MODEL 594 C.T. BATCH TESTER.
OPERATING INSTRUCTIONS.

1.0. BASIC INFORMATION.

THE MODEL 594 ESSENTIALLY TESTS AN UNKNOWN C.T. AGAINST A KNOWN SAMPLE C.T.
THE MODEL 594 IS CALIBRATED BEFORE BEING DESPATCHED FROM THE FACTORY WITH AVERAGE TEST VALUES FOR THE THREE TESTS IT PERFORMS.

THE CUSTOMER SHOULD HAVE A SAMPLE OF EACH TYPE OF C.T. INTENDED FOR TESTING WITH KNOWN VALUES OF ERROR, MEASURED ON AN ACCURATE BRIDGE.
THE SAMPLE SHOULD BE TESTED WITH THE 594 AND THE TRIMPOTS IN THE 594 ADJUSTED TO GIVE ERROR READINGS THAT ARE CORRECT.

FROM THERE ON C.T.s ARE TESTED ON THE 594 EFFECTIVELY WITH REFERENCE TO THE SAMPLE C.T.s.
THE 594 IS CHECKING THAT ALL THE C.T.s BEING TESTED HAVE:
a) CORRECT TURNS RATIO (THIS IS ACTUALLY AN ABSOLUTE MEASUREMENT).
b) CORRECT POLARITY.
c) CORRECT RATIO ERROR WHICH DEPENDS ON CORE ADMITTANCE.
d) CORRECT PHASE ERROR WHICH DEPENDS ON CORE ADMITTANCE.
TESTS c) AND d) ENSURE THE CORE MATERIAL PERFORMANCE IS THE SAME AS THE SAMPLE.

THE ELECTRICAL STANDARDS ASSOCIATION OF AUSTRALIA (ESAA) HAS A LIST OF PREFERRED C.T. METERING TYPE C.T.s WHICH COVER MOST RATIOS OF INTEREST TO A UTILITY.
IT SHOULD BE NOTED THAT THE SAME ESAA TYPE OF C.T. FROM DIFFERENT MANUFACTURERS CAN HAVE DIFFERENT ERROR VALUES AND STILL BE WITHIN SPECIFICATION. IDEALLY A TESTED SAMPLE SHOULD BE AVAILABLE FOR EACH MANUFACTURER AS WELL AS EACH ESAA TYPE, SO THAT THE MODEL 594 CHECKS CONSISTENCY OF RESULTS.

WHEN FIRST USED THE MODEL 594 SHOULD HAVE ITS TRIMPOTS ADJUSTED TO SUIT THE CUSTOMER'S SAMPLES. REFER TO THE SECTION HEADED "EXPLANATION OF OPERATION" FOR INFORMATION.

IN MANY CASES THE USER OF THE 594 WILL NOT HAVE SAMPLES OF ALL THE C.T.s INTENDED FOR TESTING. THIS IS NO PROBLEM, SINCE THE 594 CAN BE ADJUSTED AT ANY TIME TO SUIT A NEW SAMPLE WHEN IT IS AVAILABLE.

2.0. THEORY OF TESTING.

2.1. The performance of a C.T. when working into a specified burden can be calculated without a direct injection test.
The appendix at the end of this operating manual explains the theory used in the Model 590C for this type of testing. The Model 590C simulates a full C.T. test at any PF and any level of burden and primary current. The 590C is much more complicated than the Model 594.

For the 594 we make the test simple.
First we test for turns ratio and polarity.
Then we apply a complex voltage to the secondary and measure the current produced by the admittance of the core. This current is converted to an in phase and out of phase voltage which is scaled so that it gives a readout of ratio and phase errors on the DPM.

If there are compensating turns in the C.T. we can adjust the turns ratio error on the DPM to be zero by making it read zero when testing the sample C.T.

2.2. As a guide, consider the following C.T.

Ratio 1000/5, with exactly 200 turns on the core.
Rated for 15VA burden.
The voltage across the core at 15VA burden and 100% current will be 3V plus the voltage needed to drive 5A through the winding resistance (typically about 5A X 0.1ohm = 0.5V).

The error in the C.T. at 1.0PF is the admittance current needed to energise the secondary at 3.5V.
If that is 100mA at 45deg, then ratio error is 71ma/5A = 1.42%, and phase error = 1.42crad.

2.3. If the burden is smaller, or the current is less than 100%, then the admittance is measured at a lower voltage and the error will be different since admittance is not linear with voltage.

The 594 typically applies about 0.5V for the admittance test. This is a reasonable compromise since testing at different voltage levels makes the 594 and test method more complicated. For a comparative test between a known sample and an unknown C.T. then 0.5V is a sensible level to check if the unknown C.T. has a good core.

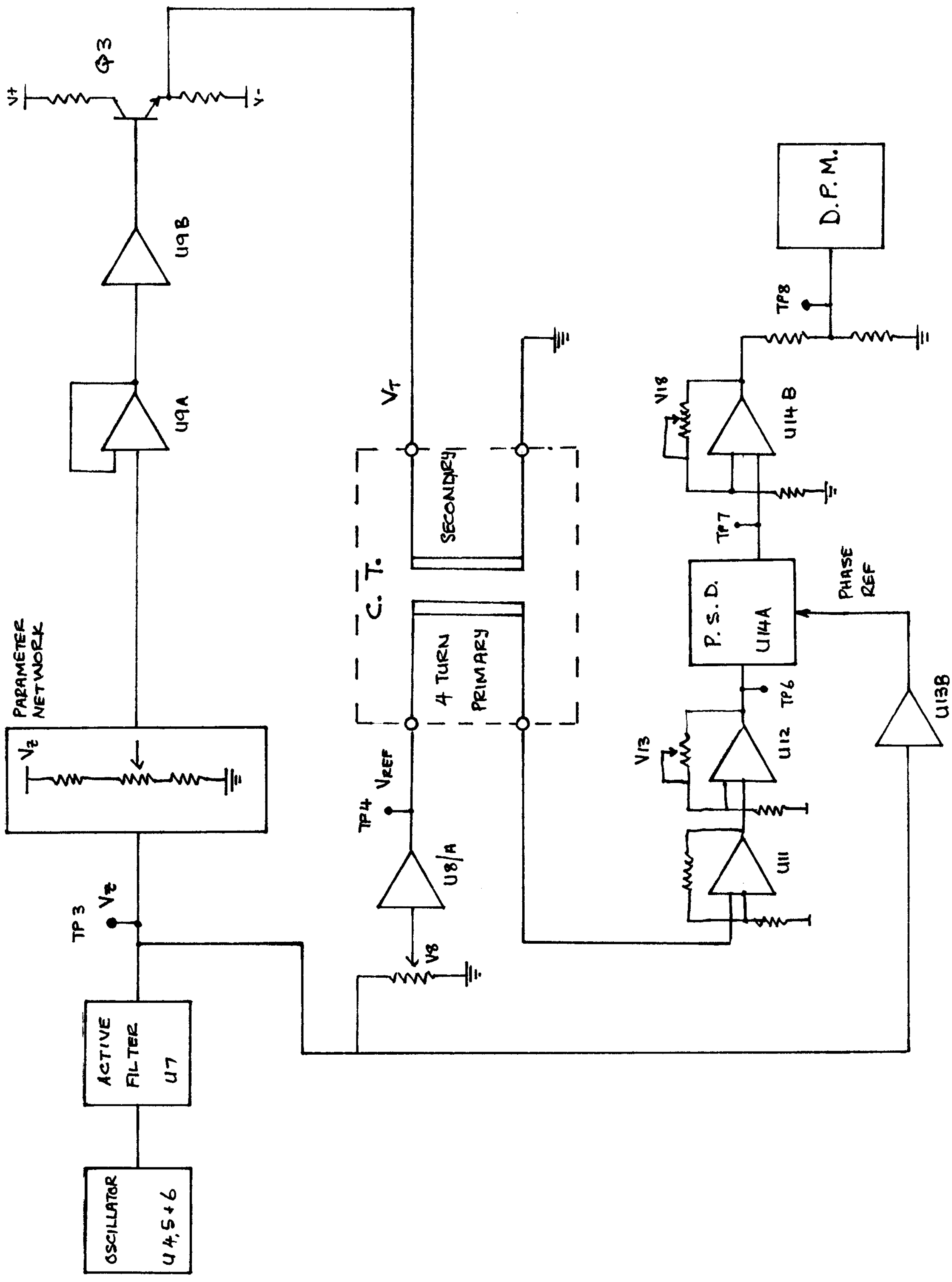
3.0. EXPLANATION OF OPERATION.

Refer to the simplified block diagrams on pages 3 and 4. For clarity they do not show the relays which are used to switch the circuits for the two type of tests.

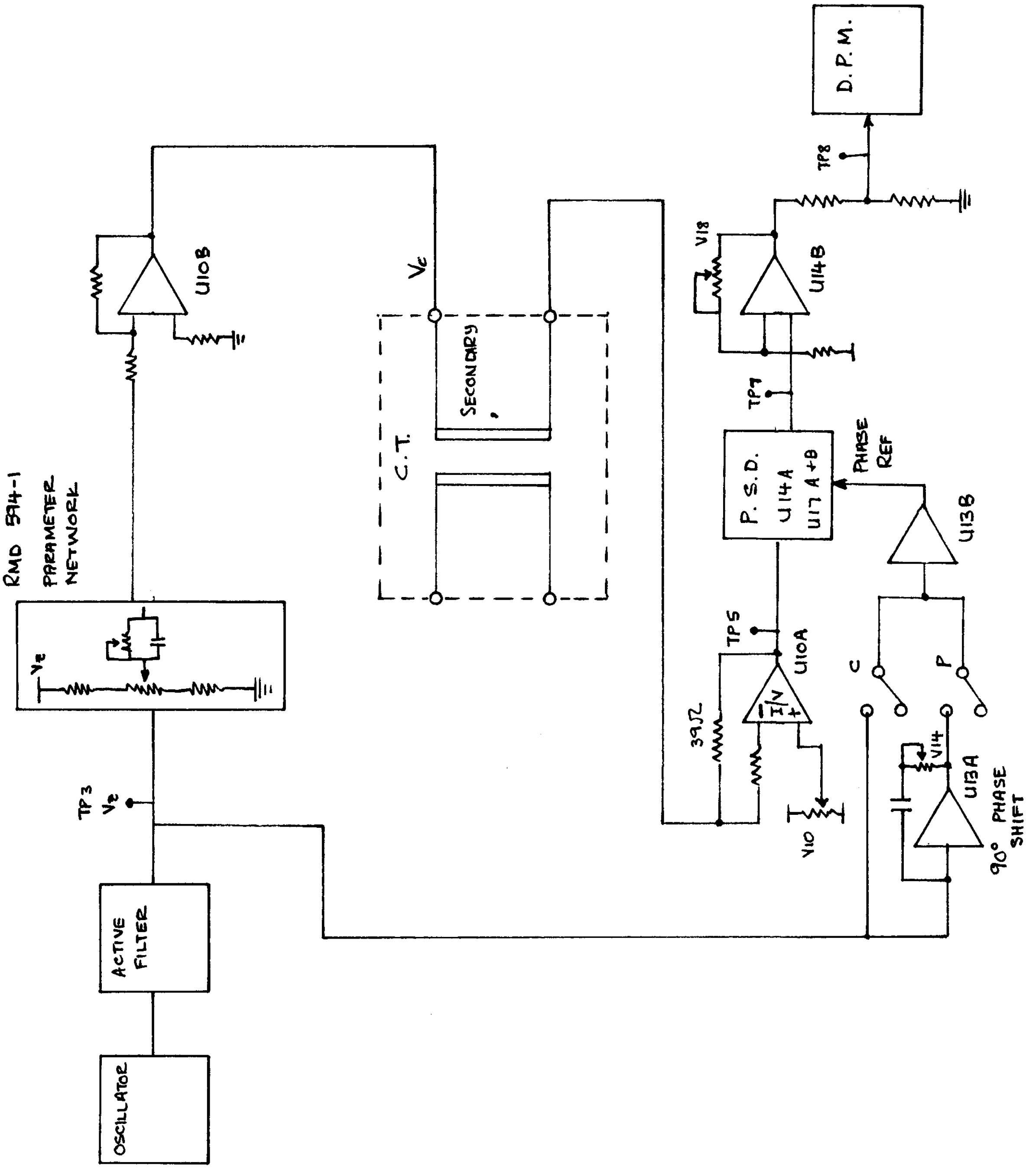
3.1. TURNS TEST.

A voltage signal "Vt" is applied to the secondary turns of the C.T.
This voltage is adjusted with a potentiometer to oppose the voltage applied to 4 primary turns on the C.T.
When "Vt" is adjusted correctly, the voltage at P2 of the C.T. primary is zero and the digital panel meter (D.P.M) displays "00.0".
Any residual voltage at P2 is amplified and processed via the phase sensitive detector. (P.S.D.)
The calibration is arranged such that this residual voltage is displayed as a percentage turns error.

SIMPLIFIED BLOCK DIAGRAM FOR TURNS RATIO & POLARITY TEST



SIMPLIFIED BLOCK DIAGRAM FOR CURRENT & PHASE ERROR TEST



3.2. CURRENT AND PHASE ERROR TEST.

In this test no voltage is applied to the C.T. primary.
A parameter network is used to generate a complex voltage (Vc/Ap) that is applied to the C.T. secondary. This in turn generates a current in the secondary that is converted to a voltage by a current summing amplifier. This voltage is processed by the P.S.D. and the in-phase and out-of-phase (with respect to "Vz") components represent "Current" and "Phase Error" respectively. The magnitude and phase of the voltage Vc/Ap has been determined by the S.E.C.V. to give the nearest absolute correct value of Current and Phase error for various ESAA C.T.s.

3.3. ADJUSTING 594 FOR CORRECT DISPLAY OF ERRORS.

Since the 594 is a comparative instrument, accurate current and phase errors can only be determined relative to a fully tested sample.

Remove the lid of the instrument. There are a number of trimpots located behind the front panel on a board carrying the "C.T.TYPE" selector switches.

Refer to the layout of the trimpots shown in RMD 594-1 PCB Component Layout Diagram and Table 3.

Place the sample C.T.s in position for testing and select the appropriate type on the rotary switch.
Select the "TURNS RATIO" error test button and adjust the appropriate "Vt" trimpot for a zero readout on the D.P.M.

The turns ratio test is the most sensitive and always needs adjustment for accurate results.

The other two test are not as sensitive, and if reasonable results are obtained with the factory settings then they can be left as they are.
The initial settings are shown in TABLE 1.

If adjustment is required to suit the sample C.T., adjust as follows:

Select the "CURRENT" error test and adjust the appropriate 10 turn "Vc" trimpots for a correct readout.
Select the "PHASE" error test and adjust the appropriate 10 turn "Ap" trimpots for correct phase error readout. Note that only positions 1,3,5,7,9 and 11 have the "Ap" trimpots fitted.
(NOTE: Depending on the trimpot wiper position, adjusting for Vc and Ap may be interactive and adjustment has to be done using an iterative process.

3.4. TEST METHOD.

Note that ideally C.T.s should be demagnetised before testing.
Residual magnetisation can affect the test results, generally causing higher core admittance which in turn gives larger C.T. errors.

3.4.1. Apply mains power to the 594, and set the "C.T. TYPE" selector as required.

3.4.2. Place the C.T. to be tested over the 4 pin socket with the socket centrally located in the C.T. window, and the P1 side of the C.T. facing upward.
CAUTION: With large and heavy C.T.s take care not to drop the C.T. on the 4 pin socket pillar.
Insert the 4 pin plug into the socket.

3.4.3. Attach the black crocodile clip to the S1 C.T. secondary terminal and the red clip to the S2 terminal.

3.4.4. Select the "CURRENT" function. The current error is read directly on the digital meter.

3.4.5. Select the "PHASE" function and read the phase error on the digital meter.

3.4.6. Select the "TURNS RATIO" function and read the turns ratio error.
A large negative reading, around -199.9, or a -ve over-range indication, means that the polarity of the C.T. is reversed.
Disregard any reading corresponding to less than 1/2 turn. The actual no of turns, Na, can be calculated as:

$$Na = Nn/(1 + 0.01\ Te)$$

Where Nn is nominal no of turns, Te is turns ratio % error.
(Note: Te is the % error for C.T. with a 1 Amp secondary)

3.4.7. For multi ratio ESAA C.T. types B, C and CB, move the crocodile clips to terminals S2 and S3 and repeat test 3.6.
Then, move the clips to S3 and S4 and repeat test 3.4.6.

3.4.8. For ESAA C.T. type A first move the clips to S2 and S3 and repeat test 3.6. Then repeat the test with the clips across S1 and S3, and again across S3 and S4.
During the latter two tests the digital readout will be approximately -50%. The difference between the readings, if any, is a measure of incorrect turns of section S3 - S4 since sections S1 - S2 and S2 - S3, (i.e. S1 - S3) have been verified in previous tests.

NOTE: For type A C.T.s, the voltage drop across lengths of test leads may be significant due to higher admittance of the C.T. Slight adjustment of "TURNS RATIO" function test voltage Vt may be necessary. Adjustment can proceed as follows:

Perform a "TURNS RATIO" function test as described in 3.4.6., using a proven type A C.T.

If the error reading is equivalent to more than 1/2 turn, remove top panel of instrument case and adjust appropriate potentiometer so that the D.P.M. reads 00.0. There is a diagram inside the instrument case to identify potentiometers.

4.0. CALIBRATION ADJUSTMENTS (For repair or troubleshooting by experienced technician).

INITIALLY DISCONNECT J4 AND DO NOT INSERT 4 PIN PLUG INTO SOCKET. THE RED AND BLACK CLIPS SHOULD BE UNCONNECTED. CHECK POWER SUPPLY RAILS:- +9V, -9V, +7.5V, -7.5V and +5V (ref circuit diagrams).

4.1. Note that this first step is not required if the external 4026-2 sine wave source is used.
Monitor signals at TP1 (triangular waveform) and TP2 (sine wave) with CRO.
Adjust V1 for frequency of 53Hz at TP1 and check for symmetry and distortion (adj value of R14 if necessary).
Adjust V2 for waveform amplitude of approx 3.6V p-p at TP1 and check that waveform at TP2 undistorted (approx 2V~ p-p).

4.2. Monitor waveform at TP2 and U7 pin 7 (top of R23) with CRO. Adjust V4 in active filter to produce maximum O/P at U7 pin 7 & and check that there is no distortion.
Adjust V3 for unity gain across filter (adj values of R19 & R22 if necessary).

4.3. Adjust V6 for output of 4.30V~ (RMS) at TP3.
Adjust V8 for output 28mV~ +/- 1% (RMS) at TP4.

4.4. Power down to remove U7 and link top of R23 to 0V
Adjust V5 for zero offset at U8 pin 7.
Adjust V11 for zero offset at TP6.
Power down to replace U7 and remove link.

4.5. Connect J4.
Select "C.T. TYPE" pre-set for ESAA type "T" C.T. on the rotary switch (i.e. Type 4).
Select "TURNS RATIO" error test.
Adjust V9 for zero D.C. offset at pin 7 of U10 (if unstable, remove connection to J2/5).

4. 6. Adjust V16 for equal mark space ratio monitored at U13 pin 7 (left side of R59) with C.R.O. Adjust VR15 for zero phase shift between Vz (at TP3) and square wave output at U13 pin 7.

4.7. Select "PHASE" error test.
Connect the black clip (RMD 594-2 J3/4) through a 39 Ohm resistor to earth and adjust V10 for zero offset at TP5 (if unstable, remove connection to J2/5).
Adust V17 for zero on the D.P.M. display.

4.8. Disconnect the black clip from the 39 Ohm to earth.
Connect the 39 Ohm resistor between the red and black clips.
Adjust V14 for a zero D.P.M. display (adj value of R51 if necessary).

4.9. Remove the 39 Ohm resistor across the clips.
Refer to the data on Table 1 for information on the ESAA type C.T.'s.
Select the different "C.T. TYPE" in turn on the rotary switch.
Adjust trimpots V1A to V12A for the correct values of Vt measured between the red and black clips with "TURNS RATIO" selected.

Connect 39 Ohms across the red and black clips.
Adjust V1B to V12B to produce correct values of "Vc" measured between the red and black clips with "CURRENT" selected.
Trimpots V1C to V11C are adjusted to give phase angle "Ap" between Vz (TP3) and TP5. Only positions 1,3,5,7,9 and 11 have the "Ap" trimpots fitted.
(NOTE: Depending on the trimpot wiper position, adjusting for Vc and Ap may be interactive and adjustment has to be done using an iterative process.)

4.10. Select "C.T. TYPE" position for Type "T" C.T.'s (i.e. Type 4) and "CURRENT" error function.
Connect a 39 Ohm resistor between the red and black clips. Adjust V18 for a D.P.M. display of -2.00.

4.11. Remove 39 Ohm resistor, select "TURNS RATIO" error test.
Power down to unplug U7 and link top of R23 to 0V.
Adjust V7 for zero D.C. offset at black clips. Monitor signal on black clip for distortion.

4.12. Insert plug into primary socket and with the red and black clips unconnected, adjust V13 for an output of -100.0 on the D.P.M. (This indicates a 100% turns ratio error).

4.13. Test C.T.'s with known turns ratios and make minor adjustments to C1A to V12A so as to achieve a display of zero turns error.

(NOTE: Even if the turns ratios are correct, differences in the admittance will affect the error detected by the instrument. For this reason it is preferable for the client to make final adjustments with his own particular brand of C.T.)

NOTE:

Vt - This voltage is applied to the C.T. secondary. The 4 primary C.T. turns have 0.028 V~ applied. If the C.T. ratio is correct, the two voltages null each other.

Vc/Ap - This voltage vector is defined as the voltage amplitude and phase difference in msec at 50 Hz. It has been determined by the S.E.C.V. to give nearest absolute value for the Current and Phase errors for the typical ESAA type C.T.'s.

TABLE 1: PRESET POSITIONS FOR ESAA TYPE C.T.'s

The unit has been pre-set as follows for the ESAA type C.T.'s

"C.T.TYPE" Position	ESAA TYPE	RATIO	Vt	Vc	Ap
1	A	150/5	0.210	0.12	0.39msec (7.1 deg)
2	S	200/5	0.280	0.125	-
3	B	400/5	0.560	0.255	0.49msec (8.9 deg)
4	T	800/5	1.120	0.39	-
5	C	1000/5	1.400	0.415	0.31msec (5.5 deg)
6	CB	1000/5	1.400	0.39	-

Note:

Vt: This voltage is applied to the C.T. secondary. The 4 turn primary C.T. turns have 28 mV~ applied. If the C.T. ratio is correct, the two voltages null each other.

Vc/Ap: This voltage vector is defined as the voltage amplitude and phase difference in msecs at 50 Hz from Vz. It has been determined by the S.E.C.V. to give nearest absolute value of Current and Phase error for typical ESAA C.T.'s.

TABLE 2: CURRENT RATIO ("Vt") SPAN PER "C.T. TYPE" SWITCH POSITION

Component values have been chosen to facilitate adjustment of "Vt" values for "C.T.TYPE" selector positions as follows:-

C.T. RATIO	"Vt"	"C.T. TYPE" POSITION
100/5	0.140	1,2,7
125/5	0.175	1,2,7
150/5	0.210	1,2,7
200/5	0.280	1,2,7
250/5	0.350	1,2,7
300/5	0.420	3,8
400/5	0.560	3,8
500/5	0.700	4,9
600/5	0.840	4,9
800/5	1.120	4,9
1000/5	1.400	5,6,9,10
1200/5	1.680	5,6,9,10
1500/5	2.100	11
1600/5	2.240	11
2000/5	2.800	11
2400/5	3.360	12
2500/5	3.500	12
3000/5	4.200	12

TABLE 3: TRIMPOT IDENTIFICATION FOR PARAMETER ADJUSTMENT

Trimpots for the adjustment of parameters are as follows:-

"C.T.TYPE"	"Vt"	"Vc"	"Ap"
1	V1A	V1B	V1C
2	V2A	V2B	-
3	V3A	V3B	V3C
4	V4A	V4B	-
5	V5A	V5B	V5C
6	V6A	V6B	-
7	V7A	V7B	V7C
8	V8A	V8B	-
9	V9A	V9B	V9C
10	V10A	V10B	-
11	V11A	V11B	V11C
12	V12A	V12B	-

APPENDIX TO MODEL 594 OPERATING MANUAL.

This appendix is extracted from the Model 590C operating manual.
It explains the theory behind indirect testing of C.T.s as used in the Models 590C and 594.

.4.2. C.T. TESTING.

4.2.1. The traditional method of testing a C.T. is to use primary injection testing. In such a test the primary of the C.T. is injected with various percentages of rated current, typically 125%, 100%, 50% and 25% depending on the particular standard to which the C.T. is tested, into its rated burden.

The same primary current is applied simultaneously to a reference C.T.
The secondary current of both the reference C.T. and C.T. under test are compared. Any difference in the two secondary currents is expressed as a ratio and phase error. The accuracy of the measurement depends on the accuracy of the comparator and reference C.T.

4.2.2. A typical test will give accuracies of 100PPM (0.01%). The problem with this method of testing is the cost of the comparator and reference C.T., both of which are relatively expensive, and the weight and bulk of the test equipment. Primary injection testing requires a high VA mains power supply.
This test method is not easy to use in the field.

4.2.3. The Model 590C uses a different technique to establish the errors of a C.T. operating at various percentages of rated current into rated burden.
The essence of the test is to measure the following parameters:
a) Turns ratio of the C.T.
b) Secondary winding resistance.
c) 50Hz admittance of the secondary winding.

Taking the information provided by the measurements, the errors of the C.T. under load conditions can be calculated to better than 0.1% accuracy. This is not so accurate as the traditional method, but it is perfectly acceptable for field testing metering C.T.s.

4.2.4. The technique offers the following advantages:
a) The connections are made quickly with reasonably light 4mm cables, since only low currents are involved.
b) The test is quick, easy and automatically controlled by the onboard microprocessor.
c) The 590C power requirement is around 10VA in standby mode and peaks at 40VA to 70VA for 20 seconds during the actual test. A small petrol driven alternator, or a battery/inverter pack can easily supply this power if a mains supply is not close by.
d) The 590C is moderately priced and easily carried by one person. This allows much speedier testing and higher productivity.

4.2.5. The performance of a C.T. can be characterised by measuring a few parameters, making some reasonable assumptions and performing calculations on the parameters. None of this involves testing at high currents.

The parameters are:
a) N = winding turns ratio.
b) Rs = secondary winding resistance.
c) Y = secondary winding admittance.

The operator must key in the ratio of the C.T. under test and its rated burden in VA.

By far the most important influence on the C.T. accuracy is the turns ratio. This will account for 99.9% of the accuracy of a high ratio C.T. (1000/5 upwards) and usually about 99.5% of the accuracy of a 100/5 C.T.

The balance of accuracy, 0.1% to 0.5%, is determined by the winding admittance and winding resistance.

4.2.6. It can be seen that the most critical characteristic the 590C measures is the turns ratio. This is done by applying a 51Hz voltage to the secondary winding and measuring the voltage produced on the single turn in the primary. The voltage applied varies from about 2V in a 100/5 C.T. to 50V in a 3000/5 C.T.

The software has a number of routines to determine the optimum voltage by iteration. This is done so the voltage is as high as possible to maximise measured signals, but not so high as to cause excessive magnetising current and saturation effects.
Using 51Hz guarantees rejection of stray 50Hz signals when measuring the small voltages from the single primary turn.
To meet the required measurement error budget on turns ratio the 590C takes into account the complex voltage drop on the test leads and secondary winding due to magnetising current.

Over the range specified, the 590C measures turns ratio to at least 0.05% accuracy.

4.2.7. The secondary winding resistance is measured with a low DC voltage of typically 0.05V to 0.5V.

After this it is possible to demagnetise the C.T. by ramping up and down a 51Hz voltage across the secondary winding to the highest value short of causing saturation. Although not essential, it is always good practice to demagnetise the C.T. in case there is any remanence effect in the core which is caused by the DC applied for the winding resistance measurement, or may have been caused by faults while the C.T. was in service.

4.2.8. The admittance of the secondary winding is measured in microSiemens (uS).
The admittance is the inverse of impedance, so 1uS = 1 / 1Mohm.
It is calculated by applying a voltage to the C.T. secondary and measuring the current.
To derive the C.T. error, the admittance (Y) is measured as the real and imaginary components. The real part is the in phase component and the imaginary part is the quadrature component.
These parts are designated as Y = G - jB.
It is typically written in the form 805 - 785j.

The admittance is frequency dependent and also varies with the voltage applied. Although the admittance should be measured at 50Hz, the 590C measures at 51Hz. The 2% frequency difference is compensated for in the software.
In the error budget to determine overall C.T. performance under load the admittance measurement only accounts for 0.1% to 0.5% of the error.

4.2.9. The theoretical basis for calculating the load performance of a C.T., refering to FIG. 4.2. is as follows:

Data keyed into 590C:

SR =	Specified C.T. ratio (e.g. 300/5).
VA =	Rated VA burden of C.T.
PF =	Power factor of C.T. burden. (Phase angle = ϕ)

Parameters measured by 590C:

N =	Measured turns ratio.
Rs =	Secondary winding resistance in ohms,
Y =	G – jB = 50hz admittance of winding measured in uS.

Values calculated by 590C software:

Zb =	Secondary external burden in ohms.
Es =	Effective voltage generated by C.T. winding to drive current around secondary loop through Rs + Rb.

Zb is calculated from rated burden at 100% rated current.
e.g. for any 5A secondary 15VA C.T.:
Zb = 15/(5 X 5) = 0.6ohm.

Es is calculated from Zb and Rs:
For any 5A secondary C.T.,
Es = 5 X (Zb + Rs).
(Note: Admittance of Rs is typically a factor of 20 or more greater than admittance Y, hence Es calculation does not compensate for voltage drop over Rs).

Xs = Leakage reactance.

The 50hz admittance is measured with voltage Es applied to the secondary terminals of the C.T. for the calculation of overall C.T. error at 100% rated current.
It is also measured at typically 120%, 20% and 5% of Es for the calculation of overall C.T. error at these different percentages of rated current.
In addition, the admittance measurements are made at (usually) 25% or 37.5% of the above values to simulate a lower VA burden.

4.2.10. We consider in FIG. 4.2. the simplified equivalent circuit for a 1:1 ratio C.T.

Current error:
$\Delta = -\{G(Rs + Zb\cos\phi) + B(Xs + Zb\sin\phi)\} \times 1/10000.$

Phase error:
$\delta = \{B(Rs + Zb\cos\phi) - G(Xs + Zb\sin\phi)\} \times 1/10000.$

When the admittance is measured in uS (micro Siemens) the factor of 1/10000 is used to convert the result directly to a percentage error.

In actual fact, C.T.s have ratios that are not 1:1. This does not invalidate our error calculation assuming 1:1 ratio, because it does hold true for any C.T. ratio.
The reason is that all the parameters of interest to our error calculation are restricted to the secondary side of the C.T.
From this we see that it does not matter if we apply 100A through 1 turn or 1A through 100 turns to the primary, the overall C.T. error is still governed only by the characteristics of the secondary side of the C.T.

The effect of leakage reactance, Xs, is negligible in a toroidal C.T. and Xs is taken as zero.

It can be seen that the error increases as the burden and internal winding resistance increases, and also as the admittance increases.

4.2.11. The 590C calculates the value of burden at typically 100% and 25% or 37.5% of rated VA burden from the burden value keyed into it.
Knowing Rs and Zb, It then calculates the value of Es for 120%, 100%, 20% and 5% rated current.

Note that only the admittance at 100% of burden and current level is presented in screen #21 for general interest. This information can be used for troubleshooting when there is an apparent problem in testing a C.T.

In screen #21 the phase error figure presented is that which is measured during the turns ratio test. This phase error is of general interest and is not actually used in calculating the final C.T. ratio and phase error, which depends on the admittance results.

4.2.12. In a C.T. we designate SR to be the specified turns ratio (such as 300/5).

The actual measured turns we designate as N. To achieve compensation the C.T. manufacturer often winds fewer turns than the specified ratio which increases output current.

Taking into account the turns ratio of the C.T., the two components of the overall error are the current (ratio) error and the phase error, given below with correct sign and in percentage.

$$\Delta = -\{G(Rs + Zb\cos\phi) + B(Xs + Zb\sin\phi)\} \times 1/10000 + \{100 (SR/N - 1)\}.$$

$$\delta = \{B(Rs + Zb\cos\phi) - G(Xs + Zb\sin\phi)\} \times 1/10000.$$

This means if the actual turns ratio of the C.T. is the same as the specified ratio, then the turns ratio plays no part in the overall C.T. error.

However, the actual turns ratio may not be the same as the specified ratio. Secondary turns may be dropped by accident in manufacturing or to increase output current to overcome design compromises.
The turns ratio will only affect the current (ratio) error since it has no influence on the phase error.

4.2.13. The error equations explains some C.T. characteristics observed in practice.

If the factor (SR/N - 1) is the right value it can reduce Δ to zero. This happens when N is less than SR (dropping turns to give compensation) although it is not easy to get the factor exactly equal to the inherent error. With low ratio C.T.s, such as 150/5 where SR = 30, dropping a turn so that N = 29 immediately boosts current by 3.45%. This is certainly too high a compensation.

Dropping 1 turn on a 1500/5 C.T. gives 0.334% more current which might be just right.
However, G does not vary linearly with exciting voltage Es which means getting the current error to zero at 100% rated current into 100% rated burden will not guarantee zero error over the complete operating range.

Dropping a turn never improves the phase error.

The burden a C.T. must work into is fixed by metering needs and cannot be varied by a C.T. design. The secret of a low error C.T. design is:

Minimise secondary winding resistance with plenty of copper.

Minimise 50Hz admittance of the secondary winding. This requires many turns on a large, high permeability low loss core.

As usual there has to be a sensible compromise.

In practice, high ratio C.T.s have many turns on the core and a relatively low admittance. The high number of turns also means that the winding resistance rises, which offsets the low admittance. However, working into a 0.6ohm load (Zb) which is the typical 5A/15VA burden, errors of 0.05% are easy to achieve with C.T.s of 3000/5. Low ratio C.T.s are much more of a problem. With few turns they have much higher admittance, and the lower value of Rs which results from fewer turns does not compensate because Rb is still fixed at 0.6.
Hence, low ratio C.T.s struggle to achieve as good as 0.5% into a 15VA burden.
Low ratio C.T.s are more often specified at lower rated burdens, such as 10VA or 5VA.

It is much more common to find some type of compensation used in low ratio C.T.s.
The technique most often used is a parallel winding of one less turn than the main winding. For instance a 150/5 C.T. may have a main winding of 30 turns and a parallel winding of 29 turns in a lighter gauge enameled wire. This gives an effective turns ratio of perhaps 29.7, which will increase the output current and can,

at a specified burden and current, give zero current or ratio error.
However, the output current is not so "flat" over the operating range as with a high ratio C.T. since the inherent errors of the C.T. are still relatively large.

Another means of compensation is split core compensation. To make a split core toroidal C.T. the main core of electrical grade steel has another core of mumetal or similar placed around it, either in the middle or around the edge of the main core. The mumetal core has higher permeability at low flux levels and will tend to boost the output current at low levels of primary current.

This technique is often used in conjunction with parallel turns. All turns will be wound around the main core, but one turn will dropped from the mumetal core. This tends to give a lower ratio, hence more output current, at lower values of primary current. The mixture of parallel turns and split core can be used to give a "flatter" output current response over the operating range of the C.T. so that it meets the required specification.