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PANEL ON NON-DESTRUCTIVE TESTING OF REACTOR CORE COMPONENTS AND PRESSURE VESSELS

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AN INSPECTION SYSTEM FOR USE PRIOR TO AND DURING SERVICE FOR THE PRESSURE VESSEL IN THE ATUCHA REACTOR

Juan N. Báez
Argentine National Atomic Energy Commission (CNEA)

1. INTRODUCTION

The first Argentine nuclear power station, for which the CNEA concluded a contract with the West German firm of Siemens in 1968, is at present under construction at the Atucha site, on the River Panará, and is due for start-up in 1973. This station, with a natural-uranium fuelled, heavy-water cooled and moderated pressurized reactor, will be able to supply 319 MW(e).

The original design of the station did not provide for the inclusion of an inspection system for checking the operation of the primary circuit. In view of the experience gained to date on the international level, and the engineering codes and regulations already approved or provisionally in force in the United States and Europe, the CNEA decided to incorporate a system which would permit volumetric inspection of the welding of the reactor pressure vessel.

The first snag arising out of that decision was the fact that there could be no question of inspecting welds from the inside of the pressure vessel. Bearing this limitation in mind, the CNEA, after considering a variety of proposals, decided to commission the Southwestern Research Institute (SWRI) (United States of America) to study, design and build automatic equipment for ultrasonic inspection of the welds in the pressure vessel, nozzles and locking bolts that could be operated from the outside. The commissioned equipment includes transducers, inspection modules and an electromechanical system for positioning and moving them. The CNEA kept for itself the work of designing the data acquisition system and the inspection programme. In due course the contracting firm was requested to introduce certain modifications into the design of the insulation system and the containment for the pressure vessel so that the inspection system could be installed and operated.

2. CHARACTERISTICS OF THE PRESSURE VESSEL

Material:

Forged steel 22 Ni Mo Cr 37 (equivalent to ASTM, A508 class II) containing 0.9% Ni in the core area and 1.5% Ni in the flange and head. The inside is lined with 5.5 mm of arc-deposited austenitic steel.

Dimensions of vessel body:

Internal diameter	5360 mm
Radius of hemispherical base	2735 mm
Internal height	9730 mm
Height of flange	1850 mm
Height of cylindrical shell	5695 mm
Thickness of cylindrical shell	220 mm
Thickness of flange	455 mm
Thickness of hemispherical base	135 mm

Dimensions of vessel head:

Internal diameter	4900 mm
Radius of concave section	3000 mm
Height of flange	800 mm
Thickness of concave section	340 mm

The head is secured by 60 bolts. The flanges and cylindrical sections are composed of three segments welded together.

Working conditions:

Pressure	115.0 atm
Mean temperature	267.8°C

3. AREAS TO BE INSPECTED

The design of the reactor does not permit complete access to all the welds that require examination in accordance with the recent codes. In these circumstances the CNEA had to consider the extent to which maximum volumetric inspection of the welds in the pressure vessel was feasible, bearing in mind how accessible and how critical the different areas were. The inspection system designed by SMRI enables ultrasonic inspection to be made of:

All of the welding between the cylindrical shell and flange;

All of the longitudinal welds in the cylindrical shell;

All of the circumferential welds joining the two segments making up the cylindrical shell;

All of the welding between the shell and hemispherical base;

All of the welds in the nozzles used for the coolant and moderator;

All of the joins between the piping and nozzles;

Locking bolts for the head.

4. DESCRIPTION OF THE INSPECTION EQUIPMENT

The inspection equipment designed and constructed by SWRI consists of three separate systems (for vessels, nozzles and bolts) and a console that also supplies data relating to the positioning and movement of the transducers.

4.1. System for inspecting the vessel

This item is designed for ultrasonic testing of the circumferential and longitudinal welds in the pressure vessel, located between the flange and hemispherical base. It consists of the following parts:

(a) A permanent structure situated in the circular space, approximately 300 mm wide, left for this purpose between the pit insulation and vessel;

(b) An inspection module containing the ultrasonic transducers, permitting the selected areas to be scanned;

(c) A drive unit for the inspection module;

(d) A drive unit for rotating the permanent structure.

The permanent structure consists of a circular rail fixed to the walls of the pit, and supporting a rotating section fitted with a vertical rail, along which the inspection module can travel. This structure was installed in the pit before the pressure vessel was lowered into it.

The inspection module and its drive unit were mounted during each inspection at the top of the pit by removal of one of the blocks forming the insulation.

The drive unit for the permanent structure is hooked up during the inspection through a tunnel providing access in the lower part of the pit.

Scanning of the areas requiring inspection is accomplished by combined movement of the module up and down the vertical rail and of the permanent rotating structure for horizontal motion. In this way the transducers can be set in any position at all on the cylindrical body of the vessel, below the nozzle line.

The inspection module was designed in accordance with the inspection technique applied by [3], which requires three transducers arranged in a line, of which the two outer ones can shift relative to the central one and be turned at different angles. The central one is fixed and normal to the tested surface. The arm supporting the three transducers can rotate 90° about its mid point in a plane parallel to the surface in question, thereby permitting inspection of both horizontal and vertical welds. The transducers are lodged in receptacles with a pressurized water feed for coupling purposes.

The use of three transducers in the module enables one to apply different examination methods, and the possibility of varying the angle provides maximum indicating of a flaw and the greatest amount of information relating to it when detected.

4.2. Arrangement for inspecting nozzles

This consists basically of an annular rail mounted permanently around the nozzle at a convenient distance from the weld, and an inspection module similar to the one used for the pressure vessel. The rail is fitted over the nozzle by means of Inconel springs, which absorb the difference in thermal expansion.

4.3. Arrangement for inspecting bolts

The head locking bolts have an axial aperture running through which makes it possible to inspect them ultrasonically from the inside by means of a special self-centring probe which is guided by a rod from a device on the outside, and fixed to the end of the bolt during each inspection operation.

4.4. Console and positioning controls

There is only one console for all the control and positioning devices in the system, and there are separate independently operating units for the functions relating to the different devices. Those for the drive unit of the permanent structure and the drive unit of the inspection module indicate and control the following: on/off, direction of movement, attitude, coupling mechanism and speed.

The unit for the inspection module provides for indication and control of the following: on/off, transducer angle, translation of transducer signal in the module, rotation of module, and pressure of transducer receptacles.

5. INSPECTION TECHNIQUE

The pulse-echo technique is applied to the longitudinal and circumferential welds in the cylindrical shell in the following form:

(a) Scanning of the weld from both sides at an angle of 45°;

(b) Scanning of the weld from both sides at an angle of 60°;

(c) Scanning of weld zone and adjacent area with normal beam (90°).

The scans in (a) and (b) are carried out consecutively, whereas (c) is effected at the same time as one of the other two.

The tandem technique is applied at the same time as the pulse-echo scanning, an additional transducer being used as a receiver for this purpose.

For the welds between the cylindrical shell and the flange, and in the part where the cylindrical shell is joined to the hemispherical base, we use only the pulse-echo technique and scan at 45° and 60° from just one side of the weld. Scanning with normal light is effected in the same way as for the cylindrical shell.

For the nozzles and bolts we only use the pulse-echo technique, at suitable angles for the geometry of each area.

6. DATA ACQUISITION SYSTEM

When commissioning SWRI to design and construct the inspection equipment in service, the CNEA detailed an ultrasonic test expert from its END service to work at the Institute so that he could get familiar with the design and construction of the equipment, undergo training in inspection procedures prior to and during service, and work on the design of the data acquisition system.

The equipment supplied by SWRI described above provides information relating to the ultrasonic inspection in analogue form, and digital data on the positioning of the module.

The data acquisition system designed by CNEA is designed to provide a permanent record of all inspections and to enable the recorded data to be subsequently processed for handling by computers.

Two sets of ultrasonic equipment are used to actuate the three transducers in the inspection module. One of them operates simultaneously with two transducers - an emitter-receiver and normal angle of incidence instrument - and the other acts as a receiver (45° or 60°). The data (in analogue form) sampled by four gates plus the information received from the X, Y position indicators on the control panel are recorded on magnetic tape by an FM recorder with multiple channels for simultaneous recording.

This FM recorder, which provides a recording that can be processed for subsequent computer analysis, is supplemented by simultaneous recording on a multichannel oscillographic recorder. The latter is thus used as a graphic display system which is simultaneous with the inspection and also permits compensation for the magnetic ink recording, since the signal is received, after a certain delay, from the playback head of the same magnetic recorder.

Incorporated in the magnetic recorder is an audio recording channel so as to include all the additional information required, for example changes in angle of inspection, number of scan and so forth.

Finally, the system includes a video tape recording of the console and oscilloscope screens.

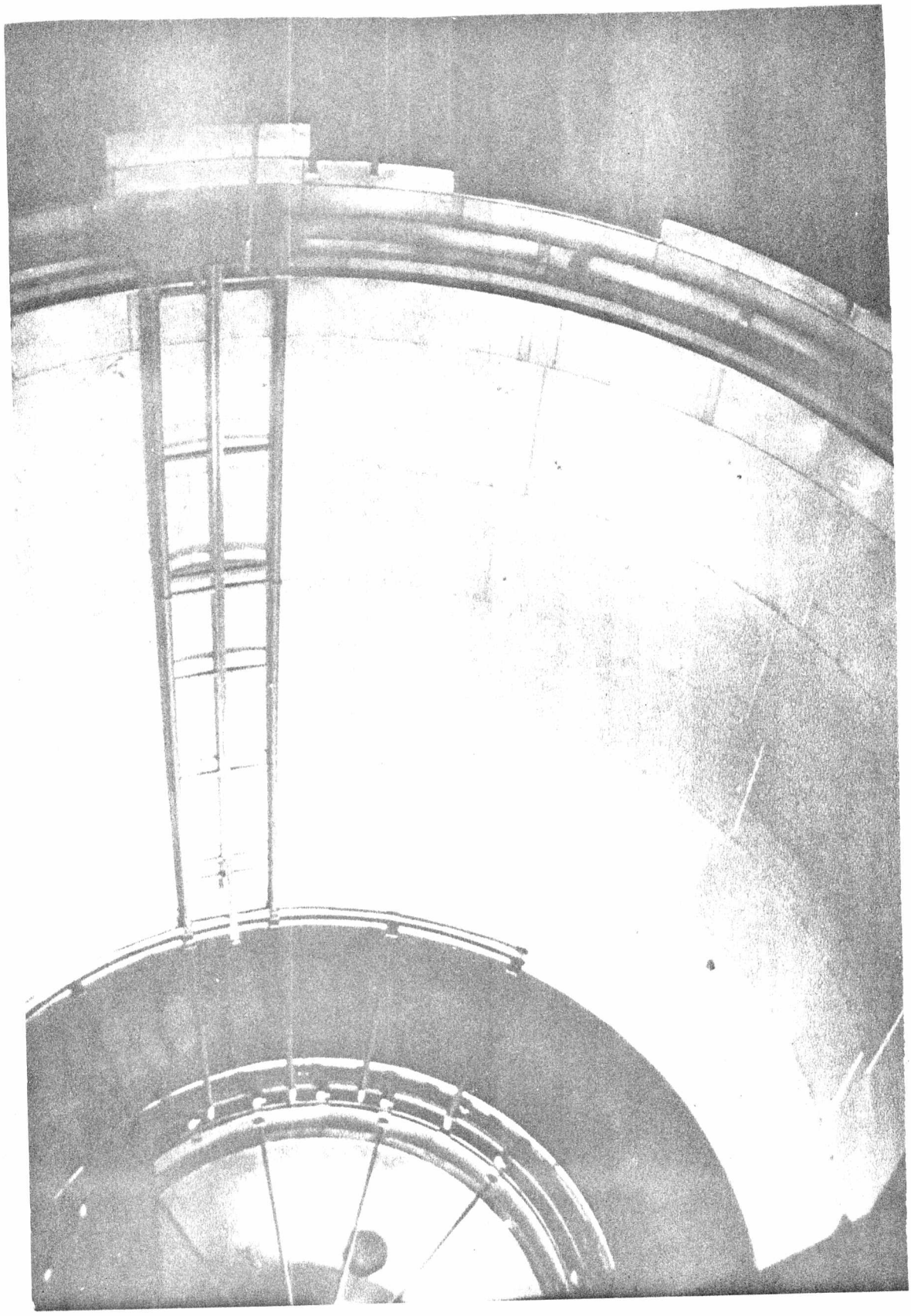

Fig 1.- View of the permanent rotative assembly in the Vessel Pit .-

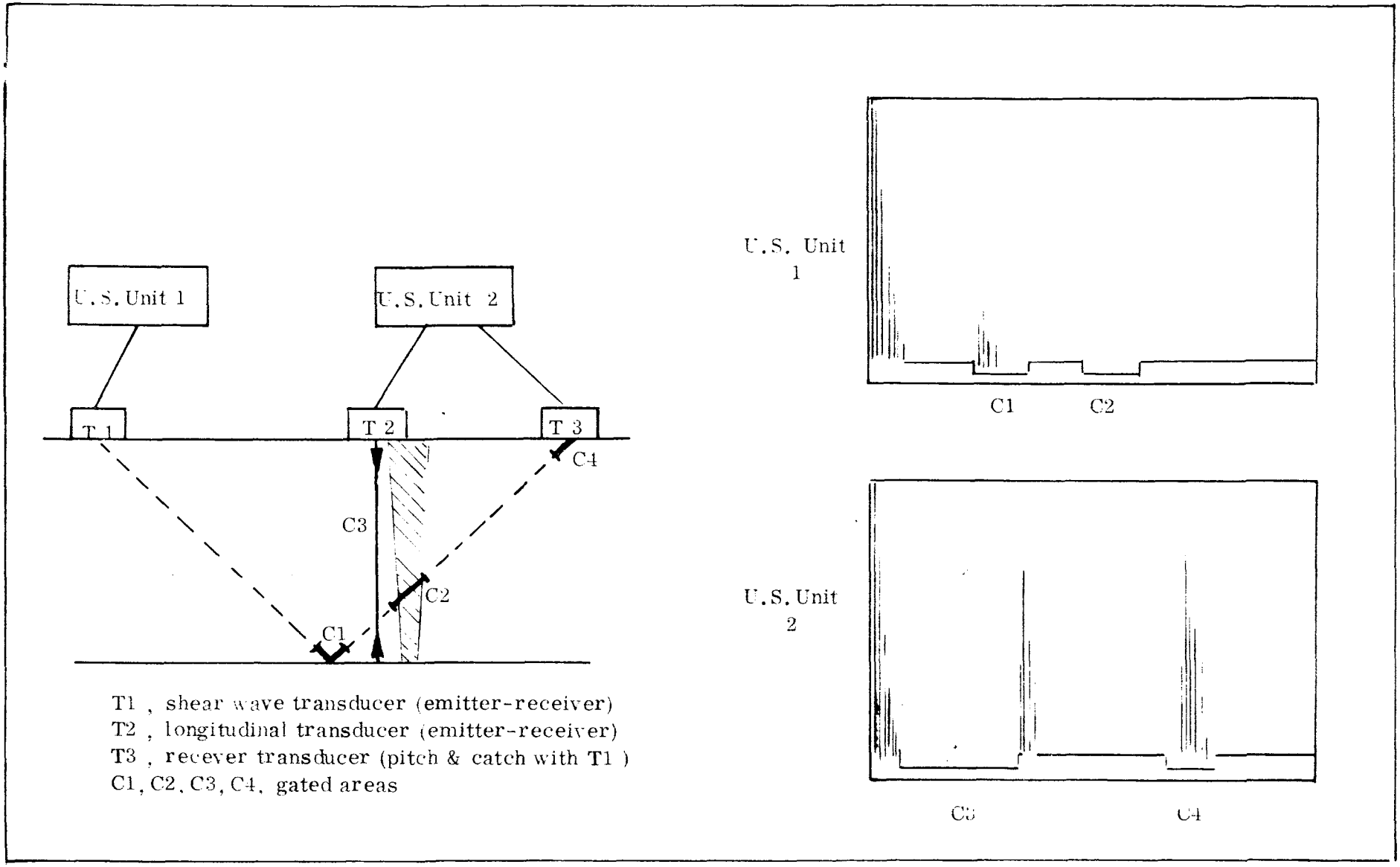

Fig. 2.- Draw illustrating the inspection technique

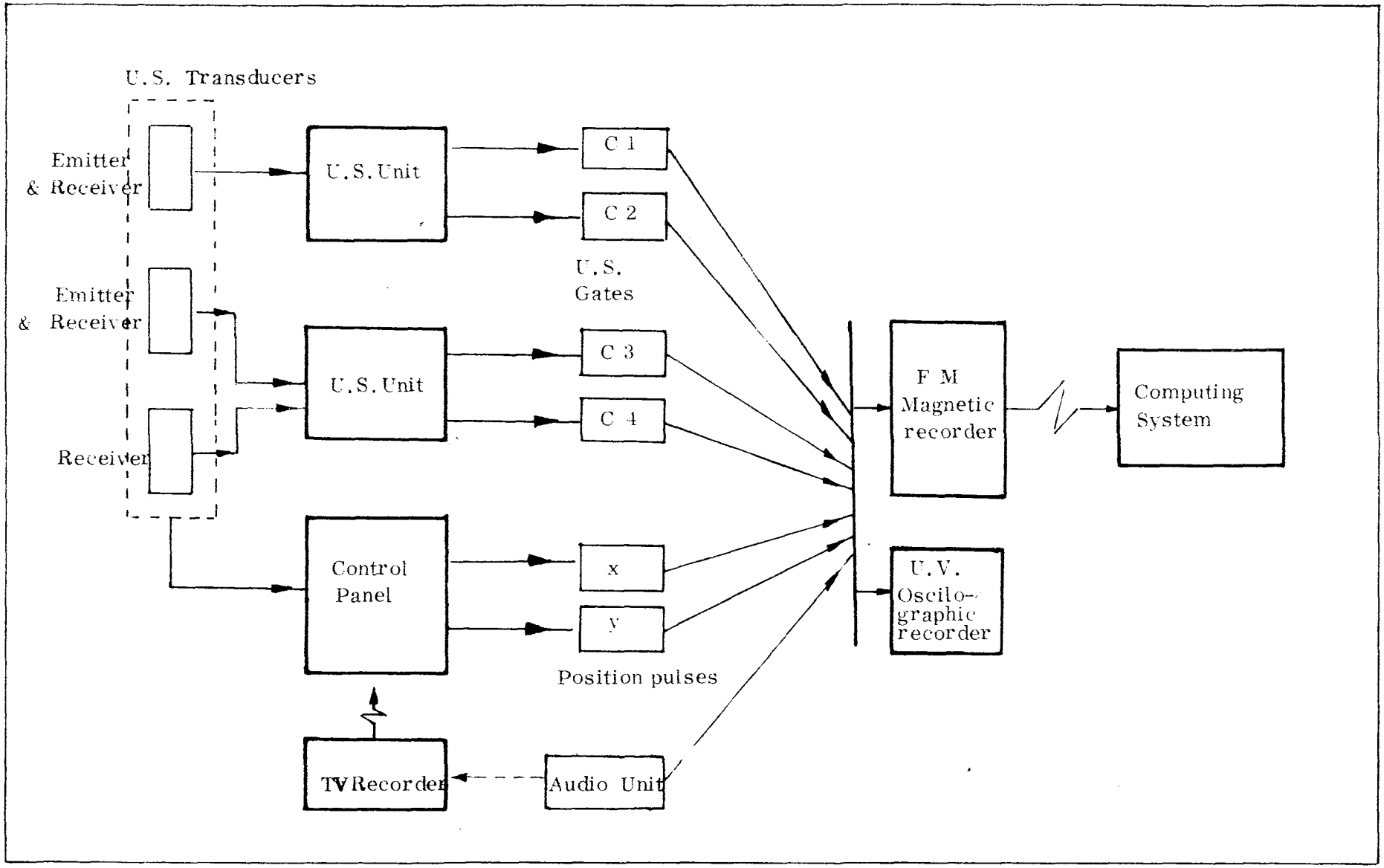

Fig. 3.- Instrumentation and Data Acquisition System