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ABSTRACT

At the invitation of the State Rivers and Water Supply Commission of Victoria, the Australian Atomic Energy Commission conducted acoustic emission monitoring during the proof testing of a large steel bifurcate on the outlet of the Dartmouth Dam under construction on the Mitta Mitta River in Victoria.

No indications of defects or local yielding were recorded during pressure testing by the acoustic emission equipment. This result was supported by extensive strain gauging which had been conducted by the Snowy Mountains Engineering Corporation.

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ACOUSTIC EMISSION TESTING; PIPE JOINTS; PIPELINES

CONTENTS

1. INTRODUCTION

In January 1977 the acoustic emission (AE) group of the Australian Atomic Energy Commission (AAEC) was invited by the State Rivers and Water Supply Commission (SRWSC) of Victoria to participate in the proof testing of a bifurcate ('Y' junction) in the outlet pipe of the Dartmouth Dam. This dam is currently under construction on the Mitta Mitta River in Victoria. The outlet divides at the main bifurcate (D1) into two branches, one which supplies the power station and another which supplies water for irrigation (Figure 1). The irrigation branch divides again at the bifurcate of interest (D9 - Figures 2 and 3) and feeds through two valve chambers. The bifurcates were designed by the Snowy Mountains Engineering Corporation (SMEC) and fabricated on site under the SRWSC's scrutiny.

Although they were of advanced design, only bifurcate D9 gave any significant fabrication problems. Distortion due to welding and fitting-up stresses produced a flat spot on the top of the main upstream section of D9, and required the building up of a circumferential weld on the downstream, right-hand branch. Because of these problems it was decided that D9 would be extensively strain gauged during proof testing and, as a further assurance of safety, AE monitoring would be carried out.

AE may be generated in a structure in regions where plastic strain is occurring. By monitoring AE and using suitable electronic circuitry, areas can be located in which AE is being generated, and regions of localised plastic strain can be detected. In a steel structure, AE may result from the cracking of microscopic carbides, slag inclusions or the ferrite itself, or from the movement of cascades of microscopic dislocations. Useful AE occurs in the form of bursts of elastic energy, with frequencies ranging from several hertz to several megahertz. These bursts generally have some frequency components in the audible frequency range. However, most useful information is obtained by monitoring the ultrasonic components of a burst.

In a structure designed to sustain only elastic stresses, the stress concentrating effect of a crack, a delamination, or a welding defect may cause local stresses to exceed the yield stress, and acoustic waves may be emitted from these areas. Similarly, AE may result from unexpectedly high local stress caused by faulty design or poor workmanship.

AE bursts may be detected by piezo-electric transducers attached to the structure. These transducers produce an electrical signal which may be amplified and recorded in a variety of ways. If three transducers are attached to a structure, the arrival times of the same signal can be monitored at each transducer, and the position of the source of the emission can be calculated. Areas of the structure from which recurrent AE bursts are detected should then be regarded with suspicion and examined more closely by other techniques.

The AAEC has recently obtained a flaw location computer (FLIC 3) from Southwest Research Institute, San Antonio, USA (Figure 4). This is an analogue device which monitors the output of three transducers, calculates the origin of AE bursts, and displays the location of the source as a stored spot on a storage oscilloscope. The unit, which works in real time, is suitable for field work such as the Dartmouth Dam test.

2. TEST PROGRAM

The two bifurcates (D1 and 9) and the pipe section shown in Figure 1 were filled with water and pressurised using a four-stage positive displacement pump. Dial gauges were placed on a manifold at the lower blanked-off end (Figure 5). Pressurisations were carried out in three cycles to the proof test pressure of 3320 kPa. The pressure was reduced to $\sim$ 650 kPa between each cycle. During each pressurisation, pumping stopped for $\sim$ 15 min every 650 kPa to permit SMEC personnel to record strain gauge readings.

3. ACOUSTIC EMISSION MONITORING

The AAEC mobile AE laboratory, a caravan, was towed to $\sim$ 30 metres from the bifurcate. Coaxial leads were connected through preamplifiers to six AE transducers attached to the bifurcate, in the positions shown in Figures 6 and 7. An additional transducer, an accelerometer, was also attached to record the audiofrequency component of the emissions and to monitor extraneous noises. Because the acoustic waves detected by the transducers travel within only the steel shell and do not enter the water, the 'unfolded' shell of the bifurcate (Figure 7) is used to determine the sound paths in the structure.

The AE transducer outputs were divided into two channels, representing two different monitored triangular areas on the bifurcate (Figures 6 and 7). Because the computer could monitor only one area at a time, switching was provided through co-axial relays.

These triangles were set up specifically to monitor the flat spot on top of the main pipe (Circuit A) and the circumferential weld on the right-hand branch (Circuit B); however, the sensor placement was also made to obtain the maximum coverage of the rest of the bifurcate.

The equipment and programming accuracy were checked by injecting an artificial signal source into the bifurcate at known locations and ensuring that each of these appeared at the appropriate place on the FLIC screen. The artificial source was provided by pressing the corner of a refractory brick against the bifurcate wall. The fragmentation of the asperities, in the brick, yield copious emission in the high frequency region monitored by the equipment. However the amplitude was too low, and the attenuation caused by the long signal path (up to 6 metres) was too great for easy detection. The establishment of the location of the source required much patient brick crushing. For future tests a more sophisticated ultrasonic transmitter should be used as an artificial source.

The data were recorded during testing on a video tape recorder and monitored on a small TV unit. The data were mixed on the TV screen to provide simultaneous records of a number of events. One camera watched the pressure gauges, another the output of the accelerometer on a small cathode ray oscilloscope (voltage vs time), and another monitored the FLIC screen. On the audio track of the video tape recorder were recorded the output of the accelerometer, the conversations on two-way radios of the SMEC and SRWSC personnel who were supervising the tests, and technical comments by the AAEC team watching FLIC and the oscilloscope. In addition, the output of the accelerometer was fed to a true r.m.s. voltmeter and recorded on one channel of a two-channel chart recorder. The other channel recorded an analogue signal from the FLIC unit. This signal was proportional to the total number of AE bursts which occurred within a particular area in the monitored triangle. In this way a complete and detailed history of the tests and the AE behaviour could be recorded for later review.

4. RESULTS

At all stages of testing, AE sources were recorded in both of the triangular areas monitored; however at no stage of the testing was any localised repetitive source detected, indicating that no plastic deformation was occurring in any monitored area.

On numerous occasions, FLIC recorded sources in the monitored area when extraneous noises from outside the area were heard on the accelerometer; however most of the noises heard were rejected by FLIC. Those extraneous noises recorded by FLIC are of no significance, as the computer has often been observed to be 'fooled' by external sources, and the frequency of their occurrence was not sufficient to cause a problem. At the time of testing, construction was still being carried out on adjacent concrete structures, steel reinforcement and formwork, and as these were often in physical contact with sections of the pipe it is surprising that the computer rejected the majority of external signals so well. The audio track on the video tape contained a continuous succession of extraneous noises resulting from the operation of rock drills, jack hammers, welders and motors.

Although AE testing is still in its infancy and cannot be used to guarantee the integrity of a structure, it seems unlikely that any significant defect grew during the proof test, or that any yielding occurred. No AE from yielding was detected around the flat spot on top of the main inlet branch of the bifurcate, and none was detected near the circumferential weld on the right-hand branch. These results confirm earlier weld radiography and concurrent strain gauge monitoring. Verbal reports from SMEC personnel at the time of the test suggest that none of the strain gauges on the bifurcate detected any yielding.

The test was of benefit and interest to the AAEC, as this was the largest structure we have yet monitored. The equipment was proved and some of the minor deficiencies noted are being rectified. The experience gained by AAEC personnel will undoubtedly be of value in carrying out tests on other large structures.

5. CONCLUSIONS

No evidence of any defect or of localised yielding of the bifurcate was detected by acoustic emission monitoring during proof testing.

6. ACKNOWLEDGEMENTS

We are grateful to the State Rivers and Water Supply Commission of Victoria for the opportunity to participate in this test. We thank specifically Mr. J. Kilkenny and Mr. N. Mills for their assistance and Mr. J. Wade of SMEC for providing the contact. Thanks are due also to the various people of the AAEC who helped get the caravan and vehicle ready in time for the tests.

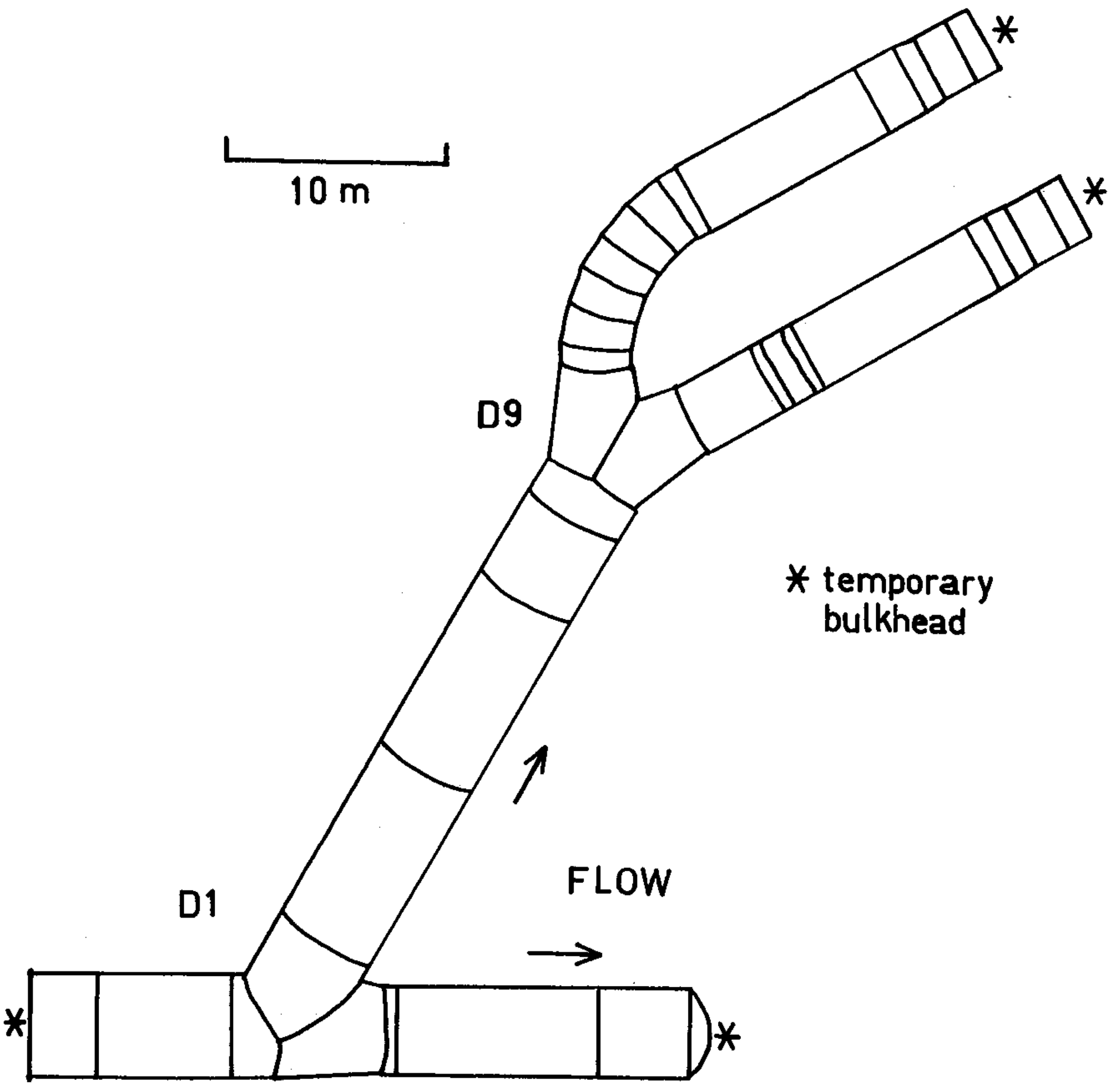


FIGURE 1. OVERALL PLAN OF THE DARTMOUTH DAM OUTLET.
BIFURCATE D9 WAS TESTED FOR ACOUSTIC EMISSION

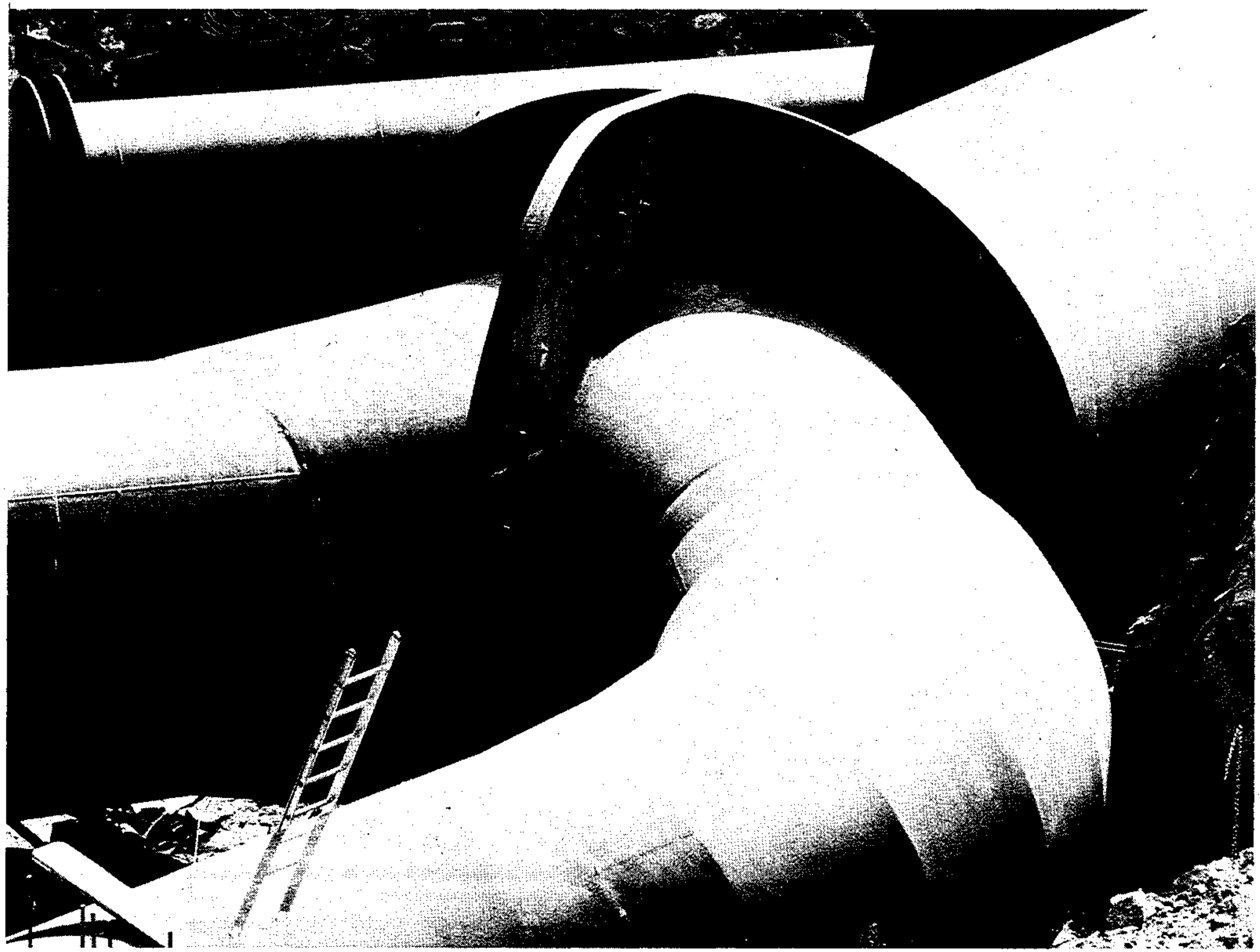


FIGURE 2. BIFURCATE D9. VIEW FROM ABOVE SHOWING REINFORCING RING GIRDERS

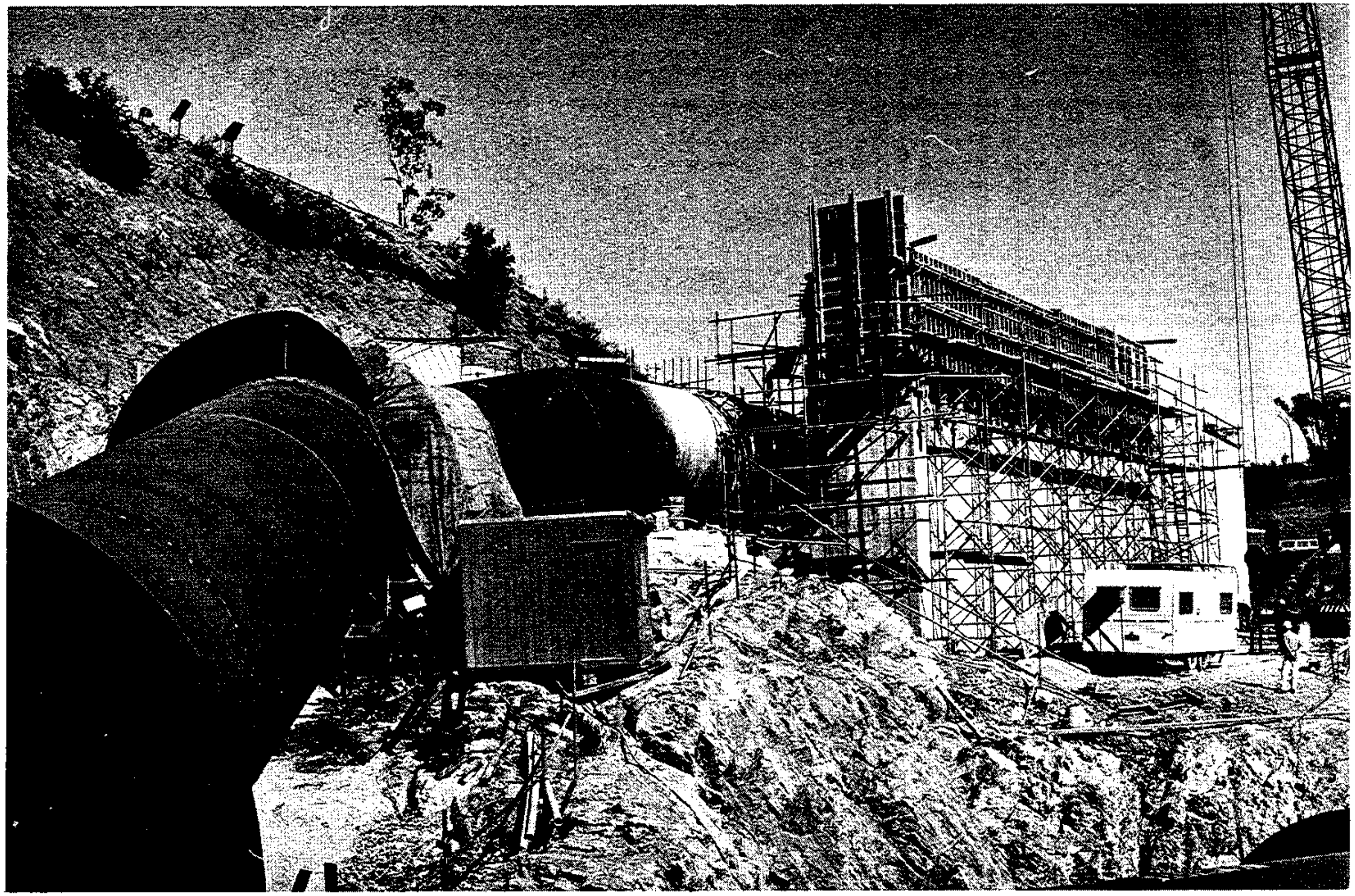


FIGURE 3. TEST LOCATION SHOWING THE AAEC MOBILE ACOUSTIC EMISSION LABORATORY IN POSITION. The D9 bifurcate is on the lett of the picture. The SMEC strain gauging equipment was located in the hut adjacent to D9.

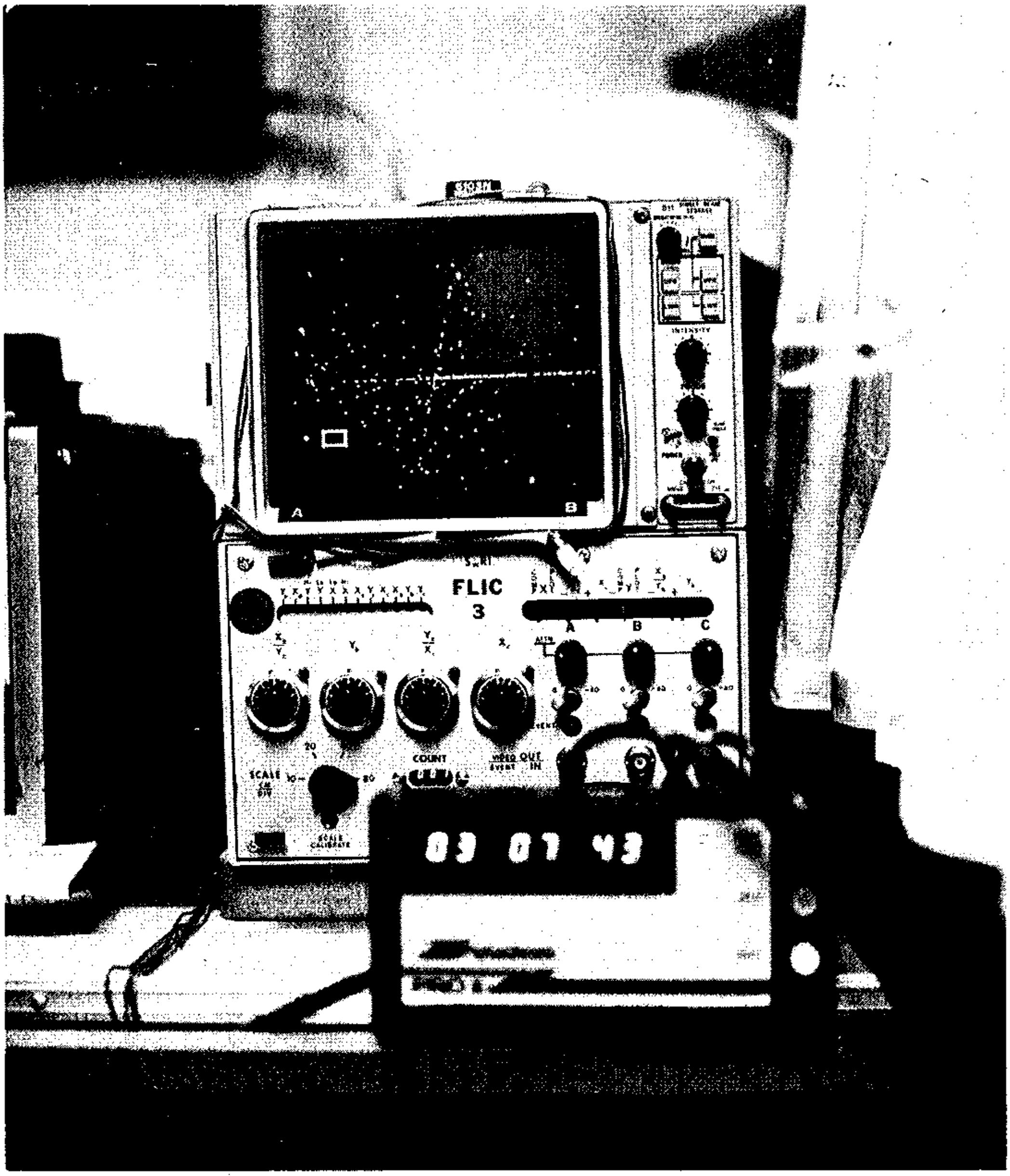
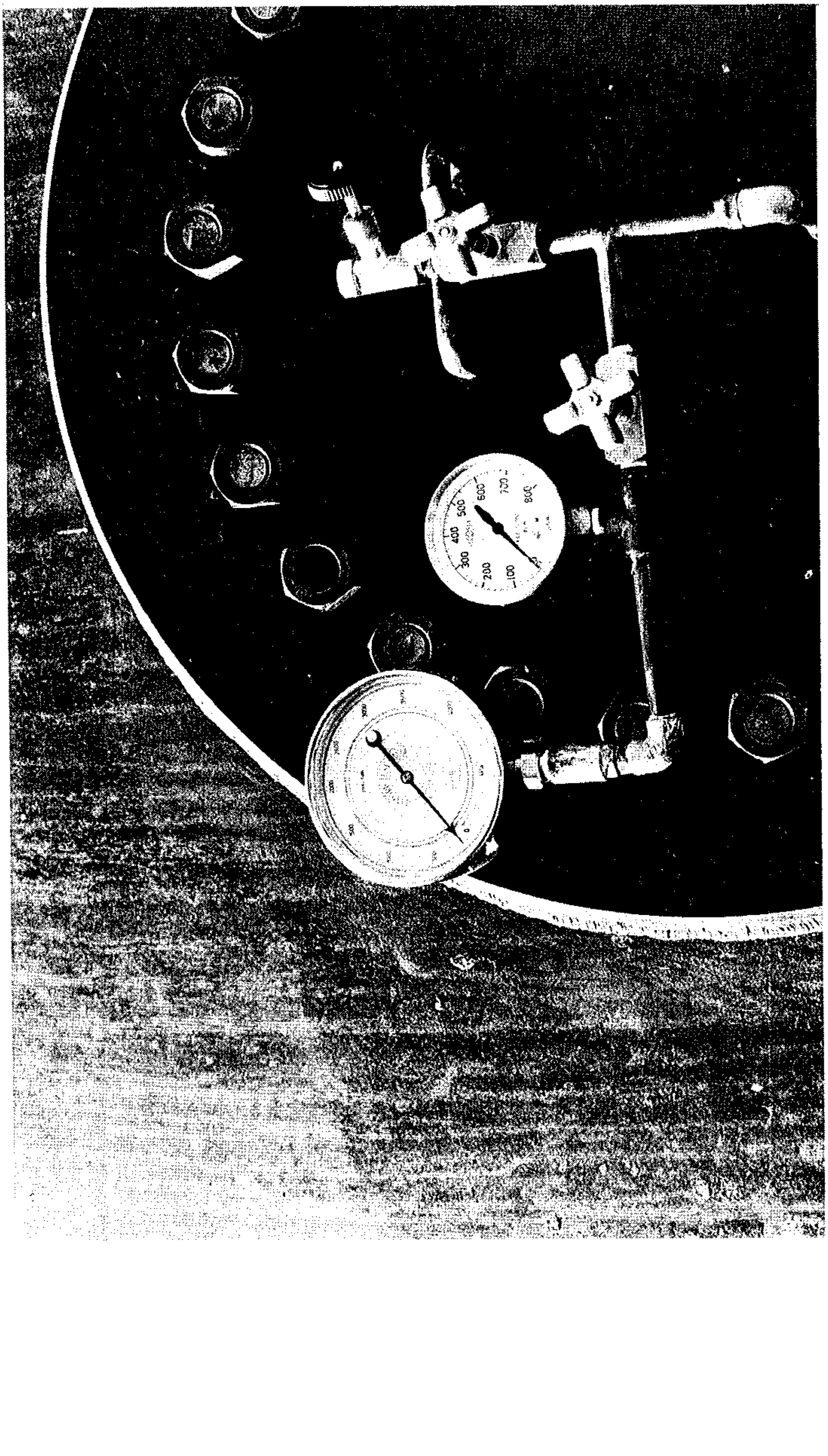


FIGURE 4. THE FLAW LOCATION AND IMAGING COMPUTER, (FLIC 3.) USED FOR LOCATING SOURCES OF ACOUSTIC EMISSION ON D9.



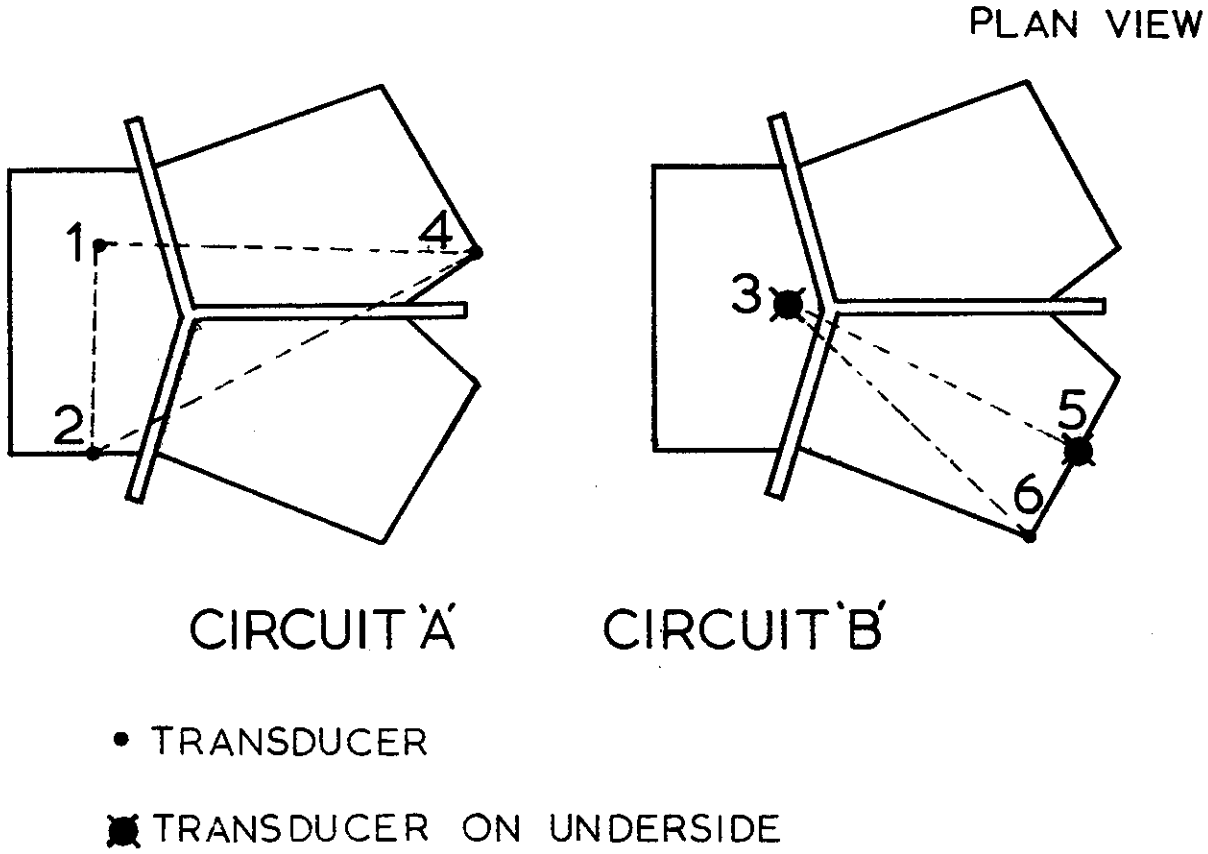


FIGURE 6. LOCATION OF TRANSDUCERS ON BIFURCATE D9. The six numbered transducers were divided into two circuits A & B to monitor two separate triangular areas Note that the dotted lines are guides only and do not represent the projection of the sides of these triangles

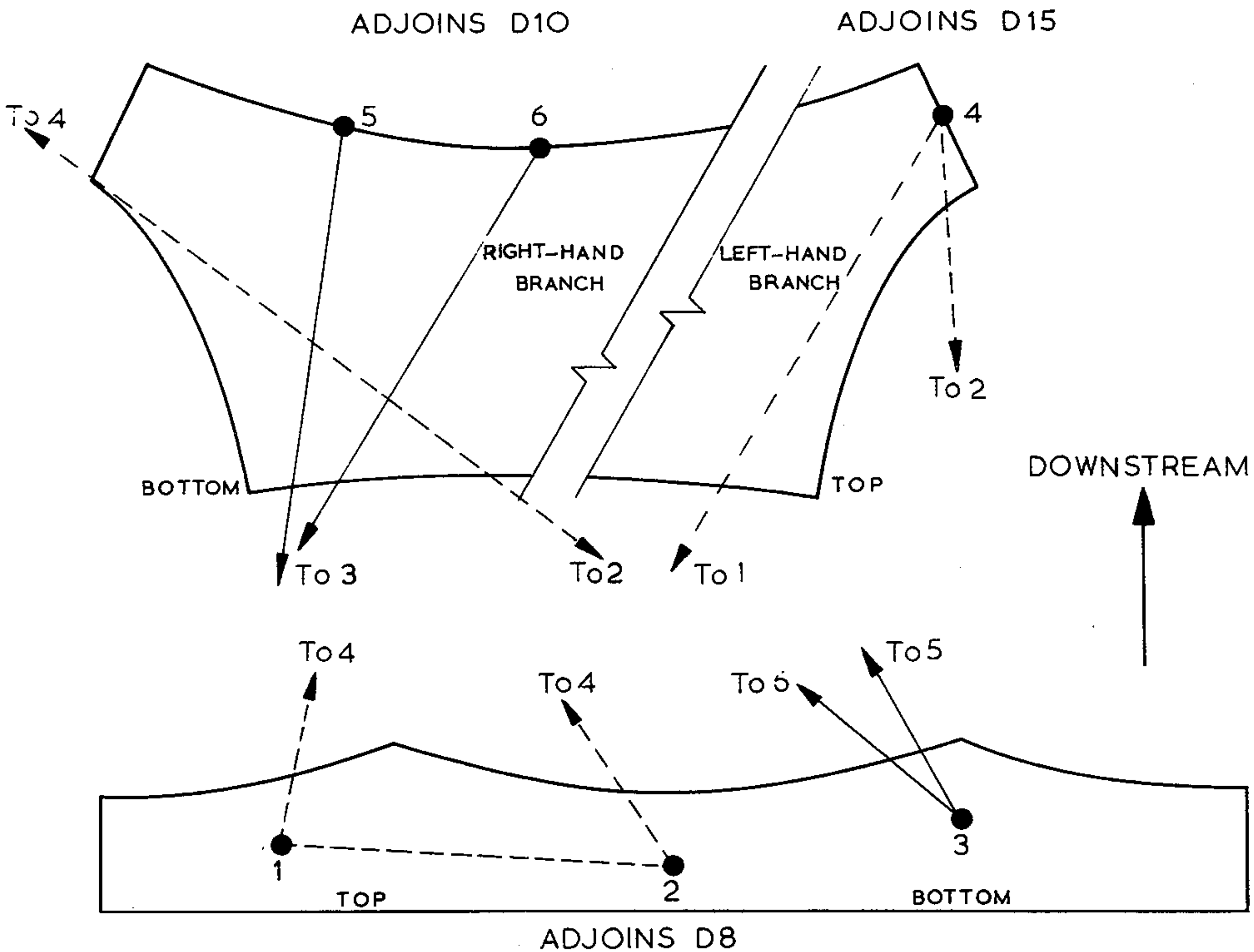


FIGURE 7. UNFOLDED SHELL OF BIFURCATE D9 SHOWING THE SIDES OF THE TWO TRIANGULAR AREAS MONITORED BY FLIC 3. (CIRCUIT A — DASHED LINES)