DEVELOPMENT OF AN ACOUSTIC EMISSION EQUIPMENT FOR VALVES OF THE NUCLEAR POWER STATION ATUCHA I.

by

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ABSTRACT.

A four channel Acoustic Emission was developed by the Acoustic Emission Group, INEND Department, of the Atomic Energy Commission of Argentina, for the detection of leaks in valves of the pressurized air system: "Sistema de desconexión de emergencias por ácido deuterobórico".

Basically, the system consists of four piezoelectric transducers with their corresponding preamplifiers coupled to the piping close to the valves. The following stages: amplifiers, threshold levels, channel identifications and visual alarm system are gathered in a box.

The system was installed in the controlled zone of the Nuclear Power Station Atucha I. It was calibrated and works on line.

The values shown on the display are registered daily in order to separate the normal values from the leak ones.

Part of this work was supported by the IAEA Research Contract Number 5987/R1/RB.

1- Introduction.

Acoustic Emission testing offers a new method to perform nondestructive testing of materials, manufacturing processes and structural components. When a material is strained, it emits a characteristic sonic signal that is called Acoustic Emission (AE). Detection of AE signals allows in the engineering or scientific field to predict when a material is about to fail and gives him the opportunity to prevent the failure in such cases.

The family physician employs one form of AE testing when he listens to the human heart-beat with a stethoscope. However, the sound emitted by a deforming metal or nonmetalic structure is much more difficult to detect. Sensitive piezoelectric transducers must be utilized to hear the events of deformation and fracture, and convert these pulses to electronic signals. Filters are required to screen out unwanted background or extraneous noises. The electronic signals need to be amplified, processed and presented to the user in a simple display (1).

An extra capability of those equipments is to detect, and to hear, leaks in pipes and valves, because leaks produce elastic waves in a large frequency spectre included in AE frequencies (50 kHZ up to 1 MHz).

A typical nuclear power station has more than 70 safety-related check valves, the majority of which control water flow (2).

Among the various on-line monitoring techniques for a prompt leak valve detection, particularly attractive appear to be the acoustic techniques based on the detection of acoustic noise associated with leak outflow. The acoustic techniques have a unique set of features: omnidirectional monitoring, remote sensing, high sensitivity, reliability, low cost.

Besides, if we use the part of acoustic energy which propagates through the metal of the structure, it is possible to use a non-invasive sensor, i. e. set on the outer side of the component.

Leaks in any pressure or vacuum system can be located by using the ultrasonic energy generated by molecular collisions when gas is forced through a small orifice. The ultrasonic frequencies involved are well outside the audible range, thus enabling the instrument to be used in areas of extremely high audible noise level.

Ultrasonic energy is picked-up by a high frequency piezoelectric sensor. The signal is amplified and conditioned in order to provide a visual indication (3).

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2- Development.

Nuclear Power Station Atucha I required the AE Group to develop an AE equipment able to detect leaks in four valves of the "Sistema de Desconexión de emergencia por ácido deuterobórico". This equipment controls the valves of an air system that must be ready to stop quickly the reactor in case of accident. Leaks on valves produce the compressor to work continually to keep a constant pressure.

Figure 1 shows the scheme of valves location, TB11-S001, TB21-S001, TB31-S001 and TJ50-S050.

Basically, the equipment consists of four piezoelectric transducers which are coupled near the valves with their corresponding preamplifiers; the following stages: amplifiers, threshold levels, channel identifications and visual alarm system are gathered in a box.

Figure 2 shows a block diagram of the main parts of the AE system.

It is worth noting that all parts of this four channel equipment were developed and constructed at the Atomic Energy Commission of Argentina.

2.1- Transducers.

Basically transducers consist of a PZT (lead, zirconium, titanium) piezoelectric crystal, with their faces silvered. It has one or more preferred frequencies of oscillation, governed by crystal size and shape. In this case its diameter is 25.5 mm and 2 mm of height, getting a resonant frequency of 75 kHz.

The crystal and its electrodes were enclosed inside an aluminium capsule, the base is made of plastic. To ensure good contact with the tube where the detector was placed, a special plastic shoe with tube shape was constructed; vacuum grease was used for couplant.

The transducers are plugged into a differential connector, via a coaxial cable; the signal is fed into the preamplifier, some 50 cm away. Figure 3 shows a photograph of the detectors.

All transducers were characterized using the published standards (4). The calibration yielded the frequency response of the transducer to waves, such as those normally encountered in AE works, at a block surface. The transducer voltage response was determined at discrete frequency intervals of approximately 10 kHz up to 1 MHz.

2.2- Preamplifiers.

The signals generated by the transducer are amplified to provide a higher, more usable voltage.

The amplifier was designed to have low noise. Because electric inputs are about 10 μV, it must be placed not farther than 0.50 m, to minimize pickup of electromagnetic interference. The preamplifier has a wide dynamic range and can drive the signals over a long length of cable, so that the main instrumentation can be placed far away if necessary.

The preamplifier provides a fixed gain of 100 (40 dB) and includes a high-pass filter to eliminate the mechanical and acoustical background noise that prevails at low frequencies. The band pass is 30 kHz up to 1 MHz, encompassing the 75 kHz resonant frequency of the transducer used. At lower frequencies, there are increasing problems with mechanical background noise. At higher frequencies the waves attenuate (damp out) more rapidly, and the detection range of the transducer will be smaller. Choice of operating frequency is therefore a trade-off between noise and detection range. In this case, as on pipelines, low frequencies were used.

Figure 4 shows a photograph of the preamplifiers.

All the preamplifiers were adjusted to get a gain of 49.5 dB near the sensor resonant frequency.

2.3- Amplifiers.

The amplifier was also low noise designed. It provides a variable gain up to 30 dB in steps of 1 dB, attainable by the combination of a potenciometer and different keys. They were included in the main box.

2.4- General system.

The system provides a mean for discriminating between signals of interest and noise sources as friction, impact and electromagnetic interference.

In each of the four channels, the signal is measured by its RMS value and compared with an independent and variable threshold, attainable by a potenciometer from 0 V up to 10 V.

Each RMS value is showed on a voltmeter. By means of a key the channel can be selected, so the operator can read the RMS value for each channel.

To make the inspection of the valves easier, the equipment provides an audible indication too. This is achieved by means of a frequency converter from AE frequencies to audible frequencies. The sound is a real one, as leaks are, and is emitted by a low noise speaker. Its volumen is controlled by a potenciometer.

The system works online. To supply an easy and quick indication to the technician who controls the equipment daily, a visual alarm on the front pannel indicates which valve is exceeding the settled threshold.

To avoid false indications produced by noise sources such as friction or impact,the visual alarm has a delay time. The leds in front panel light on only for signals which exceed the threshold continuously for longer than 20 seconds. The whole system is reseted by a button.

Figure 5 shows a photograph of the front panel of the equipment.

To enable calibration and subsequent analysis, the system can be output to an oscilloscope and to a transient recorder.

The system works with 220 V, 50 Hz AC.

3- Installation.

At a first step, the system was tested in the lab with different pressurized air leaks for long time periods. In figure 6 one of the test can be seen.

At last, the system was installed in the controlled zone of Atucha I Nuclear Power Plant. This work was complicated due to the safety requirements to work in that zone, i.e.,special clothes and gloves.

The valves controlled by the AE technique are: TB11-S001, TB21-S001, TB31-S001 and TJ50-S050.

Each sensor was coupled to the tube, as close as possible to each valve, with vacuum grease as acoustic couplant between the metal and the shoe, and held with a plastic holder. The preamplifier was held in the same form. Figure 7 shows in detail the sensor and the corresponding preamplifier fixed to the tube close to the valve.

Cables from each preamplifier to the control box were held with plastic tape to the pipes, the longest of them about 14 m.

In figures 8 and 9 the equipment and its inside pannel in its present location can be seen.

4- Calibration.

The gain was fixed at the maximun level for all channels.
At a first step we measured the noise level in each channel, which was about 50 mV.

To test each channel, the signal produced by an ultrasonic probe sensor excited with a sine wave was used as a source for the AE transducer. The ultrasonic sensor was placed on the pipeline, 4 cm away from the AE sensor,and excited by an oscillating signal, 85 kHz, 1 V amplitude. The threshold was lowered to light on the corresponding leds ligths on in the front panel.

To check the whole system, we used a portable pressurized air cylinder. Placing the air peak over the pipe 5 cm away from each valve, we augmented the air leak until the corresponding led light were on.

5- Discussion.

Acoustic monitoring of valve leaks is perceived to be a viable and valuable technique.

Pipe and valve leaks are significant contributors to power plant unavailability and are therefore targets for on-line AE monitoring for incipient failure detection.

At present, we are constructing a portable equipment, to detect leaks in other pipelines of difficult access.

At this moment too, we are studying a project to develop a 24 channel AE system to detect leaks in the primary circuit system by mean of thermocuples and AE transducers and PC controlled.

6- Acknowledgments.

The authors would like to express their gratitude to the authorities and technicians of the Nuclear Power Plant Atucha I, for the cooperation in the installation and calibration of this EA prototype.

7- References.

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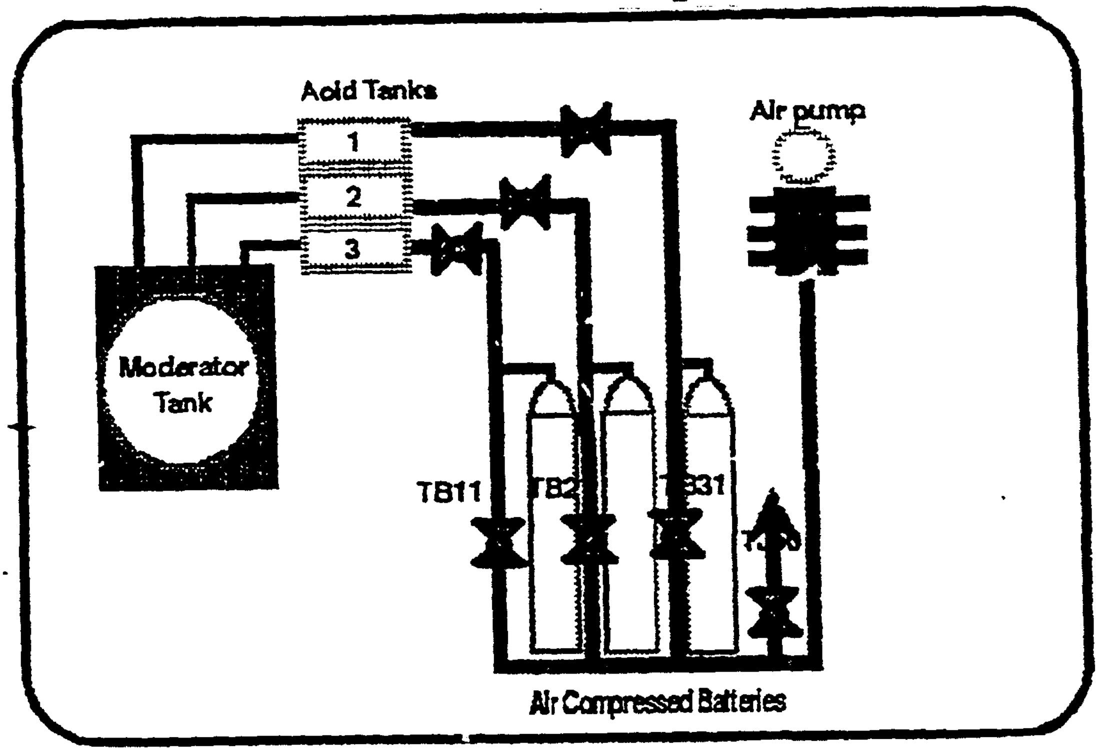


Figure 1. Scheme of valves location

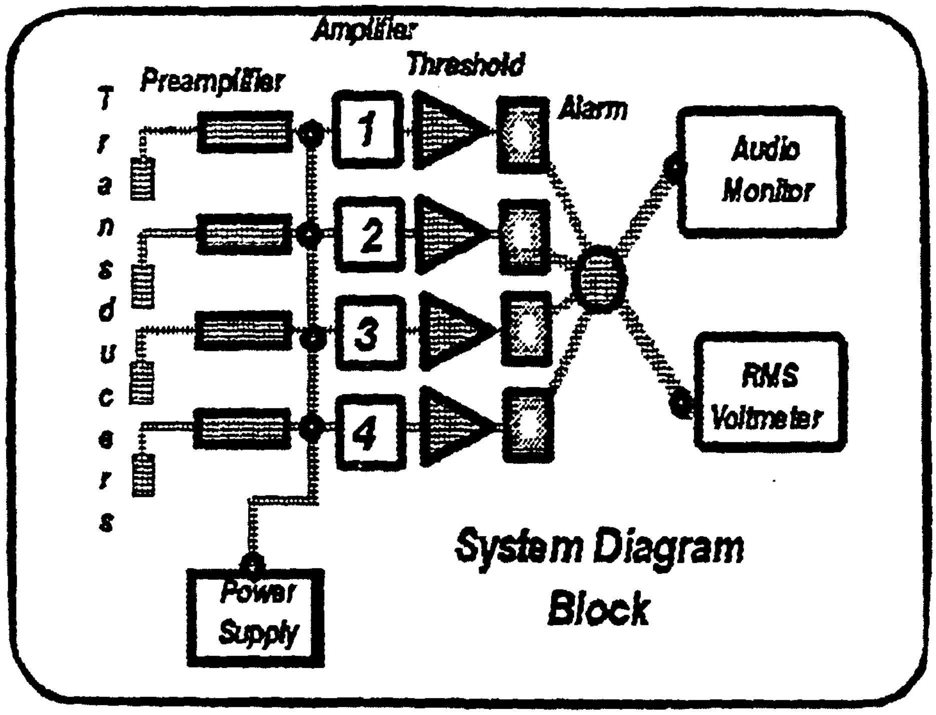


Figure 2. Block diagram of the AE system.

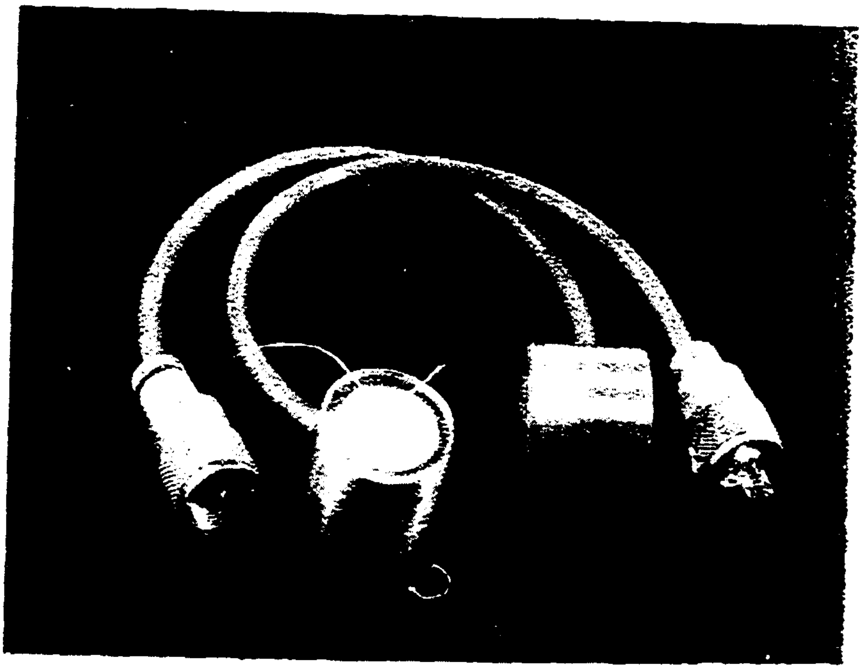


Figure 3 AE transducers

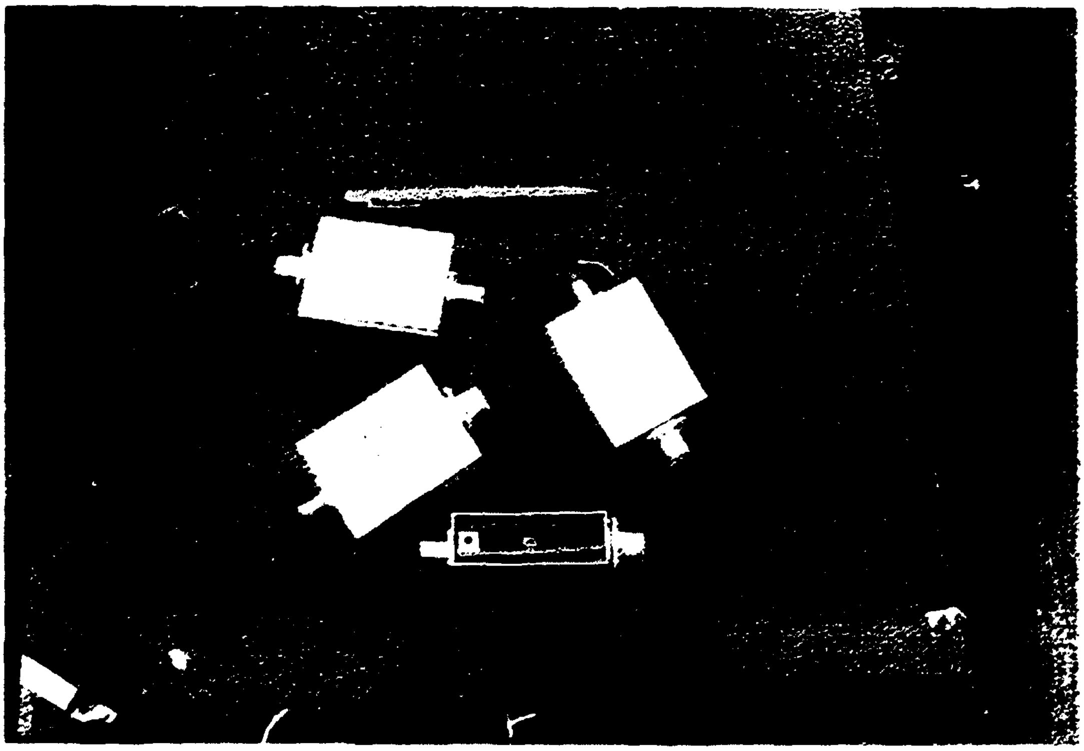


Figure 4 AE preamplifiers.

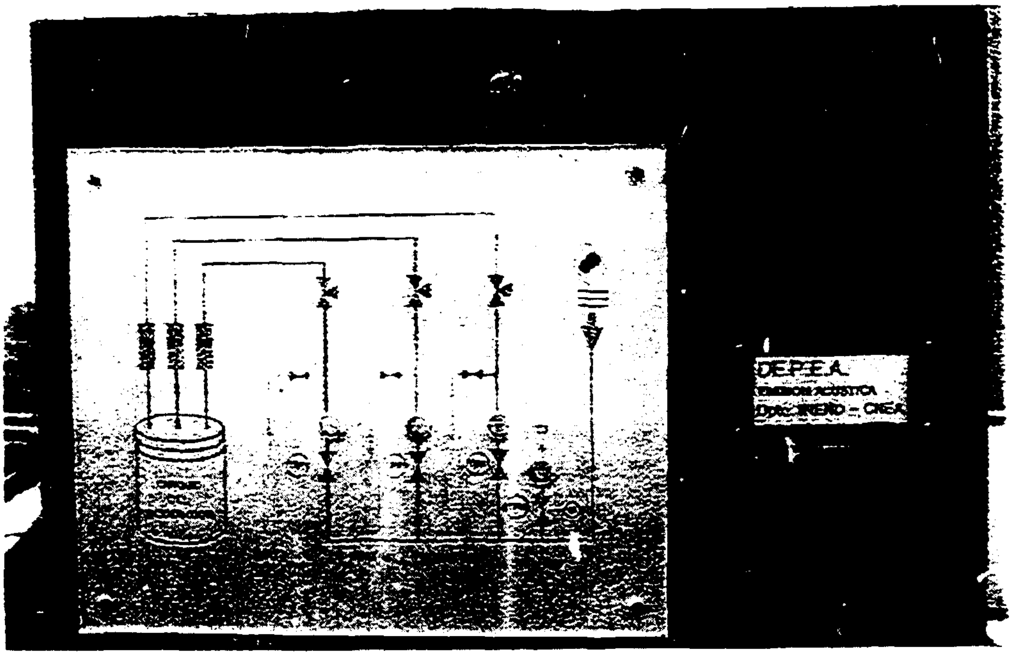
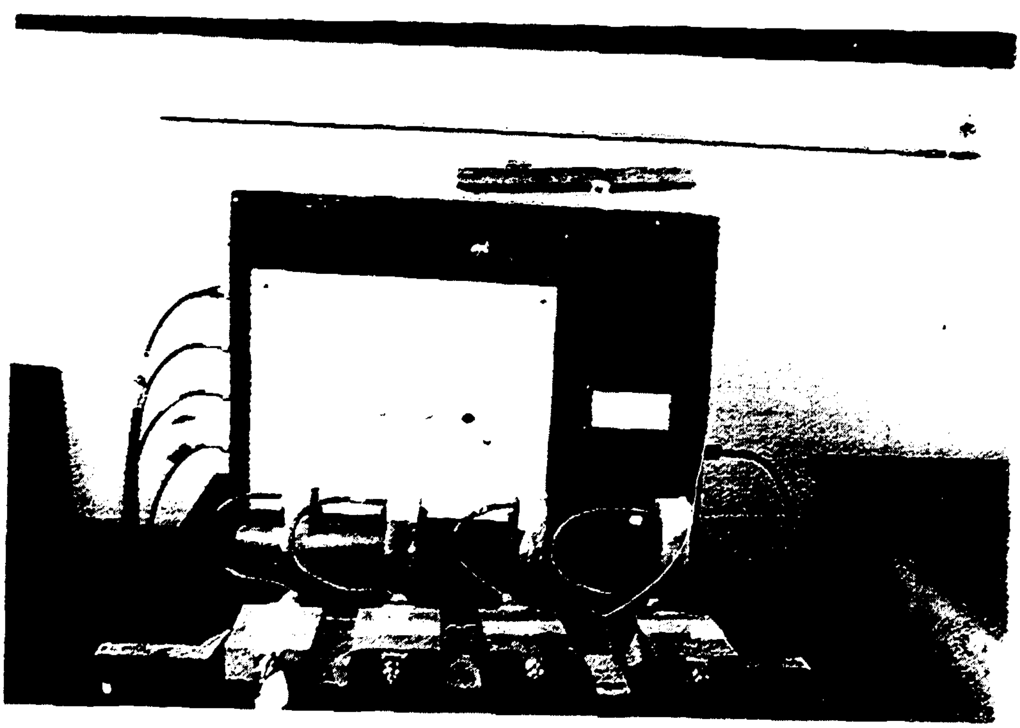
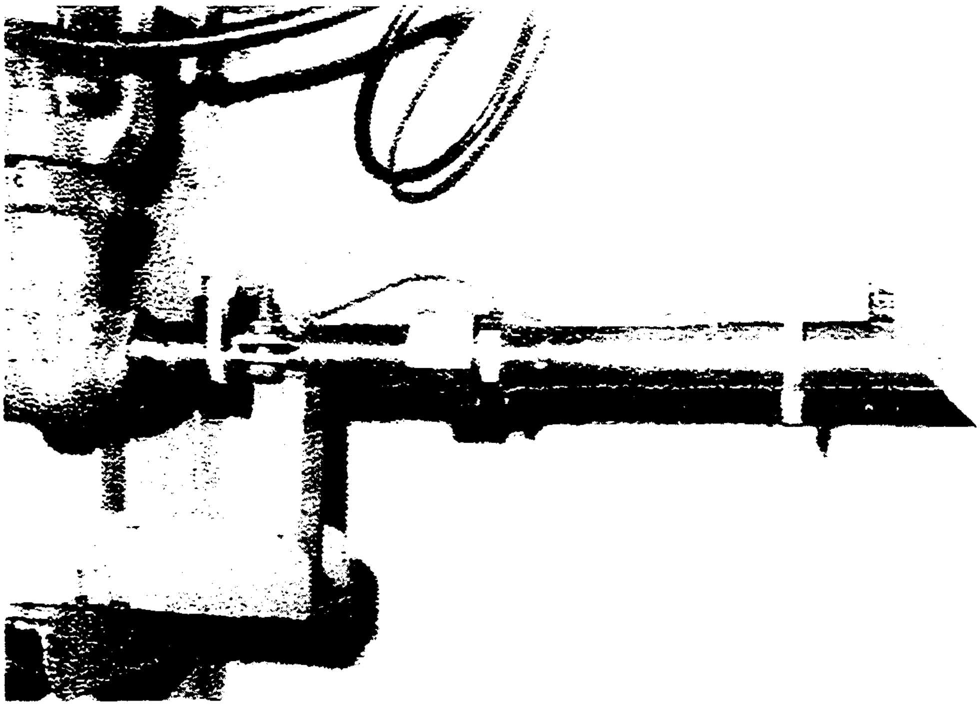
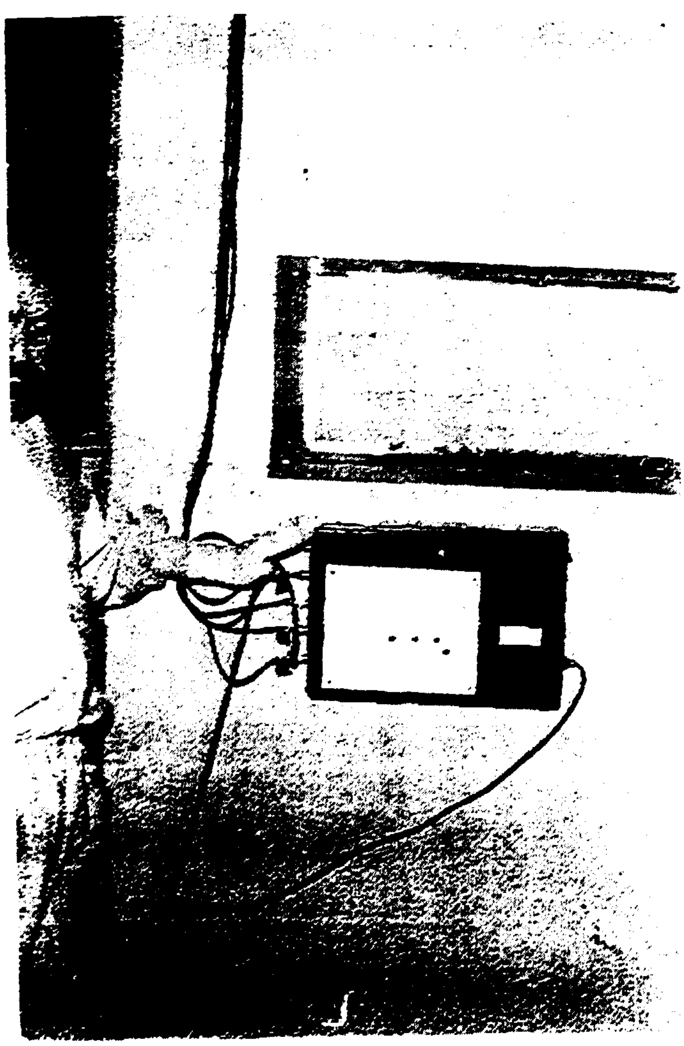


Figure 5 Front panel of AE system



Figore 6 Lab. test





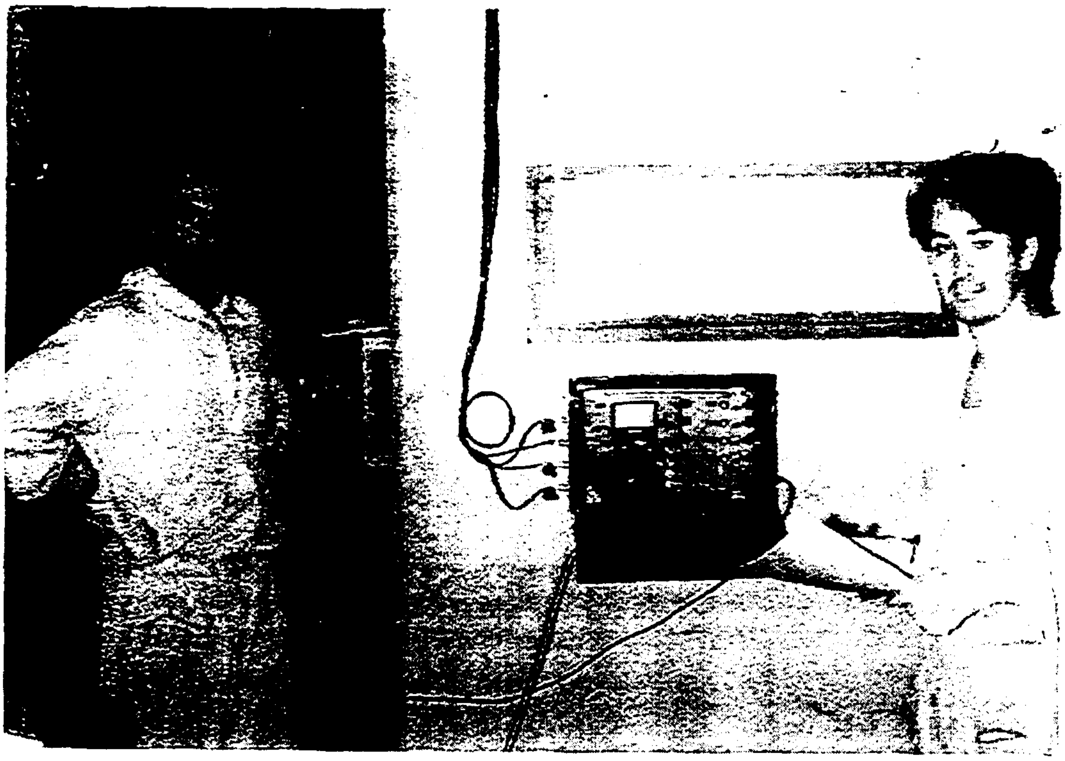


Figure 9. Inside panel of the AE system.