1500, that the error in recorded temperature should be less than 0.1°C, and that the equipment be highly reliable and convenient to use in the field environment.

Existing temperature loggers in the market were reviewed. Many use magnetic tape transports to store the data, with attendant problems of transport reliability, tape binding, and case sealing. Others which did not use magnetic tape still required opening to retrieve the data. In others the temperature sensor was not sufficiently accurate for water research. In all, it was decided that available equipment was too expensive, inaccurate, or unreliable.

The NWRI Logger design was based on CMOS low power random access memory chips, and a temperature sensitive crystal oscillator. A single connector was used to start the logger, select the sampling interval, stop the logger, recharge the battery, and extract the data. The case was PVC pipe with permanently sealed ends. See Figure 1.

The requirement for high accuracy was met with a set of crystal oscillators for measuring temperature and time. The requirement for high reliability was met by the elimination of moving parts, and the use of a sealed case. The simplicity of the single multi-function connector aids reliability of operation. The operator needs only to insert a timing plug to start the logger in the field.

The interrogator unit, to extract the data, uses a microprocessor to interface between the logger and a microcomputer. See Figure 2.

The operator can display the data graphically or numerically immediately with no intermediate data processing such as tape transcribing. The microcomputer can change the time scale and temperature range for replotting selected sections of the data as shown in Figure 3.

3.0 TESTS AND RESULTS

The results of testing over a span of three years have shown that the prototype logger is capable of the following specifications.

Capacity	4095 readings
Range	0 to 30°C
Long-term Drift	50 m°C per year
Medium-term Drift	25 m°C per month
Short-term Drift	10 m°C per 48 hours
Sensitivity Change	0.05% in 4 months
Resolution	10 m°C
Linearity 0 to 30°C	± 0.15°C
5 to 25°C	± 0.07°C
5 to 20°C	± 0.035°C
Quadratic fit 0 to 30°C	± 0.06°C
Timing Accuracy	better than 1 in 4095
	crystal: 50 ppm
Dimensions	12 cm dia. by 45 cm

The logger was operated in the field in close proximity to a conventional, dual-channel, temperature logger normally used at the NWRI. The two loggers tracked within 0.18°C over a 27 day period. The difference was systematic and is accounted for by the nonlinearity of the solid state logger and the error in the conventional logger which showed a consistent difference of 0.1 to 0.2°C difference between its own two readings.

4.0 ONGOING WORK

Five pilot run units have been built under contract at a cost of $2500 each, and are now under test. These units were expanded

to a capacity of 16 thousand readings. More field testing of these pilot units will be done as opportunities arise.

Another logger prototype, based on a microprocessor and lower frequency crystals, has been built under the same contract. Considerable savings in size and battery costs were made in this design. The tentative price is about $1300 each for a run of five units.

5.0 CONCLUSION

The logger appears to have met the requirements for accuracy, reliability and low cost for aquatic research. The product may have a wider appeal in industry as a replacement for older style temperature monitoring equipment.

6.0 ACKNOWLEDGEMENTS

The authors acknowledge the support of SEDWG in encouraging the development of this system, and the valuable contributions to this report made by F. Roy, Head, Engineering Services Section.

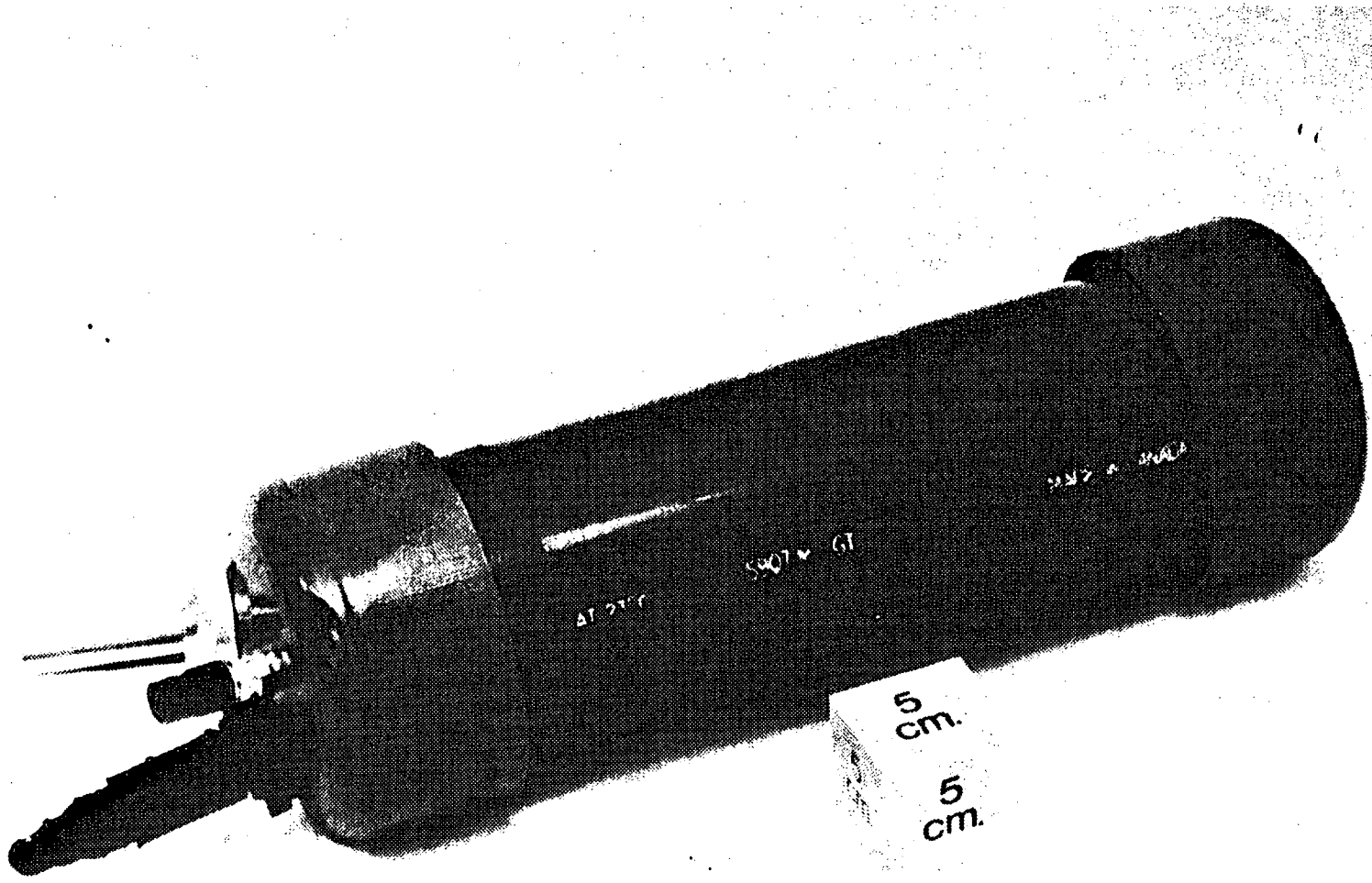

FIG. 1 SOLID STATE TEMPERATURE LOGGER

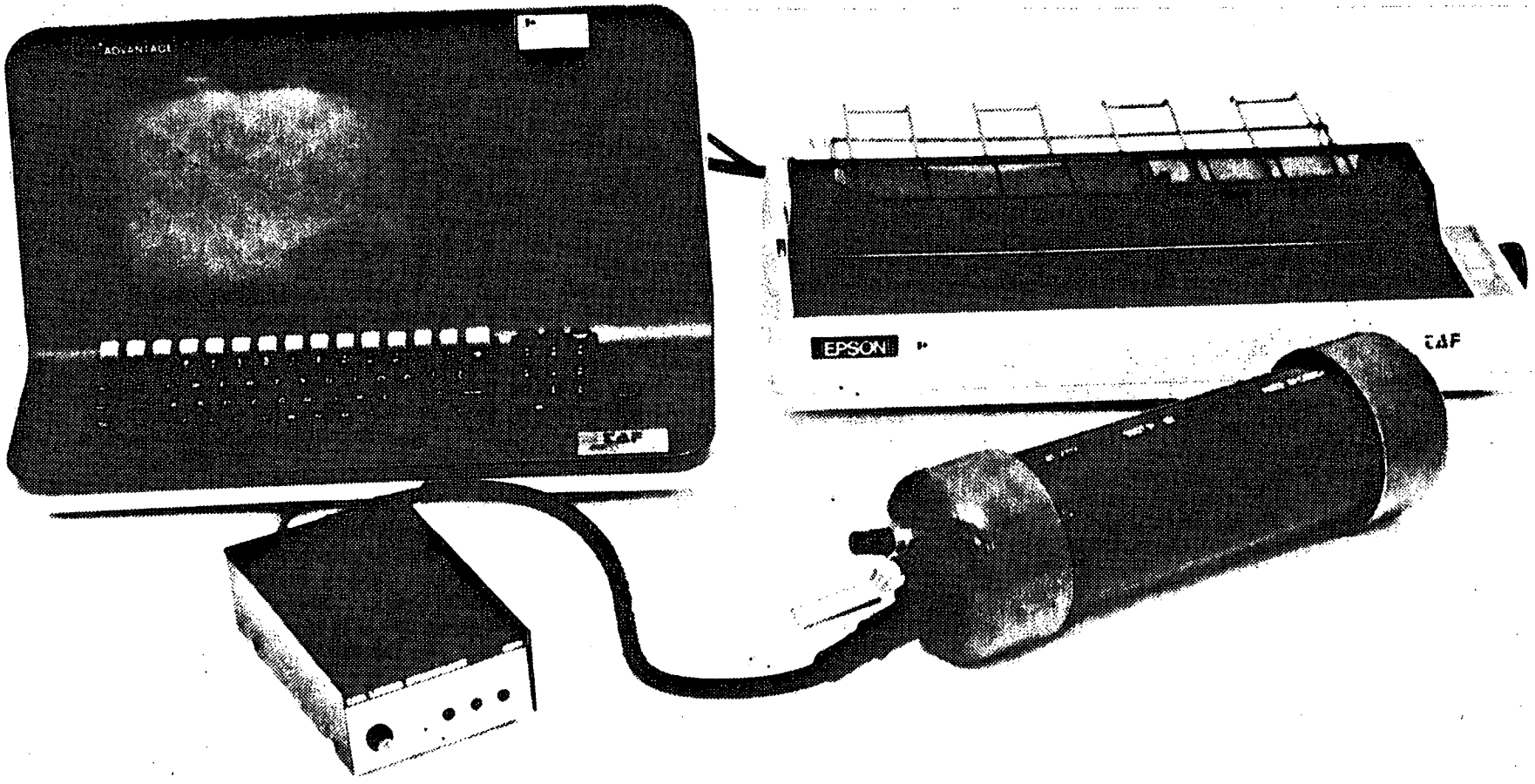

FIG. 2 INTERROGATION AND PROCESSING SYSTEM

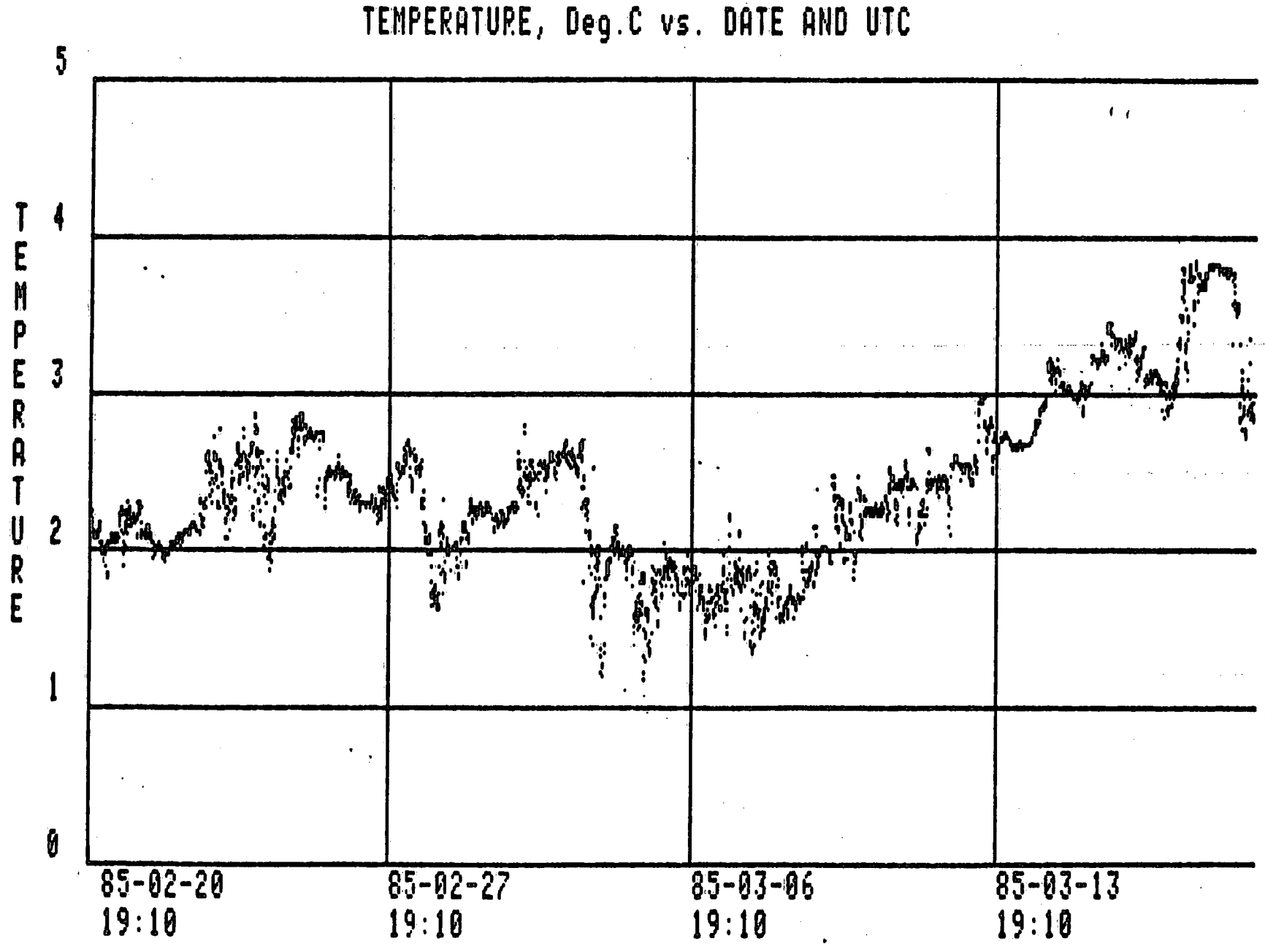

FIGURE 3 DATA PLOT