

## INSTRUMENTS AND METHODS

### AUTOMATED SEISMIC MONITORING SYSTEM FOR LAKE MICHIGAN ICE STUDIES

By R. W. TAYLOR, J. P. KOVACH and N. P. LASCA

(Department of Geological Sciences, University of Wisconsin-Milwaukee, Milwaukee, Wisconsin 53201, U.S.A.)

**ABSTRACT.** A simple, relatively inexpensive system for signal recovery in retrospect was designed to record lake-ice seismic events. The system is broad-band, D.C. to 100 Hz, light-weight and may be added to any existing data-acquisition equipment. The system may be used (1) to initiate high-speed paper recordings in the field, (2) to store transient events on magnetic tape while in the field, or (3) for the unattended laboratory-recovery of transient events from a continuous field recording. Continuous, high-resolution, broad-band recordings of seismic events occurring in lake ice over a period of weeks may be stored on a single reel of magnetic tape. The initial cost of the device is rapidly equaled by the savings in tape cost and man hours expended in signal recovery.

**RÉSUMÉ.** *Système d'enregistrement sismique automatique pour les études de glace sur le lac Michigan.* On a construit un appareil simple, relativement bon marché pour retrouver rétrospectivement un signal afin d'enregistrer des secousses sur la glace de lac. Le système consiste en une large bande, de D.C. à 100 Hz, d'un faible poids et que l'on peut ajouter à n'importe quel appareil enregistreur déjà existant. On peut utiliser cet appareil: (1°) pour faire démarrer sur le terrain un enregistrement sur papier à haute vitesse, (2°) pour stocker des phénomènes passagers sur une bande magnétique pendant qu'on est sur le terrain, (3°) pour retrouver au laboratoire des phénomènes passagers inattendus à partir d'un enregistrement continu sur le terrain. Un enregistrement continu à haute résolution, sur large bande de phénomènes sismiques qui se sont produits sur de la glace de lac tout au long d'une période de plusieurs semaines peut être emmagasiné dans une seule bobine de bande magnétique. Le coût initial de l'appareil est rapidement amorti par les économies en prise de bandes et en heures de personnel pour le dépouillement.

**ZUSAMMENFASSUNG.** *Automatisches seismisches Überwachungssystem für Eisstudien am Lake Michigan.* Zur Aufzeichnung seismischer Ereignisse in See-Eis wurde ein einfaches, relativ billiges System zur nachträglichen Signalregistrierung entworfen. Das System besitzt Breitband, Gleichstrom bis 100 Hz, geringes Gewicht und kann mit jedem bestehenden Datenaufnahmeggerät verbunden werden. Das System lässt sich verwenden (1) zur Auslösung von Papierregistrierungen hoher Geschwindigkeit im Feld, (2) zur Speicherung vorübergehender Geschehnisse auf Magnetband im Feld oder (3) zur unbeaufsichtigten Laborerfassung vorübergehender Erscheinungen aus kontinuierlichen Feldregistrierungen. Kontinuierliche Breitband-Registrierungen hoher Auflösung von seismischen Vorkommnissen im See-Eis über eine Periode von Wochen können auf einem einzigen Magnetband gespeichert werden. Die Beschaffungskosten für das Gerät werden schnell durch die Ersparnisse an Bandkosten und Personalausgaben für die Einholung der Signale amortisiert.

#### INTRODUCTION

Since 1973, a group of geologists and geophysicists from the University of Wisconsin-Milwaukee have studied the large floating fresh-water ice sheets formed during the winter months on northern Lake Michigan and Green Bay, Wisconsin, U.S.A. The continuing studies include: (1) a study of variations in lake-ice fracture patterns as related to snow cover, ice thickness, crystal orientation and size, and air, water and ice temperature, and (2) a series of seismo-acoustic investigations of the elastic properties of fresh-water lake ice. Relatively little work of this type has been done on fresh-water naturally-occurring lake ice on large lake bodies such as the Great Lakes of the north-central U.S.A. The data derived from the studies are important to an understanding of lake-ice deformational processes and stress propagation within the ice.

#### MONITORING SEISMIC EVENTS

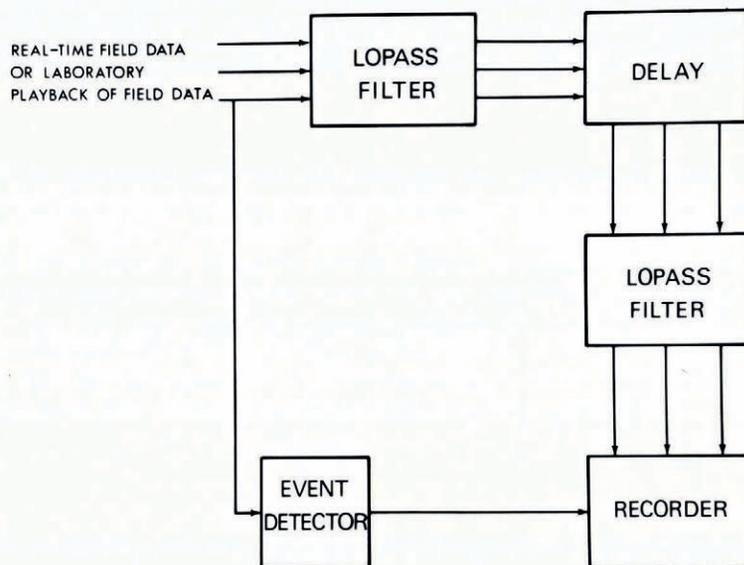
The long-term monitoring of transient seismic phenomena is one method for the investigation of body stresses, stress changes and displacements (Lasca and others, 1975). The need for actual wave shapes and accurate arrival times, however, requires the use of recording

instrumentation with a pass band on the order of D.C. to 100 Hz, and time resolution on the order of 1 ms. The requirements effectively eliminate analogue paper recorders and require the use of magnetic tape recordings. While low-speed magnetic tape recorders can provide the necessary band-width and time resolution, the recovery of a few transient events from a long-term field tape requires the attended laboratory play-back of the tape. Thus it is necessary for the operator to scan the entire field tape, possibly with time compression through the use of higher play-back speeds, and to select each event manually. In actual practice this may require several passes through the tape, which severely limits the utility and reliability of the original data. To improve data reliability and to eliminate manual recovery of seismic event data from continuously recorded field tapes, an automated seismic recovery system was designed.

#### AUTOMATED SEISMIC RECOVERY SYSTEM

An automated means of signal recovery or storage may be achieved by (1) monitoring the output of one or several input data channels and (2) starting the recording process only after the output level has reached some predefined level. The number of false starts due to noise bursts can be reduced by the use of R.M.S. amplitude in some predefined time window. The majority of seismic wave-forms, however, are characterized by peak amplitudes arriving after the initial arrivals. For reliable operation the predefined R.M.S. starting level must center on the high-amplitude, late arrivals. Therefore, to record entire wave trains, it is necessary that the recording process be initiated prior to any output from the monitoring system. In practice this requires a delay between the incoming data and the permanent recording of these data or what is commonly termed "signal recovery in retrospect".

The system for recovery in retrospect described here is relatively inexpensive (approximately \$700), utilizes standard components, and is intended as a simple addition to an existing field system rather than a complete replacement. The required circuitry may be used directly in the field or in the laboratory for unattended recovery of data from a field tape.



*Fig. 1. Block diagram of the automated seismic recovery system used for signal recovery in retrospect.*

A block diagram of the total data-collection system is shown in Figure 1. The required delay is achieved through a NIMBUS Digital Data Delay which will accept up to 8 analogue inputs; this system is produced by Nimbus Instruments of West Sacramento, California. In operation the incoming data are converted to digital form in the delay circuit and delayed for a time dependent upon the digitizing frequency. Following this delay, the signals are put out as discrete voltages at the sample rate. The initial low-pass filtering of the input is necessary to prevent aliasing, or the generation of lower-frequency signals as a result of improperly sampled higher frequencies. The final low-pass filter is required for a continuous analogue signal. The maximum allowable frequency, delay value, and number of input channels are set by initial design parameters. The system provides a maximum frequency of 125 Hz with a delay of 1.024 s on four channels of input data.

The event detector (Fig. 1) is shown in greater detail in Figure 2. The detector consists of TTL integrated circuits, beginning with a Schmitt-trigger fed through an attenuator. The trigger output lights an LED to assist threshold adjustment, and simultaneously fires the

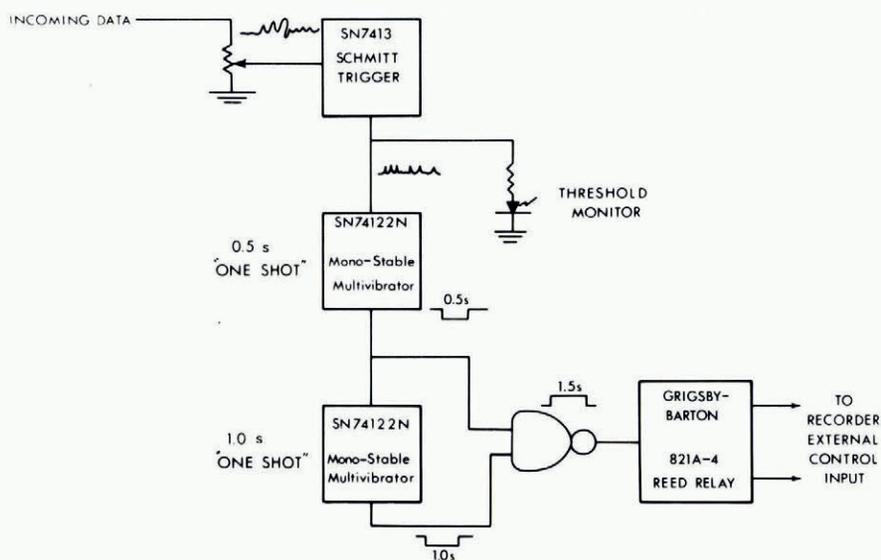


Fig. 2. Block diagram of the event detector.

first one-shot multivibrator. A half-second delay is programmed into the one-shot multivibrator to assure proper recording of low-level signals arriving after the trigger initiating burst. The first multivibrator starts the recorder via a reed-relay. The recorder then records the output of the NIMBUS circuit or all incoming data 1.024 s prior to the start of the recording process. As the first multivibrator returns to normal state, it fires a second one-shot multi-vibrator, programmed at one second, to keep the recorder running, thus insuring that data still in the NIMBUS circuit are recorded. Both multivibrators are re-triggerable so that a multiple- or long-duration event is completely recorded.

In operation the recovery system is highly reliable and simple to operate. It may be used (1) to initiate high speed (on the order of 100 cm/s) paper recordings in the field, (2) to store transient events on magnetic tape while in the field, or (3) for unattended recovery of transient events from a continuous field recording. The latter approach is the most desirable as the field recording may be searched at several detection thresholds, and the field-system weight is minimal. We have used the system for the completely unattended recovery of 43 seismic

events, recorded at four different sites, occurring during a continuously recorded 72 h period. Manual recovery of the events from the continuous field tapes would have required at least two man weeks.

#### ACKNOWLEDGEMENT

The research which led to the development of the automated seismic monitoring system was supported by N.S.F. Grant No. KG-41011 for the study of the elastic properties of fresh-water ice.

*MS. received 18 August 1975*

#### REFERENCE

- Lasca, N. P., and others. 1975. Lake Michigan ice studies, by N. P. Lasca, R. W. Taylor and D. E. Willis. *First annual meeting, Midwestern region, American Geophysical Union, September 25 to 27, 1975, University of Wisconsin, Madison*, 1. [5]. [Abstract].