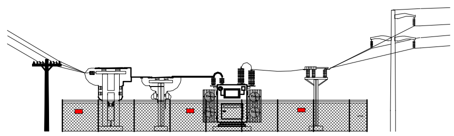
FDA SONIC /ULTRASONIC
FAULT DETECTOR



SOURCE LOCATE/DETECT

PARTIAL DISCHARGE/CORONA

LOOSE PARTS

PUMP CAVITATION

BAD BEARINGS

LEAK DETECTION

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FDA FAULT DETECTOR

OPERATOR'S MANUAL

REVISION H

MAY 2013

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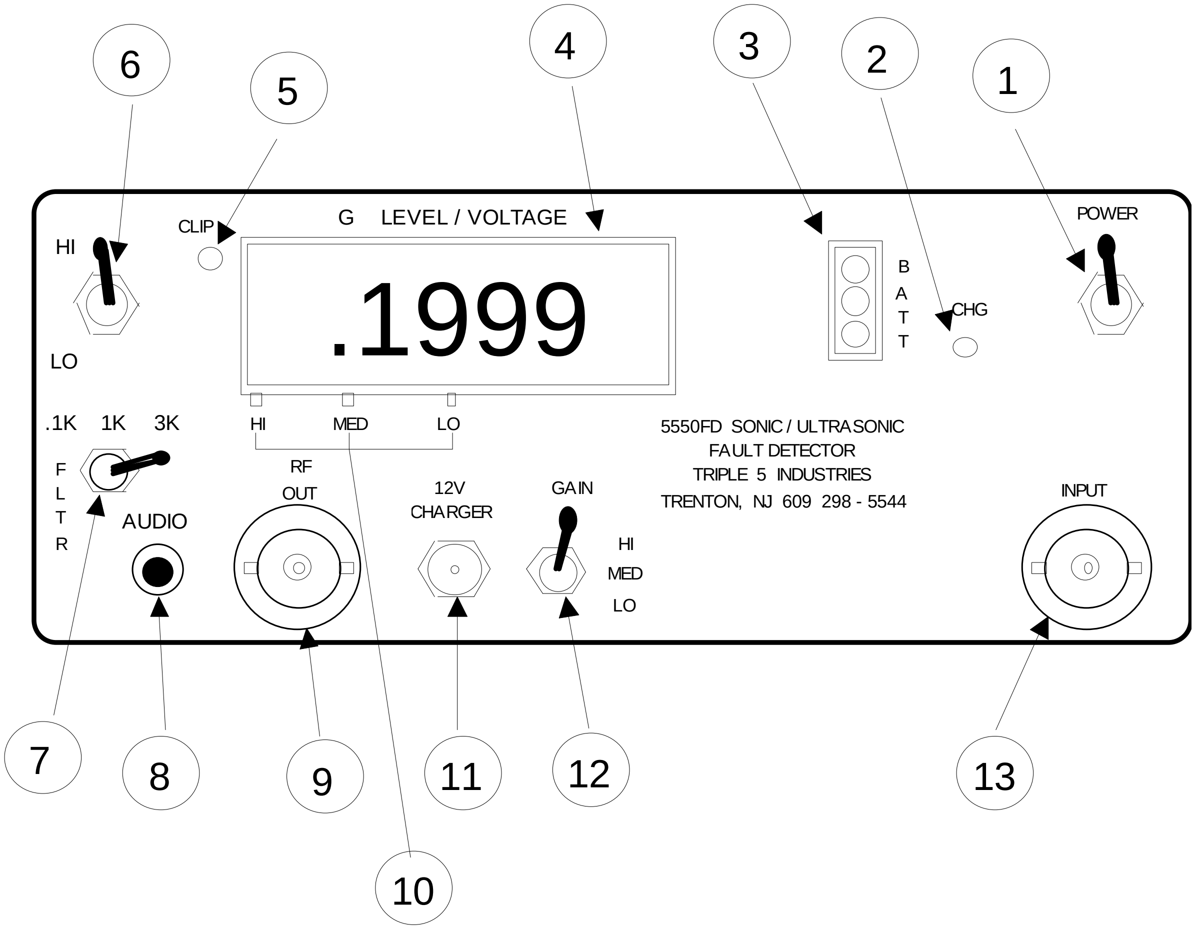
Figure #1

FRONT PANEL of the FDA FAULT DETECTOR



1. ON / OFF POWER TOGGLE SWITCH
2. BATTERY CHARGING INDICATOR
3. LOW BATTERY INDICATOR
4. LCD AMPLITUDE DISPLAY
5. CLIP INDICATOR
6. FREQUENCY RANGE TOGGLE SWITCH
7. FREQUENCY FILTER TOGGLE SWITCH
8. AUDIO OUTPUT FOR HEADPHONE JACK
9. BNC RF OUTPUT CONNECTOR
10. RANGE DISPLAY INDICATOR
11. BATTERY CHARGER INPUT
12. GAIN TOGGLE SWITCH
13. BNC SENSOR INPUT CONNECTOR

1.0 GENERAL DESCRIPTION

The FDA Sonic/Ultrasonic Fault Detector is a portable instrument specifically designed to detect and source locate internal anomalies in energized oil filled equipment. The FDA detects corona, partial discharges, pump cavitation and loose internal parts. Also, it is a leak detector that will detect valve leaks, compressed air leaks, faulty steam traps and bad bearings. In addition, the FDA can be used to monitor flow and valve position and airborne ultrasonic noise.

The FDA operates in both the sonic and the ultrasonic frequency ranges. Internal filters make the unit most sensitive in the 100Hz to 20KHz (sonic) and the 20KHz to 250KHz (ultrasonic) frequency bands. The FDA was initially designed as a leak detection device then modified for fault detection on energized substation/switchyard equipment. The ultrasonic mode is not sensitive to the low frequency, background noises of a plant environment, but it is very sensitive to the high frequency energy produced by corona and partial discharges. A brief description of partial discharge detection and sonic/ultrasonic listening techniques follows:

Partial discharge detection was initially performed on transformers, load tap changers, and circuit breakers, with typical “off-the-shelf” partial discharge detection (PDD) equipment that counts activity at approximately 150KHz. Continuous low level activity was not accepted by the typical (PDD) equipment; and partial discharges were hard to detect in any mode except peak-hold because of their randomness, sometimes 30 seconds to minutes between discharges. Although this technique is useful for quantifying partial discharge energy content, it was found that most transformers do not have levels of internal activity high enough to trigger the detectors. The difficulty is that no active ultrasonic levels are available for benchmarking/trending and therefore no judgment of changing transformer condition can be made with time.

Assuming that internal arcing is low level continuous activity, and would contain all frequencies, data would be accepted in two both the sonic and ultrasonic frequency bands, the data would be “listened to” in addition to being logged. Listening to the data is important in determining the presence unusual sounds or non-periodic random events.

The FDA is used to give RMS levels in both frequency bands, along with audio out and LED display of the RMS level. Applying this dual band technique provides the ability to document the detection of low level continuous activity and partial discharge events. This coupled with increasing levels of combustible gases in the oil provides for early warning of internal faults. Therefore, this technology would be more appropriately named ULTRASONIC NOISE ANALYSIS/PARTIAL DISCHARGE DETECTION.

If a transformer is in good condition, the normal detected (heard) energy, especially in the low frequency range, is the hum coming from line frequency with no “popping” or “buzzing”. When abnormal discharges occur, the “bacon frying” sound can be heard in the ultrasonic band. The “fault detector” is then used to locate the source of activity.

NOTE: The FD is an extremely sensitive device, full scale in the high gain position is only .2 g’s. The detection of internal faults, such as activity between windings, at the transformer walls requires this maximum sensitivity. Always use ultrasonic couplant on the accelerometer face when taking readings on energized electrical equipment.

1.1 Five Easy Steps to Familiarize Yourself with the FDA

Familiarize yourself with operating and using the FDA by performing these simple steps.

1. Connect the Coax Cable between the INPUT connector of the FDA and the end of the T5-013 Accelerometer. (Refer to Figure #1)

2. Connect the headset to the AUDIO jack of the FDA, put the headset on, and set the GAIN switch on the FDA to the Hi position and the Hi/Lo toggle switch to Lo (sonic).

3. Turn the unit ON using the toggle switch on the instrument marked POWER. If the FDA turns off when the POWER switch is released, recharge the battery.

4. Take the T5-013 Accelerometer and rub its face on any flat metallic object. A sizable level of activity should be indicated on the LED and heard through the headset. Hold the sensor against the surface and tap lightly near the sensor (6 to 10 inches away). A good response should be heard. The LED display will ramp up and then quickly return to near zero.

4A. Change the Hi/Lo Switch to the Hi (ultrasonic) position. (Energy in this frequency range is more difficult to generate.) Holding the accelerometer tightly against a metallic surface and moving it quickly back and forth will usually provide a low level of high frequency data that is audible through the headset. Taping near the sensor can be heard, but is difficult to detect because of a lack of high frequency content generated.

5. Replace the accelerometer with the T5-3 Air Probe, keeping the switches in the same positions, Hi gain and Hi frequency.

An air bottle is supplied with the unit to produce a simulated ultrasonic noise level. Squeeze the bottle while pointing the T5-3 probe at the noise source.

NOTE: You will hear the sound of the air leak through the headset. You can even hear the initial vacuum “suck” when you release the exhausted bottle. Only ultrasonic noise is detected by the air probe, therefore it should only be used in the Hi frequency position.

2.0 FRONT PANEL: (Figure #1)

2.1 Power Switch

This is a 2-position, spring release toggle switch located in the upper right hand corner of the unit. To turn the unit on, hold the switch in the up position and then release. To turn the unit off, press the switch to the down position and release. The FDA shuts off automatically after approximately 10 minutes of in-activity.

2.2 Battery Indicator Lights

There are three red battery indicator lights located directly to the left of the power switch. When the unit is fully charged, all three lights will be lit. As the battery is used, the lights will go out one at a time. When only one light is lit, the battery is charged to approximately 10% of its full capacity. Normal battery life is 8 hours.

2.3 Input BNC Connector

This port, labeled, INPUT, is the site for probe and sensor connections. Connections are made using coax cable and BNC connectors. To connect the sensor or probe, line up the “ears” on the FDA input connector with the slots on the cable connector, push into place and quarter turn clockwise. To disconnect, push the cable connector towards the unit and quarter turn counter-clockwise before pulling off.

2.4 Charge Current Indicator Lights

This red indicator light is labeled CHARGE CURRENT and is located to the left of the POWER switch. Whenever the battery is charging, the light shows red. When the battery is fully charged, the light goes out. When the instrument is turned on with the charger connected, the light will remain lit, and the battery will not reach full charge.

2.5 G Level/Voltage LED

The FDA has one voltage LED display. The voltmeter display is 3.5 digits with a maximum reading of .1999 in the HI GAIN position, 1.999 in the MED GAIN position and 19.99 in the LO GAIN position. Note that the GAIN toggle sets the position of the decimal point. The first zero to the right of the decimal point is not displayed. This conserves power and increases the battery life.

When the FDA is used with an 8pc/g sensor, like the T5-013 Accelerometer, the low frequency output on the LED display reads directly in rms g’s (gravity units).

2.6 Audio Out Jack

This is a miniature phone jack located in the lower left corner. The miniature connector on the headset plugs into this jack. The headphone jack supplies audio signals to the headset. When in the ultrasonic range, and internal converter changes the ultrasonic signal to an audible range.

2.7 12V Charger Connector

The charger connector is located to the left of the GAIN selection switch. This port is labeled 12V CHARGER and is used to charge the battery when connected to the external charger. The Stancor W120DUJ50-1 charger supplies 12 volts, unregulated and 0.5 amps to charge the 6-volt battery and powers the instrument. The charger is modified to supply +12 volts to the center pin of the charger jack. The FDA contains an internal regulator to convert the 12 volts charger voltage to 6 volts to charge the battery. Normal current consumption is 0.15 amps unless the battery is low. The battery does not have to be installed to operate the FDA from the charger or an external power supply.

2.8 Gain

This is a three-position switch used to adjust the gain or sensitivity of the FDA.

HI = most sensitive position (0.2 rms g's full scale)

MED = 10 times less sensitive than HI = 20 db decrease in gain. (2.0 rms g's full scale)

LO = 100 times less sensitive than HI = 40 db decrease in gain. (20.0 rms g's full scale)

In general, the GAIN switch will be used in its HI position, but the adjustment is available should the incoming signal be so large that a reading cannot be displayed.

2.9 Hi/Lo Toggle

This toggle selects either the high frequency (ultrasonic) range or the low frequency (sonic) range. When in the LO position, the FDA filters and amplifies signals which are between 100Hz and 20KHz. When in the HI position, the FDA filters and amplifies signals which are between 20KHz and 250KHz. These signals are available through the RF Out connector. An internal beat-frequency-oscillator is filtered and heard through the AUDIO OUT jack.

2.10 Filter

This is a 3-position switch that effects sonic band only.

0.1 = Lo band (100 Hz to 20 KHz). This frequency band is used for all fault detection work in substations.

1.0 = Lo band (1.0 KHz to 20 KHz). This frequency is used in leak detection to eliminate low frequency background noise.

3.0 = Lo band (3.0 KHz to 20 KHz). This frequency is used in leak detection to eliminate additional background noise.

2.11 RF Out Microdot Connector

This connection is available for customers who wish to view spectra and waveforms. Connection to an oscilloscope will give waveforms of the incoming signals.

2.12 Clip LED

When lit, indicates that input signal peaks are off scale for gain level selected.

3.0 ACCESSORIES

3.1 Battery and External Charger

The instrument has a sealed 6 volts, 1.2 A/h lead acid battery which is externally rechargeable. The instrument comes with a Yuasa NP 1.2-6 battery, which is available from Falcon Solutions or can be purchased from a commercial electronics distributor.

The lead/acid battery has a long shelf life between charge cycles. When stored at room temperature, it retains 87% of capacity after 3 months and 75% of capacity after 6 months. A new battery should provide approximately four hundred cycles to a 50% discharge state. Partial discharge will not degrade the battery or cause "memory" effects. The battery is damaged by long periods of storage in the discharged state. Recharge the battery immediately after each use. Replace the battery when the CHARGE light stays on after reasonable charge period or when the battery fails to provide sufficient operating time. The battery reaches full charge only when charged with the instrument off. The charger requires 120v AC, 60Hz.

The lead/acid battery gives at least 8 hours of operation.

The battery charger does not have a power switch. AC power energizes the charger.

When the battery is fully charged, the charger will "trickle-charge" and may be left with the AC applied for an indefinite period of time without damaging or degrading the battery.

CAUTION: Use only the charger supplied with this unit. Use of alternate chargers may damage the unit.

The battery is located at the bottom rear of the instrument. To access, remove the instrument from the carry-bag. Slide the battery tab on the rear of the instrument. Remove the battery by tipping the case downward. Insert new battery and slide battery tab to hold in place.

CAUTION: Do not let the battery tabs touch the metal housing.

3.2 T5-3 Air Probe

This transducer, shown on the front cover, is sensitive to ultrasonic, airborne acoustic energies and is used to scan pumps and motors for airborne, ultrasonic noise. A transformer oil recirculation pump/motor will emit ultrasonic noise when it pumps against restrictions or has bearing or internal problems. The transducer is mounted in a 1" diameter aluminum tube. The tube guides airborne sound energy to the sensor face. It can also be used to scan for pressurized air or vacuum leaks.

3.3 T5-013 Accelerometer

This transducer, shown on the front cover, is sensitive to both the sonic (100Hz to 20KHz) and ultrasonic (20 to 250KHz) frequency ranges. It is used to detect activity in either range by heterodyning into the headset the spike energy and electrical noise from corona and partial discharges. This technique is much like a doctor listening to a patient's heartbeat with a stethoscope. Couplant (supplied) must be used between the face of the transducer and the test surface to permit effective transmission of ultrasonic energy. This transducer can also be used to detect valve leaks, faulty steam traps, worn bearings, feedwater heater tube leaks and boiler tube leaks.

The T5-013 Accelerometer is shipped with a 10/32 stud that can be used to attach to a metal rod or to a permanent mounting onto a test surface. Remove the stud and install the accelerometer into the magnetic mounting for testing transformers.

3.4 T5-203 Magnetic Accelerometer Housing

The magnetic housing provides the user with many benefits. It eliminates the need to hold the sensor in place for extended periods of time. When used with an extension stick it eliminates the need to climb. It also provides a uniform method of attachment for more consistent results.

Figure #2

3.5 T5-204 Extension Stick with 10ft. cable

The extension stick provides the operator easy and safe access to all data acquisition points on a transformer, load tap changer or circuit breaker. Figure #2 demonstrates the use of the stick.

3.6 Headset

The headset is sound attenuating and is designed to fit under a hard hat.

4.0 OPERATIONS

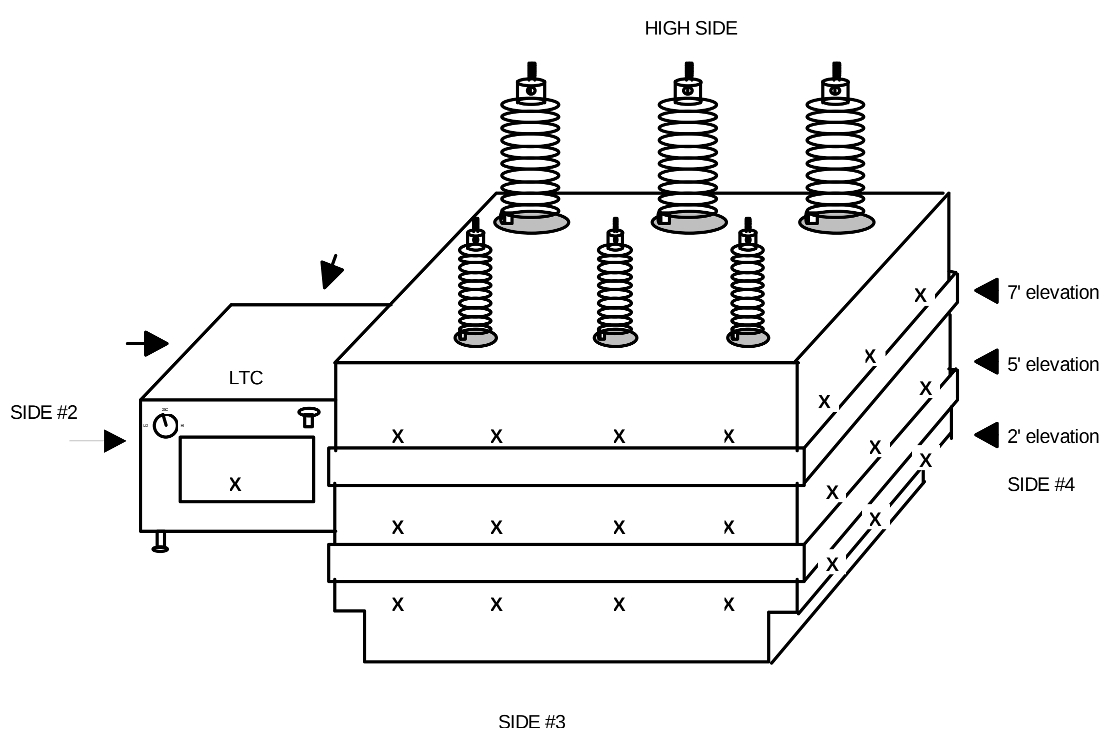
4.1 Guidelines for Surveying a Transformer

1. Verify transformer load. (Internal activity is effected by percent of load on transformer. Results are generally more conclusive when the transformer is operating between half and full load).

NOTE: Pump noise may effect results on the transformer wall surveys. Turn pumps off, if possible, before surveying transformer wall.

2. Using couplant, place the T5-013 Accelerometer for the FDA on the transformer shell in the desired survey area. (See figure #3) Hold the accelerometer in position for a minimum of 10 seconds and record data levels in both the sonic and the ultrasonic range.

Figure # 3



NOTE: Headset must be worn and audible sounds must be monitored while performing transformer surveys.

3. Step 2 should be repeated at several locations on each side of the transformer and, on transformers with tap changers at least one location on each side of the tap changer. The number of survey locations is at the operator's discretion but they should not exceed 6 feet in any direction. However, the preferred method is to lay out a grid relative to the size of the transformer.

4. If non-periodic bursts (partial discharges) are detected, source location should be performed and an oil sample should be obtained for a dissolved gas analysis (DGA). If random bursts are occurring and acetylene is in the oil, locating the source of activity becomes invaluable information to aid in the internal inspection.

If high levels of continuous ultrasonic activity are detected, the area of highest activity should be checked for hot spots and a DGA should be performed, looking for hot metal gasses, i.e. methane, ethane, and ethylene.

4.2 Instructions for Ultrasonic Scanning with the Air Probe

To scan the test areas for ultrasonic activity, air and vacuum leaks, follow these directions:

1. Connect the BNC cable between the T5-3 Air Probe and the INPUT connector on the front of the FDA.

2. Turn power on. Check battery indicator lights to make sure that battery is sufficiently charged. If the FDA turns off when the POWER switch is released, charge the battery.

3. Plug the headset into the unit at the audio jack and place on head under hard-hat.

4. Set the HI/LO frequency switch to the HI position (ultrasonic range).

5. Set the GAIN to the HI position (most sensitive gain setting). Qualitatively check the operation of the unit by using the squeeze bottle provided to obtain a response on the voltage display as well as hear the signal through the headset. For more precise, quantitative verification, it's recommended that each user devise a test procedure which controls leak orifice size, air pressure, through the orifice and the distance between the sensor and the noise source.

Scan the environment or a specific test site by directing the probe towards possible noise sources, pumps, motors, etc., to be scanned by both listening through the headset, and looking at the G LEVEL/VOLTAGE LED display. Leaks can be pinpointed by moving the probe back and forth/up and down across areas which give the greatest signal response.

If any measurement saturates the G LEVEL/VOLTAGE (greater than .1999v), move the gain control to the MED position or the LO position to bring the reading onto scale.

NOTE: Record the rms level and gain setting for each measurement, and use the same settings for subsequent measurements at that test site.

4.3 Guidelines for Valve Testing

4.3.1 Introduction

Meaningful valve inspection, using sonic and ultrasonic equipment, requires specific knowledge about the valve under test. Initially, it must be known if the valve is normally open, normally closed or positioned somewhere in between. In most cases, it is valves, which are normally closed that will be checked for unwanted leakage. It is helpful to discuss potential problems with plant engineers and operators who are familiar with the valves under test. Their input regarding suspected problems and plant operating conditions involving the valves can be invaluable when trying to diagnose a problem. The testing technique is also applicable to check for proper valve operations (i.e. does it open, does it close).

4.3.2 Testing Valves Which are Normally Closed:

The FDA senses both sonic and ultrasonic noises from leaking valves. The ultrasonic range is sensitive to valve leaks, but may not recognize full flow. The sonic range is less sensitive to small leaks, but is useful to detect flow. The unit is most effective when data is taken on a regular route and trended with time.

1. Valves associated with high-pressure steam, water or air are potentially hazardous. Therefore, before any testing begins, the valve should be visually inspected from a distance to determine the safety of the testing environment.

2. Upon approaching the valve, visually inspect it for signs of leakage. Is there visible water on or near the valve body? Is there unusual corrosion or dirt on the valve? Is there visible/audible leakage from the flange or valve packing?

3. Set the gain on the front of the FDA to the HI position. Using the T5-3 Air Probe and the FDA HI/LO frequency switch set to the HI position, scan the valve body and listen through the headphones for the hissing sound of escaping gas. Leaks are most common through the valve packing or at the flange.

4. Set the gain on the front of the FDA to the HI position. Using the T5-013 Accelerometer, touch the valve stem or body as close to the seat as possible, and observe the digital readout. If necessary, adjust the GAIN switch so that the reading on the LED is on scale. Listen through the headset for a corresponding sound. Valves, which are not leaking, will have a very low acoustic output in the ultrasonic range (HI frequency). The digital readout will typically be below .100v.

   Readings which are greater than .100v may be normal, but further investigation is needed. If a baseline has already been established for a valve at less than .100v and the conditions during testing are the same as previously encountered, a leak is highly probable. Refer to the section in this guideline entitled "Determining the Baseline."

5. Further investigation requires knowledge about the valve. Valves, which are of similar construction and are located in similar positions in high-pressure lines, will have similar acoustic

signals when they do not leak. If the valve with the suspect leak is part of a group of similar valves, compare the reading to these similar valves. If possible, stroke the suspect valve and look/listen for a change in reading. Valves, which are leaking, may not demonstrate a change in reading when they are reseated.

NOTE: Valves, which are in close proximity to a severely leaking valve, may experience crosstalk. That is, a good valve may appear to be leaking because the acoustic energy from a nearby noisy valve is transmitted via metal pathways to the good valve. Repair the valves suspected of having the largest leaks first and then retest valves, which may be responding to crosstalk.

6. Low frequency analysis of the valve can sometimes confirm the high frequency findings. When used in the LO frequency mode with the T5-013 Accelerometer, the digital reading on the LED display will be in gravity units. Gravity units can be used to qualify the leak as small, medium or large.

Less than .1g = small or no leak
Greater than .1g and less than 3g = medium leak
Greater than 3g = LEAK (repair this one first)

NOTE: In those cases where the valve is inaccessible, it may still be possible to inspect it using the low frequency range of the FDA. Low frequency flow noise through the leaking valve will be detectable through the downstream piping at the location where there is a sharp bend (90 degree or more) in the direction of the pipe. Use the T5-013 Accelerometer and couplant to take the readings.

7. When possible, results should be compared against a known baseline. Record voltage readings for each valve tested and trend these against time.

For consistent data, tests should be conducted during the same operating conditions, at the same location on the valve body and with the same type probe or accelerometer.

4.3.3 Determining the Baseline

There are two ways to determine the baseline reading for a valve, which is operating under normal conditions:

1. Take readings on new valves, which are assumed to be non-leaking. This becomes the baseline reading against which all future test data is compared.

2. Compare the readings from groups of valves having similar design, which are operating under similar conditions. A group of low readings becomes the baseline reading for the entire group and is assumed to be the reading for the non-leak condition.

5.0 FDA AMPLIFIER VERIFICATION TEST

5.1 Sonic Amplifier

1. Obtain a signal generator and set the frequency to 5 kHz and the amplitude to 1Volt RMS (2.8V peak - peak)

2. Connect the generator to the input of a 60dB attenuator, and connect the output to the RF Input BNC connector on the FDA. (Refer to drawing # 8A2454A0)

3 Set the HI/LO switch to the LO position, and set the GAIN switch to the HI position. It does not matter which position the FLTR switch is in.

4. Verify the display reads approximately .1000.

5.2 Ultrasonic Amplifier

1. Obtain a signal generator and set the frequency to 40 kHz and the amplitude to 1Volt RMS (2.8V peak - peak)

2. Connect the generator to the input of an 80dB attenuator, and connect the output to the RF Input BNC connector on the FDA. (Refer to drawing # 8A2454A0)

3. Set the HI/LO switch to the HI position, and set the GAIN switch to the HI position. The FLTR switch does not apply when the FDA is in the Ultrasonic mode.

4. Verify the display reads approximately .0700.

NOTE: If the above procedures do not supply the correct results it is recommended to send the FDA back to MISTRAS GROUP for calibration.

GLOSSARY OF TERMS

Acoustic Emission: Elastic waves generated by the rapid release of energy from sources within a material.

Anomaly: Deviation from the common rule, i.e. irregularity.

Cavitation: The formation of partial vacuums in a liquid by a swiftly moving solid body (as a propeller) or by high frequency sound waves; the pitting and wearing away of solid surfaces as a result of the collapse of these vacuums in surrounding liquid.

Clipping: A peak signal that exceeds the dynamic range of an amplifier; causes non-linear reading.

Corona: Electrical stressing resulting in ionization. Corona produces localized, high amplitude energy detected by the FDA in the ultrasonic frequency band. RMS readings are typically greater than 300mV.

Couplant: A substance used between the face of the transducer (accelerometer) and test surface to permit or improve transmission of ultrasonic energy across this boundary or interface.

DGA: Dissolved gas analysis

Partial Discharge: An electrical discharge that partially bridges the insulation between conductors. It manifests as random, high amplitude, non-periodic events in the ultrasonic range; easily detected by listening through the headset of the FDA.

PDM: Predictive Maintenance.

Peak Amplitude: The momentary, high amplitude response typical of partial discharge easily detected by listening through the headset of the FDA.

RMS: Root-mean-square: method for converting an AC sensor signal to a DC voltage. The resultant number reflects the energy content of the incoming signal.

Sonic Range: The frequency within the audible range of the human ear: a range of 20 Hertz to 20,000 Hertz.

Ultrasonic Range: The frequency range greater than the highest audible frequency, generally regarded as being higher than 20,000 Hertz to approximately 1,000 Megahertz.