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AN ELECTRONIC TIME INTERVAL METER WITH MAGNETRON BEAM SWITCHING--ETC(U)
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AN ELECTRONIC TIME INTERVAL METER WITH MAGNETRON BEAM SWITCHING TUBES

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SOUND DIVISION

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U. S. NAVAL RESEARCH LABORATORY
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ABSTRACT

An electronic time interval meter employing the NIXIE[1] in-line readout tubes and magnetron beam switching tubes has been designed and constructed. The device employs a tuning fork oscillator as a time base, and has an over all accuracy of 1 part per 20,000 ± 1 count. The resolution of count is one millisecond. Maximum counting interval is 99.999 seconds. Input power supply requirements are 117 volts, 60 cycles, a. c., single-phase at 0.54 amperes. A remote readout accessory was also developed employing five miniature NIXIE tubes and is used to facilitate photographing data output on an instrument panel.

PROBLEM AUTHORIZATION

NRL Problem 55S05-13

BUSHIPS 402-934/44003, RF 001-03-43, AS 05401

PROBLEM STATUS

This is a final report on this phase of the problem.

1. The word NIXIE is a registered trademark of Burroughs Corporation and is referred to throughout this report.

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INTRODUCTION

The need for an accurate electronic time interval meter with an output display that could be photographed became apparent with the sonar range accuracy problem. Burroughs decade counter units were employed. These units use a NIXIE type BD 302 indicating-tube whose numerals are visible at a distance of 30 to 40 feet under ambient light conditions. The numerical figures, therefore, are easily photographed.

Overall construction and size were to be compact. Rack mounting and/or cabinet mounting was to be desired. Power supply source was to be 117 volts, 60 cycles, single phase.

DESIGN

Figure 1 illustrates in block diagram the complete system of the electronic time interval meter. Briefly, the time base consists of a tuning fork oscillator, amplifier and wave shaping stages. From here the signal passes through a gate stage and then to the Burroughs decimal counting units with local or remote readout. The gate stage is driven by the gate control stage. This facilitates the use of separate start and stop signals. An electronic reset is also incorporated. A separate, unregulated power supply is used for the decimal counting units whereas a regulated power supply is used for all other stages. A constant voltage transformer is incorporated for use aboard ship.

Figures 2A, 2B and 2C illustrate the complete circuit design of the device. V_1 a 12AT7 dual triode vacuum tube is employed in the oscillator stage. This stage is unique in that it uses a precision tuning fork, which is temperature controlled, as the frequency controlling element. The accuracy of this frequency source is $\pm$1 part in 20,000 ($\pm$0.005%) in an ambient temperature of -65° to +85° Centigrade. Next, V_2 a 6C4 triode vacuum tube is used in an LC tuned amplifier stage. This stage amplifies the oscillator output signal. The plate circuit is tuned by means of a high Q inductance shunted by a silver mica capacitor. This circuit reduces the distortion from the tuning fork oscillator stage. The signal is then coupled into V_3 a 12AT7 dual triode vacuum tube utilized as an over-driven amplifier stage. This stage reshapes the waveform from a sinusoid to a square wave.

A sharp cutoff pentode vacuum tube 6BH6, V_4 is used as a gating stage. The suppressor grid of V_4 is controlled by the output of V_5 a 12AX7 dual triode vacuum tube used as a bistable flip-flop. Separate start and stop signals are fed into the grids of V_5 the gate control stage. The output signal from the gating stage drives a single Burroughs decimal counting unit Model DC 102. This is a 100-kc counting unit. This unit is used because the driving requirements are fairly low (i. e., negative 50 volts) as compared to the DC 101 (negative 125 volts, one-half sine wave). The output of the DC 102 then drives four DC 101 decade counting units connected in cascade. The maximum counting rate of the DC 101 decade counter unit is 10-kcs. Each of these units employ a beam switching magnetron tube and a NIXIE in-line readout tube.

Manual resetting of the decade counting units is accomplished by a simple RC circuit and a manual shorting switch. An automatic reset feature is also incorporated to facilitate data taking. A positive pulse is obtained from the output of V_4 which fires V_9 a 5696 thyratron tube. This circuit generates a negative pulse of approximately 150 volts which is used to reset the Decimal counting units. The ionization and deionization time of a type 5696 tube is 0.5 microsecond and 40 microseconds, respectively. Since the resolution of count is 1 millisecond, this zero reset time is considered adequate. Accuracy checks mentioned under the section on characteristics correlate this.

The power supply circuit employs two M500 silicon diode rectifiers. The rectifiers are connected with polarities such as to give positive and negative voltages with respect to ground. A double RC network with OA2 voltage regulator tubes V_6 and V_7 filter the negative and positive voltage outputs of this supply. A separate power supply utilizing type 5Y3GT dual diode rectifier tube, V8, supplies the decade counting units. This supply delivers 300 volts, d.c. at approximately 125 ma and is not regulated. However, an LC matrix filters the output voltage.

Figures 3 and 4 illustrate the manufacturer's schematic diagrams of the Burroughs decade counting units Model DC 101 and DC 102, respectively.

CONSTRUCTION

The entire unit is housed in a gray Hammerstone cabinet having dimensions of 21-5/8" high, and 14-1/2" deep. The panel space mounting requires 19" long, 7" high, and 13" deep. Thus the instrument can be either rack or cabinet mounted. Total weight including cabinet is 50 pounds. The weight of instrument itself is 35 pounds.

Forced ventilation is provided for by a Rotron type KS-2501 blower. This keeps the surface temperature of the magnetic shields, covering the BD 300 beam switching tubes, below 120°F. to maintain reliable operation in high ambient temperatures.

Standard chassis type construction was followed. Vector sockets were employed whenever possible. All small components were rigidly fastened and mounted to minimize shock and vibration effects. The tuning fork time-base was shock mounted on rubber grommets. Power supply components such as the power transformers and filter chokes were mounted as far as practical from the time base. This was done to minimize the effects of strong magnetic fields on the tuning fork element. The Burroughs decade counting units are of the plug-in variety and can be easily exchanged.

Pictures illustrating the packaging, design, and construction details showing top, bottom, and two front views are given in Figures 5, 6, 7 and 8 respectively.

MODIFICATIONS

The completed time interval meter was further modified to incorporate five miniature NIXIE readout tubes at a distant point. These tubes were used in place of the regular NIXIE readout tubes. However, in extending the lead length a serious problem became apparent. Each tube required 11 single wires or a total of 55 single wires for the combination of five readout tubes. Figures 9, 10 and 11 illustrate the fabrication of the NIXIE bulb holders and the 36-inch extension cables. Isolation resistors had to be placed into each counting element at location 2 on Figures 3 and 4 to reduce the effects of interwiring capacity of these long extensions. This resistance was increased to 82 Kilohms to reduce the anode currents of the miniature NIXIE tubes. The base plugs for insertion into the standard NIXIE tube sockets were manufactured from the empty tube bases of a standard NIXIE tube. An epoxy resin was molded around the glass base after extension strips were spot welded to the tube prongs. A photograph of the instrument energized with a numerical display can be easily seen and read as shown in Figure 11.

CHARACTERISTICS

The B+ voltage to the decade counting units was initially set to 300 volts, with an a.c. line voltage of 117 volts, by adjusting the bleeder resistor R_{42}. Once set, no further adjustment is required when utilizing the miniature NIXIE tubes with their extension lines.

Two graphs are presented to show the accuracy of the Time Interval Meter versus time. Figure 12 illustrates warm-up accuracy using standard NIXIE tubes. Figure 13 illustrates the warm-up accuracy when using the miniature NIXIE tubes with the 36-inch extension cable. Line voltage during this test was 117 volts $\pm 1/2$ volt. In analyzing these graphs approximately one to two minutes is required for the TIM to commence counting properly. After five minutes the equipment is sufficiently stabilized to be within the ±1 count of the standard.

The equipment with standard NIXIE tubes was subjected to line voltage variations from 109 volts to 133 volts. The counting interval over this voltage range remained within one count of the standard time counted. This is illustrated in Figure 14. The B+ voltage supplying the decade counting units, varied during this test from 290 to 348 volts. This particular power supply is not voltage regulated. The effects of varying only the B+ voltage to the decade counting units is illustrated in Figure 15 for both standard and miniature NIXIE tubes.

A line voltage variation test was performed with the miniature NIXIE tubes and the 36-inch extension cable. The results are shown in Figure 16. The a.c. line voltage was varied from 111 to 125 volts without exceeding the accuracy limitations. The operating voltage differential changed from 24 volts standard NIXIE tubes to 14 volts for the miniature NIXIE tubes. This decrease is attributed to the added cable capacitance when long extension cables are employed. A Sola constant voltage transformer, Type CV1, was inserted between the TIM and 60 cycle line. The operating range of the instrument was now from 81 volts to 130 volts, or a differential of 49 volts as illustrated by Figure 17. Since the equipment was to be operated on board ship, the Sola CVT was incorporated into the system.

The time interval meter results were compared using a Hewlett-Packard 522B electronic counter as a standard and employing a Hewlett-Packard 202A function generator to open and close the gates. The square wave output of the function generator is fed into the gating circuits of the two instruments. Figure 18 illustrates in block diagram the instrumentation employed to make these accuracy tests.

APPLICATIONS

This device was first used to instrument and display sonar travel time aboard ship while on a field trip North of Puerto Rico in March, 1958. Since then the basic instrument had been improved by the addition of the electronic reset circuit which facilitates monitoring. Further, the addition of a blower fan increased the reliability of operation for the succeeding shipboard installations.

Two more field trips were completed using the above instrument. One North of Puerto Rico in November 1958 and one Northeast of Newfoundland in August 1959. During these trips at sea, the instrument was subjected to shipboard vibration and shock as well as wide temperature variations. No difficulty was experienced with the instrument. The Burroughs beam switching tubes, although then relatively new on the market, performed quite well. No substitutions have been made to date.

Several replacements were made with the early type miniature NIXIE bulbs due to shorts developing between numerals. However, no difficulty has been experienced with the replacement bulbs.

A single photograph taken with a type 302 Dumont oscillograph Land camera can be seen in Figure 19. An adapter was used to eliminate light leaks and fix the bulbs within the field of focus of the camera. ASA type 400 film with camera settings of F8 at 1/10 second was used to obtain this picture.

An enlargement of a frame of 35 mm movie film as employed on a field trip can be seen in Figure 20. This was taken with an Air Force 35 mm movie camera converted to single frame operation. Good contrast was obtained using Tri-X film (ASA 200) at F8 and 1/10 second operative setting shutter speed. The NIXIE bulbs may be viewed in the center of the photograph. This picture has been magnified approximately ten times. The other data as seen in this photograph of a data panel was taken by means of an electronic flash triggered during the 1/10 second interval when the shutter was opened. This panel was light proof and is part of the overall instrumentation as reported in NRL Memorandum Report #887, "Effects of the Ocean Medium on Sonar Range Accuracy."

ILLUSTRATIONS

PARTS LIST FOR TIME INTERVAL METER

B_L	Rotron type KS2501 blower motor 25CFM@.1 inches of water
$C_{1,20,21}$	.002 μfd at 400 volts
C_2	.00047 μfd at 400 volts
$C_{3,4,5,8,13}$	.01 μfd at 600 volts
$C_{6,9,12,14}$	5 μfd at 150 volts
C_7	25 μfd at 25 volts
C_{10}	.25 μfd at 200 volts
C_{11}	.1 μfd at 200 volts
$C_{15,16,17,18}$	40 μfd at 400 volts
$C_{19,22}$	.0033 μfd at 600 volts
C_{23}	.1 μfd at 600 volts
$C_{24,25}$	8 μfd at 450 volts
C_{26}	1 μfd oil filled cond@ 600 v.
C_{27}	.01 μfd paper condenser@ 400 v.
C_{28}	100 μμfd mica " " @400 v.
C_{29}	.1 μfd paper " " @400 v.
CH_1	Halldorson E1030, 15 Henrys at 110 ma
DC 101	Burroughs 10 KC decimal counting unit
DC 102	Burroughs 100 KC decimal counting unit
F_1	1 amp fuse with holder
$M_{1,2}$	Sarkes Tarzian M500 silicon rectifiers

$M_{3,4,5}$	1N55 diode
$R_{1,17,18,19,24}$	47 Kohm, 1/2 watt resistors
R_2	250 Kohm potentiometer
R_3	22 Kohm, 1/2 watt resistor
$R_{4,20}$	4.7 Kohm, 1/2 watt resistor
$R_{5,6,14,21,25}$	1.5 Kohm, 1/2 watt resistors
$R_{7,16,46}$	100 Kohm, 1/2 watt resistors
R_8	470 Kohm, 1/2 watt resistor
R_9	470 ohm, 1/2 watt resistor
$R_{10,11,30,38}$	500 Kohm, potentiometers
R_{12}	2.7 Kohm, 1/2 watt resistor
$R_{15,44}$	1 Megohm, 1/2 watt resistor
R_{22}	100 Kohm potentiometer
R_{23}	56 Kohm, 1/2 watt resistor
$R_{26,27,28,29}$	1.2 Kohm, 2-watt resistors
R_{31}	75 Kohm, 1/2 watt resistor
$R_{32,33}$	750 Kohm, 1/2 watt resistor
$R_{34,36}$	240 Kohm, 1/2 watt resistor
R_{35}	27 Kohm, 1/2 watt resistor
R_{37}	75 Kohm potentiometer

R_{39}	5 Ohm, 2-watt resistor
$R_{40,41}$	62 Kohm, 1/2 watt resistors
R_{42}	15 Kohm, 50 watts adjustable
R_{43}	820 Kohm, 1/2 watt resistor
R_{45}	150 Kohm, 1 watt resistor
R_{47}	10 Kohm, 2 watt potentiometer
R_{48}	270 Kohm, 1/2 watt resistor
$R_{49,50}$	62 Kohm, 1 watt resistors
S_1	SPDT toggle switch
S_2	SPST momentary close push switch
S_3	DPST toggle switch
T_1	Thordarson 22R12 power transformer, 150 volts at 50 ma 6.3 volts at 1.5 amps.
T_2	Chicago PSC105 power transformer 345-0-345 volts at 105 ma 5 volts at 2 amps, 6.3 volts at 3.5 amps.
L	UTC Type VIC-12 inductor 1.3 Henry at 10 ma.
C	.02 μfd silver mica at 400 volts
$PL_{1 \text{ to } 5}$	Winchester Type MRE9S Plug
V_1	12AT7
V_2	6C4
V_3	12AT7
V_4	6BH6

V_5	12AX7
V_6	OA2
V_7	OA2
V_8	5Y3GT
V_9	5696
Y_1	American Time Products, Inc. type W2003C precision tuning fork 1000 cps $\pm$.005%

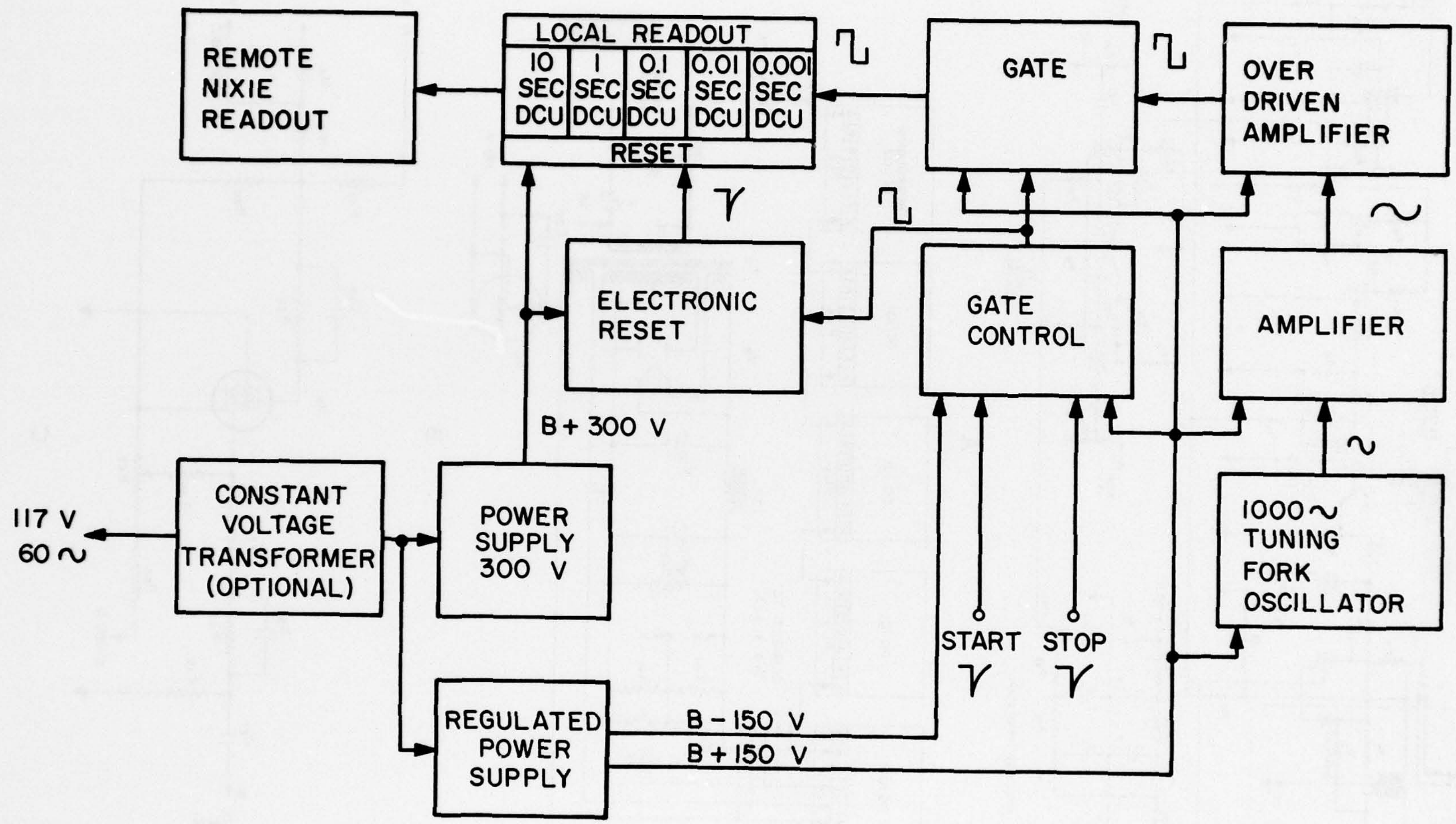

Figure 1 - Block diagram of Electronic Time Interval Meter

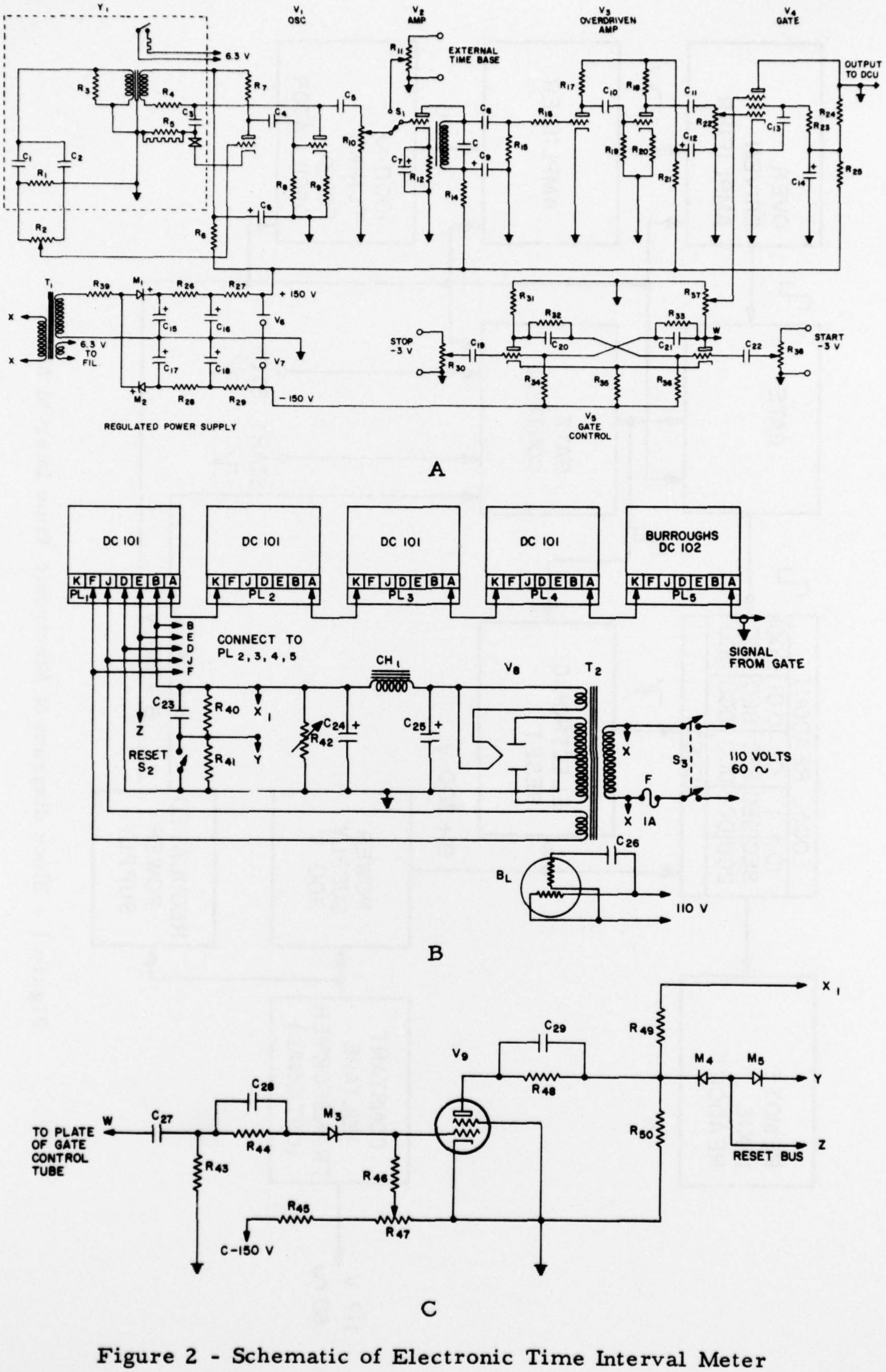

Figure 2 - Schematic of Electronic Time Interval Meter

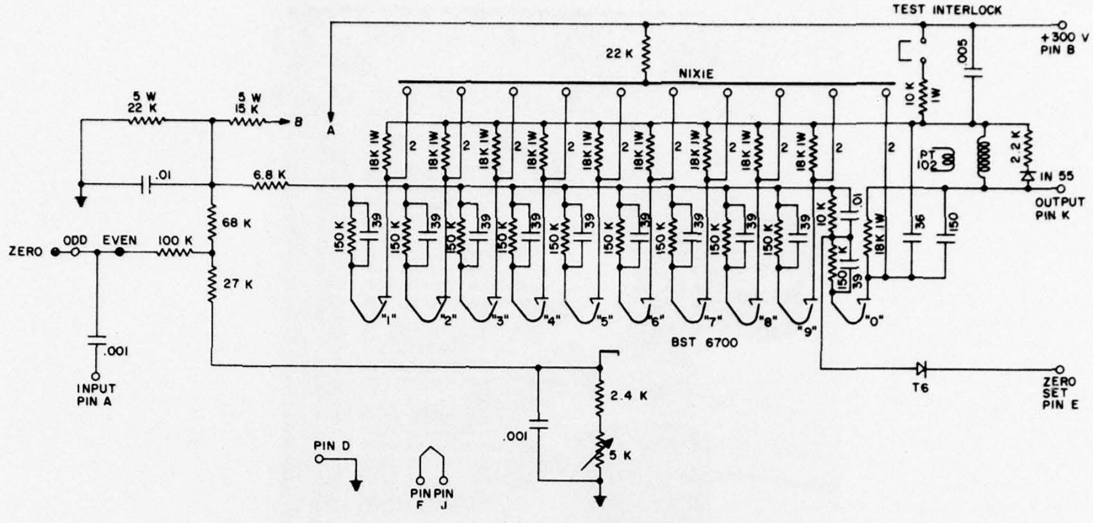

Figure 3 - Schematic of Burroughs Model DC 101 Decade Counting Unit. Copyright Burroughs Corporation.

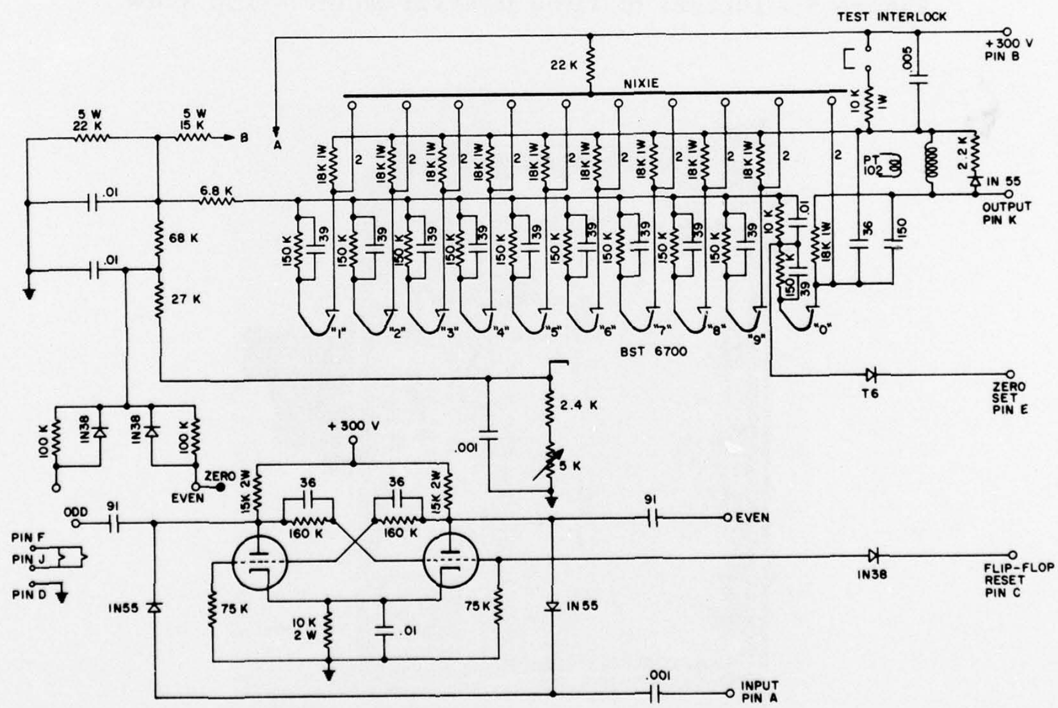

Figure 4 - Schematic of Burroughs Model DC 102 Decade Counting Unit. Copyright Burroughs Corporation.

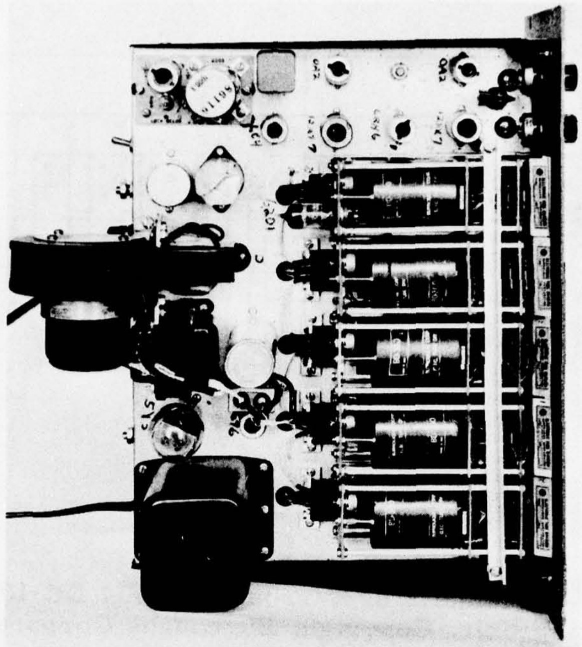

Figure 5 - Picture of Time Interval Meter - Top View

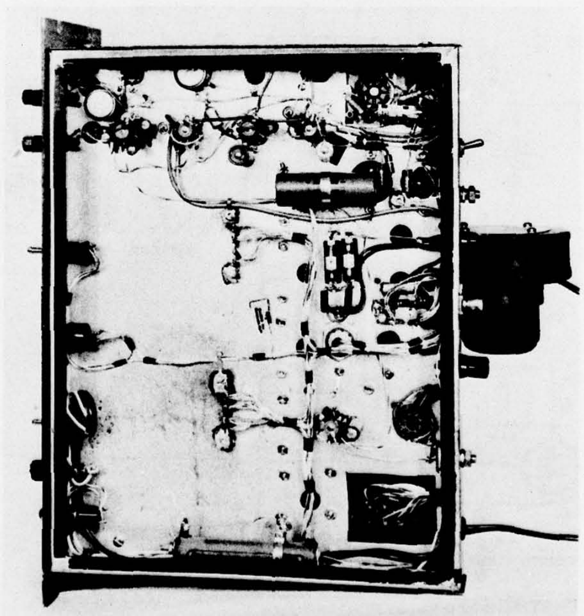

Figure 6 - Picture of Time Interval Meter - Bottom View

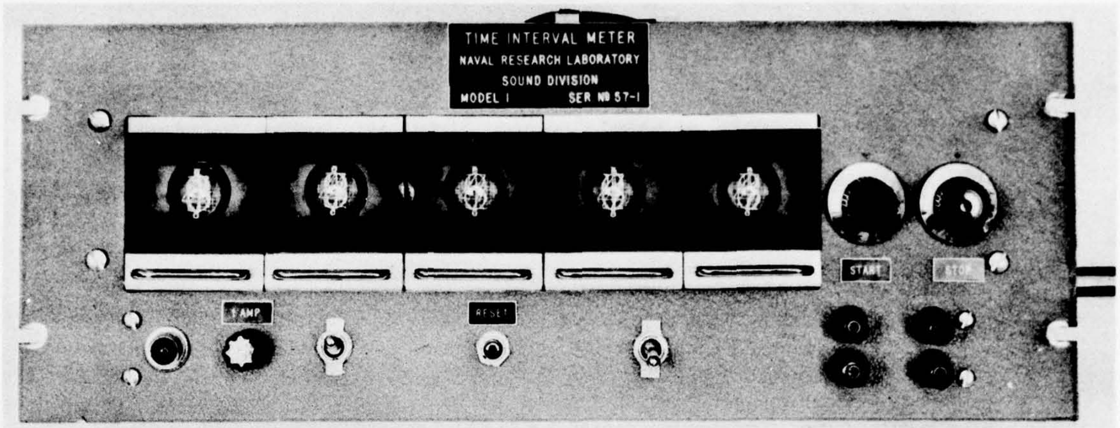

Figure 7 - Picture of Time Interval Meter - Front View

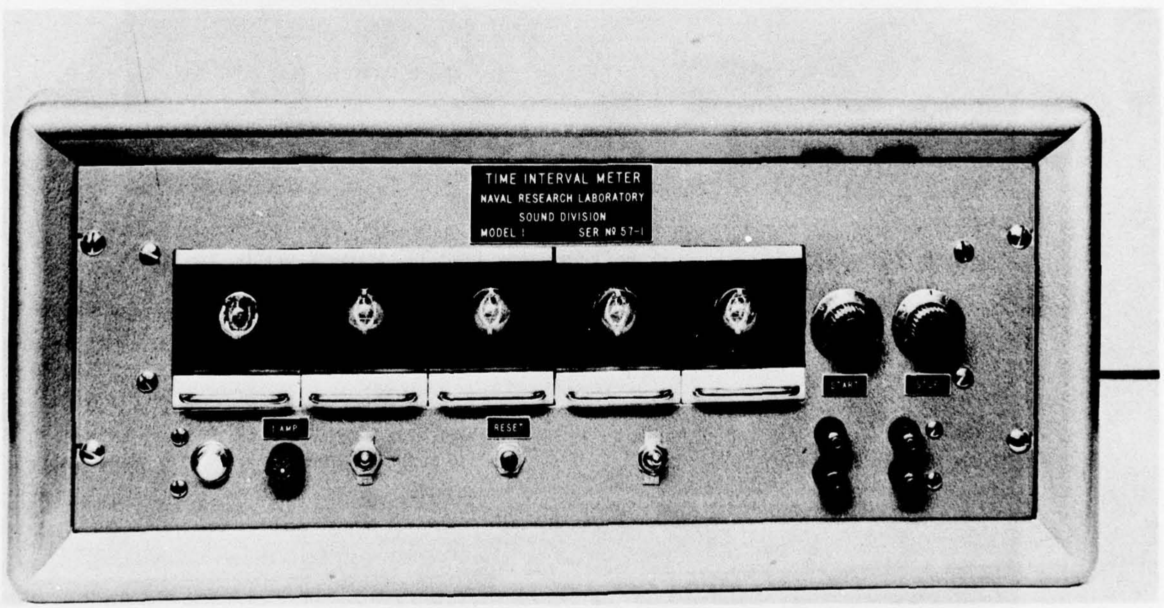

Figure 8 - Picture of Time Interval Meter in case

Figure 9 - Front view of miniature NIXIE tubes with 36 inch long extension cable

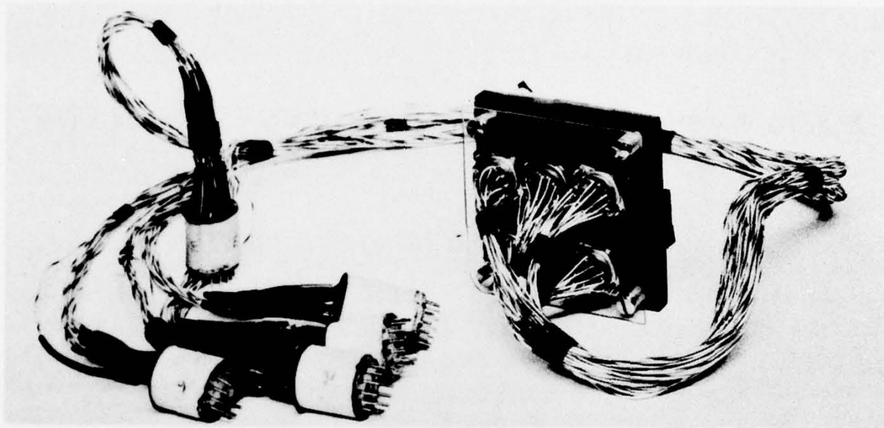

Figure 10 - Back view of miniature NIXIE tubes with 36 inch long extension cable

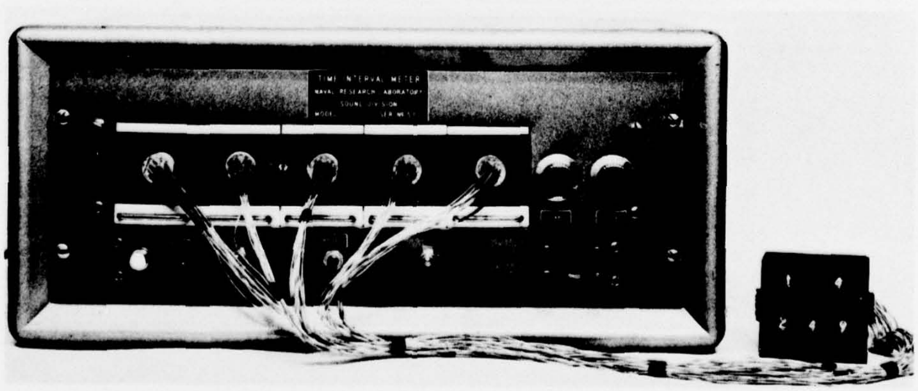

Figure 11 - Front view of Time Interval Meter with miniature NIXIE tubes and extension cable

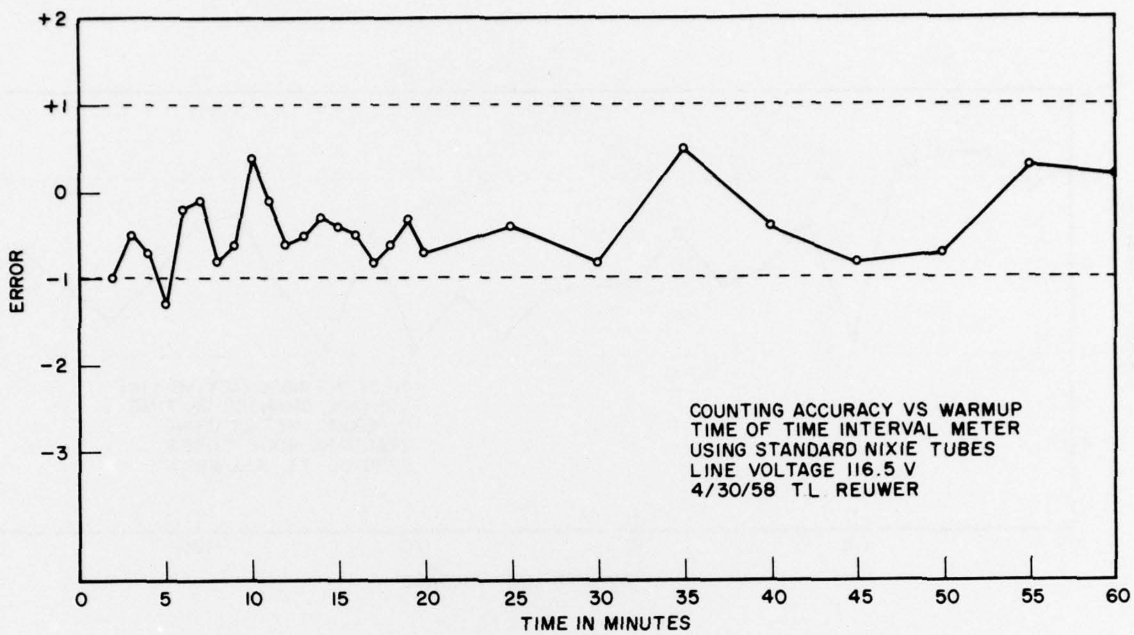

Figure 12 - Graph of warmup accuracy using standard NIXIE tube

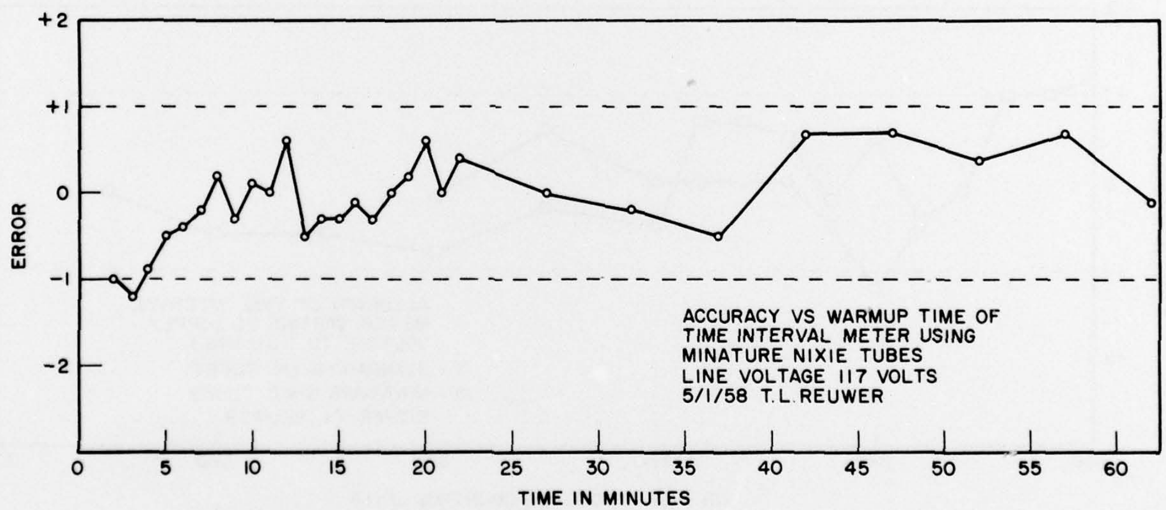

Figure 13 - Graph of warmup accuracy using miniature NIXIE with extension cable

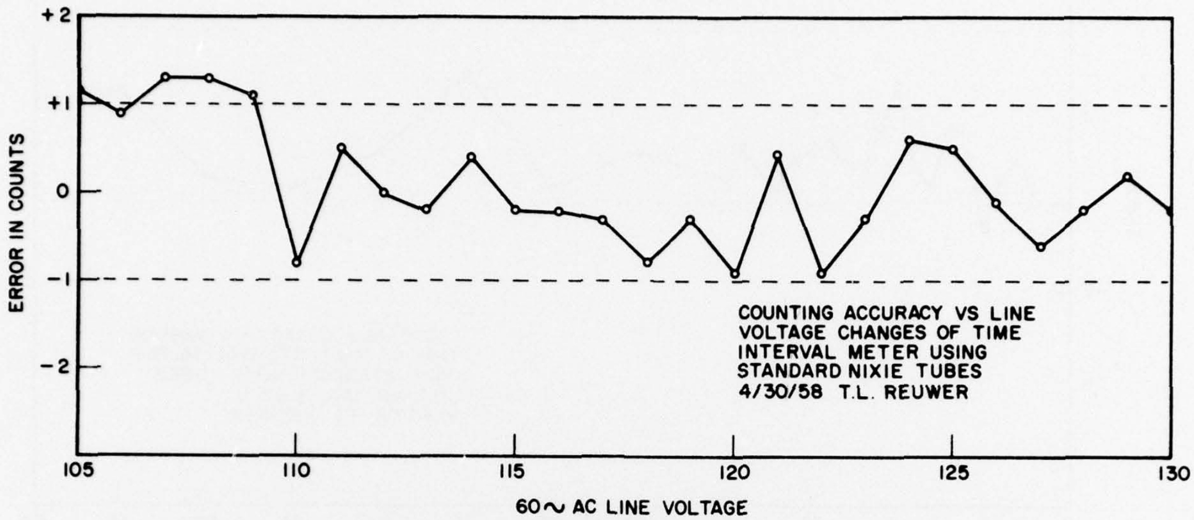

Figure 14 - Line voltage variation versus accuracy using standard NIXIE tubes

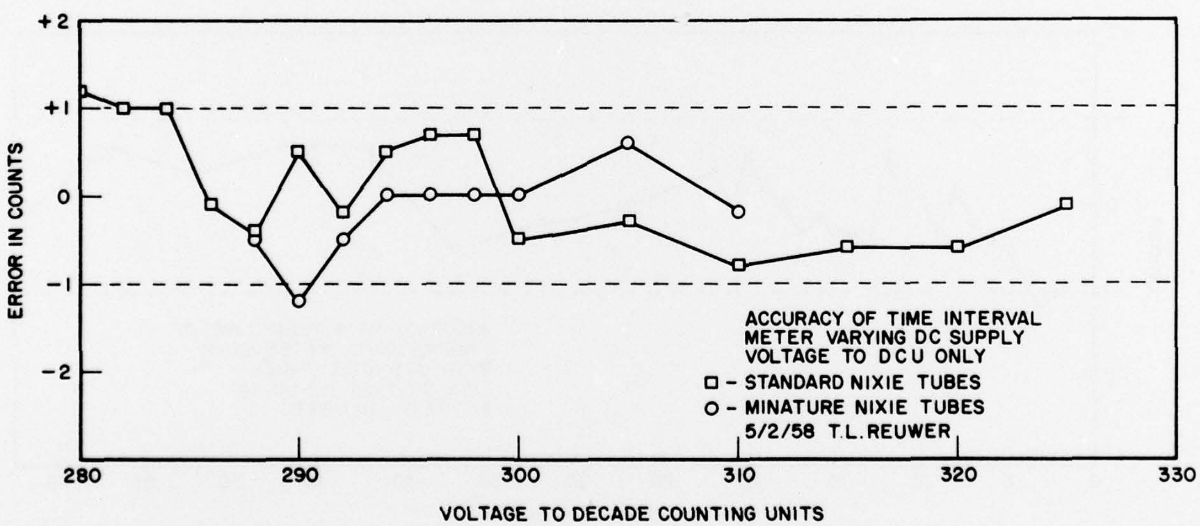

Figure 15 - B+ variations versus accuracy using standard NIXIE tubes

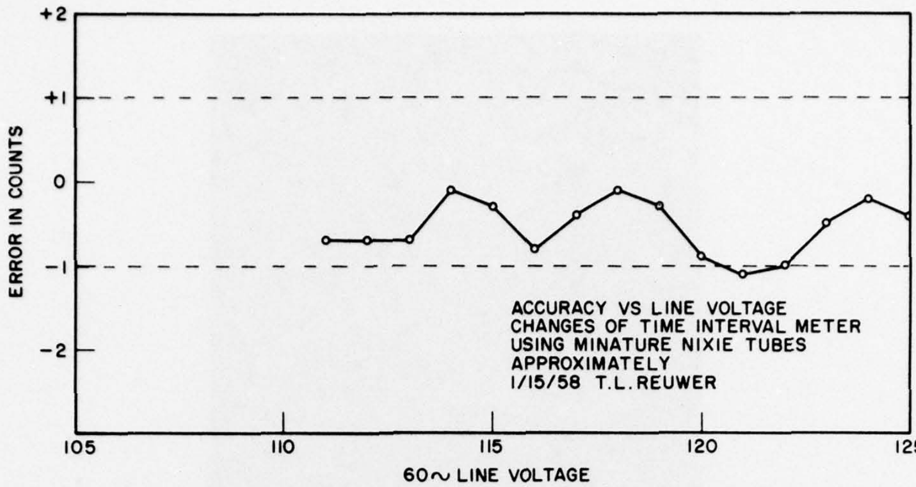

Figure 16 - Graph of accuracy of T.I.M. vs line voltage changes using remote readout accessory

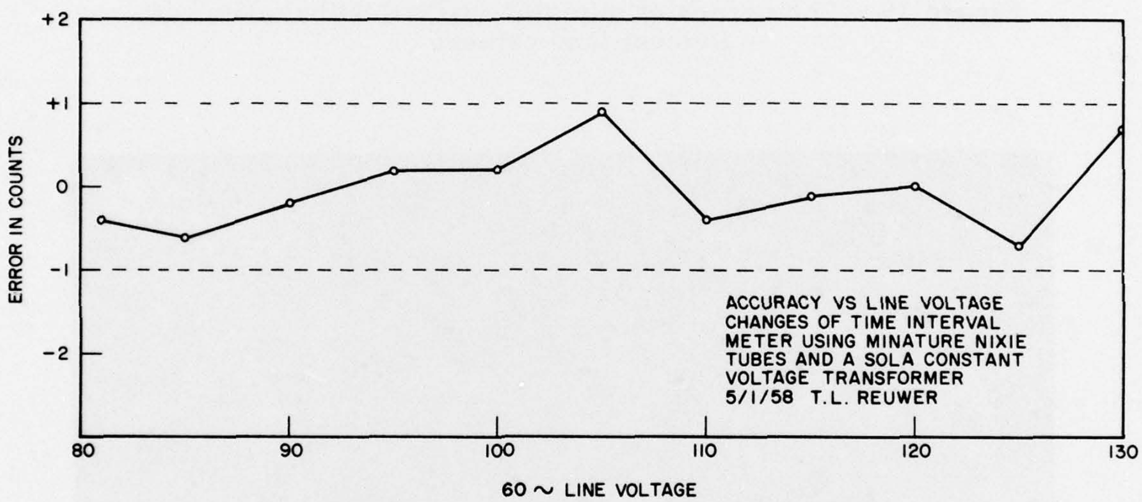

Figure 17 - Graph of accuracy of T.I.M. vs line voltage changes using remote readout accessory with addition of constant voltage transformer

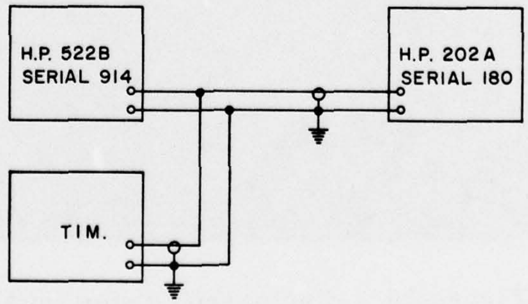

Figure 18 - Block diagram of instrumentation to check accuracy of T.I.M.

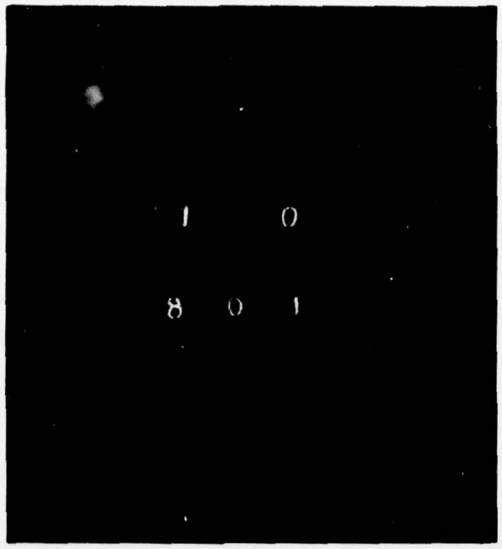

Figure 19 - Photograph of miniature NIXIE bulbs taken with Dumont land camera

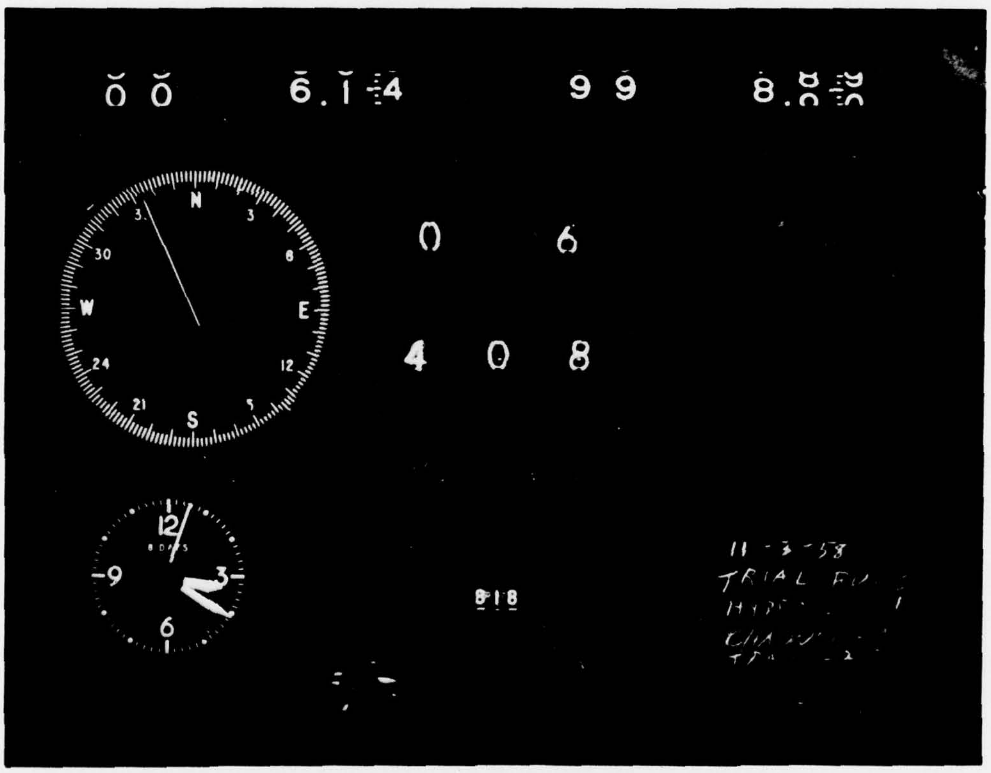

Figure 20 - Photograph taken with modified Bell and Howell camera under actual operating conditions