TSQ-3 TIME AND FREQUENCY DOMAIN IP AND RESISTIVITY TRANSMITTER

P/N 734700

SCINTREX LIMITED
222 Snidercroft Road
Concord, Ontario
L4K 1B5

Telephone: (905) 669-2280
Fax: (905) 669-6403
E-Mail scintrex@scintrexltd.com

Dated: September, 1992

734700

MK/MAN-22/34

DANGER HIGH VOLTAGE

This geophysical transmitter is designed to produce high voltages and currents for geophysical survey purposes. **The voltages present at either the generator or transmitter outputs are extremely lethal (deadly) and extreme care must be exercised at all times.** Whereas Scintrex has taken reasonable precautions in its design to minimize the possibility of personal injury in its normal and proper use, Scintrex can bear no responsibility in this regard.

All users are cautioned to establish and adhere scrupulously to safe operating procedures in the field, as well as safe practices in the maintenance and repair of this unit.

It is recommended that all field operators be fully advised of the potential hazard from high voltage and of the operating procedures necessary to avoid accidents.

Testing and repair of this transmitter when out of its (grounded) case should be done only by an experienced technician and with the greatest of caution.

WARNING

Operator must read Sections 5.2 and 5.3 before operating this instrument or serious damage may occur due to improper electrode and wire contacts.

TABLE OF CONTENTS

1. INTRODUCTION

The basic equipment required for an induced polarization survey consists of a transmitter, a receiver, wire and electrodes. The transmitter consists of a power source and an electronic control unit. Power is derived from a motor-generator set or from batteries. A block diagram showing a basic IP system is presented in Figure 1.

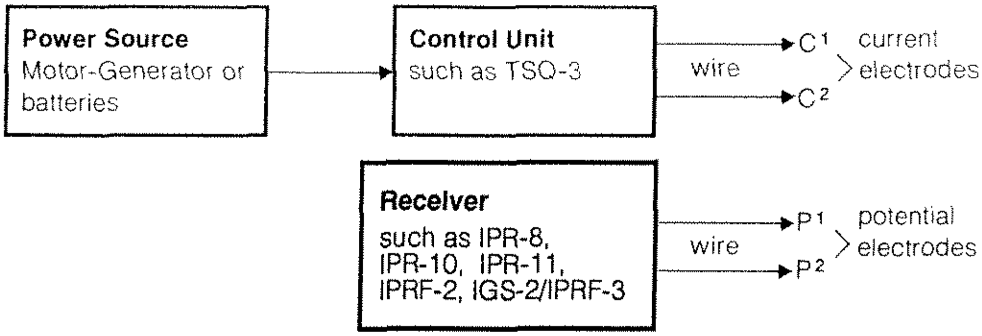


Figure 1
Basic IP System

The purpose of the present instruction manual is to describe the operation of the TSQ-3 Time and Frequency Domain IP and Resistivity Transmitter. Receiver operation is covered in the Scintrex instruction manuals for the receivers normally used with the TSQ-3 such as: RDC-8 Resistivity, IPR-8 IP/Resistivity, IPR-10/10A IP/Resistivity all for time domain measurements and IPRF-2 IP/Resistivity for frequency domain measurements. The TSQ-3 is also compatible with most other induced polarization receivers.

WARNING: Poor electrode contact with ground or poor wire contact with the electrode may cause serious damage to the instrument. Refer to Sections 5.2 and 5.3 before operating the instrument.

For information on electrode arrays, field procedures, interpretation and other matters pertaining to induced polarization surveying, the reader is referred to other Scintrex literature as well as technical journals such as "Geophysics" and "Geophysical Prospecting". There are also an increasing number of text books available specifically written on the induced polarization technique.

The TSQ-3 complete unit shown in Figure 2 is a transmitter supplied by Scintrex Limited for frequency domain or time domain IP operations and resistivity measurements. It is a low weight, portable, solid-state, compact and highly versatile unit which lends itself to operation in most geological and geophysical environments.

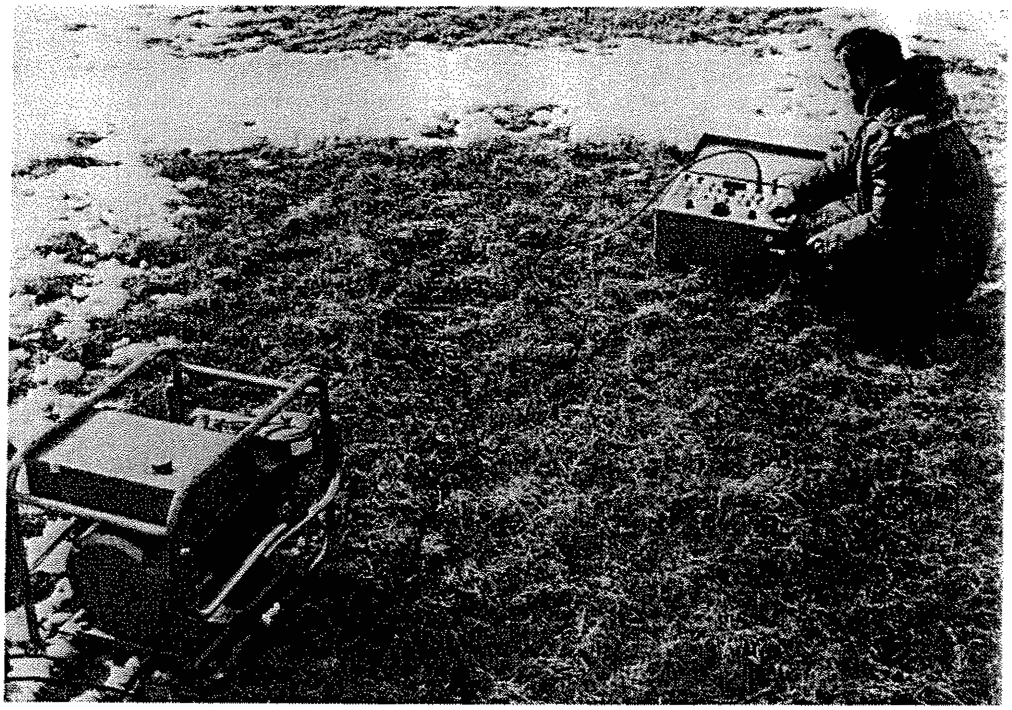
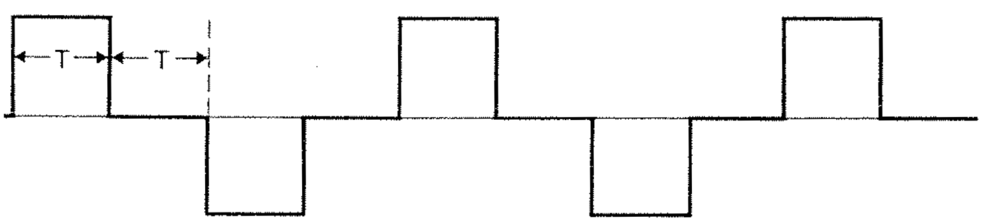


Figure 2
The TSQ-3 Transmitter and Motor-Generator Set

Time Domain: T = 1,2,4 or 8 seconds, switch selectable



Frequency Domain: $T = \frac{1}{f}$ and f = 0.1, 0.3, 1.0 or 3.0 Hz.

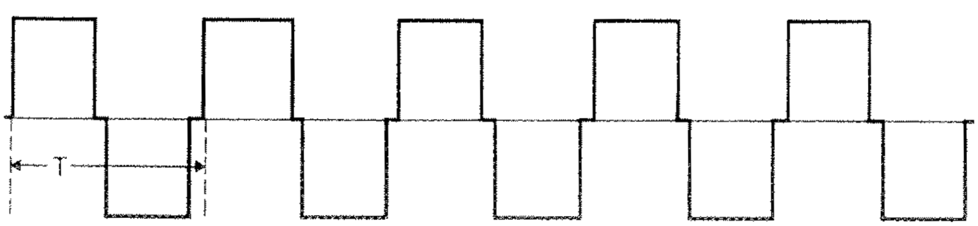


Figure 3
The TSQ-3 Output Waveforms

The Motor-Generator Set consists of a reliable Briggs and Stratton four stroke engine, coupled to a brushless permanent magnet alternator. The transmitter design employs solid-state components both for power switching and control circuits. Output waveforms and frequencies are switch selectable; square wave continuous for frequency domain and square wave interrupted for time domain. The programmer is crystal controlled for high stability. While care still must be taken when working with high voltages, the TSQ-3 features overload, underload and thermal protection for maximum safety. Stabilization circuitry ensures that the output current is automatically controlled to within ±0.1% for up to 50% external load or ±10% input voltage variations. Voltage, current and circuit resistance are presented on a LED digital display.

Basically, the Motor-Generator and Transmitter function as follows. The motor turns the generator (alternator) at twice the rated speed, which produces 800 Hz, three phase, 230 V AC. This energy is transformed upwards according to a front panel voltage setting in a large transformer housed in the TSQ-3. The resulting AC is then rectified in a rectifier bridge. Commutator switches then control the DC voltage output according to the waveform and frequency selected.

2. TSQ-3 TRANSMITTER & MOTOR-GENERATOR SPECIFICATIONS

Transmitter Console	
Output Power	3000 VA maximum (except at 300 V range)
Output Voltages	300, 400, 500, 600, 750, 900, 1050, 1200, 1350 and 1500 volts, switch selectable
Output Current	10 amperes maximum
Output Current Stability	Automatically controlled to within ±0.1% for up to 50% external load variation or up to ±10% input voltage variations.
Stabilization Over-range Protection	High voltage shuts off automatically if the control range of 50% is exceeded, except at maximum output power, where the range is limited to 12%.
Digital Display	Light emitting diodes permit display up to 1999 with variable decimal point; switch selectable to read input voltage, output current, external circuit resistance, dual current range, switch selectable.

Current Reading Resolution	10 mA on coarse range (1-10A). 1 mA on fine range (0-2A)
Frequency Domain Waveform	Square wave, approximately 6% off at each polarity change
Frequency Domain	Standard: 0.1, 0.3, 1.0 and 3.0 Hz, switch selectable. Optional: any number of frequencies in range 0.1 to 5 Hz.
Time Domain Cycle Timing	t:t:t:t; on:off:on:off: automatic
Time Domain Polarity Change	Each 2t; automatic
Time Domain Pulse Durations	Standard: t=1,2,4,8,16 and 32 seconds Optional: any other timings
Time and Frequency Stability	Crystal controlled to better than 0.1% with external clock option better than 20 ppm over operating temperature range.
Efficiency	.78
Operating Temperature Range	-30°C to +50°C
Overload Protection	Automatic shut-off at 3000 VA.
Underload Protection	Automatic shut-off at current below 85 mA
Thermal Protection	Automatic shut-off at internal temperature of 85°C
Dimensions	350 mm x 530 mm x 320 mm
Weight	25.0 kg
Motor-Generator	
Type	Motor flexibly coupled to alternator and installed on a frame with carrying handles.
Motor	Briggs and Stratton, four stroke, 8 HP

Alternator	Permanent magnet type, 800 Hz, three phase 230 V AC at full load.
Output Power	3500 V A maximum
Dimensions	520 mm x 715 mm x 560 mm.
Weight	72.5 kg.
Total System	
Shipping Weight	150 kg includes transmitter console, motor-generator, connecting cables and reusable wooden crates.

In Table 1 the maximum output current from the transmitter at certain values of load resistance is given for each position of the output voltage selector switch. The maximum load resistance limit occurs because of the built-in underload protection which shuts off the transmitter if the output is less than 85 mA. Figure 4 is a graph of output current vs voltage.

3. THEORY OF OPERATION

Power is supplied to the TSQ-3 transmitter through the alternator input connector from the three phase, 800 Hz alternator driven by a single cylinder, 4 stroke 8 HP engine. The main advantages of this brushless, permanent magnet alternator are: high efficiency, high overload capacity, short circuit immunity and minimum maintenance. The 10 m long input cable has four conductors, three for the three phases and the fourth to connect the alternator housing and the back pack to the TSQ-3 grounding lug. An additional grounding lug is provided on the mounting frame of the motor-generator which must be grounded as well.

Figure 5 is a block diagram showing the basic function of the TSQ-3 transmitter.

Two of three input phases are sensed by the Overload Sensors. In case of an overload, the Protection Circuits open the solid-state Input Switches. The same action takes place if the output current drops below 85 mA, which is sensed by the Open Loop Sensor. If the current stabilization range of 50% is exceeded, the Over-Range Sensor initiates the same action.

Switch Position	Output Voltage V	Maximum Current A	Minimum Load Resistance Ω	Maximum Load Resistance kΩ
1	300	10.0	30	4.0
2	400	7.5	53	5.3
3	500	6.0	83	6.7
4	600	5.0	120	8.0
5	750	4.0	187	10.0
6	900	3.33	270	12.2
7	1050	2.86	367	14.0
8	1200	2.5	480	16.0
9	1350	2.22	608	18.0
10	1500	2.0	750	20.0

Table 1
Maximum output currents for minimum and maximum load resistances.

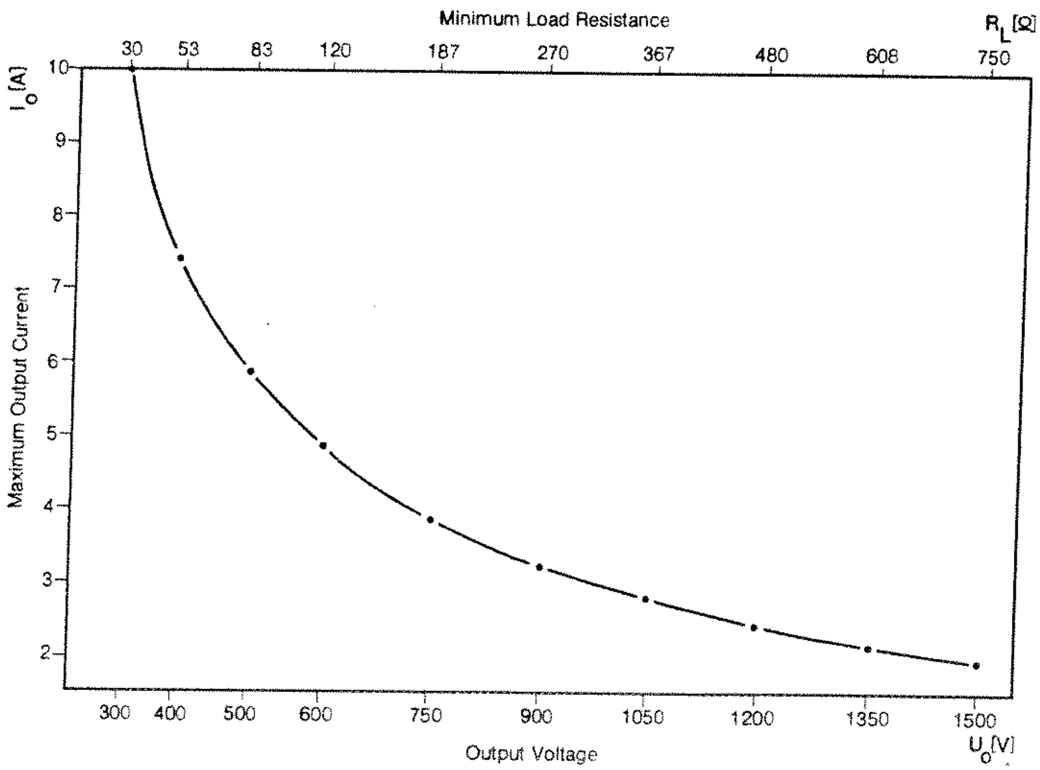


Figure 4
Output Characteristics of the TSQ-3

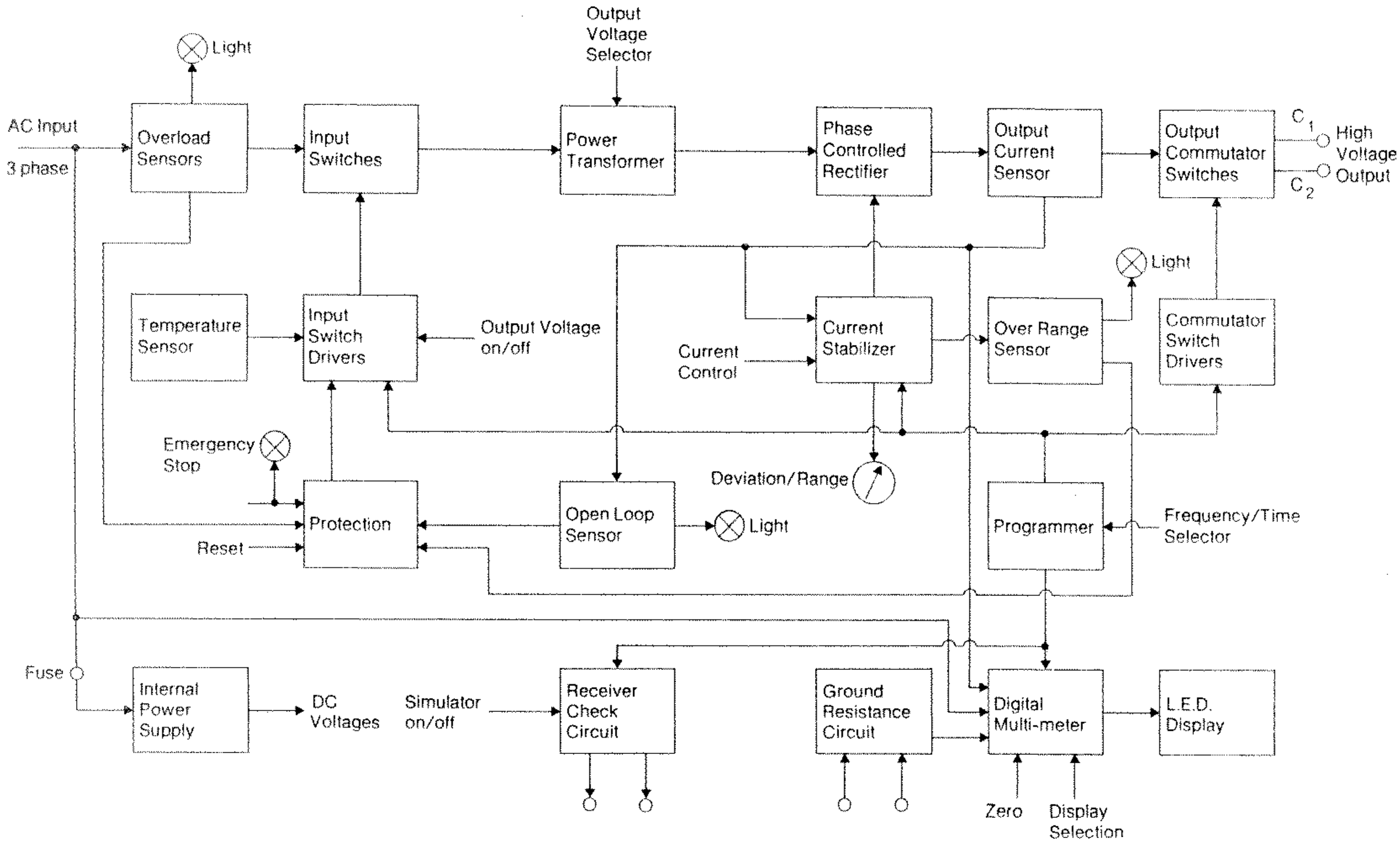


Figure 5
TSQ-3 Block Diagram

Any excessive temperature inside the transmitter is sensed by the Temperature Sensor and opens the Input Switches as well. The corresponding Warning Lights indicate these unsafe conditions. Pressing the Reset Button causes the Input Switches to close. Pressing the emergency stop button opens the Input Switches by disabling the Input Switch Drivers.

The high voltage output is selected by the Output Voltage Selector Switch which connects the different secondary winding taps of the Power Transformer to the Phase Controlled Rectifier.

The conduction angle of the output voltage is controlled by the Current Stabilizer in such a way as to keep the output current constant, within limits, regardless of the variations of the input voltage or the ground (load) resistance. The deviation between the actual output current and the required stabilized value has zero **average** value, however the **instantaneous** deviations may be seen on the Deviation/Range Meter. The same meter is used to display the DC voltage, which controls the conductance angle when the Deviation/Range Function Switch is in the RANGE position. The current can be stabilized at a value as much as 50% lower than the unstabilized value. In two current stabilization OFF modes, the conduction angle control of the Phase Controlled Rectifier is fixed at two values and the output high voltage has either 85% or 100% of the maximum value for the selected output voltage setting. In the current stabilization ON mode, the output current scaled by the current control is compared with the stable reference and their difference is brought to zero by the current control circuits.

The output current is sensed by the Output Current Sensor and measured by the Digital Multi-meter. The same multi-meter is used to measure the input AC voltage and the ground resistance.

The polarity of the output voltage is reversed by the Output Commutator Switches which are driven by the Programmer Controlled Commutator Switch Drivers.

The Frequency/Time Domain Selector Switch selects the output voltage frequency or ON-OFF times. The crystal-controlled Oscillator in the Programmer ensures high frequency stability of the output waveforms.

The Receiver Check Circuit provides at its output the waveforms shown in Figure 3. The Receiver Check Circuits can be used to check the receivers for zero stability and sensitivity. With the switch in the OFF position, Vp will be present without chargeability. In the ON position a reactance is entered into the circuit which simulates an induced polarization effect.

All the power switching is done by solid-state switches. The digital circuits are high noise-immunity CMOS chips. This should ensure high reliability and long life of the TSQ-3 transmitter.

4. FRONT PANEL DESCRIPTION

The features of the TSQ-3 correspond to the numbers indicated in Figure 6.

1. **High Voltage Output Terminals.** The ends of the wires to the current electrodes C_1 and C_2 are connected here. A set of special high voltage plugs is supplied with the unit which should be used to connect the wires. This assures proper and safe connection. Merely stripping the wires and inserting them into the receptacles should be avoided to prevent melting of the insulation.

2. **Alternator Input Connector.** The interconnecting cable from the motor-generator is connected here.

3. **Overload Indicator.** Lights amber when the output is overloaded. The output voltage switch should be set at a lower level before resetting.

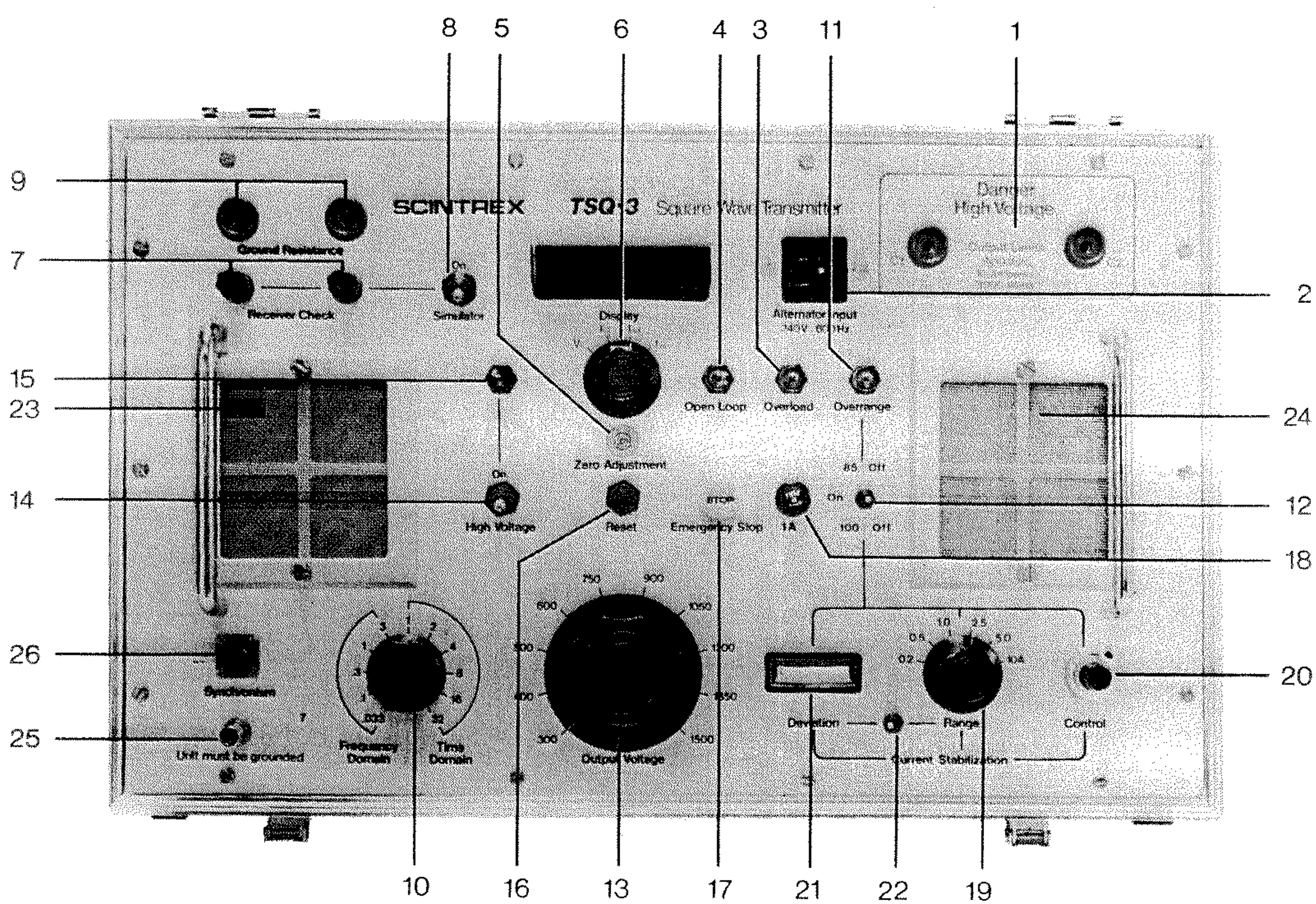
4. **Open Loop/Overheat Indicator.** This lamp lights amber when the output current falls below 85 mA such as when the current wires are broken or disconnected. It also glows if the internal temperature is too high.

5. **Display Zero Adjustment.** This potentiometer is adjusted with a screwdriver when necessary to show zero current on the display when the high voltage is OFF.

6. **Display Function Switch.** Used to select whether input voltage, ground resistance or output current are displayed on the digital display.

7. **Receiver Check Terminals.** A low output voltage is available here for the purpose of testing IP receivers.

8. **Simulator Switch.** The action of this switch alters the output waveform at the above terminals. With the switch OFF, the Vp function of the receiver can be checked, as well as the zero stability of time domain receivers. It is also useful to adjust the zero controls of frequency domain receivers. With the switch ON, a reactance is entered into the test circuit which simulates an induced polarization effect. Note that this is not a quantitative calibration since the transmitter output voltage and current waveforms cannot be considered to be the same. This occurs because the external load is not purely resistive.



SCINTREX TSQ-3 Square Wave Transmitter
Danger High Voltage
Ground Resistance
Receiver Check
Simulator
On
Display
Alternator Input
Open Loop
Overload
Overrange
Zero Adjustment
High Voltage
Reset
Emergency Stop
STOP
1A
85 Off
On
100 Off
Synchronism
Unit must be grounded
Frequency Domain
Time Domain
Output Voltage
Deviation
Range
Control
Current Stabilization
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26

Figure 6

9. **Ground Resistance Terminals.** Prior to turning the output voltage ON, it is best to check that the C_1C_2 circuit has been properly connected. This is done by inserting the current wires in the ground resistance terminals and reading the resistance in kilohms on the digital display. The design of the TSQ-3 employs this separate circuit rather than a switch across the high voltage output terminals for obvious safety reasons.

10. **Frequency/Time Domain Selector Switch.** This switch is used to select the frequency domain frequency (Hz) or time domain pulse duration (sec) desired. Note that the term 'pulse duration' refers to the symbol T in the time domain diagram of Figure 3, i.e. one pulse duration = $\frac{1}{4}$ cycle.

11. **Current Stablization Over-Range Lamp.** This lamp lights amber when the current stabilization reaches the upper or lower limit of its range and the stabilization is no longer effective. The output voltage is then automatically shut off. The Current Stabilization Switch (12) has to be set to OFF before the proper stabilized current value is reset.

12. **Current Stabilization Switch.** This three position toggle switch activates the stabilization circuitry when in the centre ON position. The two OFF positions provide either 100% or 85% of the maximum current.

13. **Output Voltage Selector Switch.** Used to control the level of the output voltage. To prevent high voltage arcing, this switch should only be turned when the output voltage is OFF. If this switch is manipulated when the output voltage is ON, the output voltage will automatically shut off and the Emergency Stop Button (17) will glow yellow. The same will occur if the switch is not properly indexed. To restore operation, the Reset Button (16) must be depressed. This will also extinguish the Emergency Stop Light.

14. **Output Voltage Toggle Switch.** Used to turn output voltage ON or OFF.

15. **Output Voltage Indicator Lamp.** Lights red when the output voltage is ON.

16. **Reset Button.** This button must be pushed to reset the circuitry after plugging in the Motor-Generator Power Connector to the Alternator Input Connector(2) of the TSQ-3, an emergency stop or overload, underload, open loop or overheating conditions have occurred. It will not reset unless the Output Voltage Selector Switch is at a proper setting - i.e. low enough if the problem was overload, or high enough if the problem was underload.

17. **Emergency Stop Button.** Depress to shut down in an emergency. This action cuts the AC voltage delivered to the primary of the transformer so that the entire transmitter is inactive. The light

inside the switch lights up yellow. The emergency stop is activated as well if 1) the Output Voltage Selector (13) is not properly indexed; 2) if the switch has been turned while under a load; 3) if the Frequency/Time Domain Switch was activated; or 4) if the transmitter overheated.

18. **Fuse.** This 1A fuse protects the internal power supply circuit.

19. **Output Current Selector Switch.** Used to select the proper range of the current to be stabilized.

20. **Output Current Control.** Used to finely adjust the Output Current to be stabilized.

21. **Deviation/Range Meter.** This meter displays either the output current deviation (DEVIATION position) or the amount by which the stabilized current is reduced from its unstabilized value (RANGE position) depending on the position of the Deviation/Range Function Switch.

22. **Deviation/Range Function Switch.** Selects which one of the two values is shown on the Deviation/Range Meter. Set the Deviation Range Function Switch in RANGE position if the current stabilization is not employed.

23/24. **Air Inlet/Outlet.** Allows intake and exit of cooling air. It contains an air filter.

25. **Grounding Lug.** To lessen the possibility of the operator receiving a shock should high voltage leak to the chassis of the transmitter, a wire should be used to connect this lug to a well grounded stake.

26. **Synchronism.** To connect an optional master clock to provide synchronization timing for transmitter and receiver.

5. OPERATING PROCEDURES

5.1 Safety Procedures

The TSQ-3 Transmitter has been designed with over and underload protection circuits. However like other high voltage instrumentation, it should be used with extreme caution. The following points should be clearly understood and followed, not only by the transmitter operator, but by the entire survey crew.

1. There should be good voice communication between all members of the crew. This normally means that portable radios should be used.

2. The transmitter operator should never turn the high voltage on before checking the ground resistance in the C_1C_2 circuit. If the resistance is above normal for the survey area, it is possible that the current electrodes are not yet grounded and that men may be working with the wires. A sure sign of this is if the C_1C_2 circuit resistance is changing, i.e. the meter needle is swinging.

3. The Transmitter Console and Motor-Generator should be well grounded.

4. The Output Voltage Toggle Switch (14) should be OFF ech time the Output Voltage Selector Switch (13) is moved. This avoids high voltage arcing.

5. When working in populated areas, explain the potential danger to the local people, hire a watchman to guard remote current electrodes and post signs warning of high voltage.

6. It is advisable to unplug the Motor-Generator power cable from the transmitter whenever operations are stopped.

7. The most dangerous situation is for a man to hold the bare end of a wire in one hand and a grounded electrode in the other hand. A proper insulated clip should be used at the wire end and this should be connected directly to the grounded electrode.

8. Extra care should be taken when working in wet or swampy conditions.

5.2 Problems That May Occur If Good Electrode Contact To Ground Is Not Achieved

If you do not take adequate care to make good electrical contact to ground with your current electrodes, you may run into some or all of the following problems:

1. Low Signal Level

   If our signal levels are too low, you will have to wait longer to get accurate measurements, or else suffer from errors in measurement.

The signals that you measure on your IP and resistivity receivers are directly proportional to the current that flows into the ground, not to the voltage that your transmitter applies to the ground. That is:

$V = kI$

where V is the voltage that you measure with your receiver,

I is the current flowing into the ground in amperes, and

k is a factor which depends on the electrode array employed (its geometry and scale) and the electrical properties of the ground.

The current I is related to Vo, the voltage applied by the TSQ-4 to the ground, by the equation

$I = Vo/Ro$

where Ro is the resistance of the external circuit, including the cables and the grounding resistance of the electrodes.

Except in highly unusual circumstances, that is with very long lines and very highly conducting surface soils (usually in saline areas), in resistance of the grounding electrodes will dominate the external circuit resistance and control the current flow into the earth.

Ideally, we would like to obtain the maximum possible current into the ground for each set-up, consistent with the limitations of current and power rating of the transmitter and its motor generator set. The more current we achieve, the higher will be our measured signal levels and the better chance we will have to overcome natural or manmade electrical noise in the area. This requires us to make as good electrical contact to ground as is practically achievable.

2. <u>Leakage From the Cables to Ground</u>

When your electrode resistance is high, the usual tendancy is to increase the output voltage of the transmitter in order to achieve a higher current level, and thereby, higher signal levels in the ground. The higher this output voltage may be, the greater is the tendancy for leakage to occur, between the cables and the ground, at places other than at the electrodes. Typical locations for leakage are where there is a weakness in the insulation due to abrasion or attack by a rodent, and where that section of the cable may lie on wet ground or vegetation, etc. The effects of such leakage paths may include: 1) errors in the calculation of resistivities, b) erratic readings because the leakage paths are not generally stable, and may change with the passage of current, c) the IP and resistivity values may not relate to the geometry and scale of the array being employed, and therefore, cause errors in interpretation and, d) IP errors may be introduced because of polarization currents circulating in the leakage loop during the current off time.

The potential for leakage from a cable is more extreme if one electrode is well grounded and the other is poorly grounded. In this case, the voltage to ground on the poorly grounded side may be nearly equal to the total applied voltage, which, in the case of the TSQ-4, may be as much as 5000 volts.

3. Current Imbalance

Occasionally, you may observe that the current being passed in one polarity of the cycle is considerably greater than that in the other polarity. Normally this is a sign that one current electrode has relatively poor contact and the other has much better contact, and should be rectified.

This imbalance is usually caused by electro-osmosis effects. Water is "electrode positive". This is, when it occurs in granular material or capillaries, under the action of an electric field, it tends to move away from the anode or positive electrode and towards the cathode or negative electrode. Thus, when the electrode with the poor contact becomes the anode, the small amount of water, which provides the actual path for the current from the electrode into the ground, is driven away from the electrode, thus deteriorating the contact and reducing the current.

5.3 Obtaining Good Electrode Contact

1. Choose your electrode location carefully. Avoid patches of sand, gravel or permafrost or areas of outcrop. Look for nearby patches of moist soil, even if this may be at the expense of departing somewhat from the ideal geometry of the array. It is better to have good signals, and a 10% uncertainty in the geometry of the array or in the interpretation of the depth to an anomalous indication, rather than have a poor signal which is totally useless.

2. Go deeper where necessary to get good contact. When operating in areas which may be totally covered with a layer of dry sand, snow or ice, and where adequate ground contact cannot reasonably be obtained in the surface material, then it may be necessary to take steps to penetrate below this adverse cover in order to emplace the electrodes into the more highly conducting layer below. This usually entails driving long metal electrodes to the desired depth. Also, check your electrodes after they have been placed. Electrodes should always be in tight contact with the surrounding soil. They should never be loose to the touch.

   If your current is too low, that is, if your external resistance is too high, it is usually one cable or the other which is not sufficiently well grounded. To determine which electrode has the poor contact, you should measure the resistance between each electrode and a third electrode, which might be the ground stake for the transmitter chassis, for example. **Remember to reverse the polarity of the ohm meter and take a second measurement of resistance and average the two each time, to overcome the effect of polarization at the electrodes.** Otherwise, you may mislead yourself as to which electrode is the bad one. Once you find the bad one, you must improve it or move it.

3. Water Your Electrodes. When working in areas of dry surface materials, it may be necessary, as a matter of routine, to apply water to the electrodes in order to create a sufficiently good contact. Use water with a high ionic content. If necessary, add salt to the water. Be liberal with the water and allow a reasonable amount of time, e.g. 10-20 minutes, after pouring the water on it, for a sufficient region of higher conductivity to be built up around the electrode.

4. Use multiple electrodes in parallel. If you can not succeed in getting your contact resistant down low enough with one electrode at the end of the cable, then you can improve the situation by using multiple electrodes, in parallel, to reduce the net contact resistance. In order for the additional electrodes to be effective, they must be placed sufficiently far from one another so that their electrical fields do not interfere with one another. In practice, this means that each electrode should be more than about 5 times its maximum in-ground dimension from all other electrodes, e.g. 5 meters apart for metal rods which are each driven one meter into the ground.

5. Choice of Electrodes. The choice of electrodes to be used depends somewhat on the local conditions, and even on historic practice in the area. Steel rods, usually 1 meter to 1.5 meters in length, are commonly employed. These range from stainless steel (which are expensive, but non-corrosive) to angle iron and fence posting (unpainted, of course). These are usually driven into the ground using sledge hammers.

Sheets of aluminum foil, e.g. 30 cm x 60 cm, are often used as well. They are buried in trenches, which have been dug into the ground, thoroughly wetted with salt water and covered with soil.

6. Long Current Lines. In the rare event that very large electrode spacings are employed and the ground resistance is very low, then the resistance of the current lines may be the limiting factor in respect to the amount of current to be passed into the ground. In this event, either heavier cables must be used for the current lines, or the current lines may be doubled, using extra lengths of the same cable, to reduce the resistance and the voltage loss in the lines.

5.4 Preparation

1. Set the motor-generator and the TSQ-4 on level ground or a suitable support (such as a wooden packing case). Ensure that the TSQ-4 is as far from the motor-generator as the interconnecting cables will allow. Check the gas and oil levels in the motor-generator.

2. Plant two grounding stakes in moist soil and connect one of them with a wire to the Grounding Lug (13) on the Transmitter and the other to the similar lug on the motor-generator. This procedure is important in protecting the operator from shock.

3. Lay out the C_1 and C_2 current wires and connect them to their electrodes (usually steel stakes) in locations determined by the electrode array and spacing to be employed.

4. Connect the current wires to the Ground Resistance Terminals (9).

5. Before connecting the Motor-Generator to the Transmitter and starting the engine prepare the Transmitter as outlined in paragraphs 6 to 10.

6. Set the High Voltage Toggle Switch (14) to OFF. It is a safe practice to keep this switch off when not required to be on, both from the operator safety point of view as well as to prevent damage to the high voltage section due to possible overshoot of the supply voltage when the engine is started.

7. Select the domain and frequency of pulse duration using the Frequency/Time Domain Selector Switch (10).

8. Set the Current Stabilization Switch (12) to either OFF 100% or OFF 85%. The latter position is recommended if current stabilization is to be employed subsequently.

9. Select the voltage using the Output Voltage Selector Switch (13). The voltage selected depends on the ground contact resistance of the current circuit as well as the current desired to achieve a reasonable signal across the receiver dipole (P_1P_2). Unless one is certain of the voltage required, it is best to begin on the lowest (300 V) setting.

10. Set the Display Function Switch to (6) for the V_{in} position.

11. Before first time operation, or after servicing the Motor-Generator it is advisable to connect the generator output first to the Test Meter which is supplied with the TSQ-3 as accessory for verification of the generator output voltage. It should be between 240 and 250 V. If it is not, the engine governor should be adjusted as outlined in the engine manual.

12. During normal operation the generator and the transmitter may now be interconnected and the engine started up. The display shows the input voltage which should be between 245 and 250 V under no load. If it is different, governor adjustments should be made as outlined in the engine manual. Under heavy load the voltage will drop and no attempt should be made to keep the output voltage within the above levels.

CAUTION

Do not race the engine by playing with the throttle or by misadjusting the governor. The generator output voltage is proportional to the engine speed, and, if excessive, may cause damage in the transmitter.

13. Turn the Display Function Switch (6) to the I_{out} positionand after a warm up of 2 to 4 minutes re-adjust the Display Zero Adjustment (5) to zero using a screwdriver, if necessary.

14. With the current wires connected as in Item 4 above, turn the Display Function Switch to the k position and measure the value of the current circuit resistance on the Digital Display. Check Table 1 and Figure 4 to determine what voltage level setting is required for the desired current given the measured current circuit resistance. If this resistance is above 20 k ohms then the TSQ-3 will not operate since it will see an underload condition. If the resistance is too high to allow delivery of the desired current, an effort must be made to ground the current electrodes better by sinking them farther into the ground or by pouring water on them. Set the Output Voltage Selector Switch (13) to the required position.

CAUTION
Whereas this transmitter is designed for 3000 W output power it is advisable to minimize operation at full power as much as possible to optimize the service life of the engine. It is suggested that the maximum power output is restricted to 15 minutes at a time separated by equal intervals of lower power. No such restrictions apply below 2500 W.

15. **Ascertain that the current wires are properly connected to the electrodes and that no one is near the electrodes. This should be confirmed by checking the C_1C_2 circuit resistance and by voice contact with all helpers using portable radios if required.**

16. Transfer the output wires to the High Voltage Output Terminals (1).

17. Turn the Display Function Switch (6) to the I_{out} position. Set the Output Toggle Switch (14) to ON. The Output Voltage Indicator (15) should light, indicating that the voltage is on.

18. If current does not flow, keep pressing the Reset Button (16) for a few seconds. If current still does not flow, check the Overload (3) and Underload (4) Indicators and correct ground contact, broken current wires or Output Voltage Selector Switch (13) setting. **Before doing any of these, however, switch OFF the Output Voltage Toggle Switch (14) as a matter of safety. Also, never touch the current wires or electrodes, or stand close to the electrodes when the output voltage is ON.**

19. If current stabilization is required, set the Current Stabilization Switch (12) to the 85% OFF position, then set the Output Current Selector Switch (19) to the proper range and adjust the Output Current Control (20) until the Deviation/Range Meter (21) shows zero with the Deviation/Range Function Switch (22) in the DEVIATION position. When the Current Stabilization Switch (12) is turned to ON, the current will be stabilized at a value approximately 15% less than the maximum value. Under this condition, however, the regulation range is limited in one direction to 15%, and in the other direction (lower current) to 35%.

20. If the C_1C_2 load is expected to vary with time, for example, a) due to loss of moisture at the current electrodes due to heating, or b) to gain of moisture due to melting of frozen ground, it may be advisable to stabilize the current at some value other than one close to the unstabilized (maximum) value. If the load resistance is expected to increase (case a), then the Output Current Control (20) should be turned counter clockwise to reduce the current level by up to 50% of the unstabilized maximum value so that some reserve is left for when the resistance increases. If the load resistance is expected to decrease, then the Output Current Control (20) should be left as it is or increased by 5-10% so that some reserve is left.

This Output Current Control (20) adjustment should be made with the Current Stabilization Switch (12) in the ON position and the Deviation/Range Function Switch (22) in the Range position. The meter will indicate by how much the current is reduced from the unstabilized value. The maximum amount is generally -50%, but for low currents the range is reduced somewhat. The changes in current output as the Output Current Control is turned can be more precisely measured on the Digital Display.

Since the ground resistance generally increases with passage of time, the range is set so that stabilization will occur at a stabilized output current at least 10% to 15% below the unstabilized current. By adjusting the Output Current Control (20) so that the Deviation/Range Meter is at a position other than zero in step 19, the operator can adjust the range limits, but always with a total range of 50%. For example, if the operator feels that there is equal chance that the ground resistance will decrease or increase, he should set the meter at -20% in step 19.

If the load drifts outside the stabilization range, then the Current Stabilization Overrange Lamp (11) will glow, indicating that the output voltage and/or currents must be set up again to match the changed load.

Note that the output current is measured ('strobed') at the end of each half cycle. Consequently there is a short lag between the Output Current Control (20) adjustment and the displayed current. In the DEVIATION position, the Deviation/Range Meter (21) displays a certain instability which could be misconstrued as a deviation between the actual output current and the required stabilized value. However, the design of the TSQ-3 is such that there can be no DC deviation between the actual output current and the required stabilized value. In support of this statement, it will be noted that the instability of the Deviation/Range Meter is centered around the zero point. The amplitude of the instability depends on variation of the input voltage, which is a function of the Motor-Generator condition (fuel purity, governor and calibration adjustments) and the change from output voltage OFF to ON. Under heavy load conditions it is normal that the motor speeds up during the current OFF time causing a short 'overshoot' in the output current when it comes ON, as the control circuit has a limited speed of reaction (approximately 0.5 sec).

21. In case of overload, underload, internal overheat or when the Output Current Control (20) is out of adjustment (overrange condition) the output voltage will be automatically shut down and the appropriate indicator light will glow. The operator should then turn OFF the Output Voltage Toggle Switch (14). He should then measure the load resistance and reset the Output Voltage Selector Switch (13) and Output Current Selector Switch (19) and Output Current Control (20) as required.

As indicated in Section 4, the STOP indicator is triggered by either 1) manual stop, 2) operation of either Frequency/Time Domain Selector (10) or Output Voltage Selector (13) or 3) by internal overheating. If the first three switches were not activated, the last is the probable cause. If this is the case, then the high voltage should be turned off until the fan driven air circulation cools the Transmitter.

22. The Emergency Stop Button (17) should be used as its name implies. After it has been used, the Reset Button (16) must be depressed. It should not normally be used to turn off the high voltage since, upon resetting, the high voltage may come on unintentionally, posing a safety hazard.

23. The Receiver Check Terminals (7) and Simulator Switch (8) can be used in the manner described in the section on FRONT PANEL DESCRIPTION. The output voltage amplitude is 1 volt peak in the simulator OFF (Vp) position and has the idealized waveform selected on the Frequency/Time Domain Selector Switch (10). With the Simulator Switch (8) ON, it reads approximately 14 mV/V on the Scintrex IPR-8 or IPR-10/10A time domain receivers in each of the six slices, using the 2 second transmitter and receiver timings.

For the frequency domain IPRF-2 receiver the values with the Simulator Switch (8) ON are given approximately as follows. The values for your specific combination of IPRF-2 and TSQ-3 should be determined by experiment.

f(Hz)	3	1	0.3	0.1
PFE (%)	+0.8	+1.1	+1.1	+1.1
RPS (deg)	-1.4	-1.7	-1.7	-1.7

6. MAINTENANCE AND TROUBLE SHOOTING

Most of the problems which will occur while using the TSQ-3 will involve the current circuit, i.e. overload, underload and over-range. Proper manipulation of the transmitter and experience will overcome most of these problems.

For service convenience, the major system functions of the TSQ-3 Transmitter are performed on removable circuit boards. An extender board is supplied for servicing individual boards while maintaining the circuit.

Progressive checking of the boards is the simplest means of determining in which portion of the circuit a malfunction exists. Providing the input voltage from the Motor-Generator is stable at approximately 245 V, regulated supply voltages of +10 V +6 V and -10 V can be checked. Trouble shooting of the boards and rest of the circuitry can be done with the assistance of schematics available on demand from Scintrex.

In order to ensure good performance of the unit, keep the connectors and the front panel clean. Inspect the cables occasionally to make sure they are in good order. Open the Air Intake and Air Outlet covers and wash the air filters in water and detergent solution if they are dusty.

Scintrex is prepared, in our plant in Concord, Ontario, to carry out any necessary repairs. Further, we are pleased to assist in trouble shooting by telephone, telex or written communication. Please advise us of the exact symptoms of the problem, and chances are we can suggest the cause of the problem and ship replacement parts from our inventory.

7. SHIPPING

The TSQ-3 Transmitter and Motor-Generator set are supplied in stout, reusable wooden crates filled with packing material such as polyfoam. We advise that the system always be shipped in this manner.

For international shipments we have found air freight to be the best method. This is fast, traceable and leads to the least customs problems.

8. WARRANTY AND REPAIR

All Scintrex equipment, with the exception of consumable items, is warranted against defects in materials and workmanship for a period of one year from the date of shipment from our plant. Should any defects become evident under normal use during the warranty period, Scintrex will make the necessary repairs in its plant, free of charge.

This warranty does not cover damage due to misuse or accident and may be voided if the instrument consoles are opened or tampered with by persons not authorized by Scintrex.

To validate the warranty, the warranty card supplied with the instrument must be returned to Scintrex within thirty days of shipment from our plant.

Instruments shipped for repair from outside Canada should be sent by air and addressed to Scintrex Limited,
Lester B. Pearson (Toronto) International Airport, Toronto AMF, Canada. Three sets of customs documents should be included: one set inside the package, one attached and sealed to the outside of the package and one attached to the airway bill. Documents should state clearly "Canadian Goods Returned to Canada for Repair" and should include: 1) name of equipment, 2) value, 3) serial number(s), 4) reason for return, 5) packaging and weight, 6) country of origin (Canada). Since Scintrex instruments are manufactured in Canada there is no customs delay or duty payable in Canada. Within Canada, ship by air directly to Scintrex Limited, 222 Snidercroft Road, Concord, Ontario, L4K 1B5. No instrument will be accepted for repair unless it is shipped prepaid. After repair it will be returned collect.

Please mention the instrument serial number in all communications regarding equipment leased or purchased from Scintrex.

MK/MAN-22/34