work with a meter 1M and the resistor 7R similar to the network in which the resistors are connected in the FIG. 1 embodiment. The mounting provisions for the apparatus shown in FIG. 3 and its use is similar to that for the apparatus shown in FIGS. 1 and 2.

With the apparatus shown in FIG. 4, Equation 6

$$2 \log O_e - \log 12 - \log s - \log m + \log K = 0$$

and Equation 4

$$K = \frac{(B+I)C + ZA(1-R)}{2}$$

are solved. This apparatus includes a Log Unit and a K Unit which may be selectively set to operate in networks with a common meter M2 by selector switch SSW. The apparatus is supplied from conductors SL1 and SL2.

The Log Unit includes a transformer 42T having a primary 42TP supplied from conductors SL1 and SL2 and a plurality of secondaries 42TS1, 42TS2, 42TS3, 42TS4 and 42TS5. Each of these secondaries corresponds to a term of the log equation; 42TS1 to 2 log Q_e, 42TS2 to log 12, 42TS3 to log *S*, 42TS4 to log *M* and 42TS5 to log *K*. The secondaries 42TS1, 42TS3, 42TS4 and 42TS5 are shunted by variable resistors R8 through R11. In one position of the switch SSW these resistors and the secondary 42TS2 are connected in a network with the meter M2 and its sensitivity resistor R11, the resistors R8 through R11 being poled correspondingly to the sign of the logs of the corresponding parameters in Equation 6. The K Unit includes transformer 41T and variable transformer 43T. The transformer 41 has a primary 41TP connected across conductors SL1 and SL2 and a plurality of secondaries 41TS1, 41TS2 and 41TS3. Across the secondary 41TS3, a variable resistor R15 is connected. A variable resistor R14 is connected between the adjusting arm R15 and one terminal of 41TS1. The resistor R15 corresponds to R and a potential equal to 1 is derivable from 41TS1. The resistor R14 then corresponds to ZA (1–R). Across the secondary 41TS2 a variable resistor R16 which corresponds to K is connected.

The secondary of transformer 43T corresponds to the factor C of the term $(B+I)$ *C* of the equation for K. Between one of the terminals and the adjustable arm of the transformer 43T, a fixed resistor R13 in series with variable resistors R12 and R′12 are connected. The resistors R12 and R′12 correspond to the terms B and I of the term $(B+I)$ *C*.

The resistors R12 through R16 are connected in a network with the meter M2 in the other position of the switch SSW. In this network the resistors are so poled and so set that as to correspond to the terms of Equation 4

$$K - \frac{(B+I)C + ZA(1-R)}{2} = 0$$

Like the apparatus of FIGS. 1, 2 and 3 the apparatus of FIG. 4 is mounted in a cabinet (not shown) with a panel top. The panel carries scales and knobs for the resistors R8 through R12 and R14 through R16 and for 43T. The scales for resistors R8 through R11 are logarithmic and the scales of the resistors R12, R14, R15 and R16 and of 43T are linear. The potential of the secondaries 42TS1 through 42TS5 correspond to the range of magnitudes of the terms of the Log equation. The potentials of the secondaries of the other transformers 41T, 43T correspond to ranges of the term of the equation for K.

The data for the former is presented in Table II.

Table II

Term	Secondary	Potential, v.	Parameter	Range of Variation
2 Log Q_e	42TS1	230	Lot size	0 to 1,000,000 items.
Log 12	42TS2	12.4		
Log S	42TS3	57.5	Cost of setting up machines and the like.	0 to $1,000.
Log M	42TS4	95.8	Items used per month.	0 to 100,000 items.
Log K	42TS5	57.5	Given by equations for K.	0 to $1,000.

Table III presents similar data for the equation for K.

Table III

Term or Factor	Secondary	Potential, v.	Parameter	Range of Variation
C	43T	115	Unit cost of item.	0 to $1,000.
B+I	43T, R12 and R′12.	57.5	Taxes, insurance and the like and desired rate on capital.	0 to 50%.
A	41TS1 and part of R12.	115	Cost of storing each item.	0 to $500.
1-R	41TS1 and 41TS3.	115	Ratio of M to P.	0 to 1/10.
K	41TS2	172.5	K factor	0 to $750.

In the use of this apparatus, the selector switch SSW is first set so that the resistors R12, R14 and R16 are connected in a circuit with the meter M2. The resistors R12, R14 and R15 are then set to correspond to the various parameters. Thereafter, R16 is adjusted until M2 reads zero. The sensitivity push button PB2 is then closed to shunt out resistor R11 and resistor R16 is reset.

The switch SSW is then set in the other position. Resistors R9 and R10 are set to correspond to the terms log S and log M of the log equation and resistor R11 to correspond to the log of the setting on resistor R16. Resistor R8 is then adjusted until the meter M2 reads zero. Thereafter the push button PB2 is closed and the resistor R8 reset. The setting of resistor R8 gives the desired economical lot size.

The apparatus shown in FIGS. 5 through 8 is used in the solving of the Equation 7 for return-on-added-investment. This equation is

$$L1i + P1 + (I1 - L1)CR1 = L2i + P2 + (I2 - L2)CR2$$

and may be written

$$L1i + P1 + (I1 - L1)CR1 - L2i - P2 - (I2 - L2)CR2 = 0 \qquad (10)$$

The apparatus shown in FIGS. 5 through 8 is supplied from conductors SL1 and SL2 and includes a plurality of transformers 101T, 102T, 103T and 104T. In addition, this apparatus includes a plurality of variable transformers 1VAR, 2VAR, 3VAR and a selector switch SSW1. The primary 102TP of transformer 102T is connected between conductors SL1 and SL2. The primaries of transformers 1VAR, 2VAR, and 3VAR are also connected between conductors SL1 and SL2. The primary 104TP of transformer 104T is connected between the adjustable tap of 3VAR and one of its end taps.

The switch SSW1 has two positions. In one position, the primaries 103TP and 101TP are both connected between the adjustable arm and one terminal of transformer 1VAR. In the other position of the switch SSW1, the primary 103TP is connected between the adjustable arm of 2VAR and one of its terminals and the primary 101TP is similarly connected to transformer 1VAR. The primary 101TP is in this circuit shunted by a resistor 100R.

The transformer 1VAR corresponds to the factor CR1 in Equation 10. The transformer 101T has a pair of secondaries 101TS1 and 101TS2, one of which corresponds to I1 and the other to L1. The transformer

2VAR corresponds to the factor CR2, the transformer 103T has a pair of secondaries 103TS1 and 103TS2 which correspond respectively to L2 and I2. The variable transformer 3VAR corresponds to the factor i and the transformer 104T which is supplied from this variable transformer includes a pair of secondaries 104TS1 and 104TS2 which corresponds to the terms $L1i$ and $L2i$, respectively. The transformer 102T has a pair of secondaries 102TS1 and 102TS2 which corresponds respectively to the terms P1 and P2.

The apparatus shown in FIGS. 5 through 8 also includes a plurality of potentiometers 1P, 2P, 3P, 4P, 5P, 6P, 7P and 8P. These potentiometers 1P through 8P are of the type including a plurality of resistors RZ of equal resistance and a tap switch TS for determining the number of resistors to be connected between one of the terminals of the potentiometers and the switch. The apparatus also includes a plurality of potentiometers 1P′, 2P′, 3P′, 4P′, 5P′, 6P′, 7P′, and 8P′. The latter are of the continuously variable type and have a maximum resistance approximately equal to each of the resistors of the potentiometers 1P through 8P. Thus, a potentiometer 1P′ through 8P′ may be used to provide a precise or vernier adjustment between two settings of a potentiometer 1P through 8P, respectively.

The potentiometers 1P and 1P′ are connected in series with a resistor 109R across secondary 104TS1. Potentiometers 2P and 2P′ are similarly connected in series with resistor 105R across secondary 102TS1. 3P and 3P′ are similarly connected to 101TS1, 4P and 4P′ to 101TS2, 5P and 5P′ to 103TS1, 6P and 6P′ to 103TS2, 7P and 7P′ across 102TS2, and 8P and 8P′ across 104TS2, the potentiometers 1P and 4P and 1P′ and 4P′, respectively, and the potentiometers 5P and 8P and 5P′ and 8P′, respectively, are ganged.

The following Table IV shows the factors of Equation 10 which are set by the various components:

Table IV

Term	Factor	Symbol	Component
$L1i$	Salvage Value, Alt. I.	L1	1P and 1P′
$L1i$	Rate-of-Return	i	3VAR.
(I1-L1) CR1	Salvage Value, Alt. I.	L1	4P and 4P′.
(I1-L1) CR1	Initial Investment, Alt. I.	I1	3P and 3P′.
(I1-L1) CR1	Capital Recovery Factor—Alt. I.	CR1	1VAR.
P1	Annual Cost of Operating Equipment.	P1	2P and 2P′.
$L2i$	Salvage Value, Alt. II.	L2	5P and 5P′.
(I2-L2) CR2	Salvage Value, Alt. II.	L2	8P and 8P′.
(I2-L2) CR2	Initial Investment, Alt. II.	I2	6P and 6P′.
(I2-L2) CR2	Capital Recovery Factor—Alt. II.	CR2	2VAR.
P2	Annual Cost of Operating Equipment—Alt. II.	P2	7P and 7P′.

In one position of switch SSW1 the potential across 3P and 3P′ and 4P and 4P′ is determined by 1VAR which corresponds to CR1 and the potential across 5P and 5P′ and 6P and 6P′ by 2VAR which corresponds to CR2. In the other position 103TP and 101TP are both energized from 1VAR, that is CR1 and CR2 are equal.

The apparatus includes a meter M13 having a resistor 101R which may be shunted out by a push button PB3 to increase sensitivity. The potentiometers 1P through 8P and 1P′ through 8P′ are connected in series with meter M13 and resistor 101R with the potentials across the potentiometers so poled that the potential across each potentiometer corresponds to the sign of the corresponding term in the Equation 10.

In the practice of this invention, the apparatus shown in FIG. 5 are mounted in a cabinet, the top panel of which is shown in FIG. 6. Each of the potentiometers 2P, 3P, 6P and 7P have knobs KN22, KN23, KN26, and KN27. The corresponding potentiometers 2P′, 3P′, 6P′ and 7P′ have knobs KN′22, KN′23, KN′26, KN′27. The potentiometers 1P and 4P, 1P′ and 4P′, 8P and 5P, 8P′ and 5P′ have common knobs KN14, KN′14, KN58, KN′58. A graduated scale is associated with each of the knobs. The scales of the potentiometers 1P through 8P are each graduated in dollars from 0 to $10,000. The scales of the potentiometers 1P′ through 8P′ are each graduated from 0 to 500 to correspond to one graduation of the corresponding scales 1P through 8P, respectively.

The variable transformers 1VAR, 2VAR and 3VAR each has a knob KNV1, KNV2, KNV3, respectively, which extends through the top panel. Variable transformer 3VAR which is set to correspond to the rate of return i is provided with a scale graduated in percent rate of return. Transformers 1VAR and 2VAR are each provided with a plurality of scales SCR1 through SCR8 and a scale SCY shown in more complete detail in FIG. 7. The scale SCY is inscribed on a transparent strip carried by the knobs KNV1 and KNV2. The graduations of this scale SCY are in years, n, and extend from the end of the strip to the knob (KNV1, KNV2) in years. For convenience, the years 3, 4, 5, 6, 8, 10, 15 and 25 are selected. The strip also carries a hairline HL1 centrally. The scales SCR1 through SCR8, respectively, are of circular form spaced to correspond to the time interval scale and extend around the knob. Each of these latter scales are graduated in percent return-on-added-investment; that is in i. The graduation is such that each graduation, i, on a circular scale and the corresponding number of years, n, on the scale extending from the knob corresponding to a magnitude of CR in which i is the selected point on the circular scale and n is the number of years on the scale attached to the knob. For example, as shown in FIG. 7, the knob is set at the marking 104 of the outer circular scale which corresponds to $n=3$. Thus the setting corresponds to a return-on-added-investment of 104% and a life of equipment of three years. The value of CR to which these values of i and n correspond is given by the equation:

$$CR=\frac{i(1+i)^n}{(1+i)^n-1}$$

$$=\frac{1.04(1+1.04)^3}{(1+1.04)^3-1}$$

$$=\frac{(1.04)(2.04)^3}{(2.04)3-1} \quad \text{or} \quad CR=1.18$$

In place of the apparatus shown in FIG. 7 the apparatus shown in FIG. 8 may be used. In this case the variable transformer VAR is provided with an outer plate PL1 having a window W1 and the knob KN carries a plurality of circular scales 1SCR1 through 1SCR8 which are movable past a hairline HL along the window W1. The n scale 1SCY extends along the window W1 from the rim of the outer plate of the variable transformer to the knob KN. The rates of return corresponding to each n on scale 1SCY appear on the adjacent circular scales 1SCR1 to 1SCR8.

At this point, it appears derivable to consider the accuracy of the computer shown in FIGS. 5, 6, 7 and 8. The accuracy is limited only by the preciseness of the components and the accuracy in making the dial calibrations. The most significant contribution to accuracy in the computer is the degree of linearity, total-resistance tolerance, and resolution of potentiometers 1P through 8P and 1P′ through 8P′. Linearity is the degree with which the increment of resistance is duplicated throughout the entire range of mechanical rotation. The total-resistance tolerance is the closeness with which the actual potentiometer resistance matches the nominal rating. The resolution is the measure of the smallest increment of resistance change possible. On wire-wound potentiometers the resolution is fixed by the resistance of a single turn of the resistance element.

There are extremely precise potentiometers available for instrumentation application and if these are included in the equipment the potentiometers 1P′ through 8P′ could be dispensed with, but the cost of potentiometers of this type may be as high as $125.00. As a compromise between cost and preciseness, the potentiometer corresponding to each parameter consists of a tap-switch-precision-resistor assembly (1P through 8P) with a low-resistance vernier (molded-composition type) potentiometer (1P′ through 8P′) in series. By using a tap-switch-precision-resistor assembly, the calibration of these dials is avoided, since each point on the resistance dial is set by the indexing device on the tap switch. This technique also makes feasible the replacement of components in the event of failure, without requiring recalibration. The tolerance of potentiometers 1P′ through 8P′ used on computer is ±1%. These components are each used in conjunction with the tap-switch assembly to span the resistance values between points on the tap switch. Thus, placing 3610 ohms on this combination involves setting the tap switch at 3500 and the potentiometer (1P′ through 8P′) at 110. The two add directly to give 3610.

The dial calibration for 1P′ through 8P′ was made from the actual resistance-mechanical-displacement curve of the potentiometer. The error introduced by a replacement potentiometer in the event of failure is neglected, since the error would represent a very small percentage of the total circuit resistance.

The computer circuit is symmetrical on both sides of the dividing line between 4P′ and 5P. To this extent it is important that the total resistance in 1P through 4P each match the resistance of 5P through 8P.

The preciseness of transformer voltages ranks next to that of the resistances in determining computer accuracy. Specifically the voltage across the different secondaries 104TS1, 102TS1, 101TS1, 101TS2 must match the voltages across secondaries 104TS2, 102TS2, 103TS2, 103TS1 to plus 0.5%.

The accuracy in calibrating and reading the rate-of-return dials is largely determined by the sharpness of the null indication given by the null meter M3. The voltage multiplier resistor 101R must be such that the meter M3 just reads full scale when the dials are set at maximum settings for one alternative and at zero for the other alternative. Under this condition the sum of the transformer voltages in secondaries add directly. In actual practice the dials are rarely set at such extreme settings and the meter voltage is low. To give a sharper null indication at these low voltages a push button PB3 is provided to short out the multiplier resistance 101R. This button is pushed only after a rough null adjustment has been made. The meter voltages preferably used are 175 volts full scale (push button open) and 5 volts full scale (push button closed).

The resolution of the variable transformers 1VAR, 2VAR, 3VAR (rate-of-return-dials) is approximately .5 degree rotation.

The voltages selected for the transformer secondaries 102TS1 and 102TS2 should be low enough to be well within the insulation rating of commercial tap switches. These voltages were fixed at about 42 volts. The voltages of 104TS1, 101TS1, 101TS2, 103TS1, 103TS2 and 104TS2 depend on the maximum rate of return setting of 1VAR, 2VAR, 3VAR. The maximum rate of return on the dials in FIGS. 7 and 8 is 260%. The voltages of 104TS1, 101TS1, 101TS2, 103TS1, 103TS2 and 104STS2 should then be 260% of 42 or 109. This voltage is rounded off to 115 volts.

The total resistance values for 1P through 8P should be selected to some convenient multiple of the full scale dial calibration, since the dials are each calibrated from 0 to $10,000. The resistance selected in one unit of the apparatus to represent this dollar amount is 10,000 ohms. The individual tap switch resistors are, therefore, 10,000/20=500 ohms. The resistance of the vernier potentiometers 1P′ through 8P′ is 500 ohms. In another unit of the equipment there are only 10 steps of 1000 ohms each and the vernier potentiometers are each 1000 ohms. Low magnitudes of resistance should be avoided to eliminate errors contributed by potentiometer slider and tap-switch rotor contact resistances.

The current through potentiometers 3P, 3P′ and 4P, 4P′ and 5P, 5P′ and 6P, 6P′ is proportional to the capital-recovery factor CR1 or CR2 as the case may be. The capital-recovery factor for any return i and term n can be calculated or derived from a table. The dial for 3VAR can be graduated uniformly but the rate-of-return-rate scales of 1VAR and 2VAR must be calibrated so that at each setting the value of n and i satisfies the equation for CR corresponding to the setting.

The calibration may be carried out for the special case in which the switch SSW1 is set so that both 101TP and 103TP are supplied from 1VAR that is $CR1=CR2=CR$. Also it may be assumed that $L1=L2=0$. Then

$$CR=\frac{P2-P1}{I1-I2}$$

it may further be assumed that P1 the annual cost of operating for alternative I and I2 the initial investment of alternative II are zero. Then

$$CR=\frac{P2}{I1}$$

In accordance with the above assumptions SSW1 is set in the position in which CR1=CR2, and 1P and 1P′, 2P and 2P′, 4P and 4P′, 5P and 5P′, 6P and 6P′ and 8P and 8P′ are set to zero. Now 3P and 3P′ and 7P and 7P′ may be set successively at a series of magnitudes corresponding to different values of CR and for each setting 1VAR varied so that the meter M3 reads zero. For each value of CR and for each value of n on the time scale, a value of i can be derived from a table, or calculated. The graduation at which 1VAR is set can be labeled with the value of i.

For example initially I1 may be set at 1000 and P2 at 2000 given a value of $CR=2$. Having set the corresponding potentiometers, it is then only necessary to adjust the 1VAR dial until a meter null is obtained. This locates the particular rate of recovery, i, for each n where n and i are so related that $CR=2$. In the same way other points on the scales may be determined.

In explaining the use of the apparatus shown in FIGS. 6 and 7, let it be assumed that two alternative types of equipment are under consideration and it is desirable to compare the rate-of-return. Let it be assumed that alternative I involves a higher investment I1, a lower annual cost P1, and a salvage value L1 and the life of the equipment is $n1$ giving CR1 dependent on i and $n1$. Let it be assumed that alternative II involves a lower investment I2, a higher annual cost P2, a salvage value L2 and life $n2$ giving CR2. Initially the switch SSW1 is set so that both transformers 101T and 103T are supplied from variable transformer 1VAR. In addition, 3VAR is set at zero or its secondary open circuited so that there is no voltage on transformer 104T. For convenience SSW1 may include a contact to open circuit the connection between 3VAR and 104TP or to set the voltage of 104TP at zero. The zero setting of 104T eliminates the effect of salvage value on rate-of-return. The potentiometers 2P and 2P′, 3P and 3P′, 4P and 4P′, and 5P and 5P′, 6P and 6P′, and 7P and 7P′ are now set to correspond to the given values of P1, I1, L1, and L2, I2 and P2. 1VAR is then set so that the meter M3 reads zero. The rate-of-return i for the number of years assumed for the equipment involving investment I1 may then be determined for the dials of 1VAR. This rate-of-return i may now be used as a first approximation for determining the actual rate of return.

Leaving 1VAR set as it is, 3VAR is set to the rate of return shown on 1VAR and the selector switch SSW1 is moved to the positions in which transformer 101T is supplied from 1VAR and transformer 103T is supplied