1 of 1

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PRELIMINARY DESIGN SPECIFICATIONS
FOR THE
COMPACT WEAPON EFFECTS DISPLAY SYSTEM

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MASTER

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CONTENTS

	<u>Page</u>
1. INTRODUCTION	5
2. SYSTEM DESCRIPTION	7
2.1 BLAST COMPUTATION	7
2.2 RADIATION COMPUTATION	7
2.3 THERMAL FLUX COMPUTATION	14
2.4 EQUATION SOLUTION TECHNIQUE	17
2.5 WEDS COMPONENTS	17
2.5.1 Input Section	17
2.5.2 Computer Section	21
2.5.3 Digital Display System	22
2.5.4 Map Display System	22
2.6 SPECIAL SUBSYSTEM	23
2.6.1 Built-In Test System	23
2.6.2 Weapon-Yield Selector	23
3. DESIGN CRITERIA	25
3.1 BLAST COMPUTER	25
3.2 RADIATION COMPUTER	26
3.2.1 Radiation Computer (Gamma Scaling)	28
3.2.2 Surface Correction Factor	30
3.3 THERMAL COMPUTER	30
3.4 COMPUTING COMPONENTS	30
3.5 DESIGN LIMITATIONS	33
3.5.1 Amplifier Drift	33
3.5.2 Amplifier Noise	33
3.6 ANTILOG CIRCUIT	34
3.7 DESIGN LAYOUT	35
4. CIRCUIT OPERATIONS	43
4.1 BLAST COMPUTER	43
4.2 RADIATION COMPUTER	45
4.2.1 Radiation Summing Network	45
4.2.2 Mode II Operation	45
4.3 CLASSIFIED INFORMATION HANDLING	46
5. SPECIFICATIONS & RECOMMENDATIONS	47
5.1 NUMBERING SYSTEM	47
5.2 GENERAL SPECIFICATIONS	47
5.2.1 Operational Amplifiers	48
5.2.2 Printed Circuit Boards	48
5.2.3 General Components	49

CONTENTS (Cont.)

	<u>Page</u>
5.3 INPUT SPECIFICATIONS	49
5.3.1 Potentiometer Resolution	49
5.4 EFFECTS COMPUTER SPECIFICATIONS	50
5.4.1 Thermal Computer Specifications	63
5.4.2 Radiation Computer	64
5.4.3 Blast Computer	65
5.5 ANTILOG & DISPLAY SPECIFICATIONS	67
5.5.1 Antilog Conversion and Display Units	67
5.5.2 Antilog Modules	67
5.5.3 Analog to Digital Converter	69
5.5.4 Digital Display Readouts	69
5.6 POWER SUPPLIES.	70
APPENDIX A METHODS OF CALCULATING SLANT HEIGHT .	73
APPENDIX B LOG MODULE TESTING	76
APPENDIX C ERROR CALCULATIONS.	81
C.1 DRIFT CALCULATIONS FOR THERMAL COMPUTER	81
C.2 RADIATION COMPUTER	82
C.3 RADIATION COMPUTER ERROR CALCULATIONS.	83
DRAWING NUMBERS	84

ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
1a	Peak Overpressure on the Ground for a 1 Kiloton Burst (High-Pressure Range)	8
1b	Peak Overpressure on the Ground for a 1 Kiloton Burst (Low-Pressure Range)	9
2	Dynamic Pressure-Height of Burst-Ground Range for 1 Kiloton	10
3	Vulnerability Correction, Peak Overpressure	12
4	Vulnerability Correction, Dynamic Pressure	13
5	Scaling Factor for Initial Gamma-radiation Dose	15
6	Thermal Computer	16
7	WEDS Block Diagram	19
8	Curve Used for Slant Distance D (Scale Factor of 2)	27
9	Log Gamma Scaling for Yield	29
10	Transmittance Curves	31
11	Thermal Computer K_T Curve	32
12	Typical Height Curve	44
B-1	Plot of Nexus LGP-3	77
B-2	Burr Brown Antilog 1667	79

TABLES

<u>Table</u>		
1	Equation Parameters	18
2	Input Parameters	20
3a	Blast Computer	36
3b	Radiation Computer	38
3c	Thermal Computer	40
3d	Map Computer	42

1. INTRODUCTION

This report provides preliminary design and specification information to fabricate a compact Weapons Effects Display System. The system is capable of calculating and displaying the effects of thermal flux, radiation, and blast pressure from a nuclear weapon. Under SANL-308-017 EG&G was asked to evaluate analog computer logic of an existing Weapons Effects Display System (WEDS)⁽¹⁾, make the necessary changes and develop preliminary specifications to fabricate a more compacted system. Also included was to design any new circuits required to make the system more accurate, and design new circuits to provide additional features as specified by LRL.

The WEDS consists of an analog computer to compute the effects of thermal flux, radiation and blast; a display system for displaying the pertinent digital information; and a map display system for presenting certain information on a map. The weapon effects are represented by equations taken from "The Effects of Nuclear Weapons," by S. Glasstone, other nuclear weapon effects documents, and from individuals working in the nuclear weapon field. These equations are solved with the use of an analog computer. The equation results, along with pertinent input information, are displayed on a digital readout panel and as an overlay on a map display system.

The compact WEDS will allow the operator to set into the computer certain weapon data such as yield, height of burst, distance from ground zero and weapon type. Without the use of charts or tables the operator will be able to observe both digital data and map displayed data representing the effects of a nuclear weapon. Added features such as the

(1)EG&G Tech. Manual, EG&G 1183-2067, No. S-312-Mn, December 1965, Weapons Effects Computer System.

ability to select a particular weapon and to automatically check the system for errors have been incorporated. Provisions for both unclassified and classified data has been provided.

The compact WEDS must be designed such that the total system can be incorporated into a desk size system. Space must be allowed for future additions to the system such as a "Fallout Computer." These restrictions require that the total system be held to a minimum size. It is the purpose of this program to compact all the components used into a 6 ft³ area. It is not the purpose of this program to miniaturize the components by fabricating all circuits as solid circuit networks.

In the design of the compacted WEDS only the analog computer and the digital display are presented in this report. Special specifications and recommendations have been made to provide accuracy and system reliability. The analog computer will consist of a series of operational amplifiers and special function generators designed to solve the proper equations. The operational amplifiers will be of the solid state modular encapsulated type. The function generators for the most part will be diode function generators. These function generators will be fixed-break-point, fixed-slope types and be preset to a given function as required by the equations. All modular components and discrete components will be mounted on printed circuit boards to allow for maximum space utilization.

Several basic conclusions concerning the system design are presented along with recommendations based on studies of components and sub-systems to be incorporated into the compact WEDS. The system resulting from this study will be similar to the existing WEDS; however, modifications in the equations have changed several of the computed calculations. The modifications will not be compared with the existing system since it is not the purpose of this study to analyze and modify the existing system.

2. SYSTEM DESCRIPTION

The basic equations solved by the WEDS analog computer for the effects of blast, radiation and thermal flux are given below.

2.1 BLAST COMPUTATION

The blast equation solves for two types of pressure received from the blast wave: peak overpressure and peak dynamic pressure. These pressures are represented by a set of curves (Figures 1 and 2) using a 1 KT burst as a base. No equation is known to describe these pressure curves; therefore the pressures are calculated using a function generator to generate the curves for each pressure. The curves are plotted for each pressure as a function of height of burst and range from ground zero. Scaling is required to enter yields other than 1 KT. The required relation is

$$\frac{R'}{R} = \frac{H'}{H} = W^{1/3}$$

R = range at 1 KT, ft

R' = range at WKT, ft

H = height of burst at 1 KT, ft

H' = height of burst at WKT, ft

W = yield in kilotons

the pressures can be represented by

$$P_O = F_1 (HW^{1/3}; RW^{1/3})$$

$$P_D = F_2 (HW^{1/3}; RW^{1/3})$$

F_1 and F_2 , shown in Figures 1 and 2, are the functions representing the pressure curves⁽²⁾. The overpressure and dynamic pressure are used to calculate the damage index τ .

⁽²⁾Defense Intelligence Agency, Physical Vulnerability Handbook - Nuclear Weapon, #PC 550/1-2, C. 4, 1 September 1963. (Confidential, Defense Information)

$$\frac{HOB_1}{HOB_2} = \frac{RANGE_1}{RANGE_2} = \left(\frac{W_1}{W_2} \right)^{\frac{1}{3}}$$

GROUND

Peak Overpressure on the Ground for :

1 Kiloton Burst (High-Pressure Range).

Figure 1a.

Peak Overpressure on

he Ground for a 1 Kiloton Burst (Low-Pressure Range).

Figure 1b.

$$\frac{HOB_1}{HOB_2} = \frac{RANGE_1}{RANGE_2} = \left(\frac{W_1}{W_2}\right)^{\frac{1}{3}}$$

GROUND :
Dynamic Pressure-Height of Burst

Figure 2.

$$\tau_o = a_1 \text{ Log } P_o + b_1 V_o + c_1$$

$$\tau_D = a_2 \text{ Log } P_D + b_2 V_o + c_2$$

a_1, a_2, b_1, b_2, c_1 and c_2 are constants V_o is the corrected vulnerability and is

$$V_o = V_n + V_{\text{corr}}$$

where

V_n = vulnerability number

V_{corr} = vulnerability correction factor

V_{corr} is a function of yield and a K-factor. This function is shown in Figures 3 and 4 for the two pressure values*.

2.2 RADIATION COMPUTATION

The total radiation T is the sum of the gamma and neutron radiation.

$$T = I_s + F_s$$

where

I_s = gamma radiation in rads.

F_s = neutron radiation in rads.

I_s is found with the following equation:

$$I_s = \frac{K_I N_I}{S_I} W' \left[\frac{10^7}{D^2} \right] \left[10^{-K_\gamma (5 \times 10^{-3}) \rho D} \right]$$

K_I = surface burst correction gamma dose

N_I = weapon type factor

S_I = shielding factor gamma dose

W' = scaled yield, tons

D = slant distance and is

$$D^2 = R^2 + H^2$$

*Taken from Reference (2).

Figure 3. Vulnerability Correction, Peak Overpressure.

Figure 4. Vulnerability Correction, Dynamic Pressure.

K_γ = gamma radiation factor

ρ = relative air density (% of standard)

The factor W' applies only to the gamma radiation and is given by the curve shown in Figure 5.

W' is a scaling yield for initial gamma-radiation dose.

$$F_s = \frac{K_F N_F}{S_F} W \left[\frac{10^8}{D^2} \right] \left[10^{-K_n (5 \times 10^{-3}) \rho D} \right]$$

The terms are the same as in the gamma radiation with the subscript F applying to neutron radiation.

The surface burst correction factors K_I and K_F are included in the equations when the weapon height-of-burst changes from air to surface burst. This decision is made when

$$H = 11.3 W^{0.4}$$

2.3 THERMAL FLUX COMPUTATION

The thermal flux in calories per square centimeter is given by the equation

$$Q = 2.9 \times 10^4 \frac{W}{D^2} K_T \bar{T}$$

where

Q = thermal flux, Cal/cm²

W = yield, tons

D = slant height in feet

$\bar{T}$ = transmittance factor

K_T = surface burst correction

The slant height is calculated as in the radiation equation. The transmittance is represented by the function shown in Figure 6.

Figure 5. Scaling Factor for Initial Gamma-radiation Dose.

Figure 6. Thermal Computer.
Transmittance (t)

2.4 EQUATION SOLUTION TECHNIQUE

Table 1 lists all the equation factors and their range of values. This table indicates that the equation parameters vary over several decades. For example, yield varies 6 decades. Also, the equations themselves have inherent factors as high as 10^8 . For this reason they are solved with the use of Log_{10} values. Due to the nature of the equations - that is - multiplication, division, and powers of numbers, the logarithmic solutions are simply addition and subtraction of the equation variables.

The solution to the equations in the logarithmic form simplifies them, however, log values at the display are undesirable. Therefore, all factors which appear either on the digital display or the map display must be converted from log to analog. The equation parameters displayed and the form in which they are displayed are given in Table 2.

2.5 WEDS COMPONENTS

Figure 7 illustrates a block diagram of the WEDS. It consists of four major blocks: the input section, a computer, a digital display unit and a map display unit.

2.5.1 Input Section

The Input Section contains console dials and switches which are used to derive the electrical signals for the computer. These input parameters constitute the coefficients of the equations. Several input parameters are considered to be pertinent, and are fed directly to the digital display. These input functions are listed in Table 2 as being digitally displayed.

Table 1. Equation Parameters.

Yield	W	10 to 10^7 tons
Height	H	10 to 3×10^4 feet
Range	R	10^2 to 10^5 feet
Peak overpressure	P_o	1 to 10^3 psi
Peak dynamic pressure	P_d	0.1 to 10^3 psi
Damage index	τ	-2 to +2
Vulnerability	V_n	0 to 50
Vulnerability Corr.	V_{corr}	-15 to +8
K factor	K	
Constants for	a_1	7.75
Overpressure	b_1	-0.615
Damage index	c_1	-0.385
Constants for	a_2	2.1
Dynamic pressure	b_2	-0.333
Damage index	c_2	3.24
Radiation	T	1 to 10^5 rads
Gamma radiation	I_s	1 to 10^5 rads
Neutron radiation	F_s	1 to 10^5 rads
Surface correction	K_I	.67 Subject to change
	K_F	.43
Shielding factor	S_I & S_F	1 to 10^5
Air density	ρ	0.75 to 1
Thermal flux	Q	1 to 10^3 cal/cm ²
Transmittance	$\bar{T}$	.5 to 1
Surface correction	K_T	0.429 to 1
Radiation constants	N_I , N_F , K_γ and K_n

Figure 7. WEBS Block Diagram.

Table 2. Input Parameters.

Yield	W	digital
Height	H	digital
Range	R	digital and map display
Pressure	P	digital
Damage index	τ	console meter
Vulnerability	V_n	console dial
K factor	K	console dial
Radiation	T	digital
Gamma radiation	I_s	console meter
Neutron radiation	F_s	console meter
Shielding factor	S_I & S_F	console dial
Air density	P	console dial
Thermal flux	Q	digital
Transmittance	$\overline{T}$	console dial

2. 5. 2 Computer Section

In the Computer Section there are four separate computers.

1. A blast computer for calculating the effects of blast pressure and damage index.
2. A radiation computer calculating the total radiation.
3. A thermal computer to calculate the thermal flux on a target.
4. A map computer used to display the effects of blast, radiation and heat on a map.

The equations are solved by the first three computers as previously discussed.

The map computer solves the equation:

$$R_c = \frac{R}{R_{MS}} \times \frac{M}{M_o} \times 100$$

R_c = circle radius

R = range

R_{MS} = map scale radius

M = magnification

M_o = lowest magnification

The circle radius R_c is solved for each range value, i. e. ,

R_{cb} Blast

R_{cr} Radiation

R_{ct} Thermal

In mode one the equation for pressure, radiation and heat are solved for a given single range. In mode two a desired P, T and Q is chosen and a range is calculated for each effect.

In mode one, when a single range is used for all three effects computers, all three circle radii are equal. These operate a circle generator and are displayed on the map display as an overlay showing

the range to which the effects extend. In mode two, when the effects values are chosen and a range calculated three separate range, circles are calculated and are presented to the map display. The radius of any one circle can be changed by changing the desired quantity which controls that range.

2. 5. 3 Digital Display System

The digital display system receives the output effects and the pertinent input data displaying this information on a digital readout. The digital display will display any value presented to it. Since all calculations are made using the log values, antilog conversion is required. This antilog conversion is made in order that the digital display will be presented with linear values.

The Antilog Conversion solves the equation:

$$e_o = \text{Log}^{-1} e_i$$

where e_o and e_i are the output and input voltages representing the equation factors.

The converted log signals cannot be fed directly to the digital readouts. An analog to digital converter (ADC) is used to convert the analog signal into a 8-4-2-1 binary code. This binary code is used to operate the digital readouts.

2. 5. 4 Map Display System

The map display system receives data from the map computer. This display system will project a map on a screen using either front or rear projection. Overlaying the map will be the range circles from each effect. This report will not be concerned with the design of the map display system, as it has been preconcluded that this system will be furnished by a film projection manufacturer. The signals to operate the circle radius will be obtained from the map computer.

2. 6 SPECIAL SUBSYSTEMS

2. 6. 1 Built-In Test System

The built-in test system is a subsystem by which a test problem may be set into the computer and the outputs checked for errors. This system simply checks the computer performance for a particular set of data points.

Each computer will be provided with test points that connect to the built-in test system. These test points are located following critical calculations. The test system connects test points and input parameters to a digital voltmeter. The input functions are set to a particular value, and the voltmeter reads the log value. The test points are then checked for error. By a process of elimination one can find portions of the computer which are introducing an error.

The computer test points are listed on each computer drawing.

2. 6. 2 Weapon-Yield Selector

This circuit is used to select a weapon type and number using the yield dial and the type switch. When a yield corresponding to a particular weapon is reached, the number of that weapon and other data pertaining to the weapon is displayed.

The yield voltage is compared to a pre-selected voltage level corresponding to a known or weapon yield one wished to display. When the yield voltage, derived by the yield pot, is equal to one of the pre-selected voltage levels a comparator closes a relay. The relay in conjunction with the display units inducting the weapon information.

Two signals must be present to operate the display unit the relay signal and the type signal. If a weapon type is chosen only the yield values for that weapon type can be displayed. For example if fission weapon (type 1) is chosen and known yields of 1 kt, 10 kt and 20 kt have been preselected it is possible to display the weapon effects and weapon designation for a type 1, 1 kt weapon; a type 1, 10 kt weapon; and a type 1, 20 kt weapon.

The yield selector switch or weapon selector switch can be a multiposition switch with one pole per deck. A $7\frac{1}{2}$ degree indexing angle, for example, will provide 48 positions over 360° rotation. This switch can be programmed to choose 48 yield values for a maximum weapon selection of $(48 \times n)$ where n is the number of weapon types.

Two decks will be required for the yield selection. A third deck will mate the weapon type and yield together.

Using a $7\frac{1}{2}^{\circ}$ indexing angle the phasing between the yield pot and the selector switches need not be exact. This will provide for the use of a reduction gear on the switch if a multiturn pot is used for the yield. Such a reduction will also allow for smoother operation of the yield pot. The switch to be used will have no stops and the torque shall be as small as possible. There also should be no snap action between contacts, this will allow for a smooth continuous operation of both the yield pot and the selector.

3. DESIGN CRITERIA

The equations to which the WEDS is designed are given below in their log form. This is the form which is best suited for the solutions required.

3.1 BLAST COMPUTER

$$\log P_O = F_1 [(\log H + 1/3 \log W), (\log R + 1/3 \log W)]$$

$$\log P_D = F_2 [(\log H + 1/3 \log W), (\log R + 1/3 \log W)]$$

The equations for damage index require $\log P_O$ and $\log P_D$. There is no change from the equations given in Section 2.

The special functions, F_1 and F_2 , describe the curves given in Figure 1 and 2.

The blast computer is basically designed to calculate:

$$\log H + 1/3 \log W \text{ and}$$

$$\log R + 1/3 \log W$$

thus forming the scaled range and height values. These values can work in many ways to produce the pressure values.

One method, presently being used in the WEDS, is to form two mechanical cams whose shape follows the pressure curves. The functions F_1 and F_2 are represented by these curves. The scaled height is used to servo-drive the cams about their axis and the scaled range physically moves a pick-off potentiometer parallel to the cam axis. The cam contours define the $\log P_O$ and $\log P_D$ values. The electrical signals derived from the pick-off potentiometer riding on the cam surface are $\log P_O$ and $\log P_D$. The cam description and operation is adequately given in EG&G Tech. Manual S-312-Mn in Section 2.2.1.

The functions need not be mechanical cams, as control field devices can also be used. These devices utilize resistance materials, optical filters or magnetic fields. The pressure contours are defined

by the shape and driving function of the system used. The operation is similar to the mechanical cams where the scaled range and height are used to servo-drive the device used. The controlled field devices will probably introduce less error than the mechanical system.

3.2 RADIATION COMPUTER

The log forms of the radiation equations are:

$$\begin{aligned} \text{Log } I_s &= \text{Log } K_I + \text{Log } N_I + \text{Log } W + F_3 \text{Log } W + 7.00 - 2 \text{Log } D \\ &\quad - \text{Log } S_I - (5 \times 10^{-3}) K_{\gamma} \rho D \end{aligned}$$

$$\begin{aligned} \text{Log } F_s &= \text{Log } K_F + \text{Log } N_F + \text{Log } W + 8.00 - 2 \text{Log } D \\ &\quad - \text{Log } S_F - (5 \times 10^{-3}) K_n \rho D \end{aligned}$$

$$(5 \times 10^{-3}) \rho D \text{ is found from } \text{Log}^{-1} (\text{Log } \rho + \text{Log } D + \text{Log } (5 \times 10^{-3}))$$

$$\text{Log } D = \text{Log } R + \text{Log } \sqrt{1 + (H/R)^2}$$

$$\text{Log } D = \text{Log } R + F_4 \text{Log } (H/R)$$

This equation was chosen for the solution of Log D. For an analysis of the methods (see Appendix A).

The equations for radiation are solved by first solving for the slant height "D". Log R and Log H are known input parameters. In the above equation Log D is found by plotting Log (H/R) as a function of Log $\sqrt{1 + (H/R)^2}$. From this curve (Figure 8) for each value of Log $\sqrt{1 + (H/R)^2}$ a value of Log (D/R) can be found because $\text{Log} \left(\frac{D}{R} \right) = \text{Log } \sqrt{1 + (H/R)^2}$. Since $\text{Log } D/R = \text{Log } D - \text{Log } R$ the value Log D

Figure 8. Curve Used for Slant Distance D (Scale Factor for 2)

is found by adding a Log R or

$$\text{Log D} - \text{Log R} + \text{Log R}$$

or is just Log D.

Knowing Log D the equation $(5 \times 10^{-3}) \rho D$ can be obtained by,

$$5 \times 10^{-3} \rho D = \text{Log}^{-1} (\text{Log } (5 \times 10^{-3}) + \text{Log } \rho + \text{Log D})$$

requiring the use of an antilog function - Log^{-1} .

The value $F_3 \text{ Log W}$, which is the yield scaling factor for gamma radiation, is formed using a diode function generator. Two curves for F_3 have been considered: One taken from Glasstone, the second from Civil Defense Manual CEX-62. 2*. The curve used in Glasstone was chosen.

3. 2. 1 Radiation Computer (Gamma Scaling)

The gamma scaling factor presently used in the weapons effects computer was taken from Civil Defense Manual CEX-62. 2. This gamma scaling factor, which scales the yield, seems to be in error when compared to Glasstone's gamma scaling factor. By plotting the log of the gamma scaling factor from CEX-62. 2, one observes a varying function (Figure 9). The curve taken from Glasstone is a monatomic increasing curve; therefore, it is assumed that there is no variation in the log function. By plotting the log function directly from Glasstone we obtain a very smooth monatomic increasing log function. It is therefore, recommended that we take our information from Glasstone rather than from CEX-62. 2. It is felt that a more accurate representation of the true function can be made by using the smoother curve. A diode function generator following this curve with several straight line segments should reproduce the curve with as little error as 1%.

The results, $\text{Log } I_s$ and $\text{Log } F_s$, form the total radiation T by first taking the antilog of each to form I_s and F_s with the use of a

*Civil Effects Test Operations, "Nuclear Bomb Effects Computer," E. R. Fletcher and others, CEX 62. 2, February 15, 1963.

Figure 9. Log Gamma Scaling for Yield.

operational amplifier $I_s + F_s = T$ is obtained. A brief description of this radiation summary network is given in Section 4. 2. 1.

3. 2. 2 Surface Correction Factor

Both the radiation and thermal computers require a surface correction factor. The equation solution which defines a surface burst is any height below the value

$$H = 11.3 W^{0.4}$$

This equation is solved by

$$\text{Log } H - 0.4 \text{ Log } W - 1.055 = 0$$

The factors K_I and K_F are presently constant values inserted into the equation for radiation when the above equation is equal to zero. These values are being investigated and are subject to change.

3. 3 THERMAL COMPUTER

The Thermal Computer equation is written,

$$\text{Log } Q = \text{Log } W + \text{Log } K_T - 2 \text{ Log } D + \text{Log } \bar{T} + 4.46$$

Log D is formed as in the radiation equation. Log $\bar{T}$ represents the transmittance (see Figure 10) for 10 and 50 mile visibility. These two curves are entered into the equation as Log $\bar{T}$, with Log D as the input variable. The function is formed by a diode function generator.

For the thermal computer Log K_T is a function of yield. This function is shown in Figure 11.

3. 4 COMPUTING COMPONENTS

Most computations are to be made using operational amplifiers. While these amplifiers must be compact, total integrated circuits forming the total computing network will not be used. A building block technique using modular encapsulated operational amplifiers and discrete components will be used. To save space all components will be mounted on printed circuit boards.

AIR - SURFACE SPECIAL CURVE

K_T , the correction factor for a surface burst is obtained from a pot ganged with the yield pot. The curve as a function of yield is given below.

THE LOG K_T CURVE IS GIVEN BELOW

Figure 11. Thermal Computer K_T Curve.

3.5 DESIGN LIMITATIONS

One requirement of the WEDS is that the digital readouts do not flicker. Several factors cause drift and noise in the digital output. One source of drift is the operational amplifiers. A brief discussion on amplifier drift and noise follows. Several of the design features were determined based on these concepts.

3.5.1 Amplifier Drift

Drift is related to the amplifiers and circuit components. Drift can be divided into three types: thermal, time, and supply regulation. The drift will be calculated from an average amplifier drift rate for each of the three parameters. The total drift for each computer section can be obtained by the summation of all drift rates in the computer section. This will provide an expected maximum drift rate. The draft rates when going through an amplifier are multiplied by the amplifier gains. Also, scale factors must be taken into account when the final conversions are made.

The drift rates will be expressed as a percent of full-scale, at the output, resulting in a figure representing the maximum drift rates expected.

3.5.2 Amplifier Noise

Noise is the rms voltage introduced into the computer system by components and the close proximity rms current carrying leads. This noise will cause the computer output to vary according to the amplitude and frequency of the noise.

The noise and drift levels should be such that a change is not noticed in the output. The ADC will receive voltage levels from 1.00 to 9.99 v. It is required that a change due to noise will not be seen in the last significant figure, i. e. , a change from 9.99 to 9.98. This results in a log voltage difference of $440 \mu\text{v}$, times the scale factor.

For a scale factor of 2, this value is 880 μ v at the input to the antilog circuit. Therefore, to prevent noise fluctuations at the digital readout for the worst case, the total noise levels should be below 880 μ v. Most operational amplifiers have noise levels far below this value, however, the noise level is multiplied by the gain of the amplifier.

At the other extreme, the noise level required to change 1.00 to 1.01 is 4.32 mv times the scale factor, or 8.6 mv for a scale factor of 2.

3.6 ANTILOG CIRCUIT

The antilog circuits are used to convert the log values into analog values through the use of the equation:

$$e_o = \text{Log}^{-1} e_i$$

These units utilize the volt-ampere characteristics of transistors which accurately follow the logarithmic transfer function. The use of these characteristics will be such that the log transfer function is followed to less than 1% over the range of interest.

The functions to be converted will have voltage levels between 0 ± 10 volts. This will constitute 3 to 6 decades. Therefore, different scale factors will be used to maintain a large output level. The antilog conversion circuit is set up in such a manner that only one decade need be covered by the antilog converter. A bucking current is used to reset the antilog converter after each decade. The antilog converters must have provisions for applying this reset current.

For example, a four-decade output would be represented by a voltage of 0 to 8 volts (S. F. = 2), each decade being 2 volts. The input to the antilog circuit would be 0 to 2 volts for the first decade. The output would be 1 to 10 volts. The next, and all other preceeding decades, would reset the antilog converter to zero by application of a power bucking current.

An amplifier can precede the antilog circuit in order to increase the voltage levels of 0 to 2 volts to 0 to 10 volts, giving the unit a scale factor of 5. In some cases, this would be preferred to provide a higher operating level.

The noise level on the output should be held to 1% of 1 volt. It is desired that this level be closer to 10 mv. This figure is derived from the fact that a noise change in the third significant figure is undesirable.

3. 7 DESIGN LAYOUT

Table 3a-d provides the amplifier information required by each equation function. This table with the design prints will provide the design layout. Scale factors required to bring the voltage levels up to a proper operating level are also given.

Table 3a. Blast Computer

<u>Amplifier Number</u>	<u>Function</u>	<u>Log Value</u>	<u>Voltage Value</u>	<u>Gain</u>
101 input	$-3(1/3 \text{ Log } W)$	$-1/3 \text{ to } -7/3$	$-1 \text{ to } -7$	$2/3$
input	$-3(\text{Log } R - 1/3 \text{ Log } W)$	$1 \text{ to } -3$	$3 \text{ to } -9$	$2/3$
output	$2 \text{ Log } R$	$2 \text{ to } 5$	$4 \text{ to } 10$	
102 input	$2 \text{ Log } R$	$2 \text{ to } 5$	$4 \text{ to } 10$	150
input	$-3(1/3 \text{ Log } W)$	$-1/3 \text{ to } -7/3$	$-1 \text{ to } -7$	100
input	$-3(\text{Log } R - 1/3 \text{ Log } W)$	$1 \text{ to } -3$	$3 \text{ to } 9$	100
input	Slew		± 10	
output	300 (Servo)			
103 input	$2 \text{ Log } H$	$1 \text{ to } 4.5$	$2 \text{ to } 9$	150
input	$-3(1/3 \text{ Log } W)$	$-1/3 \text{ to } -7/3$	$-1 \text{ to } -7$	100
input	$-2.88 (\text{Log } H - 1/3 \text{ Log } W + 1)$	$0 \text{ to } -3.48$	$0 \text{ to } -10$	104
input	$10(\text{Log } 10)$	1	10	30
output	300 (Servo)			
104 input	$3 \text{ Log } P_o$	$0 \text{ to } 3$	$0 \text{ to } 9$	1
input	$3 \text{ Log } P_D$	$-1 \text{ to } 3$	$-3 \text{ to } 9$	1
output	$-3 \text{ Log } P$	$1 \text{ to } -3$	$3 \text{ to } -9$	
105 input	$-.25 (a_1 \text{ Log } P_o)$	$0 \text{ to } -23.25$	$0 \text{ to } -5.813$	20

Table 3a. Blast Computer (Cont.)

<u>Amplifier Number</u>	<u>Function</u>	<u>Log Value</u>	<u>Voltage Value</u>	<u>Gain</u>
105 input	$-0.5(a_2 \text{ Log } P_D)$	-2.1 to -6.3	-1.1 to -3.15	10
input	$-0.2 (b V_o)$	0 to 50	0 to 10	25
input	$-2.5 C$	0.386 or -3.24	0.965 or -8.1	2
output	5τ	-2 to 2	-10 to 10	
106 input	$3 \text{ Log } P/P'$	-3 to +3	-9 to 9	1
output	$-3 \text{ Log } P/P'$	-3 to +3	-9 to 9	
107 input	$3 \text{ Log } P'$	-1 to 3	-3 to 9	0.667
input	$-3 \text{ Log } P$	1 to -3	3 to -9	0.667
output	$2 \text{ Log } P/P'$	-4 to 4	-8 to 8	

Table 3b. Radiation Computer

<u>Amplifier Number</u>	<u>Function</u>	<u>Log Value</u>	<u>Voltage Value</u>	<u>Gain</u>
201 input	2 Log R	2 to 5	4 to 10	1
output	-2 Log R	-2 to -5	-4 to -10	
202 input	-2 Log R	-2 to -5	-4 to -10	1
input	2 Log H	1 to 4.5	2 to 9	1
output	-2 Log (H/R)	-2.5 to 4	-5 to 8	
203 input	$2 \text{ Log } \sqrt{1 + (H/R)^2}$	DFG output equal to Log D/R		
input	-2 Log R	-2 to -5	-4 to -10	1
output	2 Log D	2 to 5	4 to 10	
204 input	2 Log D	2 to 5	4 to 10	2
input	$4 \text{ Log } (5 \times 10^{-3})$	-2.3	-9.2	1
input	$40 \text{ Log } \rho$	-1.25 to 0	-5 to 0.1	
output	$4 \text{ Log } (5 \times 10^{-3}) \rho D$	0 to 2.5	0 to 10	
antilog				
input	$4 \text{ Log } (5 \times 10^{-3}) \rho D$	0 to 2.5	0 to 10	7.5×10^{-3}
output	$0.03 (5 \times 10^{-3}) \rho D$	0 to -5	0 to -10	
206 input	2 Log D	2 to 5	4 to 10	2
	$0.15 K_{\gamma \rho} D$	0.2 to 63.5	0.03 to 9.48	13.3

Table 3b. Radiation Computer (Cont.)

<u>Amplifier Number</u>	<u>Function</u>	<u>Log Value</u>	<u>Voltage Value</u>	<u>Gain</u>
206 input	-20 Log K_I	0.176	3.52	0.1
	-5 Log N_I	0 to -2	0 to -10	0.4
	+2 Log S_I	0 to 5	0 to 10	1
	-Log 10^7	-7	-7	2
	-Log W	-1 to -7	-1 to -7	2
	-10 Log W'	0 to .95	0 to 9.5	0.2
	output 2 Log I_S	0 to 5	0 to 10	
207 input	2 Log D	2 to 5	4 to 10	2
	0.2 $K_n \rho D$	0.152 to 48	0.03 to 9.6	10
	-20 Log K_F	0.176	3.52	0.1
	-5 Log N_F	0 to -2	0 to -10	0.4
	2 Log S_F	0 to 5	0 to 10	1
	-Log W	-1 to -7	-1 to -7	2
	-Log 10^8	-8	-8	2
	output 2 Log F_S	0 to 5	0 to 10	
208 input	-2.5 (0.4 Log W)	-0.4 to -3.2	-1 to -7	1.2
	2 Log H	1 to 4.5	2 to 9	1.5
	-5 Log 11.3	-1.055	-5.275	0.6

Table 3c. Thermal Computer

<u>Amplifier Number</u>	<u>Function</u>	<u>Log Value</u>	<u>Voltage Value</u>	<u>Gain</u>
301 input	2 Log R	2 to 5	4 to 10	1
output	-2 Log R	-2 to -5	-4 to -10	
302 input	-2 Log R	-2 to -5	-4 to -10	1
input	2 Log H	1 to 4.5	2 to 9	1
output	-2 Log (H/R)	-2.5 to 4	-5 to 8	
303 input	$2 \text{ Log } \sqrt{1 + (H/R)^2}$	DFG output equal to Log D/R		
input	-2 Log R	-2 to -5	-4 to -10	1
output	2 Log D	2 to 5	4 to 10	
304 input	2 Log D	2 to 5	4 to 10	3
input	-10 Log T	0 to 0.3	0 to 3	0.3 DFG 302, 303 or 304
input	-Log W	-1 to -7	-1 to -7	3
input	-2 (4.46)	-8.92	-8.92	1.5
input	-20 Log K_T	0 to 0.368	0 to 7.36	0.15
output	3 Log Q	0 to 3	0 to 9	
305 input	DFG 302, 303, or 304			
output	-10 Log T	0 to 0.3	0 to 3	

Table 3c. Thermal Computer (Cont.)

<u>Amplifier Number</u>	<u>Function</u>	<u>Log Value</u>	<u>Voltage Value</u>	<u>Gain</u>
306 input	3 Log Q	0 to 3	0 to 9	1
input	-3 Log Q_o	0 to -3	0 to -9	1
output	-3 Log Q/Q_o	0 to 3	0 to -9	
307 input	-A 306	0 to 3	0 to -9	1
output	3 Log Q/Q_o	0 to 3	0 to 9	

} Integrator

Table 3d. Map Computer

<u>Amplifier Number</u>	<u>Function</u>	<u>Log Value</u>	<u>Voltage Value</u>	<u>Gain</u>
401 input	$-\text{Log } R_{ms}$	-3 to -9	-3 to -9	5
input	$5 \text{ Log } M$	0.477 to 1.68	2.89 to 8.40	1
input	$-5 (\text{Log } M_o - 2)$	-1.523	-7.615	1
input	$2 \text{ Log } R_T$	2 to 5	4 to 10	2.5
output	$-5 \text{ Log } R_{ct}$	0 to 2	0 to 10	
402 input	Same as above except $2 \text{ Log } R_R$			
output	$-5 \text{ Log } R_{cr}$	0 to 2	0 to 10	
403 input	Same as above except $2 \text{ Log } R_b$			
output	$-5 \text{ Log } R_{cb}$	0 to 2	0 to 10	

4. CIRCUIT OPERATIONS

Certain parts of the computers require an explanation of circuit operation. This section is designed to give a brief explanation of these operations.

4.1 BLAST COMPUTER

If one plots a dynamic pressure curve versus range for a given height of burst, two range values are often present for one pressure value. These range values are referred to as minimum range and maximum range. Located at the very ends of the range values are two limit switches, one at a range of lowest range value and one at the highest range value. These switches are used, in the case of the cam, to stop and reverse direction of rotation of the cam (see Figure 12).

In mode II, where a desired pressure is chosen and a range is calculated to fit that pressure, a choice must be made to what range is to be calculated, the minimum range or the maximum range. The choice is made by the operator using the Max-Min Range Switch. If a minimum range is sought, the min range switch is operated, energizing relay RE-3. RE-3 sends the proper signal to amplifier 102 causing the servo motor to head toward the higher range values. If the desired minimum pressure point is met during this excursion, the feedback loop will send the proper signal to amplifier 102, stopping the servo.

If the cam was initially set past the minimum point desired, the cam will continue to turn until the max. limit switch is closed. This operates relays RE-5 and RE-8. RE-8 sends slew minimum a signal to amplifier 102. RE-5 holds both relays in through the minimum limit switch. The slew minimum signal will cause the servo to be driven quickly and directly to the minimum limit switch. The minimum limit

Figure 12. Typical Height Curve.

switch drops relays 5 and 9 out. The servo is now allowed to seek the minimum range point by traversing toward the higher range value. Since it starts at the lowest range value it will reach the minimum range desired during its travel. The servo will stop when this range value is met.

The maximum range value is found in a similar manner using relays RE-4 and RE-9.

4.2 RADIATION COMPUTER

With reference to Drawings No. LE 15476 and LE 15479, the radiation circuits which require discussion are the mode II operation and the Radiation summing network.

4.2.1 Radiation Summing Network

$\log I_s$ and F_s are converted by the use of two antilog circuits, giving I_s and F_s . Comparator circuits are used to reset the antilog circuits after each decade. These same comparator circuits provide the logic to amplifier 210 which is used to sum I_s and F_s . This logic is chosen such that maximum scaling is provided to amplifier 210 over all decade.

The function $\log T/T_o$ is formed by a log module. Its proper decade is chosen by the comparator circuits used for automatically scaling amplifier 210.

4.2.2 Mode II Operation

Mode II operation is used when a range is computed for a desired total dose. When in Mode II, the calculated dose from amplifier 210 is converted to $\log T/T_o$. This value is integrated and sent to amplifier 205. The system will balance when the proper range value is calculated for the desired radiation dose T_o .

4.3 CLASSIFIED INFORMATION HANDLING

Classified data is handled in the following manner:

Classified constants in the computer are derived using a separate printed circuit board. This board is marked SRD. The SRD boards are removable from the computer. The circuits are designed such that unclassified information only can be calculated when all SRD boards are removed. Classified calculations will require the insertion of the SRD board, and in some cases a classified key switch may be required.

The resistors and pots which make up the classified constants are located on the SRD boards. Relay R-RE-2 is held in during unclassified calculations. When classified information is required the relay drops out. R-RE-2 sets the unclassified constants into the equation.

The yield selector, which ties to the yield pot, has its circuit on an SRD board. This unit can be used to develop a code for transmittal to the display panel. The display panel unit can be unclassified. With the proper code the weapon-yield selector will display the weapon type, number, model, etc.

5. SPECIFICATIONS & RECOMMENDATIONS

Following are preliminary design specifications for the WEDS.

5.1 NUMBERING SYSTEM

Inputs	1 to 99
Blast Computer	101 to 199
Radiation Computer	201 to 299
Thermal Computer	301 to 399
Map Computer	401 to 499
Outputs	501 to 599

These numbers will apply to amplifiers, diode function generators, special function generators and potentiometers.

Relays will be labeled as per print. Each relay will have a prefix of B, R, T and etc., relating to Blast, Radiation, etc.

5.2 GENERAL SPECIFICATIONS

1. Total system volume is to be held to a minimum. The maximum space allowed for the computer system is 6 cubic feet.
2. Plug-in features should be provided. A standard printed circuit plug-in rack should be used.
3. Separate ground systems are to be used for signals and other power supplies.
4. Shielded leads are to be used for all signal lines leaving or entering the computer module package.
5. To avoid noise pick-up a-c and d-c leads are to be separated and not packaged in the same harness.
6. The temperature range for all components will operate between 0°C and 65°C. The system will operate in an ambient temperature of 25°C $\pm$ 10°C.
7. All amplifier summing resistors and feedback resistors are to be temperature stable to 10 ppm/°C.

8. All diode function generators used in the WEDS are derived from set curves and changes in these curves are not required once the function is set. A DFG with fixed breakpoints and fixed slopes could be used in the WEDS. It is therefore recommended that all DFG's be of this type. This requires that the DFG's use fixed resistors rather than trimming pots, however, once a DFG is set to a particular curve its characteristics should not change. It is further suggested that the DFG's be constructed using the "cord wood" printed circuit boards. This design allows each DFG to be approximately 1" x 1" x 0.6".

5. 2. 1 Operational Amplifiers

Type	Modular General Purpose
Output Voltage	± 10 volts minimum
Output Current	± 2 ma minimum
DC Gain O. L.	$\cong 1 \times 10^5$ v/v

Drift Rates

Time	50 μ v / day
Temperature	30 μ v / $^{\circ}$ C
Supply	50 μ v / %
Supply Power	± 15 v @ 10 ma
Operating Temperature	Room Temperature

5. 2. 2 Printed Circuit Boards

All components to be mounted on printed circuit boards.

Amplifiers to be mounted using print circuit board mating connector.

This connector to be used for plug-in installation for each amplifier.

P. C. Board Size	4. 5" x 8" maximum
P. C. Board Connector	22 pin standard
Inconnections	coax for all signal leads hard wire for supply leads
Grounding	separate grounding for signal and other signals.

5. 2. 3 General Components

Trimming Pots

Tolerance	±10%
Resolution	< 0. 5%
Operating Temperature	-65 to + 125° C
Power	0. 5 watt

Other specifications use standard specifications for general purpose wirewound pots.

Relays DPDT & SPST

1. 0 Amp contacts

Coil resistance 2000 ohm

Contact resistance $< 50 \times 10^{-3}$ ohms at rated load

Size $\leq 0. 2 \times 0. 4 \times 0. 6$

5. 3 INPUT SPECIFICATIONS

The inputs to the computer are electrical signals derived from potentiometer or switches. Most of the input potentiometers are used as variable inputs operated from the console front panel. The fixed constants are set using trimming potentiometer located on the computer subsystem. The degree to which one can set a function is dependent on the potentiometer resolution.

5. 3. 1 Potentiometer Resolution

The input function accuracy is a function of the pot resolution and the spread of the resistance over the pot. The resolution of the pot can be essentially infinite by the use of conductive plastic pots, materials other than conductive plastic can be used for essentially infinite resolution pots. Vapor deposited films, cermet, and others can be used. The word "plastic" will be used in most cases to indicate this type of pot.

The resolution to which one can set on a pot is a function of electrical angle over which the resistance is spread. One can more accurately pick a particular point on a 10-turn pot than on a one-turn pot since the resistance is spread over a larger electrical angle. The sacrifice here is time required to scan the total pot.

The accuracy to which a pot can be set is also a function of the voltage range. A 1% resolution pot over a voltage range of 10 v, the smallest part of voltage is $.01 \times 10$ or 0.1 v. Wirewound pots have resolutions from 1% to less than .001%. In plastic pots the change is so small that the resolution is considered infinite. To set constant voltages such as 8.92 volts, trimming is done over a small voltage increment (such as one volt) by adding a fixed resistor to the pot. Now the voltage change can be made over a small voltage of 1 volt. The resolution required is now 1%.

Linearity and resistance tolerance do not affect the operation of the WEDS drastically. These factors affect the resistance of the pot, but do not affect the voltage output from the pot to an extent that it will interfere with the computer operation.

Pot noise is defined as a equivalent parasitic, transient resistance, in ohms, appearing between contact and resistance elements when the shaft is rotated. This effect is not a consideration in the WEDS since data is not taken during the rotation of the shaft.

5.4 EFFECTS COMPUTER SPECIFICATIONS

Following are basic specifications for three computers. The overall accuracy for the computers should be below 5% for all three computers. The thermal computer should be well within this 5% range. However, the radiation and blast computers will depend on certain functions accuracies. The major error in the radiation computer will be from the antilog conversion of 5×10^{-3} ρD . The major error in the blast computer is in the pressure functions.

INPUT SPECIFICATION

Input Range and Height of Burst

Type Linear Potentiometer

No. P-1, P-2

Drawing Reference No. LE 15481

Resistance	2 K
Resistive Element	Plastic*
Turns	3 to 10
Resolution	infinite
Linearity	0.5%
Size	
Minimum Resistance	< 1% of R
Power Rating	2 watt
Mounting	Bushing
MIL Spec	Environmental, no extreme characteristics expected during operation

*To give infinite Resolution

INPUT SPECIFICATION

<u>Input</u>	Vulnerability V_n
<u>Type</u>	Linear Potentiometer
<u>No.</u>	P-3
<u>Drawing Reference No.</u>	LE 15481
Resistance	2 K
Resistive Element	Wirewound
Turns	1
Resolution	0.1%
Size	7/8"
Minimum Resistance	1% of R
Power Rating	2 watt
Mounting	Bushing
MIL Spec	Environmental, no extreme characteristics expected during operation

INPUT SPECIFICATION

<u>Input</u>	Pressure
<u>Type</u>	Linear Potentiometer
<u>No.</u>	P-4
<u>Drawing Reference No.</u>	LE 15481
Resistance	2 K
Resistive Element	Wire Wound
Turns	3 to 10
Resolution	0.1%
Linearity	0.5%
Size	7/8"
Minimum Resistance	---
Power Rating	2 watt
Mounting	Bushing
MIL Spec	Environmental, no extreme characteristics expected during operation

INPUT SPECIFICATION

Input	Gamma & Neutron Shield
-------	------------------------

Type	Linear Potentiometer
------	----------------------

No.	P-5, P-6
-----	----------

Drawing Reference No. LE 15481

Resistance	2 K
Resistive Element	Wire Wound
Turns	1
Resolution	0.1%
Linearity	0.5%
Size	7/8"
Minimum Resistance	< 1% of R
Power Rating	2 watt
Mounting	Bushing
MIL Spec	Environmental, no extreme characteristics expected during operation

INPUT SPECIFICATION

Input Air Density ρ and Map Scale

Type Linear Potentiometer

No. P-7 and P-23

Drawing Reference No. LE 15481

Resistance	2 K
Resistive Element	Wire Wound
Turns	1
Resolution	1%
Linearity	1%
Size	7/8"
Minimum Resistance	1% of R
Power Rating	2 watt
Mounting	Bushing
MIL Spec	Environmental, no extreme characteristics expected during operation

INPUT SPECIFICATION

Input Desired Rads. and Heat

Type Linear Potentiometer

No. P-8, P-9

Drawing Reference No. LE 15481

Resistance	2 K
Resistive Element	Plastic*
Turns	3 to 10
Resolution	Infinite
Linearity	0.5%
Size	
Minimum Resistance	< 1% of R
Power Rating	2 watt
Mounting	Bushing
MIL Spec	Environmental, no extreme characteristics expected during operation

* To give infinite Resolution

INPUT SPECIFICATION

<u>Input</u>	Yield
<u>Type</u>	Linear Potentiometer
<u>No.</u>	P-10
<u>Drawing Reference No.</u>	LE 15481

Resistance	2 K
Resistive Element	Plastic*
Turns	3 to 10
Resolution	Infinite
Linearity	0.5%
Size	
Minimum Resistance	< 1% of R
Power Rating	2 watt
Mounting	Bushing
MIL Spec	Environmental, no extreme characteristics expected during operation

Note: Several other pots and switches will be ganged with the yield pot.

* To give infinite Resolution

INPUT SPECIFICATION

<u>Input</u>	Air-Surface Thermal Computer
<u>Type</u>	Linear Potentiometer
<u>No.</u>	P-11
<u>Drawing Reference No.</u>	LE 15481
Resistance	5 K
Resistive Element	Wire Wound
Turns	1 to 10
Resolution	0.1%
Linearity	0.5%
Size	7/8"
Minimum Resistance	See Note 2.
Power Rating	2 watt
Mounting	Bushing
MIL Spec	Environmental, no extreme characteristics expected during operation

Notes: 1. Tied to yield.

2. Special taps at yield value of 100 KT and IMT.

INPUT SPECIFICATION

<u>Input</u>	V_{corr}
<u>Type</u>	Linear Potentiometer
<u>No.</u>	P-12
<u>Drawing Reference No.</u>	LE 15481
Resistance	2 K
Resistive Element	Wirewound
Turns	10
Resolution	< 0.1%
Size	7/8"
Mounting	Bushing
Power Rating	2 watt
MIL Spec	Environmental, no extreme characteristics expected during operation

Special Feature

Tapped at point corresponding to 10 KT on yield pot.
Tap at 0.5 x electrical angle.

INPUT SPECIFICATION

<u>Input</u>	Trimming Pots & Fixed Resistors
<u>Type</u>	Linear
<u>No.</u>	P-13 to P-22, R-1 and R-37
<u>Drawing Reference No.</u>	LE 15481

Resistance	Set depending on voltage level
Turns	10 to 25
Resolution	1% max.
Element	Wirewound
Power	0.5 watt

Fixed Resistors

Carbon

Tol. 5%

Power 1/2 watt

INPUT SPECIFICATION

Input K-factor resistance values

Type Linear Trimming Pots

No. R-9 to R-36

Drawing Reference No. LE 15481

Resistance	Set according to resistance value
Turns	10 to 25
Resolution	1%
Element	Wirewound or Cermet
Power Rating	0.5 watt
No. Required	≈ 35
MIL Spec	Environmental, no extreme characteristics expected during operation

INPUT SPECIFICATION

Switches

Drawing # LE 15481

Mode Switch & Min-Max Switch

Master Specialities

Series 10 E

Illuminated Push Button Switch

P - Q Switch

2 position - 9 pole

Push button switch

Illuminated split scale

Transmittance Switch

1 pole - 3 position rotary switch

Magnification Switch

5- Master Soecialities

Series 10 E

Illuminated Push Button Switch

5. 4. 1 Thermal Computer Specifications

1	Equation	$Q = 2.9 \times 10^4 \frac{W}{D} \bar{T} K_T$
2	Special Curves	$\bar{T}$ See Figure 10 K_T See Figure 11 D See Figure 8
3	Drawing Numbers	#LE 15478 Basic Circuit #LE 15484 Output Conversion #LE 15481 Inputs
4	Components Required	Operational Amplifiers 8 DFG 3 to 4 Antilog Network 2
5	Total Amplifier Drift Max	0.04% f. s. /day 0.11% f. s. /°C 1.04% f. s. /% All measured after Log Conversion
6	Noise	440 μ v rms max. Measured at amplifier 304
7	DFG	Diode function generators to be fixed break point fixed slope. Maximum deviation from equation or curve 1 mv. Set to 1% of full scale value
8	Test Points	
	Function Tested	Noise Level (max)
	Log D T_1	50 μ v
	Log T T_2	10 μ v
	Log Q T_3	10 μ v

9	Components	See General Specifications
10	Recommendations:	

This computer should be fabricated on one printed circuit board, with the exception of DFG's 302, 303, 304 and amplifier 305. This would allow for some flexibility in the calculation of $\text{Log } \bar{T}$.

5.4.2 Radiation Computer

1	Equation	$T = I_s + F_s$ $I_s = K_I N_I \frac{W'}{S_I} \left[\frac{10^7}{D_2} \right] \left[10^{-K_\gamma (5 \times 10^{-3}) \rho D} \right]$ $F_s = K_F N_F \frac{W}{S_F} \left[\frac{10^8}{D_2} \right] \left[10^{-K_n (5 \times 10^{-3}) \rho D} \right]$								
2	Special Curves	W' See Figure 9
D See Figure 8								
3	Drawing Numbers	#LE 15476 Basic Circuit
#LE 15479 Summing Network
#LE 15481 Inputs								
4	Components Required	<table border="0"> <tr> <td>Operational Amplifiers</td> <td style="text-align: right;">11</td> </tr> <tr> <td>DFG</td> <td style="text-align: right;">2</td> </tr> <tr> <td>Antilog Networks</td> <td style="text-align: right;">3</td> </tr> <tr> <td>Log Networks</td> <td style="text-align: right;">1</td> </tr> </table>	Operational Amplifiers	11	DFG	2	Antilog Networks	3	Log Networks	1
Operational Amplifiers	11									
DFG	2									
Antilog Networks	3									
Log Networks	1									
5	Total Amplifier Drift	1.5% f. s. / day
4.6% f. s. / °C
50% f. s. / % reg
See Appendix C								
6	Noise	440 μv rms max
Measured at Amp. 208 and 209								

7	DFG	Diode Function Generators to be fixed break point - fixed stop. Max. deviation from equation or curve 1 mv. Set to 1% of full scale value
8	Test Points	max noise level 10 μ v
9	Component	See General Specifications
5. 4. 3	<u>Blast Computer</u>	
1	Equation	$P = F HW^{1/3}; RW^{1/3}$ $\tau = a \text{ Log } P + bVo + C$
2	Special Curves	P_D See Figure 2 P_o See Figure 1a and 1b
3	Drawing Numbers	#LE 15477 Basic Circuit #LE 15481 Input
4	Components Required	Operational Amplifiers 8 Antilog Network 2 Special Function Generators 2
5	Total Amplifier Drift and Noise	This computer requires only that the amplifiers meet general purpose drift and noise limits as set in specifications. With noise level of 440 μ v at amplifier A-104.
6	Special Functions	Two servo driven mechanical cam systems. One for each pressure curve. The specifications of the cam system is not covered in this report.
7	Test Point	10 μ v noise level max.
8	Component	See General Specifications

BLAST COMPUTER SPECIFICATIONS

Special Components Ref. Drawing #LE 15477

Pots No. P-107 and P-108

Resistance	---
Resistive Element	Plastic*
Turns	---
Resolution	Infinite
Size	---
Mounting	Depending on method of mounting

Special Features

These pots follow the cam surface. They can be rotary pots, geared to turn and follow a linear displacement or they can be linear slide wire pots.

*To give infinite resolution.

9 Recommendations:

The cam module should be designed and fabricated by a servo engineering house. This special unit should be fabricated within minimum volume. The total cam module should complete with motor drive and feedback potentiometers.

5.5 ANTILOG & DISPLAY SPECIFICATIONS

The antilog conversion circuit specifications are broken down into four parts, the general specifications for the circuit, the antilog modules, the ADC, and the digital display.

5.5.1 Antilog Conversion and Display Units

General Specifications

1	Comparator Circuits	Fairchild μ 710
	Current Out	10 ma peak
	Voltage Out	3 v typ.
	Voltage Diff.	2 mv on-off state
2	Amplifiers	General Purpose
3	Trim-pots Relays	See General Components
4	Recommendations:	

All components including the amplifiers and log modules should be mounted on one printed circuit board for each antilog circuit. One test point to be provided for each circuit.

5.5.2 Antilog Modules

1	Transfer Function	$E_o = K \text{Log}^{-1} E_{in}$
2	Drawing Numbers	#LE 15479 and 15484 to 15489
3	Decades Required	One
4	Input Level	0 to 2 volts* in most cases
5	Output Level	1.00 to 9.99 volts

*Depending on the scale factor

6	Static Transfer Accuracy	$\pm 1\%$ f. s.
7	Drift Rates	10 mv referred to the output
	Temperature	$\pm 0.1\%$ f. s. / $^{\circ}\text{C}$
	Supply	1% f. s. / %
8	Output Noise Max	0.5% f. s.
9	Output Impedance	1 K Ω max.
10	Output Current	10 ma max. required
11	Operating Temp.	0 to 40 $^{\circ}\text{C}$
12	Supply Requirements	
	Voltage	± 15 vdc
	Current Drain	20 ma

13 Recommendations:

Inquiries have been made into the possibility of having the antilog circuits fabricated into an encapsulated modular package size 1-1/8" x 1-1/8" x 0.6". This package would include the logarithmic transistors and two operational amplifiers. The operational amplifiers would be designed around the transistor package. These units would increase the system cost slightly. This cost would be off-set by the space saved.

It is recommended that this type of unit be considered the WEDS. Design changes could be easily made with this unit. Also, from a maintenance view this unit would allow for quick checking and changing in case of faulty operation.

These units are designated Burr Brown 9909. Actual size 2" x 1" x 0.7". The curve for this unit is shown in Appendix B.

5.5.3 Analog to Digital Converter

1	Channels	9
2	Resolution	$\pm 0.01\%$
3	Full Scale Input	± 10 volts
4	Code	8421
5	Output Logic Levels	
	Logic "1"	-6.0 v
	Logic "0"	0.0 v
6	Operating Mode	Sequential
7	Accuracy and Drift	0.01%
8	Sample Rate	< 1 KC
9	Recommendations:	

It is recommended that the ADC be only a set of modules as follows:

- 1) Multiplexer Switch
- 2) A. D. C.
- 3) Sample and Hold Amplifier
- 4) Sequence Control

5.5.4 Digital Display Readouts

1	Character Size	1/2" to 5/8"
2	Input Code	8421
3	Logic Level	
	Logic "1"	-6 v
	Logic "0"	0.0 v
4	Input Current	2 ma
5	Output	10 decimal + 1 decimal point
6	Number Required	3 digital readouts with decoder and driver and memory for each of 9 outputs. Other readouts will display zeros and letters.

7 Power Requirements

Lamp Power	6 volts, 200 ma
Decoder Voltage	-7.5 volts
Decoder Current	300 to 350 ma for each unit
Decoder Regulation	5%

8 Recommendations:

The IEE Inc. Series 120 readout with driver/decoder and memory will provide a rear-projection readout having a clear bright number.

This number is chosen mainly for its rear-projection feature which provides a uniform clear number. The shape of the number can be specified. Letters and other information can be projected. The 6 v lamp will give a brighter light which will last longer than a 12 or 28 volt lamp. Average light 35 to 50 foot lamberts.

9 Mounting	The IEE unit will mount in an assembly 1-1/8" high and 6.7" long for 6 units.
------------	---

5.6 POWER SUPPLIES

1 Reference Supply	± 1 - volts, 1 amp max req.
2 Regulation	0.0005% load 0.0002% line
3 Temp. Coeff.	0.001%
4 Voltage Stability	0.0002% - 8 hours 115 VAC- 60 c/s line
5 ± 15 volt supply	
1 amp total current	
0.1% regulation	
10 mv rms noise	
$\pm 0.02\%/^{\circ}\text{C}$	
115 VAC - 60 c/s line	

6 Display Supply

6 v lamp drive, 2 amp

± 7 v decoder/drive 10 amps

5% regulation

7 Relay Drive

40 v at 1 amp

5% regulation

APPENDIX A

METHODS OF CALCULATING SLANT HEIGHT

The equations for slant height, D , is used in the radiation and thermal computer, therefore, requires special attention. Due to the wide dynamic range of R and H the logarithmic form is called for to optimize the solution.

$$\text{Log } D = 1/2 \log (R^2 + H^2) \quad (1)$$

This solution requires the squaring of R and H as linear values, then the sum must be converted to logarithmic form. At the same time amplitude scaling must be changed to maintain accuracy. This results in unnecessary complication of the problem and additional source of error.

Solving equation for D as,

$$D = R \left[1 + \left(\frac{H}{R} \right)^2 \right]^{1/2} \quad \text{and using} \quad (2)$$

$$\text{Log } D = \log R + f(H/R) \quad \text{where} \quad (3)$$

$$f(H/R) = 1/2 \log [1 + (H/R)^2] \quad (4)$$

This form requires a function generator to provide $f(H/R)$. However, if log values are available the solution becomes straight forward with the only major error being developed in $f(H/R)$. This error is greatly reduced when $H \ll R$ since $f(H/R)$ approaches zero and $D \approx R$; therefore, for surface bursts or for large ranges the error in D is very small. The log value for R should be as error free as possible; furthermore, the upper end of $f(H/R)$ i. e. where $f(H/R)$ is larger should be made as error free as possible.

Writing the D equation in trigonometric form we have

$$D = H \sin \phi + R \cos \phi \quad (5)$$

where

$$H \cos \phi = R \sin \phi \quad (6)$$

in logarithmic form

$$\text{Log } D = \log R - \log \cos \phi \quad (7)$$

$$\text{Log } D = \log H - \log \sin \phi \quad (8)$$

$$\text{Log } H + \log \cos \phi = \log R + \log \sin \phi \quad (9)$$

We must first compute ϕ from Equation (9), then having ϕ we compute $\text{Log } D$. The solution for ϕ involves the functions of $\log \sin \phi$ and $\log \cos \phi$ and would tend to introduce more error than a single function of H and R .

Equation (7) can be written as

$$\text{Log } D = \log R + \log \sec \phi \quad (10)$$

$$\text{however } \sec \phi = (1 + \tan^2 \phi)^{1/2} \quad (11)$$

$$\text{and } \tan \phi = H/R$$

this is equivalent to equation (2) or $\log D = \log R + \log (1 + (H/R)^2)^{1/2}$.

From the above it would seem that the least error can be achieved by using a single function of $f(H/R)$ with no amplitude scaling required.

APPENDIX B

LOG MODULE TESTING

Testing

Tests have been made on several antilog converting modules. The features one should look for are 1) dynamic range, 2) attenuations or amplification required before entering the module, 3) output drift from a true log module curve, and 4) initial adjustment and output drift from the initial curve.

A Nexus LGP-3 was tested. This unit contains only the logarithmic transistors, two operational amplifiers are required to set the circuit up. Due to the low operating levels this circuit was found to be very difficult to adjust to its proper operations. No data was taken from this unit.

The LGP-3 was replaced with a LG-6 which is a $\pm$ log module. The results of the LG-6 Log Module are shown in Figure B. 1. The conclusions of the test are listed below.

1. Several points missed the true log curve.
2. Of the three decades tested the second decade followed the true log curve the best.
3. The third decade, between 1 and 10 volts out, is desired however, the last two points tested drifted from the true log curve by 2 mv. This is large enough to cause an output drift of 0.6 volt if located between 9 and 10 volts.
4. The low level of operation, i. e. , 60 mv per decade, is undesirable since small noise levels or drift rates will cause large changes in the output.
5. The low operating level requires attenuation of 50 db.

A Burr-Brown Log Module 1667 was tested and the results were very favorable. This unit incorporates the transistors and the amplifiers into one unit, this allows for very simple assembly. The results of this test are given on the following page.

Figure B-1.

Plot of Nexus LGP

Log Module St. Line is True Curve.

All points are shifted up slightly. Ref
current = $1 \mu\text{a}$ changing the ref current
will change the curve slightly.

APPOX.

3 CYCLES X 10 DIVISIONS PER INCH

1. Over the two decades tested the unit followed the true log curve very well; see Figure B. 2. All points hit the curve.
2. This unit has a high input level, i. e. , 0 to 10 v/decade.
3. Both positive and negative inputs can be used.
4. The input level per decade will require a change in the level of operation to 0 to 2 volts rather than 0 to 10 volts in.

Figure B-2.
Burr Brown
Antilog 1667

APPENDIX C

ERROR CALCULATIONS

C. 1 DRIFT CALCULATIONS FOR THERMAL COMPUTER

Based on max. amplifier drift rates of

50 $\mu\text{V}/\text{day}$

10 $\mu\text{V}/^{\circ}\text{C}$

50 $\mu\text{V}/\%$ regulation

max drift is added through the calculation of transmittance and D.

Slant height calculation three amplifiers in series

150 $\mu\text{V}/\text{day}$

30 $\mu\text{V}/^{\circ}\text{C}$

150 $\mu\text{V}/\%$

Transmittance adds one additional amplifier

200 $\mu\text{V}/\text{day}$

40 $\mu\text{V}/^{\circ}\text{C}$

200 $\mu\text{V}/\%$

D has a gain of 3 through amplifier 304 + the drift in amplifier 304

500 $\mu\text{V}/\text{day}$

100 $\mu\text{V}/^{\circ}\text{C}$

500 $\mu\text{V}/\%$

Transmittance has a gain of 1 + the drift in amplifier 304

200 $\mu\text{V}/\text{day}$

40 $\mu\text{V}/^{\circ}\text{C}$

200 $\mu\text{V}/\%$

The calculation of D gives the largest drift rate. When converted to analog values the errors are:

0.04% full scale referred to the output per day

0.01% full scale referred to the output per $^{\circ}\text{C}$

0.04% full scale referred to the output per % regulation.

The drift rates of the antilog circuit will have to be added to these for a total drift note. Antilog drift rates

Typ. $\pm 0.1\%$ f. s. / $^{\circ}\text{C}$

1% f. s. /% regulation

The total drift rates for the thermal computer are:

0.04% f. s. /day

0.11% f. s. / $^{\circ}\text{C}$

1.04% f. s. /%

C. 2 RADIATION COMPUTER

Slant height is calculated as in the thermal computer. Into amplifier 204 drift rates are:

300 μV /day

60 $\mu\text{V}/^{\circ}\text{C}$

300 $\mu\text{V}/\%$

After amplifier 204 the drift rates are:

90 μV /day

17 $\mu\text{V}/^{\circ}\text{C}$

90 $\mu\text{V}/\%$

Taking into account the scale factor after antilog conversion

0.03% f. s. /day

0.10% f. s. / $^{\circ}\text{C}$

1.0 % f. s. /%

This antilog converter will be required to be very stable, with good temperature and supply regulation.

Voltage values from antilog converter,

3 mv/day

10 mv/ $^{\circ}\text{C}$

100 mv/% regulation

These values enter amplifier 206 and 207 with a gain of 4; SF at amplifiers is 2.

6 mv/day

20 mv/ $^{\circ}$ C

100 mv/% regulations

Resulting drift after final antilog conversion

1.5%/day

4.6%/ $^{\circ}$ C

50 %/% regulation

These are worst case conditions and are strongly dependent on antilog conversion after amplifier 204.

C. 3 RADIATION COMPUTER ERROR CALCULATIONS

The max. error at amplifier 210 must be less than 10 mv. This requires that a log error at amplifiers 206 and 207 be less than 440 μ v x scale factor.

Radiation scale factor = 2 change at amplifiers 206 and 207 must be less than 880 μ v. Errors of (2 x 150 = 300) μ v/day at amplifier 204 results in errors of 8 mv after antilog conversion. This error should be divided by the scale factor of 4 or 2 mv. This type of error is small compared to the 1 to 10 volt range of (5×10^{-3} ρ D)

DRAWING NUMBERS

Interconnection Diagram	LE 15475-1
Radiation Computer	LE 15476
Blast Computer	LE 15477
Thermal Computer	LE 15478
Radiation Summing Network	LE 15479
Circle Radii Map Computer	LE 15480
Master Control Panel	LE 15481
Yield Selector	LE 15482 (CRD-1)
Weapon Type Control	LE 15483 (CRD-1)
Antilog Conversion and Thermal Display	LE 15484
Antilog Conversion and Blast Display	LE 15485
Antilog Conversion and Radiation Display	LE 15486
Antilog Conversion and Yield Display	LE 15487
Antilog Conversion and Range Display	LE 15488
Antilog Conversion and HoB Display	LE 15489
Relay Driving Circuit	LE 15490
Computer BITE Unit	LE 15491

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