Division 3151

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MEASUREMENT OF THE PENETRATION OF LIQUID SODIUM INTO LIMESTONE CONCRETE

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In two recent articles,[1,2] Sutherland and Kent have described a pulse-echo ultrasonic technique which measures the motion, as a function of time, of the interface of two dissimilar materials. They have illustrated the technique by monitoring the motion of an ice/flame interface, a plasma jet/concrete interface,[1] and a molten core materials/concrete interface.[2] This technique has now been used to monitor the movement of the interface created by pouring hot, liquid sodium onto limestone concrete.

The pulse-echo ultrasonic system used here is shown in Fig. 1. This system is identical to the one described in Ref. 1, and a complete description of its operation is provided there. The essence of this system is to measure the time required for an acoustic signal, generated by the transmitting transducer, to traverse the specimen, reflect at the pool/concrete interface, and then

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retraverse the sample. When this total transmission time t, measured at some time τ into the test, is combined with the acoustic wave velocity C_o and the calibration measurement of the transit time taken before the start of the test ($\tau = 0$), the distance $\Delta\ell(\tau)$ the interface has moved during this interval can be determined by

$$\Delta\ell(\tau) = \frac{C_o}{2}\left[t(o) - t(\tau) + 2\sum_{i=1}^{N}(1/C_i - 1/C_o)\,\ell_i(\tau)\right].$$

The last term inside the brackets is a temperature correction term that is obtained by dividing the path of the acoustic wave at time τ into N constant temperature zones, each with a length ℓ_i and an acoustic velocity C_i (this velocity is obtained from a velocity-temperature plot[2]).

This technique was used in coordination with the large scale sodium/concrete interaction tests that are being conducted at Sandia Labs.[3] The concrete used in this series of tests was manufactured using limestone aggregate. For each test, up to 225 kg of sodium is heated in a separate container to 550 C and then dumped rapidly into a concrete crucible. The acoustics were used to monitor the position of the sodium/concrete interface as a function of time.

The measured penetration profile for a typical test is shown in Fig. 2. In this figure, the profile has been superimposed on the temperature history measured by thermocouples in the sodium pool (approximately isothermal) and in the concrete at 1, 6, and 19 cm, respectively, below the sodium/concrete interface. As illustrated in this figure, the sodium penetrated into the concrete at an approximately uniform rate of 1 mm/min for the first three minutes of the test, and then slowed down. The final penetration depth was approximately 5 mm, which was reached 8 min. after the start of the test.

After this initial penetration, the reaction of the sodium with the concrete may stop or it may become very violent. In the former case, when the pool cools to a solid, little additional penetration is noted and the final pool is composed mainly of unreacted sodium. In the latter case, when the reaction becomes violent, the penetration of the sodium into the concrete becomes quite large and the final pool (or, more appropriately, slag) contains very little free sodium. The course of a particular experiment is governed by many factors, including the geometry of the crucible and the amount of sodium dropped into the crucible.

In addition to the penetration data, this acoustic technique allows the experimenter to draw some conclusions about the phenomenology of these experiments. Namely, large acoustic noise pulses are observed during the first few minutes of the tests, see Fig. 2. They imply that the concrete is being spalled off the sodium/concrete interface rather than being dissolved. This active period is then followed by a rather quiet period in which an occasional interface spall occurs.

In conclusion, pulse-echo ultrasonic technique has been used to monitor the motion of the interface between limestone concrete and liquid sodium. Real time plots of the position of the interface have been obtained, and interface spall has been observed.

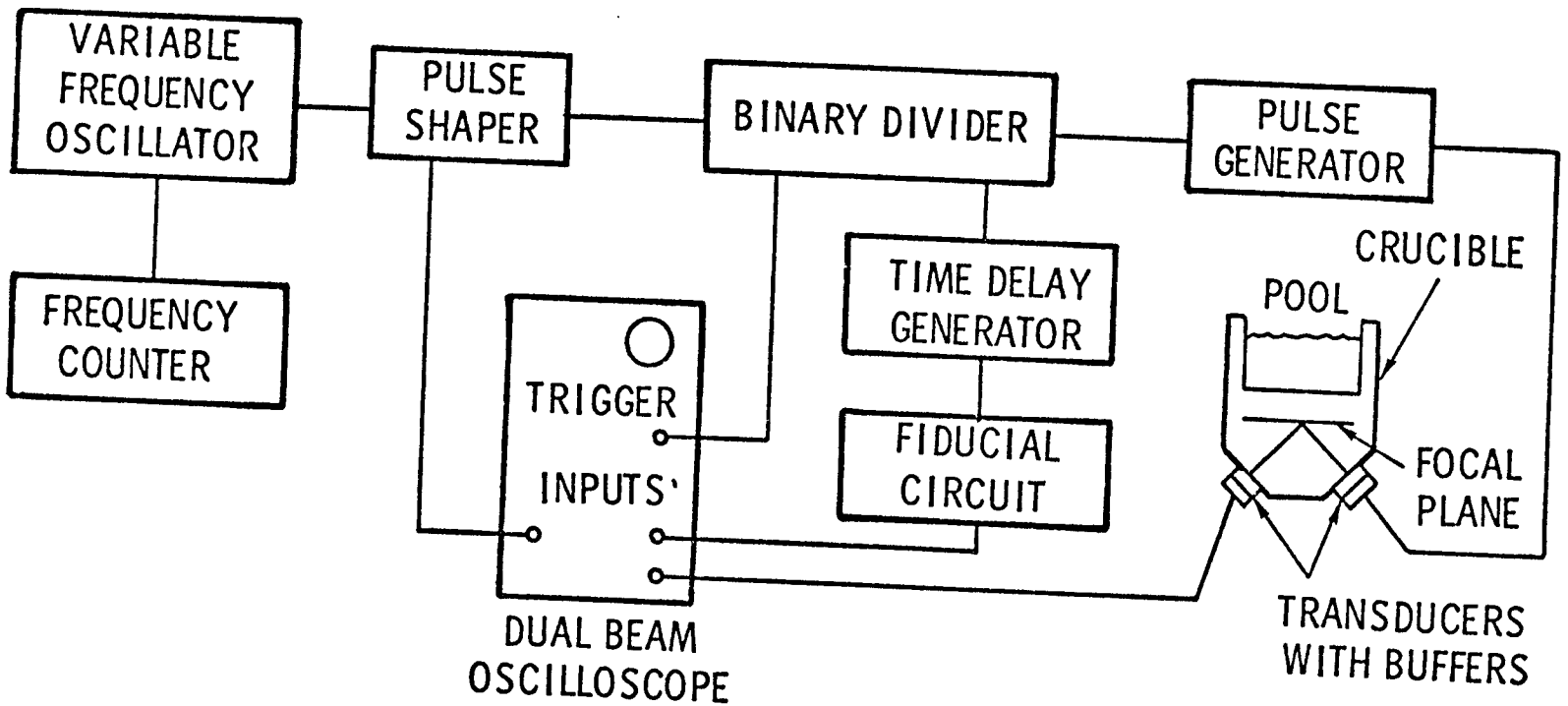
References

1. H. J. Sutherland and L. A. Kent, Rev. Sci. Instrum., 48, 1010 (1977).

2. H. J. Sutherland, Proceedings of the Annual Post-Accident Heat Removal "Information Exchange," Argonne National Laboratory (1977), (in publication).

3. J. E. Smaadyk, H. J. Sutherland, D. L. King, and D. A. Dahlgren, Transactions of the ANS 1977 Winter Meeting, 528 (1977).

List of Figures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SODIUM–CONCRETE TEST # 4