A system for the simulation of sedimentary environments

Bohdan Bubela[1], Ian A. Johns[1], and James Ferguson

A system is described capable of simulating simultaneously a number of controlling parameters occurring in sedimentary environments. The system is composed of an experimental tank, reservoir tank, hydraulic, heating and illuminating attachments, and an electronic control programmed to regulate cyclic and non-cyclic operations of duration between 1 second and 10^5 seconds. The electronic component is capable of controlling several simulating systems simultaneously, their number being dependent on their complexity.

Introduction

A proper evaluation of geobiological processes occurring in nature is frequently hindered by the complexity and interaction of the various factors involved.

Therefore a number of systems simulating environments of geobiological interest has been constructed in our laboratory (Bubela and others, 1969; Lambert and others, 1970; Bubela and others, 1973; Hallberg and others, in prep.). These systems provide an experimental tool bridging the complexity of the natural environments and the oversimplicity of studying individual parameters experimentally. Furthermore, such systems permit a controlled variation of parameters associated with the environment under study.

The experimental evidence obtained with such systems proved to be useful in the evaluation of a number of biological and abiological processes occurring in environments of geobiological interest (Davies and others, 1973; Ferguson and others, 1974; Davies and others, 1975; Bubela and others, 1975; Davies and others, 1977; Hallberg and others, in prep.; Mooney and others, 1978).

To facilitate the investigation of marine evaporative environments it was necessary to devise a simulating system capable of accommodating associated features occurring in nature. The major requirements were controlled cyclic horizontal and vertical movement of waters of variable composition through the sediments at variety of time cycles, temperature and illumination cycyles, and adjustable water level.

Therefore it became desirable to devise a simple inexpensive electronic control capable of being programmed to operate systems simulating a variety of environments, with the influencing paramenters occurring cyclically or non-cyclically with a variable mutual dependency.

This paper describes such a system (Fig. 6).

Apparatus

Hydraulics

The central (non-electronic) structure of the system is a tank (1) made of high-density polypropylene (1 m x 1 m x 1 m). The bottom of the tank is perforated by 100 holes 5 mm in diameter (2). Four horizontal rows of the same diameter are located around the tank spaced vertically at 10 cm intervals. These may be closed or open as required (3). The bottom of the tank is covered with fibreglass cloth (4). A vertical row of sampling ports (5) is located at the side of the tank. The sampling ports are fitted with polypropylene taps and flanges (Bubela & Ferguson, 1973). The tank is placed in a bath (6) made of fibreglass (1.2 m x 1.2 m x 1.5 m) and rested on supports (7) 10 cm from the bottom of the bath. The bath is connected through waterlines (8) to a reservoir (9) via a magnetic valve (10) and a pump (11). An alternative pathway for the water is provided by a waterline 12) via a magnetic valve (13). The valves and the pumps are regulated by a controller (14). Heating and illuminating cycles are provided by a lamp (15) regulated by a controller (14) and a thermo-detector (17), and monitored by a recorder (16) via thermoprobes (15). The flow through the waterlines is regulated by taps (18 and 19). The water level in the tank and the bath is regulated by adjustable level detectors (20) and a controller (14). For safety reasons all powerlines are connected through core balance earth leakage protection units to supply points.

Electronics

The main electronic control applied to this simulating system, the Synchronous Electronic Master Clock (SEMC), is divided into two sections, A and B. Section A starts and stops events at pre-selected times, whereas Section B advances only when Section A recycles, thus providing facilities for experiments of long duration.

Section A has a considerable degree of flexibility because of the range of cycle durations and time units available. Time intervals of 1 second to 3.5 x 10^5 seconds can be programmed. The start and stop functions are generated by digital comparison of clock and memory data. Each of the five channels in Section A has 16 input lines from the real-time clock coded as 4 binary coded decimal (BCD) digits. Start and stop times can be determined by a 4-digit resolution. Real time is continuously displayed on a 4-digit read-out. Section B is electronically similar to Section A, but has 3 channels—each with 12 input lines, coded and displayed as 3 BCD digits.

All channels contained in the SEMC are mutually independent, allowing time overlap and non-sequential operation. Light-emitting diodes provide continuous-state monitoring of all channels.

Block diagrams of the SEMC and the control interface are presented in Figure 2. The logic diagrams relevant to the simulated system described in this paper are presented in Figures 3 and 4.

If Section A is programmed to perform function F_1 during a cycle time T_A, then Section B may be programmed to perform functions F_A and $n_B F$, where n_B is the selected B recycle time between limits T_A and

1. **Baas Becking Geobiological Laboratory, CSIRO, P.O. Box 378, Canberra, ACT, Australia.**

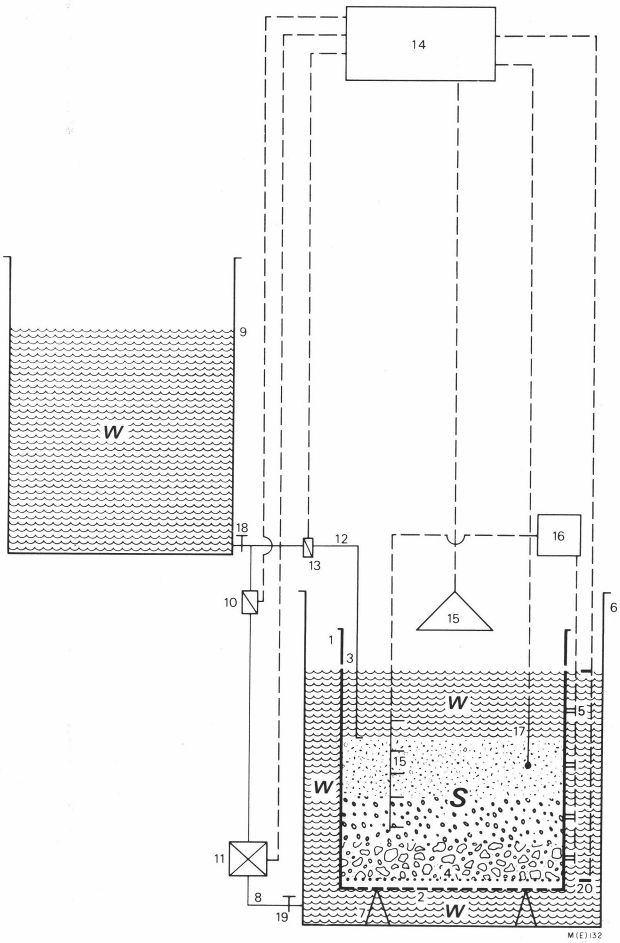

Figure 1. Schematic diagram of the simulating system. Not to scale. Description of the system is presented in the text.

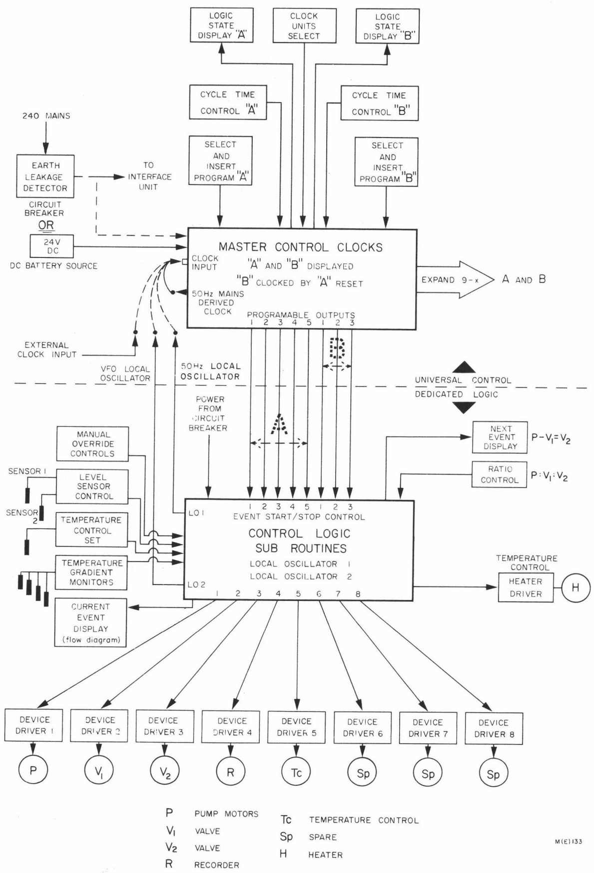

Figure 2. Block diagrams of the Synchronous Electronic Master Clock (SEMC) and the Control Interface (CI).

10^3T_A. Application of the 'cycling' capacity of the electronic component is illustrated by the following example:

Normal tides occur in 8-hour cycles, spring tides twice every lunar month. Therefore Section A will control function F_1 (normal tides), and Section B will control function F_2 (spring tide) with $n_B = 24/8 \times 14 = 42$.

An electric bell alarm is incorporated into the system to indicate that a power supply has been disconnected. Detailed information on individual circuits may be obtained on request from the authors.

Operation

Sediments

The tank is filled with sedimentary material depending on the nature of the area being simulated. It may consist of one or more layers of carbonates, sands, clays, and organic materials. They are introduced into the tank in the form of a slurry to prevent airpockets and chanelling. The composition of the aqueous phase differs with each experiment, and may be altered during the experiments. The monitoring probes are inserted into the sediments through the sampling ports, or inserted through the sediment surface. They may be left in the sediment permanently, or removed after individual measurements.

Hydraulics

The inflow of water into the tank may follow two different pathways (Fig. 1):

(a) The water is introduced to the bottom of the bath from waterline (8), and enters the sediment through the tank's perforated bottom. The water level is regulated by the level detectors. If the water is introduced into the bath at a rate faster than it can penetrate the sediment, and is brought to a position above the peripheral holes (3), it will flood the surface of the sediment—possibly without being depleted of some of its components by passing through the sediment. After the desired idential time the water is removed by reversal of the above process. The water movement is activated by pump (11).

(b) If downward penetration of the water through the sediment is required, it is introduced through waterline (12). It is then removed as in (a).

The illumination and heating sequences are produced by a lamp (15). The quality of the radiation is determined by the design of the lamp.

Electronics

The master control (Fig. 5) is set by the following procedure:

Previous memory of the system is erased with the A and B clearance button. Desired recycle time is inserted by A and B reset buttons, and corresponding time units are introduced by the toggle switch above the display window. Indication of real time on the display

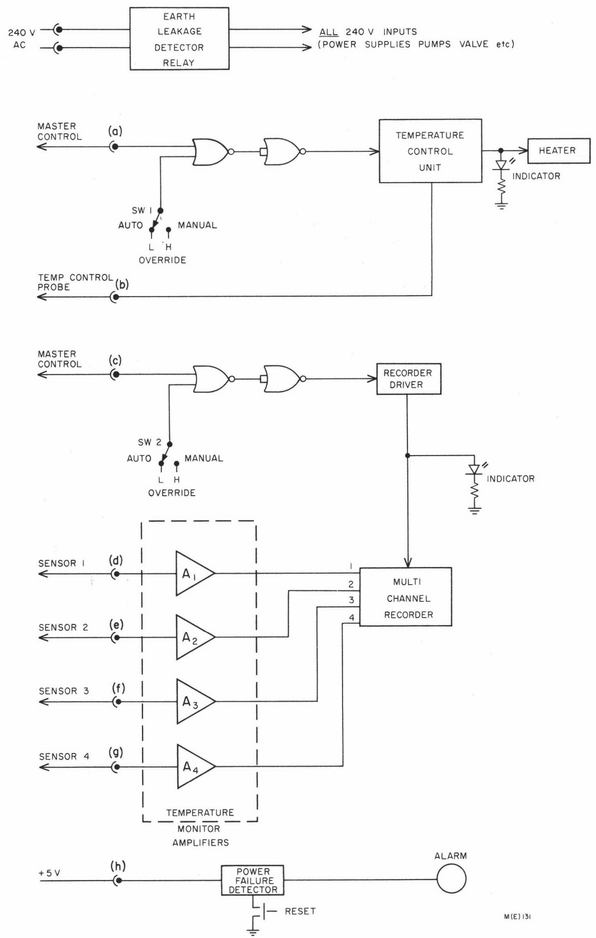

Figure 3. Block diagram showing the Control Logic for Earth Leakage Temperature Control, Recorder Driver, Multichannel Recorder, and Power Failure Detector.

window is obtained by operating the rapid-advance drive at the back of the unit.

Individual cycle programmes are inserted into the selected channel by placing the address switch into 'S' position, by selecting the desired start-time by the thumbwheel switch, and pressing the insert button. The stop-time is obtained similarly but with the address switch in 'F' position. The procedure is repeated for each individual channel. Both sections, A and B, are operated in a similar way.

The interface and logic section is operated as follows:

The desired temperature is selected by the 10-turn potentiometer. The water-flow pathway pattern is obtained by placing the main valve switch and the pump switch into 'Auto' position and by selecting the pathway cycles by the V_1/V_2 ratio switch.

If simulation of the evaporative stage of the environment is required, the hydraulic system is programmed to remove the water wholly or partly from the sediment surface, and the heating lamp is activated for a required time or until a present temperature of the sediment or overlying water is obtained. The temperature limits, duration, and repetition of the evaporative cycle is regulated by the controller (14). Sampling of the sediments and/or the overlying water is done through the sampling ports using a microsampler and/or coring rig equipped with self-closing bit. The sampling methods, probes, specifications and detailed methodology have been described previously (Bubela & Ferguson, 1973; Bubela and others, 1975).

Conclusions

The system described in this paper is capable of simulating a variety of environments. Its electronic components can independently control a number of systems, each of them performing a variety of func-

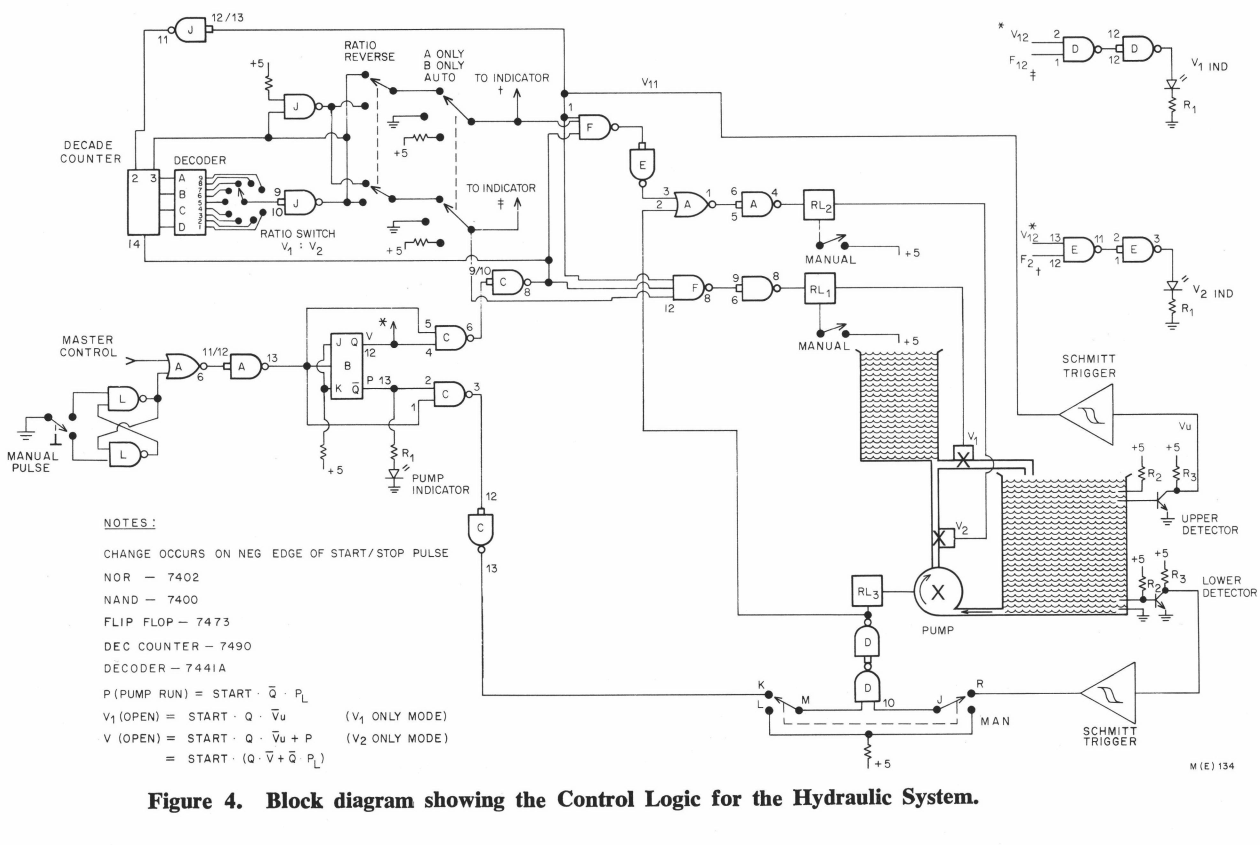

Figure 4. Block diagram showing the Control Logic for the Hydraulic System.

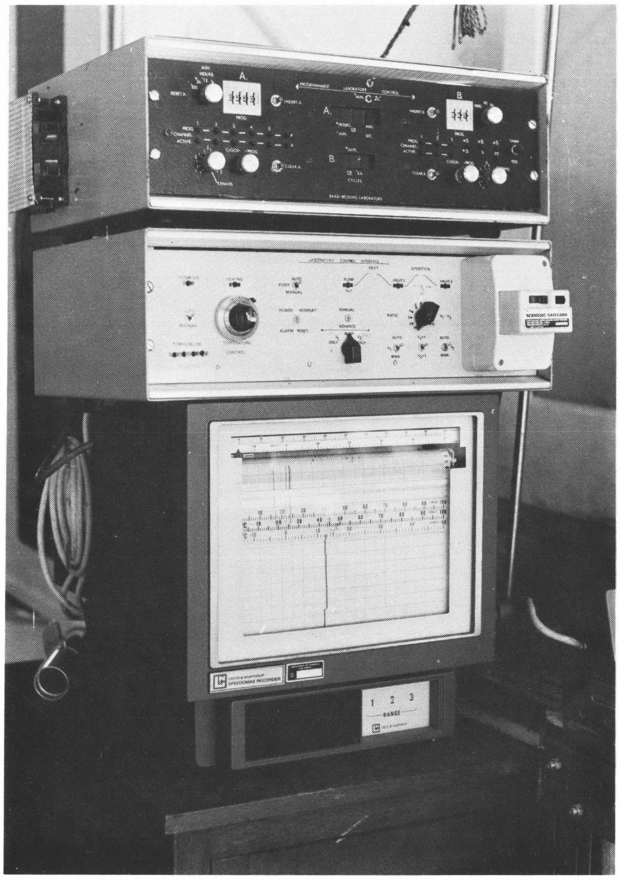

Figure 5. The synchronous electronic master clock and the interface-logic unit.

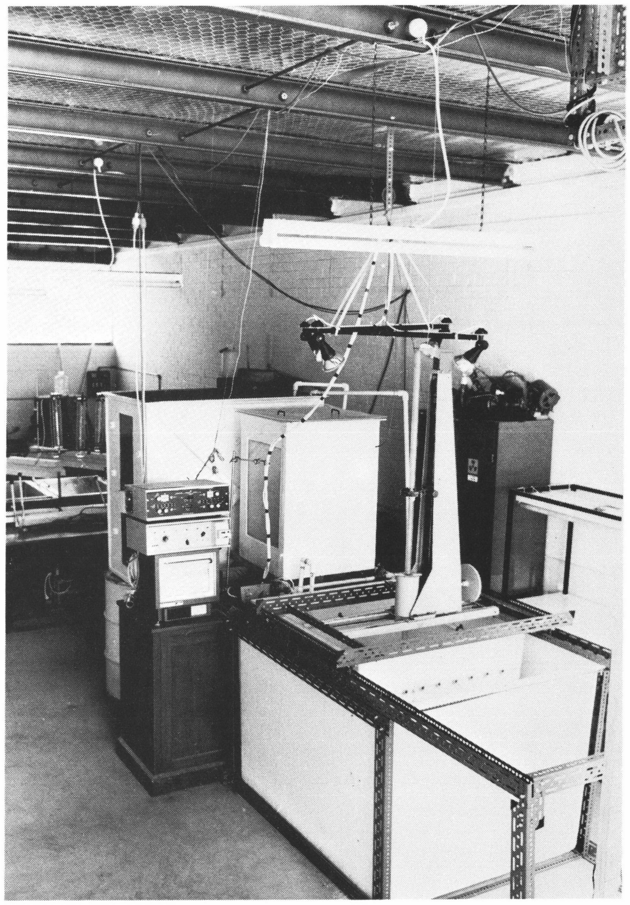

Figure 6. Photographic view of the simulating system.

tions. The cycling capacity of the system covers the range up to 10 years. At the present time the SEMC is controlling a sabkha (Fairbridge, 1968) simulating system, as well as a system (to be described later) designed to simulate an environment where polluting airborne metal particles travel through a water column before they are incorporated in sediment.

Acknowledgements

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