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A PULSED NEUTRON GENERATOR
FOR USE WITH
PULSED NEUTRON ACTIVATION TECHNIQUES

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MASTER

A high-output, transportable, pulsed neutron generator has been developed by Sandia National Laboratories for use with Pulsed Neutron Activation (PNA) techniques. The PNA neutron generator generates >10^{10} 14 MeV D-T neutrons in a 1.2 millisecond pulse.

The PNA generator has been designed to meet the requirements listed in Table I. Each operation of the unit will produce a nominal total neutron output of 1.2 x 10^{10} neutrons. The generator has been designed to be easily repaired and modified. The unit requires no additional equipment for operation or measurement of output. A more complete description of the generator is given in References 1 and 2.

The generator has a minimal operational life of 1000 pulses and can be pulsed up to 12 pulses/minute for 1 minute. After 1 minute, the neutron output falls below 10^{10}. Pulses every 30 seconds can be repeated continuously. High repetition rates (>6 pulses/minute) can cause damage to the neutron tube and shorten the operational life of the generator. When the end of operational life is reached, the neutron tube will require minor servicing to restore the neutron output.

The PNA neutron generator has been segmented into three major component assemblies. Each major assembly contains the individual components which are required to operate the generator. These assemblies, interconnected by up to 60-meter cables, allow the experimenter to conveniently place them in the available space of the experimental area. The major assemblies are shown in Figure 1. The major assemblies, from left to right, are: the Tube-Transformer Assembly (TTA), the Pulse-Forming Network (PFN) box, and the control unit.

The generator utilizes the millisecond pulse (MSP) neutron tube (Figure 2) which was specifically developed for this application. This unclassified tube utilizes a focused deuterium ion beam produced by a specially modified occluded gas ion source. The deuterium beam impinges a 100% tritium-loaded scandium tritide target to produce an isotropic distribution of neutrons with an energy of approximately 14 million electron volts.

The MSP neutron tube is housed in the TTA which is placed at the position where the source of neutrons is desired. The neutron-producing target is located 5.97 cm behind the front surface of the TTA. The TTA is enclosed in a stainless steel cylinder 32.4 cm in diameter and 66 cm long. The cylinder is pressurized to 345 kPa (50 psi) with sulfur hexafluoride gas to provide high-voltage insulation.

A neutron tube was constructed for evaluation of the final neutron generator design. The performance of this evaluation tube is described in Table II. Table II shows that the MSP tube design is capable of surpassing the 1000-operation specification. The design will probably surpass 3000 operations without difficulty. In addition to the evaluation tube, six similar neutron tubes have been constructed for use in neutron generators under construction.

Five neutron generators are being constructed for NRC programs using the PNA technique for flow measurement. An additional PNA neutron generator is under construction for use by Atomic Energy of Canada to investigate a new technique.

A neutron generator was completed in August 1979 to evaluate the final design. This unit was tested to measure the neutron flux distribution (Figure 3) and radiation dose rates (Table III) and to evaluate the neutron monitor (Table IV and Figure 4).

The neutron flux distributions and radiation dose rates were measured to determine an adequate shield design. The flux distribution is essentially uniform over the front surface of the generator and is symmetric. The radiation dose was measured using LiF thermoluminescent dosimeters.

The neutron monitor was evaluated for linearity and gain stability using a lead activation probe, a secondary standard. The gain of the neutron monitor was adjusted so that the digital display would read total neutron output.

The performance of the evaluation neutron generator made it possible to use the unit in the ID test series conducted at the PKL Test Facility of Kraftwerk Union in Erlangen, West Germany, in February 1980.

The neutron generator was installed on the downcomer of the PKL test loop at the location indicated in Figure 5. Biological shielding was required for the generator to reduce radiation exposure to personnel in the area during generator operation. The 4-tonne shield (Figures 6 and 7) was designed for a minimum thickness of 43 cm of polyethylene around the TTA to keep the dose at 1 meter from the source below 4 rem for 2500 pulses. The TTA was enclosed in a cooling jacket inside the shield to keep the TTA temperature below 38°C.

The PFN box was located 6 m from the TTA in an isolated area (Figure 8). The control unit was located 42 m from the TTA location in the control room of the test facility with the other PNA equipment (Figure 9).

This was the first fielding of the PNA neutron generator, and it performed according to specifications. The unit produces a measured average neutron output of 1.2×10^{10} neutrons/pulse and a standard deviation of 3%. The presently installed generator is expected to perform above the specification level throughout the ID test series. After completion of the series, the generator will be returned to Sandia for evaluation testing.

References

1. R. C. Dougherty, G. E. Rochau, R. W. Bickes, Jr., R. J. Walko, and R. S. Berg, "Neutron Generator For Two-Phase Flow Calibration: Annual Progress Report," NUREG/CR-0480, SAND78-2030, November 1978.

2. G. E. Rochau, "Development of a Pulsed Neutron Generator For Two-Phase Flow Measurement," Review Group Conference on Advanced Instrumentation For Reactor Safety Research, NUREG/CP-0007, November 1979.

Table I

PNA NEUTRON GENERATOR

SPECIFICATIONS

Neutron Output:	$>10^{10}$ Neutrons/Pulse
Pulse Duration:	1.2 Milliseconds
Pulse Repetition Rate:	≤ 12 Pulses/Minute
Lifetime:	≥ 1000 Pulses (Low Repetition Rate) ≥ 100 Pulses (High Repetition Rate)
Life-Limiting Mechanism:	Neutron Tube
Exclusive Lifetime:	$\geq 10,000$ Pulses
Neutron Monitor:	Integral Part of Generator. Sensitive to High Neutron Fluxes, Insensitive to Experimental Geometry.

FEATURES

Repairability:	Completely Demountable
Flexibility:	Easily Modified
Portability:	Two People Required
Safety:	Cannot be Triggered Accidentally
Completeness:	Requires AC Line Power Only
Availability:	Most Parts Commercially Available

Table II

PERFORMANCE OF EVALUATION NEUTRON TUBE

Serial Number:	MSP83C
First Tested:	August 24, 1979
Beginning Output:	$1.3 \times 10^{10}/0.13$
Present Output:	$1.27 \times 10^{10}/0.08$
Source Operations:	3117
Tube Operations:	1968

Performance Parameters:

	Source Current	Accelerator Voltage	Accelerator Current	Target Current	Neutron Rate	Neutron Efficiency
Initial	79.2 A	143 kV	50 mA	213 mA	10^7	49×10^6
Present	84.6 A	142 kV	69 mA	211 mA	10^7	48×10^6

Table III

RADIATION DOSE MEASUREMENTS AT 1 METER

	Dose for 20 Pulses (mR)		Dose/Pulse (mR)	
Angle	Neutron	Gamma	Neutron	Gamma
0	350	6	17.5	0.3
45	320	5	16.0	0.25
90	270	5	13.5	0.25
135	330	4	16.5	0.20
180	160	2	8.0	0.10
225	340	6	17.0	0.30
270	290	5	14.5	0.25
315	390	6	19.5	0.30

Table IV

PNA NEUTRON MONITOR

Detector: Quantrad 600-PIN-RM Silicon Photodiode With
45 mm Thick Proton Radiator

Location: Inside TTA, 12 cm From Neutron-Producing Target

Operation Mode: Integration of Detector Current

Calibration: ±2% of Secondary Standard (Lead Probe)

Features: LED Self-Check
DVM Readout With BCD Digital Readout
Last Reading Held Until Next Operation

Figure 1

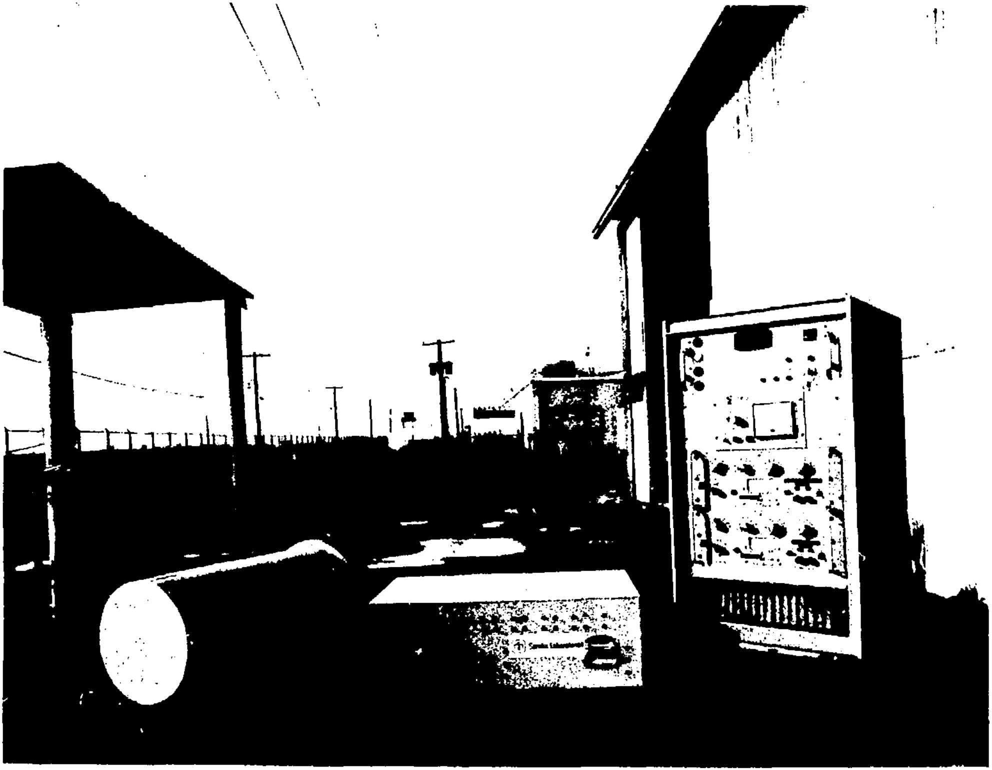


Figure 2

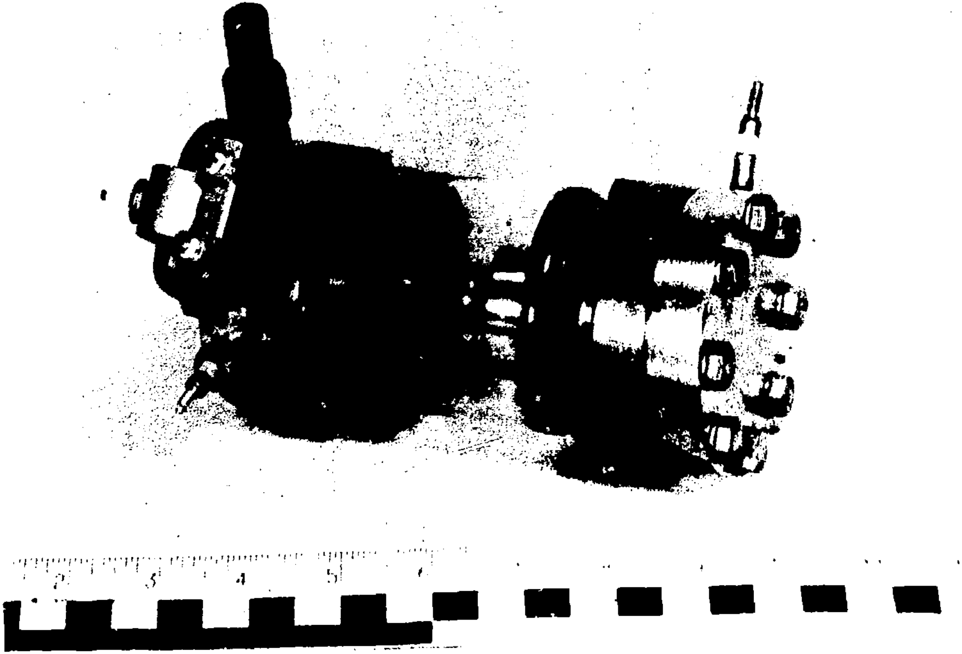
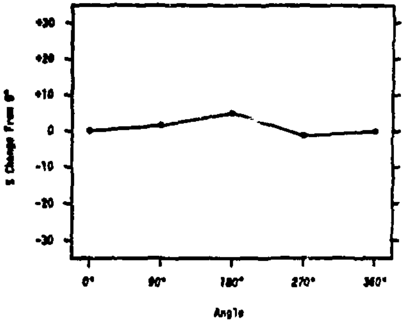


Figure 3

RELATIVE NEUTRON FLUX DISTRIBUTION
TTA ROTATED ABOUT TTA AXIS



RELATIVE NEUTRON FLUX DISTRIBUTION
TTA ROTATED ABOUT TARGET CENTER

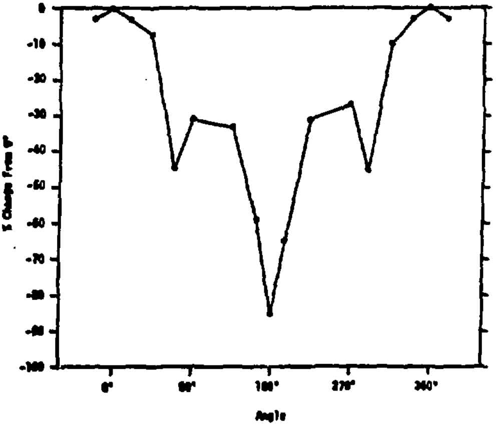
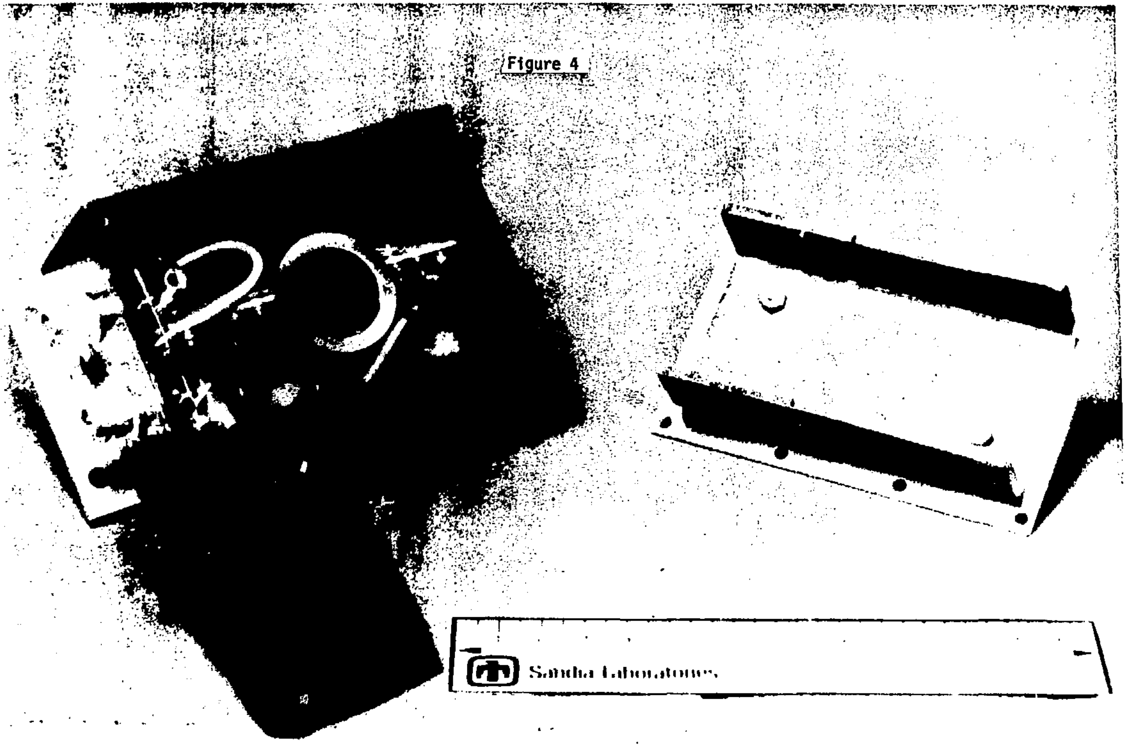
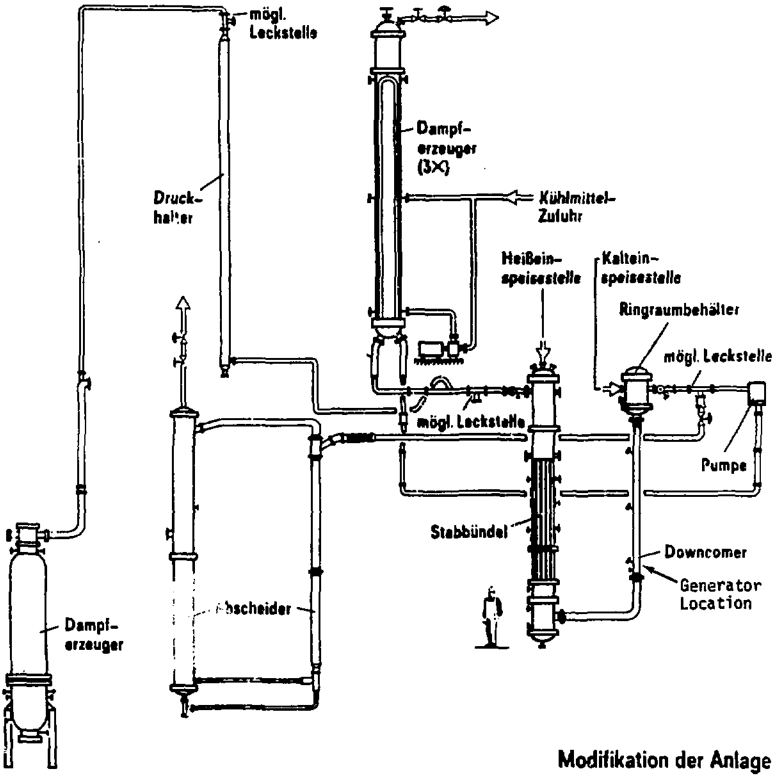


Figure 4





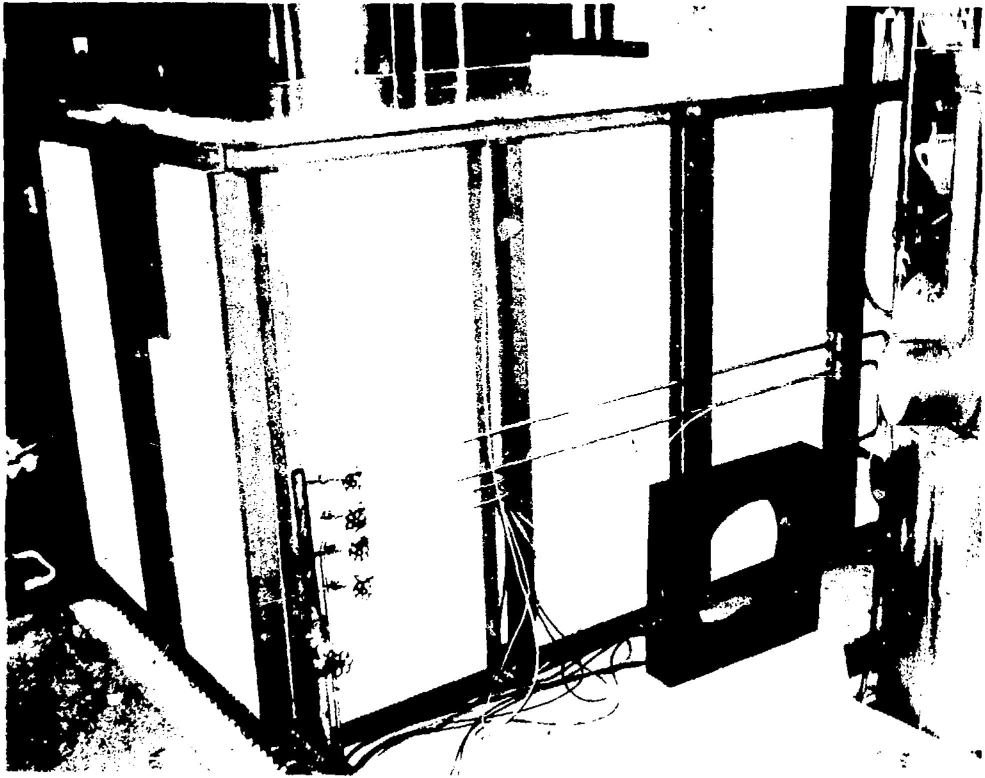
Modifikation der Anlage

PKL – Versuche mit kleinen Lecks

Figure 5

E 80 297 C

Figure 6



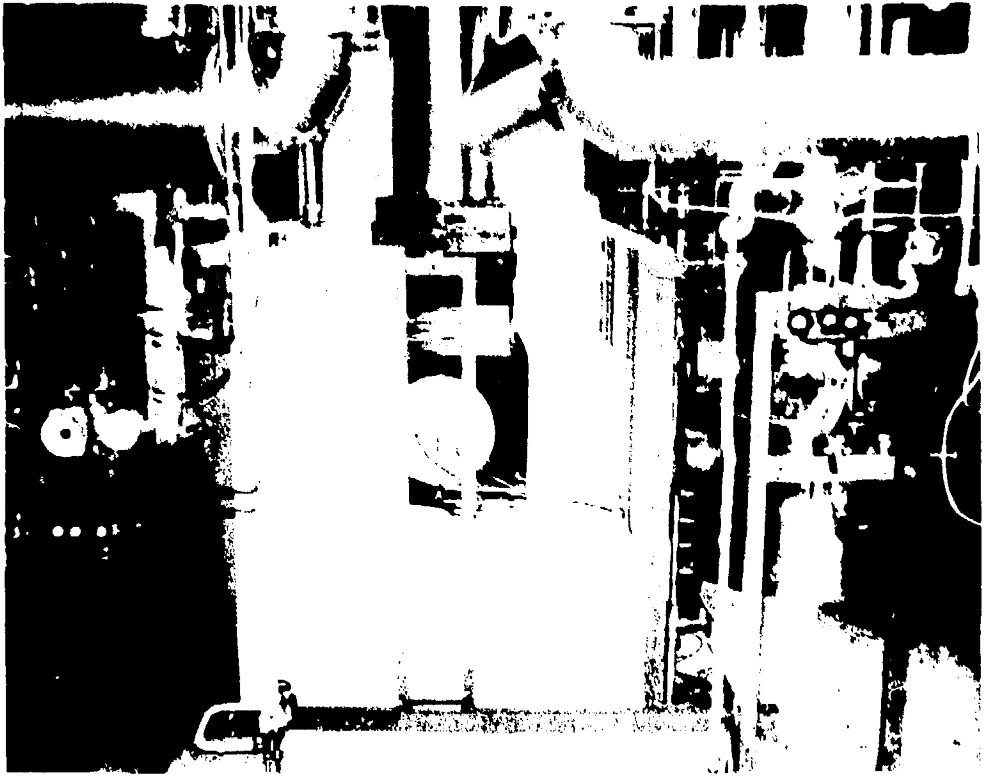


Figure 7

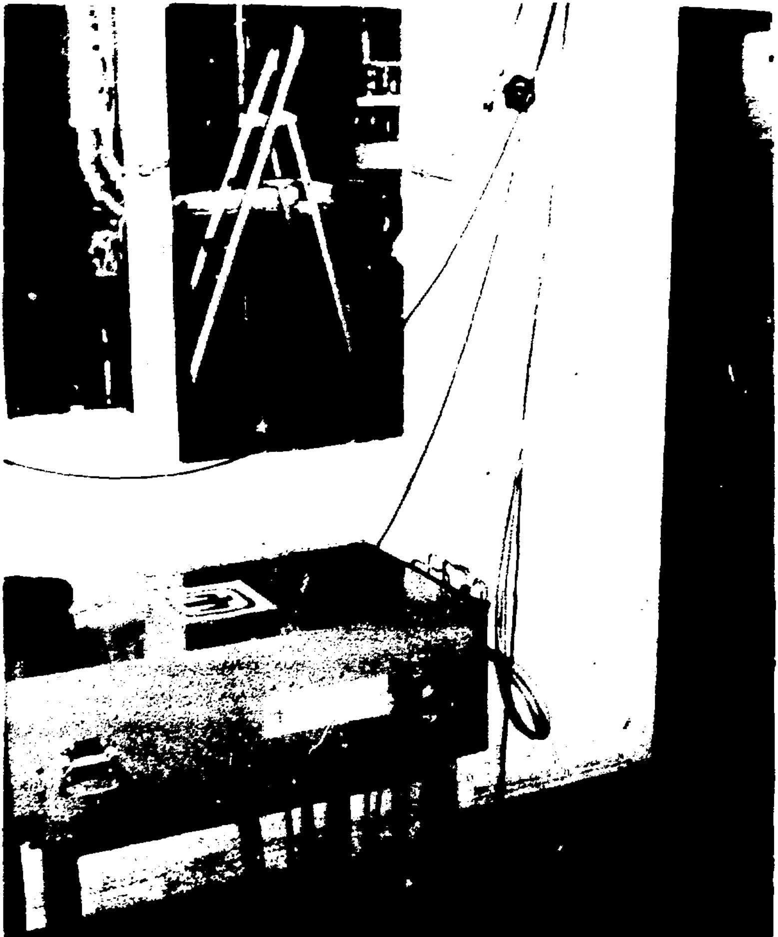


Figure 8

Figure 9