CHAPTER 20, TESTING & CALIBRATING THE SYSTEM

20.A SUMMARY:

These systems can be intimidating only if you don't understand how they are supposed to operate and if you don't have the proper test equipment.

Practically all RTUs and PLCs nowadays are microprocessor based, which means that they are computers. Some of them may be as capable as an old PC Windows computer.

What can also be intimidating is that the remote installations are often miles away on sites that can be sometimes difficult to get to.

A system Scan-Data installed for TEXACO, south of New Orleans, in the Louisiana delta, for example, has the RTUs located at pipe line pump stations. The only way to get to them is by a special service boat, through alligator infested waters.

In instances like these, you want to be sure:

- **That the equipment is installed properly.**
- **That you have the correct books and drawings.**
- **That you know how the equipment is supposed to operate.**
- **That you have the proper test equipment.**
- **That you have spares if you suspect lightning or other damage.**

ScanData manufactures a set of inexpensive, portable and easy to use test instruments. These are designed to be operated by relatively untrained personnel. They will quickly and locate faults in Telemetry and SCADA systems.

20.B BENCH TESTS:

It is always best to hook the system up on the bench, if you can, before it is shipped out to be installed. Experimenting with it on the bench certainly saves traveling time, compared to having to experiment with it in the field. It also serves to familiarize yourself with the system, so that you know what to expect, once it is in place. Having seen it work on the bench can also raise your confidence level to a considerable degree.

If you have problems with the bench test, use the test sets described below.

20.B.1 BENCH TESTING SYSTEMS COMMUNICATING OVER CABLE

Power up the equipment and connect the RTU and the master station modems together. For a small cable system with a few RTUs you can probably wire all the modem line outputs together and all the modem line inputs together.

For larger systems you may have to apply some kind of impedance matching. A 600 ohm resistor inserted at each RTU (one in the transmit branch and another in the receive branch) is crude but often sufficient.

IMPEDANCE MATCHING.

For testing purposes it is necessary to terminate all 600 ohm circuits with 600 ohm, else your level measurements will be in error. You have to do this at both ends, of course. The TTS telemetry test set signal generator has a 600 ohm impedance output which means you can connect it to any 600 ohm cable input. It has a high impedance input which means you can connect it across the RTU inputs or outputs (which terminate the circuit with 600 ohms) without upsetting the impedance matching.

When you are not measuring levels you can often ignore impedance matching. To quickly test two Mode-C RTUs, for instance, you can connect the inputs and outputs together and connect the two with two wires.

This is all right for four wire circuits. Two wire circuits are another matter. Two wire circuits are used for continuous transmission circuits only when there is only one cable pair left for the communication.

Here you have to use four wire to two wire converters, either the 4W2-A active unit (0 db loss) or the 4W2 passive unit (5 db loss). Both of these units are transformer isolated and impedance matched in all directions.

Simply wiring four wire and two wire circuits together without regard to impedance is inviting disaster. The losses will be very large and, in many instances, this may introduce instability and ringing (oscillations).

When using the TTS telemetry test set, check the instruction manual. This unit is designed with particular attention to impedance matching and loading on all continuous transmission circuits.

20.B.2 BENCH TESTING SYSTEMS COMMUNICATING OVER RADIO

Connect the equipment together. You might be able to use the antennas that come with the equipment, but be aware of two things:

- **The FCC operating license may not be valid for the testing locale.**

- **Heavy radiation from antennas may upset the operation of the RTUs and PLCs, especially if these are outside of the case.**

It is always best to unscrew the antenna cables and connect dummy loads instead. These are readily available from stores that carry communication equipment and stores that cater to radio amateurs.

Before the system is shipped to the field, check that the radio transmitters are modulating correctly. You do this by connecting an oscilloscope across the received audio (202 or FSK in) terminals on the RTU or modem.

You will see the audio sine wave originating from the transmitter. It will shift rapidly in frequency as the transmitted signal is received, but you will see the sine wave clearly. If the audio input level into the transmitter is too high, the transmitter will over modulate. You can clearly see this by the double hump sine wave this produces. Back off your audio level into the transmitter (202 or FSK out from the RTU or the modem into the transmitter) until the double hump disappears.

Too low a level into the transmitter is also detrimental. Turn it up until just below where it starts to double hump.

20.B.3 BENCH TESTING SYSTEMS COMMUNICATING OVER THE DIALING TELEPHONE SYSTEM

To test ASCII RTUs, such as Mode-A SLR, LMX, SMR and M-System RTUs, apply power and connect the RTU to the phone line over the RJ-11 jack.

Call the RTU from a PC or other computer with a modem and connected to another telephone line. Use any communication terminal emulation software such as Hyperterminal or PCLITE. Set the parameters to match those of the RTU, normally 300 or 1,200 baud, even parity. When the RTU answers you should see 'READY' on the screen from the RTU.

You can then key in requests and commands on your keyboard and see the response from the RTU on the screen. Check the protocol manual for the codes to use.

Voice telemetry RTUs, such as the VBX-7, are even easier to test. You don't need a computer. After you have powered it up and plugged it in to an RJ-11 phone jack, you simply dial it from any phone. It should answer with the test greeting phrase programmed in at the factory.

20.C RECOMMENDED FIELD TEST EQUIPMENT:

You don't need to drag a whole laboratory with you into the field. These systems are not that hard to test. You quickly want to determine what portion it is of the system that does not work. If you can bring spares, this is probably the easiest and fastest way to trouble shoot. Replace the suspected bad unit with a known good one. If the system comes back up and works, you know the replaced unit is bad. If not, the problem is elsewhere.

You can solve most problems with the following test equipment:

- **A good tester, preferably one with a frequency meter.**
- **A telemetry test set such as the ScanData TTS Telemetry Test Set.**

To check dialing lines (installed by the phone company) all you need is:

- **A regular dialing telephone, either tone or pulse (many are switchable between the two).**

If you want to check the radio communications, you may wish to bring:

- **A scanner that tunes to the frequency of the radio. You will be able to hear the master talking to the slave and the slave answering. Note that this does not work with frequency hopping Spread Spectrum radios.**

Most of the time your tests are to determine which is the bad unit in an installation. The equipment listed above should be enough for that purpose. If you want to go deeper into trouble shooting, you may wish to bring:

- **A lap top or other PC that has a communication program, such as Hyperterminal or PROCOM.**
- **An RS-232 'Y' cable. Make your own with diodes or use the ScanData MYC monitor cable and software.**

To thoroughly check the I/O (input and output) circuits, you may wish to bring:

- **An analog 4-20 mA calibrator such as the ScanData CAL 4/20.**
- **A logic probe to check pulsing flow meters and digital circuits.**
- **A tester with a frequency and pulse counter if you wish to check and calibrate flowing pulse meters.**

20.D CHECKING THE POWER SUPPLIES:

If the units don't get power or insufficient power, they will not operate properly. Check to see that the proper voltage at the proper current is being supplied. The fact sheet will tell you how much current should be drawn.

20.D.1 REMOTE STATIONS OPERATING OVER RADIO:

RTUs and PLCs may lock up if the primary power supply is insufficient or subject to momentary dips.

This is liable to happen at remote installations where the 12V DC supply supplies both the radio and the RTU. Everything looks OK. But check the 12V voltage when the radio transmitter turns on. The surge of current may cause the voltage to dip momentarily, each time the transmitter turns on.

This voltage drop is rapid and difficult to see and may (sooner or later) cause the RTU or PLC to de-rail. This is a pesky problem, sometimes difficult to find. The best is to avoid this altogether, using one of these approaches:

- **Use a different power supply for the radio and for the RTU or PLC.**
- **Use a standby battery for the RTU connected across the power supply. Such a battery acts as a very large capacitor and prevents voltage dips.**
- **Use power supplies with high enough ratings to avoid voltage dips. Note that current limiting supplies will always dip if the surge comes close to their limit.**

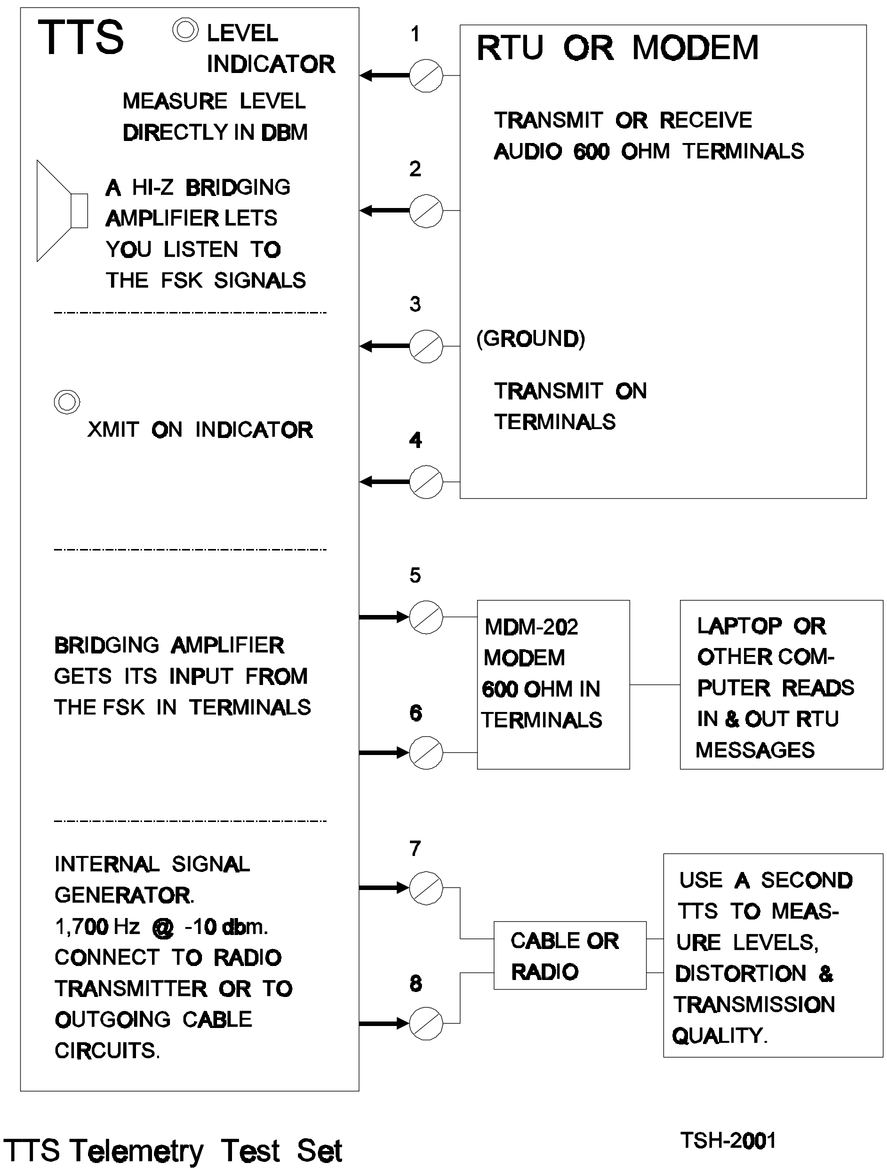
20.D.2 POWERING THE 4-20 mA LOOPS:

Check the voltage supply to the 4-20 mA transmitters. Many of these are critical, and will not operate properly on 12V supplies although the manufacturer may hint that they do. To supply these with the 24V that makes them work reliably, use a 12V to 24V converter such as the C24 12V to 24V DC converter or an isolated supply such as the IPS-24/6 or IPS-24/3.

20.E CHECKING THE COMMUNICATIONS:

RTUs always communicate with each other or with a central station. If there is no communication or faulty communication, the system will not work. Of all the problems you face, communication may be the most frustrating to deal with. It need not be. Go about it in a logical way, use good test equipment and good sense and if you get frustrated, think about it for a while and then check it again.

You can always call the factory for help. Units like the TTS Telemetry Test Set lets the man back at the factory listen to your communications over the phone and advice you on what is happening.



TTS Telemetry Test Set

20.E.1 CHECKING DIAL UP RTUs.

The dial up line installed at the remote site is probably the easiest of all communication lines to deal with. Unplug the RTU (there is always a standard RJ-11 jack) and plug in a regular phone. Call somebody and see how it works. Have them call you. If the phone line works normally, fine. If not, call the phone company and have them fix it.

20.E.2 CHECKING LEASED CABLE LINES OR COMPANY OWNED CABLE COMMUNICATIONS.

You can very easily check any leased or company owned cable circuit, if you strongly suspect that it is at fault, by placing one TTS Telemetry Test Set at one end and having it inject a -10 dbm 1,700 Hz signal into the cable. Terminate the cable at the other end with a 600 ohm resistor (or leave it terminated by the RTU) and check the received level with another TTS unit.

WHAT ABOUT db's (DECIBELS)?

Decibels are used to measure signal levels in communication circuits as they make gain and loss calculations easier. If you say that an amplifier has a gain of 15 db and the cable over which you are transmitting the signal has a loss of 13 db the resultant gain is 15 - 13 = 2 db. If you apply a signal of -12 dbm at one end of this combination you get +2 - 12 = -10 dbm out at the other end.

Simple. But what is the difference between db and dbm? Well, db is a relation. 15 db gain in an amplifier means that the difference (or relation) between the input and output signals is 15 db.

On the other hand, dbm is an absolute measurement. 0 dbm, by definition, means that the signal level is 1 mW into 600 ohms. That corresponds to about 0.77 volts RMS, should you want to measure it with a voltmeter.

If you drop a 0 dbm signal to -6 dbm you would measure half of 0.77 volts or 0.385 volts. A good thing to remember. Halving or doubling the voltage lowers or raises the level by 6 db.

You may not have to worry about this. Level meters and the TTS Transmission Test Set handles this automatically. Just make sure you have your equipment and your lines properly terminated.

The level should be no less than -20 dbm (for a 10 db loss) and the audio tone from the loudspeaker should be clear.

If you know that the master station at the central end is polling, you may not need to place a TTS at that end. Use the central's own polling signal. If you know that it goes out with an acceptable level (you can check that with the TTS), make sure that it arrives at the RTU line input terminals with an acceptable level. In most systems, you should not see a level lower than -15 dbm.

Line amplifiers such as the ScanData FWA-4 are used to boost the signal level on bad lines.

Recently, many phone companies are not maintaining their leased lines very well. Scan-Data has therefore developed a special line of automatic leased line testers, the ALT. It lets you automatically test any leased line from your office. See below for more information.

20.E.3 CHECKING RADIO CIRCUITS

Radio circuits operate much in the same way as continuous cable circuits, except that the RTU or PLC has to turn on the radio transmitter every time it wishes to communicate and that there are longer wait times at the start and at the end of transmissions.

Use the TTS to check that a good FSK (frequency shift keyed) signal with an acceptable level arrives at the input pair. The TTS will also check the radio transmitter turn on function. The RTU will turn the transmitter on and send out an FSK signal, if it receives an acceptable polling signal.

20.E.4 DETAILED ANALYSIS OF COMMUNICATION CIRCUITS

There are five ScanData test sets especially designed to make it easy to test and analyze communication circuits in detail. They are: The TTS Telemetry Test Set, the MYC Monitor Cable & Software, the LAM Line Amplifier and Mixer, the WNG White Noise Generator and the CSS Central Station Simulator.

Each unit has a technical description which describes the function of each unit in detail. The following is a brief description of the function of each unit.

20.E.4.a USING THE SCANDATA TTS TELEMETRY TEST SET

The TTS unit allows you check both radio and cable circuits and to quickly determine:

- **If a polling message is going out from the master and arriving at the slave.**
- **If an answer is delivered from a slave and arriving at the master.**
- **The level of the incoming and outgoing FSK messages.**
- **The quality of the incoming and outgoing FSK messages.**
- **The radio transmitter turn on function.**
- **The transmission gain or loss in any continuous communication circuit.**
- **The composition of incoming and outgoing messages, using a modem such as the MDM-202A and a laptop.**

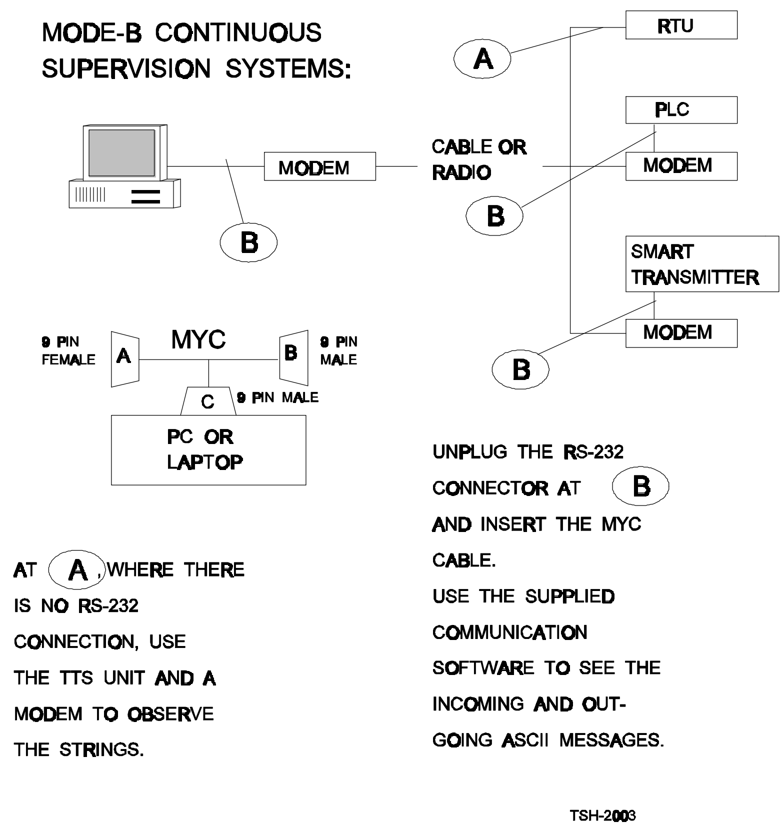
20.E.4.b USING THE SCANDATA MYC MONITOR CABLE

The MYC monitor cable is used to observe and verify the ASCII messages that pass between a computer central station and a modem or between an RTU, PLC, Smart Transmitter and a modem.

It allows you to use any PC or laptop to see the messages. Simply connect the cable, run the supplied software and see the polling messages and the corresponding answers scroll up on the PC screen.

The MYC cable consists of two 24" multi conductor cables, connected together at one end in a 9 pin female DB-9 connector (the 'B' connector). At the other end of the cables are a 9 pin female DB-9 connector (the 'A' connector) and a 9 pin male DB-9 connector (the 'C' connector).

The communications terminal emulation software is delivered on a 3 1/4" disk.



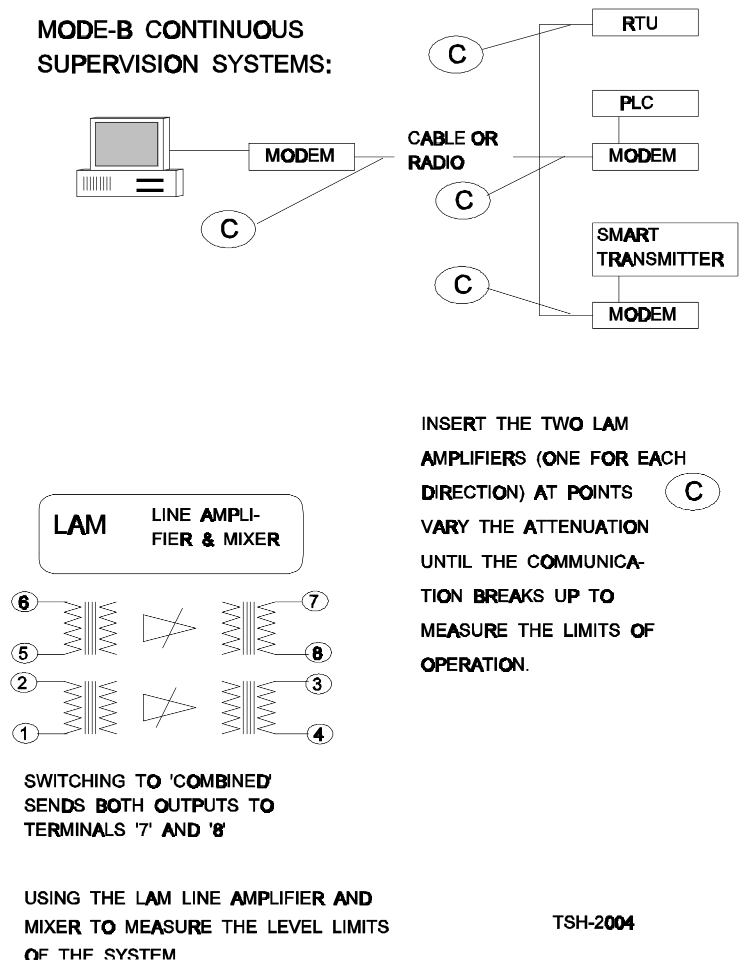
Insert the cable between the central station, RTU, PLC or Smart Transmitter and the modem. Connect the 'A' connector to your PC and run the software as explained in the manual. You will see the incoming and outgoing ASCII messages scroll up on your terminal.

20.E.4.c USING THE SCANDATA LAM LINE AMPLIFIER AND MIXER

The LAM Line Amplifier and Mixer is used to measure the level limits in Telemetry and SCADA transmission systems.

It quickly determines if a system is operating near or below unacceptable levels. It is also a powerful tool in determining system levels. It can quickly identify marginal transmission circuits.

The LAM contains two line amplifiers, completely independent of each other. Each amplifier has 600 ohm transformer isolated inputs and outputs. The gain in each amplifier is adjustable from -50 db to +30 db.



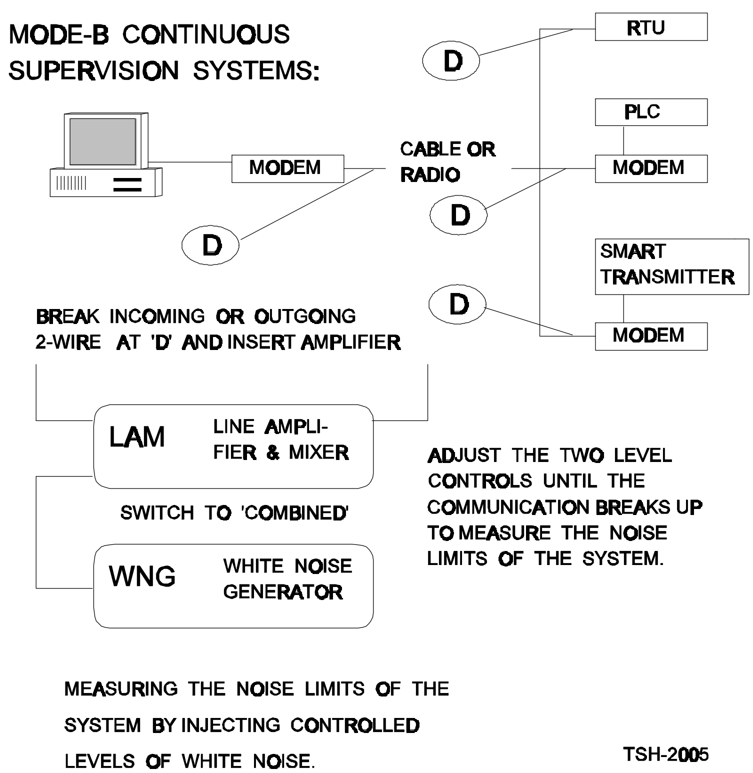
If you find that you need to continuously boost the signal level in one or more of your circuits, you can permanently install one or more ScanData FWA-4 four wire amplifiers.

You can also use the LAM unit to mix in white noise to test the noise susceptibility of your circuits (see below for a description of the WNG White Noise Generator).

20.E.4.d USING THE SCANDATA WNG WHITE NOISE GENERATOR

The ScanData WNG White Noise Generator is a self contained unit with two internal 9V batteries. It outputs a weighted white noise level of 0 dbm. Weighted white noise is used to load a measured amount of non frequency dependent interference onto a communication circuit.

Please note that the output of the WNG is spread out over the speech band. You can therefore not use an RMS detecting level meter such as the TTS or the level meter built in to most testers to measure the output of the WNG. A true power reading level meter is uncommon and is not normally found outside of specialized laboratories.

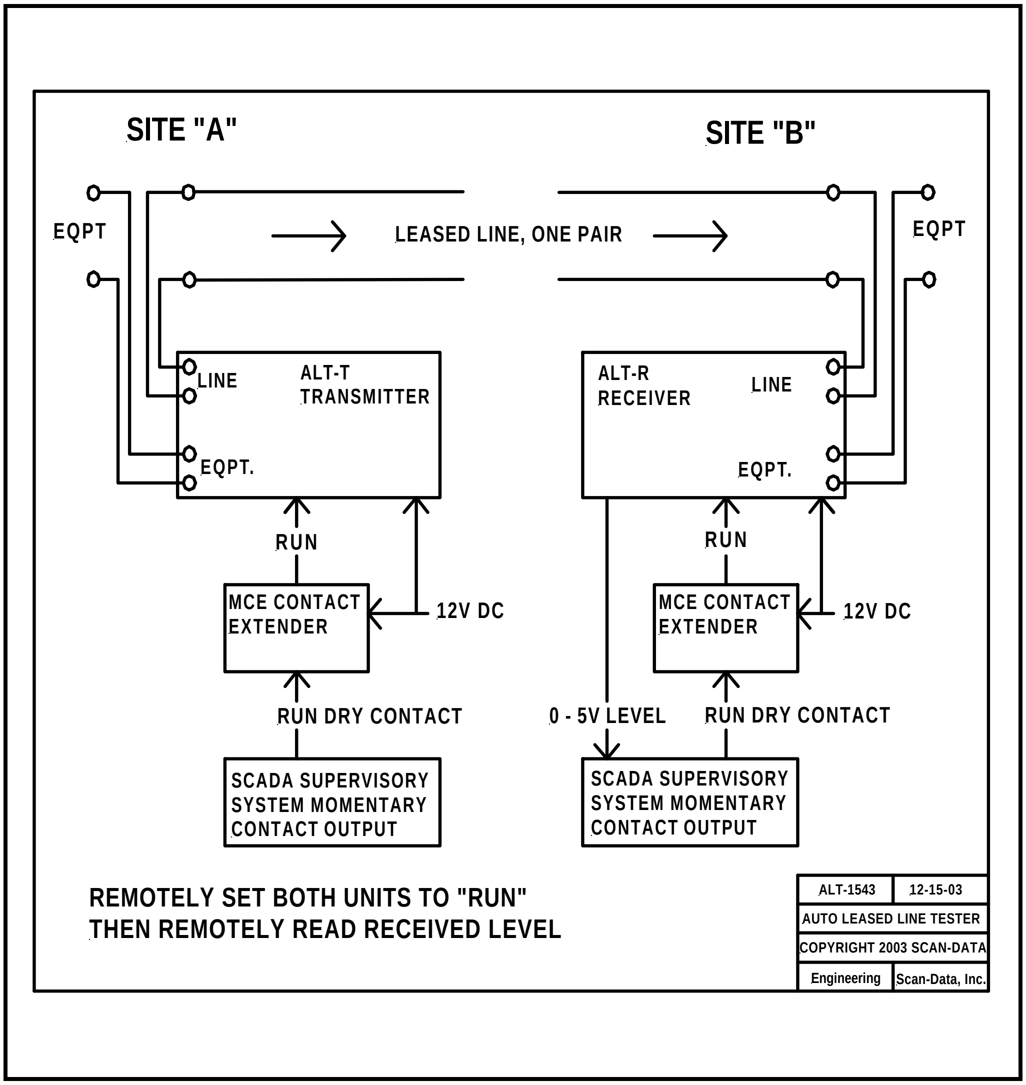


To use the WNG, connect it to one of the amplifier inputs of the LAM unit. Verify the level of the communication circuit under test with the TTS unit (say it is -10 dbm) and insert the other amplifier into this circuit. Switch the LAM to

'COMBINE'. Set the communication circuit amplifier to 0 db and the WNG amplifier to -10 db to make it equal to the level of your communication circuit.

You now have a reliable measure on how good the noise susceptibility of your circuit is. In this manner you can identify circuits that are operating close to their limits and take steps to correct the problem.

20.E.4.e USING THE SCAN-DATA ALT AUTOMATIC LEASED LINE TESTER.



The phone companies maintenance of their leased lines is sometimes not as good as it should be. When the equipment installed on a leased line starts performing badly or stops operating altogether, the question invariably becomes: Is the equipment connected to the leased line faulty or is the leased line bad?

The telephone company is likely to blame the operator's equipment, and the operator is likely to blame the telephone company's leased line.

The only way to break this deadlock is to test the leased line. The equipment operator is often forced to do this himself to prove to the telephone company that the line is at fault.

Testing a leased line.

A four wire leased line, between A and B, say, consists of two pairs. One pair transmits signals from A to B and the other pair transmits signals from B to A.

This means that two tests have to be made, one on each pair. One test connects a signal generator with a calibrated output to the outgoing line at A and measures the received signal strength at B. The second test connects a signal generator with a calibrated output to the outgoing line at B and measures the received signal strength at A.

The equipment normally operating on the line has to be disconnected while these tests are made.

Line testing costs.

Testing a 4-wire leased line means sending a crew to site A and, at the same time, sending another crew to site B. The 4-wire leased line is disconnected from the equipment and connected to two signal generators and two level meters. It is important that the level meters be true power level meters and not simple peak voltage detectors, see below.

The signal generators and level meters are turned on and the received level readings are noted. If the received levels are deemed too low for the equipment to operate reliably, the telephone company is contacted with the results of the tests and with a request to repair the line to bring the levels up to acceptable values.

The cost of performing these tests can be considerable.

Using the Scan-Data ALT Automatic Lease-line Tester.

Installing ALT Automatic Leased-line Testers a the leased line terminals cuts line testing costs way down. It is no longer necessary to send crews out to the sites. Leased line tests can be performed automatically in minutes by an operator sitting in front of a SCADA or DCS computer terminal.

To test a leased line, the operator at the SCADA terminal commands the ALT-T transmitters and the ALT-R receivers to turn on. This re-routes the line to be tested away from the equipment normally connected to the line and connects the line to the ALT equipment. The operator reads the line loss in dbm, then turn the ALT equipment off. This connects the leased line back to the equipment that normally uses the line.

For more details, check Scan-Data description ALT-1543. See below for details.
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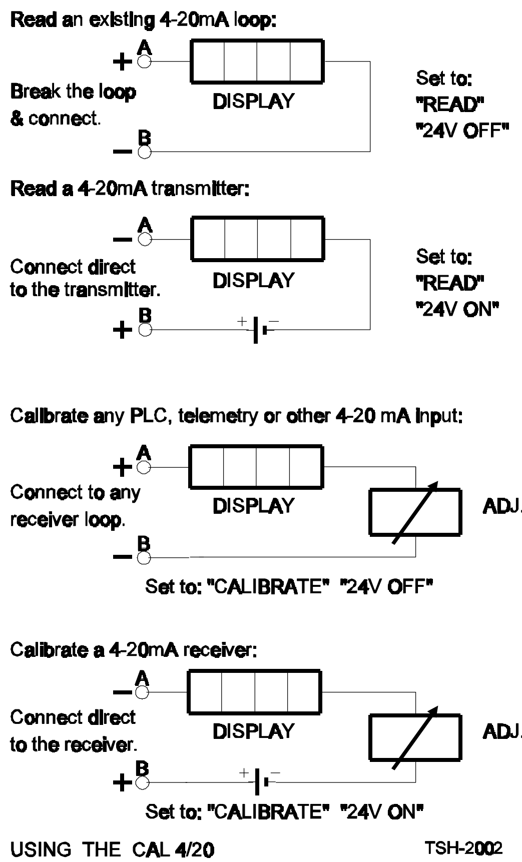
20.F CHECKING THE I/O (INPUT AND OUTPUT) CIRCUITS:

20.F.1 CHECKING ANALOG CIRCUITS

As described in Chapter 19, analog input circuits can be either voltage or current inputs. These can be verified with a tester. If you need to calibrate the analog input, use the CAL 4/20 4-20 mA calibrator. It measures and calibrates any 4-20 mA loop and any loop transmitter or receiver.



You can go from a 4-20 mA signal to a 1-5 V signal by placing a 250 ohm precision resistor in the loop.

The RTU inserts the analog input into its report. Set the CAL 4/20 to 12 mA, say, and use the MYC cable assembly (as described above) to check the value of the reported analog signal. You should be able to see the value in the ASCII report from the station. Check the manual for the format of the report from the particular RTU, PLC or Smart Transmitter under test.

Analog outputs from the RTU are always in the form of 4-20 mA signals. The analog output open collector transistor in the RTU is placed in series with the load (the receiver, in 4-20 mA parlance) and the loop power supply. The CAL 4/20 instruction manuals has detailed instructions on how to check all aspects of the 4-20 mA loop, inputs as well as outputs.

TO ISOLATE OR NOT TO ISOLATE THE I/O CIRCUITS.

There are two good reasons to place isolators (current or digital) between your field instrumentation and the RTU or PLC.

One reason is to help prevent lightning damage. If your field instrumentation is placed on tanks, towers, pipelines, etc., exposed to frequent lightning strikes, by all means use I to I (current to current) isolators for your analog circuits and solid state or relay isolators for your digital and pulse circuits.

Observe proper grounding techniques on both sides of the isolators by mounting the units close to ground, grounding both sides with short, heavy conductors, etc.

The second reason is to improve accuracy. This is seldom necessary with digital or pulse circuits but often necessary with 4-20 mA analog circuits, where even a short run of common ground can upset the accuracy.

For instance, the M-system and the SMR RTUs have an analog input resolution of 12 bits. It does not take much to introduce an analog fault current of a few micro amperes.

Scan-Data manufactures single loop, dual loop and triple loop 4-20 mA isolators and splitters to improve the performance of your instrument loops. A wide range of accessores is also available. Check our 4-20 mA WEB page, **www.4-20maloop.com**

20.F.2 CHECKING DIGITAL CIRCUITS

Digital input circuits are either on or off, shorted or open. The digital input to the RTU or PLC is almost always a terminal pair with one end internally tied to ground and the other internally tied to +5V over a 5K (or so) resistor.

You can check these circuits with a tester or with a digital probe. A shorted dry contact from the sensor should give you 0V across the input pair and an open contact +5V.

Digital output circuits are almost always open collector relay driver transistors. As with the analog output driver transistor, one end is grounded to system ground and the other (the collector) needs to see a load (a relay coil) in series with a power supply. The digital output pair in most RTUs have one end tied to the collector and the other to an internal power supply, so that you can connect the relay coil directly to this terminal pair.

If the central station computer or the central station RTU sends an 'ON' signal for this circuit, the output transistor should conduct and the power the relay.

20.F.3 CHECKING PULSE CIRCUITS

Pulse input circuits to most RTUs and PLCs accept a pulse going from 0V to +5V. The frequency of the pulse is normally less than 5 Hz and is therefore easily seen on a logic probe.

If the flow meter outputs a high frequency pulse (up to 20,000 Hz) it is often connected to a pulse divider such as the ScanData PDI which divides by 10, 100, 1,000 and 10,000.

You can test some of the lower frequency pulse outputs on your logic probe. The higher frequencies can be checked with the frequency meter on your tester.

The pulse outputs from the RTU are normally in bursts of 5 Hz pulses, exactly echoing the number of pulses input at the far end. If you wish to accurately measure the pulse transfer (for custody transfer metering, for example) place a frequency meter set in pulse count mode at both ends. The two counts should coincide exactly, taken over a period of time.

20.G COMMON CAUSES OF FAILURES

A tabulation of RTUs and other units returned for repair, over a period of twenty years, has shown the following:

70% of the returned units had nothing wrong with them.

28% of the returned units were damaged by lightning or other over voltage abuse.

2% of the returned units had other failures.

The ScanData HardCoat(tm) coating is designed, among other things, to change color when a circuit board trace or a component overheats. This makes it easy to identify boards that were damaged by lightning or other over voltage abuse.

Check the installation carefully before assuming that a unit is bad. The two most common causes for failure of an RTU to operate properly are:

20.G.1 BAD POWER SUPPLY REGULATION

The remote station often has a radio transmitter or motor starters or other momentary loads that pull the power supply voltage down. You may think that the power supply is OK, yet it may sag down momentarily from 12V each time a momentary load is applied.

The RTU or PLC is designed to work with a solid power supply. They also have a power on reset circuits which operate well when the power supply is turned off and on again. But they cannot handle momentary voltage sags. Sooner or later they will derail.

The solution is to install a better power supply or to install a small (6 ampere hour or so) accumulator, fed over a back diode from the power supply and connected directly to the RTU or PLC.

You can also install separate power supplies, a small one for the RTU or PLC and another for the radio transmitter, motor starters and other loads.

2.G.2 BAD COMMUNICATION LINES

A common complaint is that ***'the system was working fine and then it stopped'.***

When we ask, we find that ***'yes, it did rain, pretty hard, last night'.***

The technician goes out and removes the water from the cable junction boxes and the system works again. No system can work over bad, water logged communication lines.

At other times leaves from trees, appearing in the spring, can ruin a formerly perfect radio path.

Use the TTS Telemetry Test Set if you have doubts about your communication lines. The TTS will, very quickly, identify bad and high loss communication lines.

20.H CONCLUSION

It is not reasonable to try to do detailed trouble shooting and board repairs in the field. It would be too costly and time consuming. The field technician should only bring a few instruments such as a tester, a simple logic probe, a TTS Telemetry Test Set and a scanner for radio circuits.

It is also a good idea to bring spare units (if possible) to the field to help in identifying a bad unit by replacing it with a known good one. The bad unit can then be returned to the factory for repair or repaired back at headquarters (if facilities exist).

The circuits used in Telemetry and SCADA systems are basically straight forward and simple. Unfamiliarity with the techniques and terminology used may make these systems seem difficult. It is our hope that this Handbook has been of help in easing the pain of learning about these interesting and useful systems.

WHERE CAN I GET MORE INFORMATION?

Literature reference:

app-1115.pdf How the 4-20mA instrumentation loop works.

app-1127.pdf How to test RTU communication circuits.

ttsc1033.pdf	Telemetry Test Set.
alt-1543.pdf	Automatic leased line tester.
uss-1333.pdf	How to upgrade older SCADA systems.
app-1323.pdf	How to arrange for stable RTU power supplies.
ips-1495.pdf	Isolated 12V to 5V, 12V and 24V converters.
app-1239.pdf	How to connect 4-wire modems to 2-wire cables.

An easy way to get the latest and most recently updated versions of these descriptions is to go on our WEB site:

www.scan-data.com

When you are there, click on the blue button near the bottom of the WEB page that says **Technical Information.** Then click on the description # you need.

These WEB sites also have a lot of helpful information on the subject:

www.alarm-dialer.com

www.4-20maloop.com

www.4-20mamux.com

www.pumps-control.com

www.bell-202modem.com

www.telemetryandscada.com