



VLF-CM

SERIES

Safety, Operation, and Procedure Instructions for the VLF Series of AC Hipots



Danger- Lethal Voltages:

Equipment to be used by trained personnel only

This Operator Manual contains instructions for the operation of a High Voltage power source. The operator of this equipment must use good judgement and follow all safety precautions noted in this guide to ensure the protection of himself and others in close proximity to the test area. **Failure to follow the instructions could result in injury or death. Proper grounding of the test set must be done prior to connecting this unit to a power source.**

VLF Operator Manual



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Very Low Frequency (VLF) AC High Voltage Testing - Operators Manual Addendum

Instrument Summary

This instrument is a Very Low Frequency AC high voltage test system – a VLF hipot. It is an AC hipot whose frequency output is 0.1 Hz or lower, compared to the 50/60 Hz of a conventional AC hipot. The lower the frequency, the lower the current and power it takes to test a capacitive load like a cable. At 0.1Hz, it takes 600 times less current and power, compared to 60Hz, to apply an AC voltage to a cable or some other high capacitance load.

At 0.1Hz frequency output, one full cycle of the sine wave takes 10 seconds, 20 seconds at 0.05Hz, and 50 seconds at 0.02Hz. Even though each cycle of the waveform can take 10 seconds or longer, it is still alternating current – AC – and is sinusoidal.

This is not a DC hipot and it does not operate in the same manner. When the voltage output is raised, the voltage will climb to its peak and then descend back to zero. The output polarity of the set reverses (a solenoid switch can be heard) and then climbs again in the opposite polarity. This rise and fall of the voltage is obvious on the voltmeter and is normal. The current meter will also rise and fall as the cable charges and discharges every half cycle. Unlike DC, there are no leakage currents to read. This is a go/no-go, or pass/fail, AC stress test. The load under test either withstands the test voltage and passes, or it breaks down and fails.

Important note: Use the VLF test set properly. Test at the proper test voltage and time duration. Abbreviated tests or tests at reduced voltage levels should not be performed. An improper test may aggravate cable defects that may cause cable failure later in service. The proper test voltage and time duration are essential to allow the VLF to do its job.

Helpful Notes to Users

Peak Voltage: The Voltmeter on the VLF test set measures the Peak voltage. It is the peak output voltage that is used during VLF testing. If your test specification indicates a test voltage in RMS, multiply by 1.414 to obtain the peak value for the test. The IEEE400.2 chart indicating test voltages for different cable ratings shows both rms and peak. All other AC hipotting using 50/60 Hz instruments is measured by the rms voltage, not VLF testing, so make sure this issue is addressed.

Output Frequency: All VLF sets are rated by the uF of load they can test at a given frequency. The lower the frequency, the higher the capacitance, or the longer the cable, can be tested. Always use the highest frequency possible. Testing should be performed at 0.1Hz, unless the capacitance of the load is too high for the uF rating of the set at 0.1 Hz. It may be necessary to reduce the frequency to 0.05, 0.02, or 0.01 Hz depending on the capacitance of the load. The load capacitance can be measured using the capacitance meter of the VLF or be calculated, if the capacitance per foot or meter is known. Example: At 0.1Hz, 1 – 2 miles of cable can be tested, depending on size.

Test Duration: The recommended test duration is 30 minutes as a minimum. In the body of this manual are reprints from the IEEE400.2 standard discussing this issue and additional information on the subject. The longer the test duration the better, as minor defects that triggered into partial discharge due to the test voltage will have time to grow through to failure during the test. The duration indicated in the standard is based on using a frequency of 0.1Hz. If lower frequencies are used, the test time must be extended. Rather than 30+ minutes at 0.1Hz, perhaps 60 minutes should be used at 0.05 and 0.02Hz.

Cable Failure Indication: When the cable fails, the thermal Overload on the front panel will pop up. Also, the Voltage and Current meters will read erratically as the cable arcs. It may take several cycles of the voltage rising to the arc-over voltage of the fault to cause the thermal overload to warm up enough to trip.

Use a Sinusoidal AC source (generator, inverter, line power) or your VLF may not reach full output.

Know Your Test Equipment – Read the Operators Manual

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About the Operator Manual

Important

This Operator Manual describes the features and safe operation of a High Voltage AC Test Set. The instructions are intended to be clear and simple, but the operator must be trained and qualified according to the customer's established procedures for the use of this type of equipment.

This Operator Manual is organized to provide information on the **VLF Series** in steps that familiarize the new operator with the entire scope of operation of this test set.

Section 1: Specifications and Controls.

Section 2: Setup and Operation.

Section 3: Performing Special Operations.

The Functions, Features, and Specifications of the VLF Series of AC Hipots are also discussed in the VLF Brochure available from High Voltage, Inc.

General Information

This section familiarizes the operator with the features and specifications of the **VLF Series of Portable AC Hipots** manufactured by **HIGH VOLTAGE, INC.**

Features and Specifications

The VLF Series of hipot test sets provide true sine wave AC output voltage for the test of high voltage cables and other capacitive loads.

Standard features of the VLF Series of AC Hipots

- Sine wave output, 0.1, 0.05 and 0.02 Hz frequencies standard.
- Continuously adjustable output voltage
- Continuous duty rating
- Fixed thermal circuit breaker overload
- "Zero Start" and External Interlock provision
- Single-range voltmeter
- Single -range Current/Capacitance meter
- Two piece portable design
- Transit protected meter prevents damage between test sites
- Ground stick provided for increased operator safety. Can be used to safely connect the unit and the test load to ground before and after test
- 12 ft. input line cord
- 10 ft. interconnect cable with grounds

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- 20 ft. RG8/U output cable(VLF-4022), 20 ft. shielded X-Ray output cable(VLF-6022)
- Alligator clip type output connector
- 20 ft. 2 AWG clear jacketed cable for safety grounding of HV section.
- Red and Black Measuring Leads for Capacitive Load Measurement

WARNING

DO NOT OPERATE THE VLF HIPOT SET IF THE HIGH VOLTAGE TANK IS 5° OR MORE FROM LEVEL.

IF THE UNIT IS OPERATED OUT OF LEVEL, OVERHEATING AND INTERNAL ARCING MAY OCCUR.

DO NOT STORE OR TRANSPORT VLF HIGH VOLTAGE SECTION
ON ITS SIDE

Operating Environment

Indoor/Outdoor-fair weather

Altitude: 100% of rating; Sea-level, up to 5000ft.(approx.1500M). The output power is de-rated 10% above 5000 ft. altitude, 20% above 12,000 ft.(approx. 3600M), and 30% above 15,000 ft.(approx. 4500M)

Storage Temperature: -20°C to 70°C(-4°F to 158°F)

Operating Temperature: -5°C to 45°C(22°F to 113°F) Output power is de-rated linearly by 15% from 30 to 45°C ambient.

Maximum Relative Humidity: 80% up to 31°C(88°F), decreasing linearly to 50% at 40°C(104°F)

Mains supply fluctuation: +/-10% of rated voltage

Installation: Category II

Pollution: Degree 2

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Safety Symbol Identification



Warning! Please refer to documentation before operation



Protective Earth Terminal



Warning: Hazardous Voltage

MODEL VLF AC HIPOT SPECIFICATIONS

	VLF-4022CM (44 kV,2.2 μ F) Part No. VLF-1450S(120V) Part No. VLF-1447S(230V)	VLF-6022CM (62 Kv,2.2 μ f) Part No. VLF-1423S (120V) Part No. VLF-1439S (230V)
Input	120 V, 50/60 Hz, 10 A <u>Sinusoidal Power Required for full output</u> 230 V, 50/60 Hz, 6 A	120 V, 50/60 Hz, 15A <u>Sinusoidal Power Required for full output</u> 230 V, 50/60 Hz, 8 A
Output	Sinusoidal 0-44 kVac peak, 0.1, .05, and .02 Hz frequency	Sinusoidal 0-62 kVac peak, 0.1, .05, and .02 Hz frequency
Duty	Continuous	Continuous
Test Capacitance (Ins. Res. < 10G Ω)	1.1 μ F @ .1 Hz, 2.2 μ F @ .05 Hz, 5.5 μ f @ .02 Hz <u>Minimum capacitance to achieve full output- .01μF</u>	
Kilovoltmeter	3.5 in. , 0-45 PEAK KILOVOLTS 2% Full-scale Accuracy	3.5 in. , 0-65 PEAK KILOVOLTS 2% Full-scale Accuracy
Current/uF Meter CM Models	3.5 in. 0-100 PEAK MILLIAMPS, /5-0 uF, 5% FS Accuracy	
Control Case Size	22w x 11d x 15.25 high	26w x 13d x 16 high
High Voltage Tank	14.5w x 10.5d x 19 high	15w x 11d x 21.5 high
Control Case Weight	50 lbs. (23kg)	75 lbs. (34kg)
High Voltage Tank Weight	72 lbs. (33kg) Accessory Bag 10lb. (4.5kg)	120 lbs. (54kg)
Intercon. cable length	10 ft.	10 ft.
Output cable length	RG8/U 20 ft.	Shielded X-Ray 20 ft.

Table 1 VLF Series Specifications

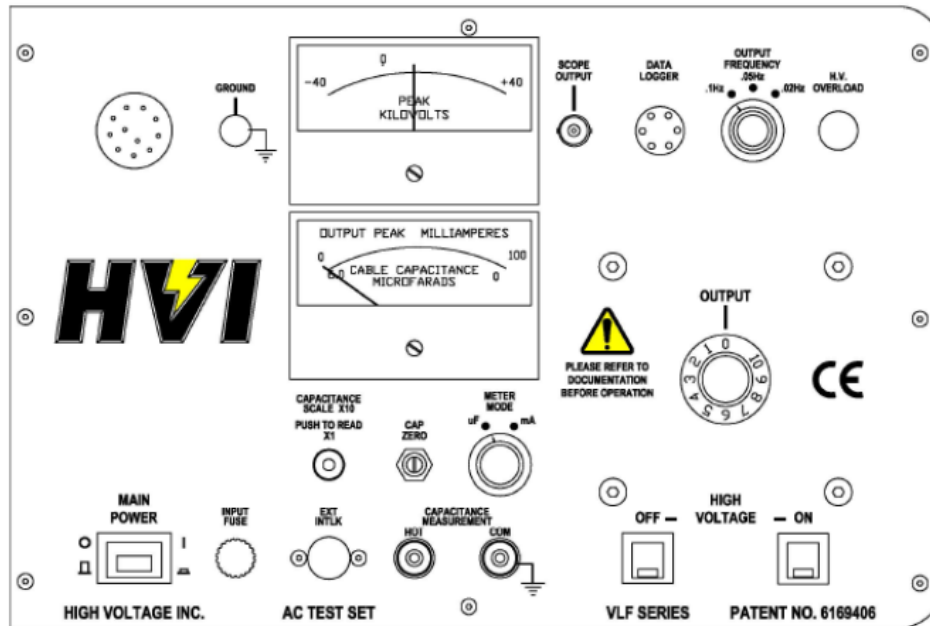


Figure 1 VLF-40 Series front panel controls

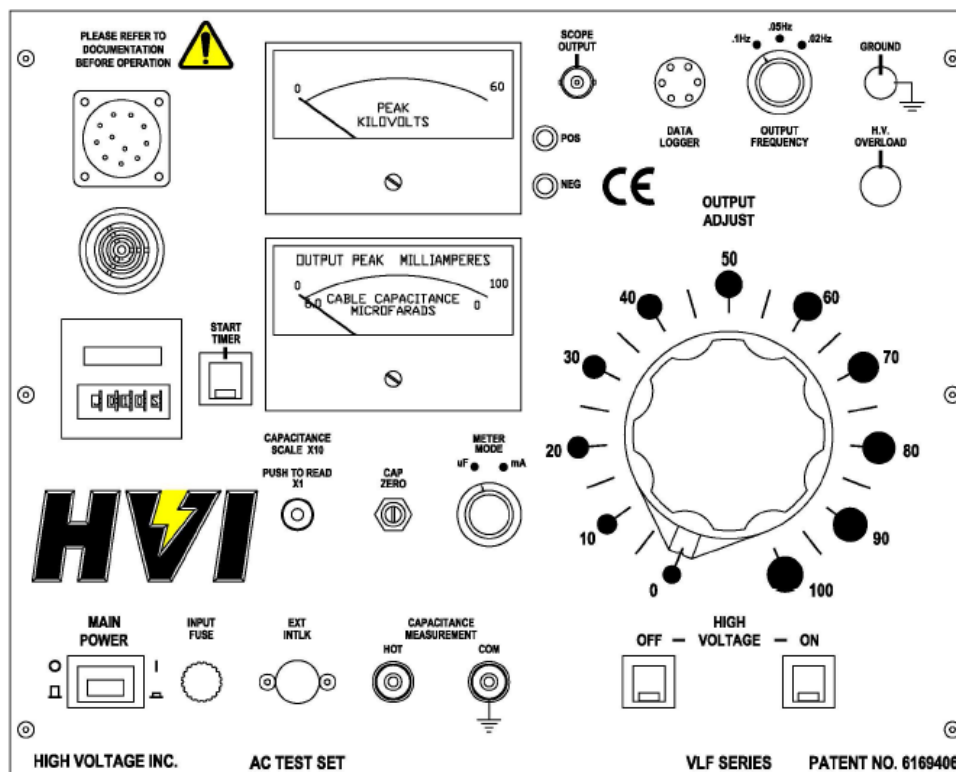


Figure 2 VLF-60 Series front panel controls

INPUT POWER

The **INPUT POWER** connector (if applicable) accepts most standard line/extension cords. The power supplied to the input connector must be from a **grounded Sinusoidal** AC source rated to match the input power specifications noted in **Table 1**. If extensions cords are used for the input, use 10 AWG cord for 25 ft, and 8AWG for 50ft cords. The output may not reach full voltage if the input extension is too small and causes a significant voltage drop under power.

PLEASE NOTE- Using Square Wave Power Generators may reduce the maximum output of this unit.

MAIN POWER

The **MAIN POWER** pushbutton switch provides the power to the control and power circuits. The neon lamp in the switch will light when the power is on and voltage is available through input line cord. The **INPUT FUSE** located electrically before the **MAIN POWER** switch provides input line protection for the unit.

EXT.INTLK (EXTERNAL INTERLOCK)

The **Ext. Intlk.** connector is provided to allow for a normally open safety interlock switch to control the energizing of the high voltage output.

HV OVERLOAD

The **HV OVERLOAD** circuit breaker protects the variable transformer output control brush. Its thermal characteristics allow for the short term overload of the variable transformer while still providing proper protection.

HIGH VOLTAGE ON/OFF

The **HIGH VOLTAGE ON (OFF)** pushbuttons activate (de-activate) the high voltage power circuits. The LED indicators provide long life positive indication of the circuit status. The **RED (ON)** LED lights when high voltage is energized, the **GREEN (OFF)** LED lights when the high voltage is de-energized.

OUTPUT CONTROL

The **OUTPUT** control variable transformer adjusts the output voltage. The 0-100 markings on the panel indicate the low to high setting. The control must be at ZERO (0) to energize the high voltage circuits. **The output control must always be returned to zero at the completion of testing, prior to de-energizing the output , allow the unit to cycle for 60 seconds to assure full discharge of the load.**

VOLTMETER

The **KILOVOLT METER** allows for accurate output voltage readings. 1-% precision resistors minimize the need for re-calibration due to aging shift. See **Voltmeter Re-calibration** in Section 3 for details on calibration.

SCOPE OUTPUT

The **SCOPE OUTPUT** allows for accurate output voltage monitoring. This connector can be fed into an oscilloscope for the looking at the actual output wave shape. The peak to peak voltage representing 40 kVac is 8 volts peak/peak. (On the VLF-6022, 60 kVac is 6 volts peak/peak.)

OUTPUT FREQUENCY

The **OUTPUT FREQUENCY** switch adjusts between calibrated frequencies for testing loads larger than normal. By allowing slower frequencies the output waveshape is maintained. Output frequency choices are .1 Hz for 1.1 μ F, .05 Hz for 2.2 μ F, and .02 Hz for 5.5 μ F.

TIMER AND START TIMER PUSHBUTTON

The **Timer** is provided for tests when dwell time is important. The timer can be set from 1 second increments up to hour increments. After the test has started, the timer can be started by depressing the **START TIMER** pushbutton. The preset time will count down to zero. Upon reaching zero, the timer will sound an alarm indicating the completion of the timing cycle. The timer will not shut down High Voltage. To Reset the timer alarm, with high voltage **OFF**, depress the **START TIMER** pushbutton.

To set the H5CX Timer

- 1) Press and hold 'mode' button for 3 seconds to enter program mode
- 2) Set the time range using the 'up/down' push buttons (default 30min 00 sec)*
- 3) Set the timer mode using the 'up/down' push buttons (default down)*
- 4) Set the timer output mode using the 'up/down' push buttons (default F)*
- 5) Set input signal width using the 'up/down' push buttons (default 20mS)*
- 6) Set key protect level using the 'up/down' push buttons (UP-1)*
- 7) Press and hold 'mode' button for 3 seconds to exit program mode

*press 'mode' button briefly after adjusting each parameter to move to next step

CURRENT METER

CURRENT/CAPACITANCE METER

The dual scale **CURRENT/CAPACITANCE** meter provides for accurate output current monitoring. The **CURRENT** portion of this circuit is for observing the charge and discharge currents in the cable load. 1% resistors minimize the need for re-calibration due to aging shift. The CAPACITANCE scale is for measuring the load cable capacitance (0-6uF/0-60uF) prior to test to determine the best operating frequency for that particular cable run.

Note: The current meter on the VLF Series of AC hipot is for reference readings of current draw. The current reading is affected by both frequency and cable length and as such is not appropriate for use in trending or leakage measurements.

METER MODE

The **METER MODE** switch configures the current metering circuit for capacitance measuring or for output current measurement.

CAPACITANCE (PUSH TO READ X1) PUSHBUTTON

The **PUSH TO READ X1** pushbutton changes the scale of the CAPACITANCE metering. The modified Wheatstone Bridge incorporated in this circuit indicates x10 readings without depressing the **PUSH TO READ X1** pushbutton. *When in the x10 scale and the reading is below 6 μ F (0.6 on x10 scale), the **PUSH TO READ X1** should be depressed to get an accurate **load capacitance** measurement.*

CAP ZERO

This potentiometer is for zeroing the capacitance range at full scale prior to measuring the cable capacitance.

CAPACITANCE MEASUREMENT POSTS

These posts are for connecting the cable to the capacitance measuring circuit. The **HOT** post is for the cable center conductor, the **COM** post is for the cable's grounded shield. Be sure the cable is de-energized before connecting this low voltage circuit or damage will result. The resulting capacitance measurement on the cable will identify the best operating frequency for that particular cable run. A frequency table is provided in the section **OPERATING THE EQUIPMENT**.

POS/NEG LED DISPLAY

These LEDs are to identify output polarity as unit cycles.

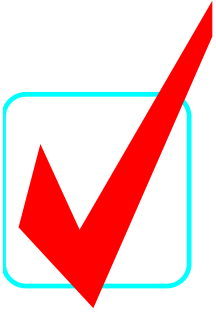
DATA LOGGER

The **DATA LOGGER** connector is for the external ADL-1 Data Logger option.

Note Regarding use of MC connectors:

The MC connector requires the operator to push IN before pulling OUT to disconnect.

List of included components with the VLF Hipot



- ☐ Ground stick with 20 ft. of ground wire
- ☐ Ext. Intlk. jumper plug
- ☐ 20 ft. long output cable RG8/U; VLF-4022 , 20 ft. long X-Ray cable; VLF-6022
- ☐ Alligator clip and hook terminations
- ☐ 10 ft. interconnect cable with grounds
- ☐ BNC to BNC scope to panel interconnect coax cable
- ☐ 20ft. 2AWG clear jacketed cable for safety grounding of the HV section
- ☐ Red and Black Measuring Leads for Capacitive Load Measurement

WARNING

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IF THE UNIT IS OPERATED OUT OF LEVEL, OVERHEATING AND INTERNAL ARCING MAY OCCUR.

DO NOT STORE OR TRANSPORT VLF HIGH VOLTAGE SECTION

ON IT'S SIDE



SETTING UP THE EQUIPMENT

The setup of this equipment has been minimized by careful consideration of the operator during design. The **VLF Series'** two-piece construction allows for convenient portability for AC testing in the field.

Select a location for the unit that will allow easy viewing of the control panel at a safe distance from the test object. Place the high voltage tank within 10 ft. of the control on a level area. The cooling and filter assembly of the VLF series will not operate properly if the high voltage tank is placed on uneven ground. A maximum angle for correct operation is 5°. Blocking the tank to a level condition is acceptable.

1. **Be sure that all the controls are off**, in their de-energized or fully counterclockwise position.
2. **Secure the interconnect cable to the high voltage tank.** Be sure the free-hanging fan/pump connector is also connected to the side connector.
3. **Secure a ground test lead to the panel.** The **Ground** post on the front panel should be used for that purpose. A lead in the high voltage interconnect has been provided for the ground connection.
4. **Secure a ground test lead to HV TANK.** The **Ground** stud the top of the tank should be used for that purpose. A 2 AWG CLEAR JACKETED lead has been provided for the ground connection. The clamp end should be connected to a solid earth ground.
5. **Connect the ground stick to a solid earth ground.**
6. **Insert the coaxial output cable into the high voltage output connector on the tank.** Tighten the clamping nut securely.
7. **When using a cable reel assembly with a VLF.** Refer to "VLF Connection Scheme with Cable Reel" in Operating the Equipment Section.

Note Regarding use of MC connectors:

The MC connector requires the operator to push IN before pulling OUT to disconnect.

8. **Insert the EXT INTLK plug into the socket on the panel.** The plug may also be wired to a normally open contact of a safety switch for added protection.

The setup of the VLF AC Test Set does not address the need for proper safety grounding of the load (test sample or cable). The grounding requirements vary for different types of tests. Please consult the local codes where applicable or reference the guidelines for grounding found under OPERATING THE EQUIPMENT.

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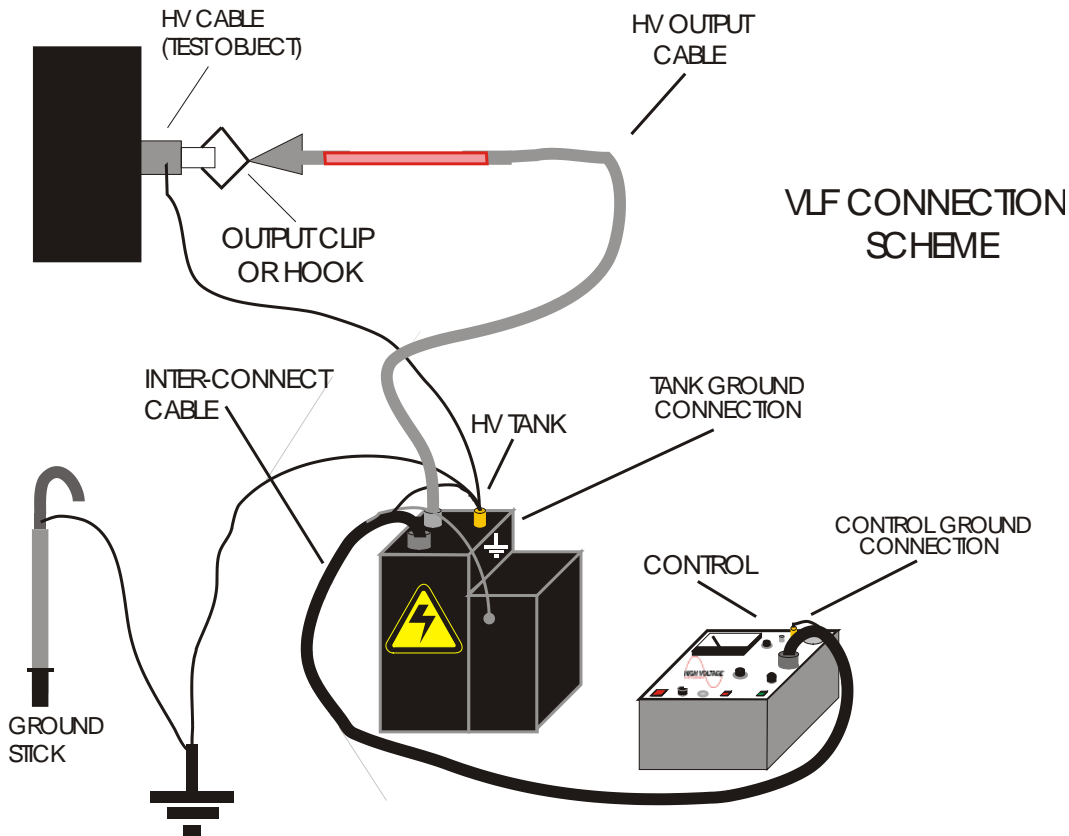
**DO NOT STORE OR TRANSPORT VLF HIGH VOLTAGE SECTION
ON ITS SIDE**

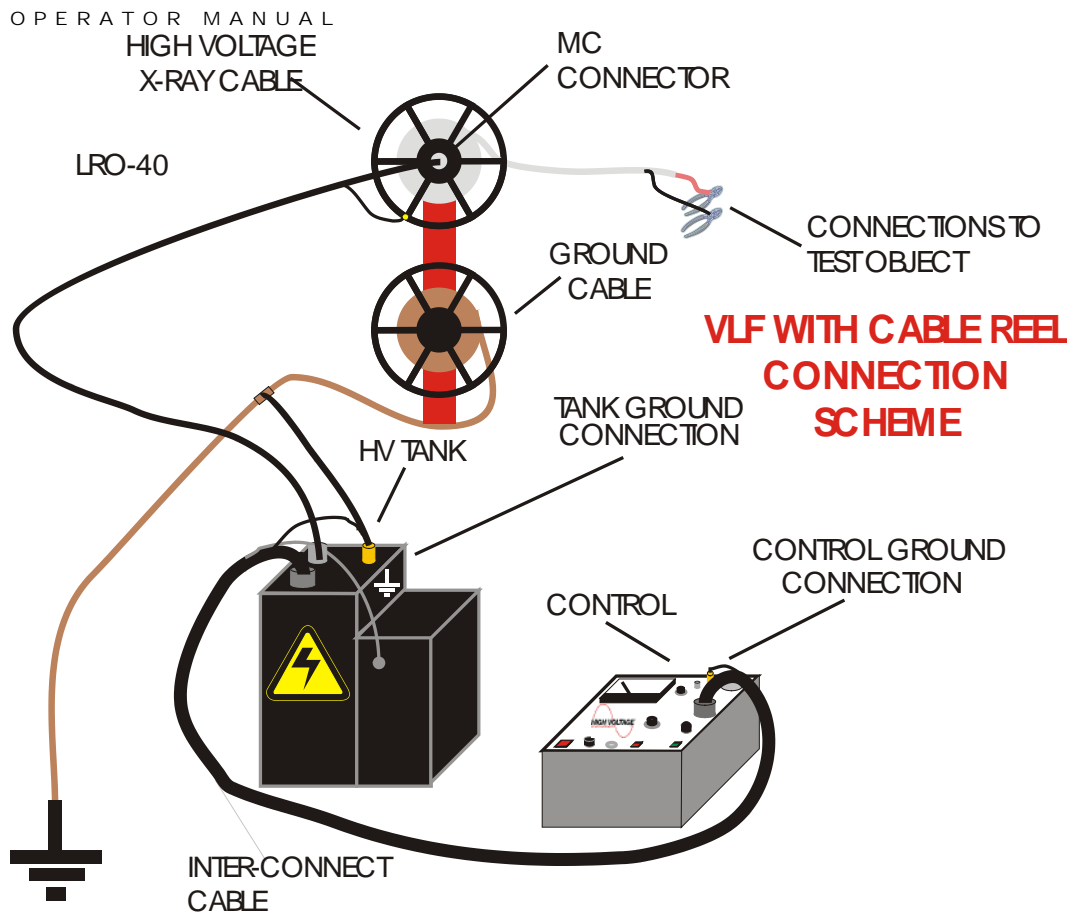
Operating the Equipment

This section provides step-by-step instruction on various test methods. Many facilities have their own in-house test procedures, and this manual is not to supercede these. The purpose of this section is to explain the capabilities of this test set in real-world applications.

When testing cables, either single or three phase, there are certain extra steps that must be observed to ensure safe operation.

It should be noted that the VLF series test sets are not intended to be used on vacuum bottles or switchgear without cables connected. The VLF requires a minimum of .01uF load capacitance to achieve full output. If the capacitance of the load is too low, the kilovolt meter will not read the actual peak output and damage to the unit (and/or load) may result.





AC Testing of High Voltage Cables

1. Ensure that all the steps listed in Setting Up the Equipment have been accomplished. Take special note to ground the control section and the high voltage tank to a solid earth ground.

Caution!!

Before making any cable connections, ensure that the cable being tested has been properly identified, de-energized, and grounded!

2. Make sure that all insulators, stress cones, and pot heads are clean and free of moisture. This will prevent flashover and minimize leakage.
3. Isolate the far end of the conductors under test for the test voltage; that may mean separating some of the conductors in a multi-conductor cable from each other *and* their shields.

The shields of all cables must be securely tied to ground at the nearest end of the cable.

4. Any conductors or wires in the cable or the vicinity not being tested must be grounded to avoid a buildup of charge and possible shock hazard.
5. Voltage must be applied according to specifications from the cable manufacturer or any other applicable test standards
6. Prior to connecting anything to the test sample, be sure the test sample is identified, de-energized and grounded until ready to test.
7. First, the cable capacitance must be measured to determine the best operating frequency. Place the control near the cable being tested.
8. Connect the input power terminal block (or cord) to a grounded, 50/60 Hz source as noted in Table 1 Specifications. A generator is an acceptable power source. If extensions cords are used for the input, use 10 AWG cord for 25 ft, and 8AWG for 50ft cords. The output may not reach full voltage if the input extension is too small and causes a significant voltage drop under power.
9. Turn on the main circuit breaker. The **MAIN POWER** light will illuminate at both the power section and the control.
10. Operate the **METER MODE** to **μF** position. Adjust the **CAP ZERO** for full scale deflection (ZERO) on the meter.
11. Connect the **HOT** post to the center conductor of the test cable. Connect the **COM** post to the grounded shield of the test cable. Read the **CAPACITANCE** scale(x10).

If the reading is below 6.0μF(0.6μF on scale) depress the x1 pushbutton. Then following table provides operating frequency versus capacitance.

<u>Capacitance</u>	<u>Frequency</u>
1.1μF or less	.1 Hz
2.2μF or less	.05Hz
5.5μF or less	.02Hz

A minimum load capacitance of 0.01μF is required to achieve full output of the VLF unit.



It should be noted that the VLF series test sets are not intended to be used on vacuum bottles or switchgear without cables connected. The VLF requires a minimum of .01uF load capacitance to achieve full output. If the capacitance of the load is too low, the kilovolt meter will not read the actual peak output and damage to the unit (and/or load) may result.

12. An oscilloscope (**optional**) can be connected to the **SCOPE OUTPUT** on the control for wave shape monitoring. The oscilloscope should be properly grounded and the input should be set to 1 volt/ division, the time base should be 5 seconds/division and the trigger should be set to roll display to view the wave shape. An oscilloscope with signal memory display is best used for this application. A BNC to BNC shielded jumper should be used for connection between the **SCOPE OUTPUT** and the oscilloscope. A digital meter can be used to monitor this connector. The voltage feedback calibration for this connector is 1 volt for 10 kV of output.

* * * C A U T I O N * * *

POTENTIALLY LETHAL VOLTAGES MAY BE PRESENT

STORED ENERGY LEVELS IN THE CABLE GREATLY INCREASE THE RISK OF FATAL INJURY IF CONTACT IS MADE WITH THE LOAD WHILE AT ANY VOLTAGE.

13. Connect the output lead to the test sample; be sure that there is enough clearance to grounded objects for the expected test voltage. The minimum clearance in air is 10 kV ac/inch.
14. Operate the Current **METER MODE** switch to **mA** position to observe cable charging and discharging currents.

Note: The current meter on the VLF Series of AC hipot is for reference readings of current draw. The current reading is affected by both frequency and cable length and as such is not appropriate for use in trending or leakage measurements.

15. With the **OUTPUT** control at zero (zero start interlock engaged), depress the **HV ON** pushbutton. The **HV ON** light will glow. At this time the pump and fan on the high voltage section will also energize. **If this is the first test at this location, leave the output control at zero and allow the pump to circulate oil for 10 minutes prior to raising the output**



voltage and starting the test. This will purge air from the cooling system. Increase the output by operating the **OUTPUT** control slowly clockwise until the desired output voltage is reached. Raising the output too fast with large capacitive loads may trip the output overload. Observe the **Kilovolt** meter to set voltage. Please recognize that the output cycle is: 50 seconds for a full sine wave @ .02 Hz, 20 seconds for a full sine wave @ .05 Hz, and 10 seconds for a full sine wave @ .1 Hz. To set the output voltage you may need more than one cycle to read the output accurately. **A minimum load capacitance of 0.01 μ F is required to achieve full output of the VLF unit.**

16. Maintain the output voltage for the test time specified in your standard procedures.

Note: Full scale current readings at the polarity reversal (zero crossing) of the output sine wave indicates an improper test frequency (too fast). Move the frequency to the next slower position if this happens. Observe the next cycle and repeat frequency reduction if necessary

The limiting factor in the VLF unit is the wave shaping discharge resistors. An excessive capacitance will not fully discharge before the next half cycle starts and causes a discharge at zero crossing through the high voltage circuit.

Excessive loads can damage the VLF test set.

17. After the test is complete, rotate the **OUTPUT** control to zero, allowing the load to return to zero and the unit to cycle for about 60 more seconds prior to depressing the **HV OFF** pushbutton. Allowing the unit to cycle for some time allows for the complete discharge of the load and avoiding the normal self re-charge that capacitive loads will exhibit.
18. If the test sample fails during the test, the overload circuit will de-energize the high voltage. Should an overload occur, the normal sine wave cycle is interrupted and the load may bleed down much more slowly than when the unit is cycling normally.

The thermal overload may not trip below 20% of full output. Due to thermal characteristics and high voltage circuit impedance, the current peaks are not enough to trip the overload. Above 20%, the overload reliably trips at the peak of the output wave.

From time to time, the input fuse may blow during a fault on the cable load, be sure to replace the fuse with a **slo-blo** (TYPE T/time delay) fuse of the proper amperage.



19. **Prior to removing the output cable from the load, observe that the output voltmeter is at zero, and then use a GROUND STICK to positively ground the test sample.**

Note: Cables exhibiting high failure rates (greater than 4 times in 18 months) should be investigated further to determine the age and likelihood of continuing problems. Replacement may be indicated.

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Very Low Frequency (VLF) AC Cable Testing

Recommended Test Voltage Levels And Durations

With much of the world abandoning DC testing of solid dielectric cable, VLF AC hipots are becoming widely used. Since an AC test is a proof (or withstand) test on a go/no-go (or pass/fail) basis, the test voltage is applied for a set duration. The cable being tested either holds the test voltage or fails. The question arises, and there is and has been much debate, as to the proper test voltage and the time length of the test. There are differing recommendations and standards in existence that define voltage level and duration. Here we will attempt to summarize what exists and offer recommendations.

Most standards call for a *Maintenance* test voltage of 2 - 3 times the normal line-to-ground operating voltage, or $2V_o$ - $3V_o$ (higher for 5 kV cable). However, the voltage applied, per IEEE400.2, is 2 - $3V_o$ rms of the operating voltage but used as the peak of the sine wave output from a sine wave producing VLF unit. For example, a 13.2 kV operating system has a line to ground voltage of 7,621 volts. Three times 7,621 equals 22,864 volts. The IEEE standard calls for a VLF *Maintenance* test on 15 kV cable to be 22 kV peak, which would be equivalent to an rms voltage from the VLF of 16kV. Test voltages may vary depending on the operating voltage. For instance, a 15 kV cable may have a phase-to-phase operating voltage of 11 kV, 12.5 kV, 13.2 kV, 13.8kV, etc.

European Standard – VDE 0276-620

The oldest standard for VLF cable testing mandates a test voltage of $3V_o$ (three times line-to-ground voltage) for 60 minutes. The 60-minute duration was/is believed to be necessary to grow any and all defects, no matter how minor, through to failure during the test. This is still the practice in some parts of the world.

IEEE 400.2 Draft Standard Recommendation.

Following are excerpts from the latest draft (D3 on 10/03) of the new IEEE VLF standard.

6.1 General VLF Testing

6.1.1 VLF Test Parameters. During a VLF test an electrical tree at the site of an insulation defect is forced to penetrate the insulation. Inception of an electrical tree and channel growth time are functions of test signal frequency and amplitude. For an electrical tree to completely penetrate the insulation during the test duration, VLF test voltage levels and testing time durations have been established for the two most commonly used test signals, the cosine-rectangular and the sinusoidal wave shapes. [The High Voltage, Inc. VLF units produce a sine wave output.]

The voltage levels (Installation and Acceptance) are based on most used practices worldwide of between 2 and $3U_o$ for cables rated between 5 and 35 kV. The Maintenance test level is about 80% of the Acceptance test level. One can reduce another 20 % if more test cycles are applied [14,15,16].

Tables 3 and 4 list voltage levels for VLF withstand testing of shielded power cable systems using cosine-rectangular and sinusoidal waveforms [7, 14, 15, 19]. [Only table 4 is shown below as that applies to the sine wave VLF.] For a sinusoidal waveform the rms is 0.707 of the peak value if the distortion is less than 5%.

Table 4: VLF Hz Test Voltage for Sinusoidal Waveform¹

Cable Rating phase to phase	Installation ² phase to ground	Acceptance ² phase to ground	Maintenance ³ phase to ground
kVrms	kVrms or (kVpk)	kVrms or (kVpk)	kVrms or (kVpk)
5	9 (12)	10 (14)	7 (10)
8	11 (16)	13 (18)	10 (14)
15	18 (25)	20 (28)	16 (22)
25	27 (38)	31 (44)	23 (33)
35	39 (55)	44 (62)	33 (47)

[VLF is also suitable for higher voltage cable. HVI offers VLF up to 200 kV.]

¹ For sinusoidal VLF the voltages are given in both rms and peak values.

² The results of field tests on over 15000 XLPE cable circuits tested** showed that ~68% of the recorded failures occurred within 12 minutes, ~89% within 30 minutes, ~95% after 45 minutes 100% after 60 minutes [19]. **The recommended testing time varies between 15 to 60 minutes although the data in [19] suggest a testing time of 30 minutes.** The actual testing time and voltage may be defined by the supplier and user and depend on the testing philosophy, cable system, insulation condition, how frequently the test is conducted and the selected test method. Testing databases or [7] may be consulted when choosing a preferred testing time. When a VLF test is interrupted, it is recommended that the testing timer be reset to the original time when the VLF test is restarted.

³ For a 0.1 Hz VLF test voltage, the suggested maintenance voltage duration is 15 minutes [7].

** Data taken from VLF testing performed in Malaysia using High Voltage, Inc. VLF products.

[It comes down to engineering compromises. One can test for an hour (which is too long for many users in this country) and catch all defects, or test for 25 – 30 minutes and be satisfied that the great majority of defects were grown to failure and be willing to live with a 2 – 3% in-service failure rate over the next few years on cables that passed the VLF test. Even at 3%, the in-service failure rate would be less by multiples than if the cable was never tested or tested with DC voltage.

In addition to the years of European and North American research, an extensive review of VLF testing performed in Japan by Furukawa Electric indicated that if a cable passes a VLF test at 3Vo for 15 minutes, there is a 97% chance that the cable will not fail in service for at least three years. This data is consistent with other users experiences.]

Typical Recommendations

The goal is to test for a long enough time and at a high enough voltage to grow significant defects thru to failure but not aggravate minor defects that would not have resulted in an in-service failure in the next 5 – 10 years. **The typical test duration is 25 - 30 minutes at a voltage of 2.5 - 3Vo at 0.1 Hz.** Very important in VLF testing is that should a failure occur, the cable must be retested following the repair. Once the cable holds voltage for the full duration, one can be satisfied that 95+% of the cables tested will not contain any further defects that will result in in-service failures in the next few years.

Other data and knowledge of the cables tested is helpful. For instance, if a cable fails twice during a VLF test, both times the insulation and not accessories, then you may want to consider not continuing the test if it is known that the cable is very old and it or like cables have a history of high failure rate. Maybe stop testing, rather than cause multiple failures, and mark that cable for replacement soon. If the failures are to the accessories, then keep testing, as the VLF is a great splice checker for material problems and/or workmanship.

All of the above numbers apply to VLF testing at 0.1Hz. If lower frequencies are used, the test duration should be longer. At 0.1Hz, the period of the sine wave is 10 seconds with a peak voltage applied every 5 seconds. At 0.05 Hz, a peak voltage is applied every 10 seconds. We suggest that **if using 0.05 Hz the test time be doubled** and perhaps tripled if using lower

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frequencies. Lower test frequencies are sometimes necessary for testing highly capacitive loads; very long cables. (Most HVI models are powerful enough to allow testing all three phases at once.)

PERFORMING SPECIAL OPERATIONS

The following section contains information on the care and upkeep of your new VLF SERIES AC Hipot. There are some notes on troubleshooting and service, which will save much time and money over the life of the unit.

Meter Re-calibration

The VLF SERIES of AC hipots uses precision metal film resistors for measurement and calibration of the voltmeter. The use of these resistors in both the high voltage tank and the metering circuits has minimized circuit drift due to aging and temperature. But, a potentiometer (R4) on the voltmeter PCB can be used to correct for movement changes from the aging of the meter.

The certification of meters on a yearly basis is recommended to ensure accurate test results.

Voltmeter Re-calibration

1. Locate the unit in a position that will allow easy reading of the meters.
2. Remove the panel screws and support the panel vertically to gain access to the calibration pot on the back of the voltmeter.
3. Zero the meter movement using the zero adjustment below the scale window.
4. Perform the steps in **Setting up the Equipment** at the start of **SECTION 2**. Be sure to ground the front panel to a solid earth ground using the supplied black ground test lead prior to connecting the unit to input power.
5. Connect the output cable to a calibrated reference meter with ability to read to the full output voltage of the unit. Be sure to ground the low side of the meter.
6. Raise the output to one half scale on the unit meter. Adjust R4 as required.

7. Check calibration at both half and full scale. If the customer facility calibration certification requires more points of reference, follow those procedures instead of these.

Miscellaneous

Note: During normal operation, the control panel will heat due to the variable transformer output control. The heat exhibited is normal and does not affect the operation of the test set at all.

Oil Insulated High Voltage Tanks

The oil-filled tanks in all the VLF SERIES of hipots are field serviceable. The only requirement is that the tank must be oil filled under vacuum at re-assembly. The parts to service the tank are available from HIGH VOLTAGE, INC. at the address noted on the inside front cover of this manual.

The oil level in the tank should be .50 - .75 inches from the lid when the oil temperature is 20°C.

Weekly Maintenance Schedule

Weekly maintenance must be developed for each individual customer and their particular needs. The typical regular maintenance items are:

- 1) Keep output cable insulation and HV tank well clean. Use a clean cloth and mild solvent oil (like WD40) to remove dirt and carbon marking from use.
- 2) Watch for accumulation of dust or foreign matter in the cooling ports on the HV tank. Clean with a damp cloth as necessary.
- 3) Watch for loose clamps on the interconnect cable. Tighten as necessary.

Yearly Maintenance Schedule

Yearly Maintenance schedules must be developed for each individual customer and their particular needs. The typical required yearly maintenance items are:

- 1) Calibration verification.
- 2) Thorough cleaning of the control and cooling section of the high voltage tank.
- 3) Replacing the HV insulating oil if necessary. Approximately every 2000 hours of use.
- 4) Replacing the oil filter if necessary. Approximately every 2000 hours of use.
- 5) Replace the thermal overload on the panel if the set has been used to burn or condition cables for fault locating.
- 5) Cleaning the slug of the reversing relay on the Sine-Wave Generator to avoid sticking and loss of polarity change.

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RETURNED MATERIAL

If for any reason it becomes necessary to return any equipment or materials to High Voltage, Inc., the Service Department of High Voltage, Inc. must be notified, and authorization received, prior to the shipment of the equipment. When notified, the following information must be provided:

MODEL:
SERIAL NO:
PART NO:
REASON FOR RETURN:
SUSPECTED DEFECT:
CAUSE OF DEFECT:

With the above information provided, High Voltage, Inc. will determine if the return of the equipment is appropriate. If deemed appropriate, a Return Authorization Number will be issued. At that time, the Purchaser will be instructed how to mark and return the equipment.

The above procedure must be adhered to in order to ensure prompt service. No equipment should be returned without the prior knowledge and authorization of High Voltage, Inc.

REPLACEMENT PARTS ORDERING

To order replacement parts, first refer to the Parts List for the product in question. Every part is issued a part number. It will be necessary for this part number and the product model and serial number to be provided. When calling High Voltage, Inc. request the Service Department.

THESE TERMS AND CONDITIONS OF SALE AND LIMITED WARRANTY OF HIGH VOLTAGE, INC. ("High Voltage") SHALL BE GOVERNED BY AND CONSTRUED ACCORDING TO THE INTERNAL LAWS OF THE STATE OF NEW YORK, USA, WITHOUT GIVING EFFECT TO ITS CONFLICT OF LAWS PROVISIONS. THE RIGHTS AND OBLIGATIONS OF ALL PARTIES AND ALL PERSONS OR ENTITIES CLAIMING HEREUNDER SHALL NOT BE GOVERNED BY THE PROVISIONS OF THE 1980 U.N. CONVENTION ON CONTRACTS FOR THE INTERNATIONAL SALE OF GOODS.

1. **ACCEPTANCE.** All orders become effective only when accepted by High Voltage's written order acknowledgment at Copake, New York, USA. Unless modified in writing by an authorized representative of High Voltage, or modified in High Voltage's Quotation or order Acknowledgment, these Terms and Conditions and Limited Warranty shall solely control Purchaser's order. High Voltage expressly rejects any additional or different provisions, terms or conditions proposed by Purchaser at any time.

2. **SCHEDULING.** High Voltage's shipping date specified in High Voltage's quotation or purchase order acknowledgment is approximate and High Voltage shall use reasonable commercial efforts to effect timely shipment. Furthermore, High Voltage shall not be liable for any delay in the performance of orders or contracts or in the delivery or shipment of goods or for any damages suffered by Purchaser by reason of such delay when such delay is, directly or indirectly, caused by, or in any manner arising from Purchaser's fault, fires, floods, accidents, riots, acts of God, war, governmental interference or, embargoes, strikes, labor difficulties, shortage of labor, fuel, power, materials or supplies, transportation delays, or any other cause or causes (whether or not similar in nature to any of these hereinbefore specified) beyond the control of High Voltage.

3. **CANCELLATIONS.** Prior to shipment, Purchaser may request cancellation or delayed delivery of an order or part thereof, but such shall be conditioned upon written consent of High Voltage and upon payment to High Voltage of cancellation or delayed delivery charges to be determined by High Voltage.

4. **SALE AND DELIVERY.** Unless otherwise agreed in writing, sale and delivery of the goods hereunder shall be made EXW or FCA (Incoterms® 2010) at High Voltage's option, High Voltage's dock at Copake, New York, USA, at which time all risk of loss or damage shall pass to Purchaser. All shipments and packaging shall be made in the manner determined by High Voltage, unless otherwise requested by Purchaser, in which case any resultant additional changes and expenses shall be paid by Purchaser.

5. **TAXES.** Any and all sales, use, excise and similar taxes, and duty and all other charges levied or imposed by governmental authority, foreign and domestic, upon any goods sold or contracted to be sold shall be paid by Purchaser and added to the purchase price unless appropriate tax exemption certificates are supplied to High Voltage in form satisfactory to High Voltage.

6. **PAYMENTS.**

a. All payments shall be in US Dollars without discount unless otherwise specified in High Voltage's order acknowledgment. Credit card payments are accepted only if specified in High Voltage's order acknowledgment.

b. Terms of payment are net thirty (30) days from date of invoice, unless otherwise agreed by High Voltage in its order acknowledgment. Delinquent payments are subject to a service charge on the unpaid balance from invoice date equal to the lower of 1-1/2% per month or the maximum rate permitted by law until all amounts are paid in full. If the financial responsibility of Purchaser becomes unsatisfactory to High Voltage for any reason, or if Purchaser has been in default to High Voltage under any order, High Voltage may require full payment in cash before shipment of goods.

c. If Purchaser so requests and makes arrangements prior to shipment

which meet High Voltage's full satisfaction, High Voltage in its discretion may accept irrevocable letters of credit in its favor issued by a United States bank which is satisfactory to High Voltage.

7. **INFRINGEMENT, ETC.** On goods manufactured to Purchaser's specifications, Purchaser shall and does indemnify and hold High Voltage harmless against any claims, damages, liabilities, costs and expenses (including attorneys' fees) arising out of or resulting from actual or alleged infringement of patent, copyright, trademark or other proprietary rights, or claim of unfair trade or unfair competition arising from or occasioned by the use, possession, sale or delivery of any such goods sold by High Voltage.

8. **REPRODUCTION RIGHTS.** Drawings, specifications, reports, photographs and other data relating to all orders and all proprietary rights and interests therein and the subject matter thereof shall be and remain the property of High Voltage. Purchaser agrees that it shall not use High Voltage's drawings, specifications or other materials covered by this order, or any similar article from any other source, or reproduce the same or otherwise appropriate them, without the prior written authorization of High Voltage.

9. **LIMITED WARRANTY.**

a. High Voltage warrants to the original Purchaser of any new goods that the goods are free from defects in material and workmanship under normal use and service for a period of one (1) year from the date of shipment by High Voltage. The obligation of High Voltage under this Limited Warranty is limited, in High Voltage's exclusive option, to repair, replace with new or reconditioned parts or issue credit for goods, parts or materials which prove to be defective. Costs incurred by Purchaser for labor or other expenses to repair or replace such goods, parts and/or materials shall be the sole responsibility of Purchaser. High Voltage shall not be responsible for any damage or lack of performance resulting from: (i) defects due to accident, negligence, alteration, modification, faulty installation, abuse or misuse, whether by Purchaser, Purchaser's agents or employees, or by others than High Voltage (ii) attempted or actual dismantling, disassembly, service or repair by any person, firm or corporation not specifically authorized in writing by High Voltage, or (iii) defects caused by or due to handling by carrier, or incurred during shipment, transshipment or other move.

b. High Voltage expressly disclaims any warranty whatsoever of (i) consumables, and of (ii) parts, components, software (including but not limited to object code and source code and software user instructions), accessories, and materials not prepared, compiled or manufactured by High Voltage, and Purchaser must deal directly with such other supplier. High Voltage may elect to assist Purchaser in settling such claim against such other supplier, but any such assistance shall not prejudice High Voltage's position as to its own liability.

c. Compliance with the following Limited Warranty Claim Procedure is a condition precedent to the obligation of High Voltage under this Limited Warranty:

i. Purchaser must notify High Voltage in writing as soon as is reasonably possible, but within the applicable warranty period, of any alleged defect in material, workmanship, or operation of any goods covered under this Limited Warranty. Such notice must describe in detail the defect, any and all defective parts, and the alleged cause of the defect. No goods may be returned to High Voltage without High Voltage's prior written permission, which permission may be withheld by High Voltage in its sole discretion.

ii. At the exclusive option of High Voltage, Purchaser may be directed in writing to dismantle the goods at the Purchaser's cost and expense and ship the goods prepaid to High Voltage (refer to "Returns" Section 10 for provisions regarding the return of any goods to High Voltage). If High Voltage elects to inspect the goods at Purchaser's site, and to repair, replace,

[Section 9.c.ii. continued on page 2]

or ship the defective goods to High Voltage's factory. Purchaser, at its own cost and expense, shall provide the facilities for such work as needed to inspect and evaluate and possibly repair/replace the goods. If inspection discloses that the defect is not one for which High Voltage is liable, then Purchaser shall promptly reimburse High Voltage for all expenses incurred.

iii. Upon receipt of the defective goods, or following access to the same, High Voltage shall inspect and evaluate the goods and determine the validity of Purchaser's claim.

iv. The validity of any warranty claim, Purchaser's compliance with the Limited Warranty and Limited Warranty Claim Procedure, and the obligation to replace, repair, or issue credit for any goods are solely and exclusively to be determined by High Voltage and any determination shall be final and binding.

d. THIS WARRANTY IS EXPRESSLY IN LIEU OF ALL OTHER WARRANTIES, STATUTORY OR EXPRESSED OR IMPLIED ON THE PART OF HIGH VOLTAGE, INCLUDING THE WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT; FURTHERMORE, HIGH VOLTAGE MAKES NO WARRANTY REGARDING NON-INTERRUPTION OF USE OR SOFTWARE FREEDOM FROM BUGS. HIGH VOLTAGE NEITHER ASSUMES NOR AUTHORIZES ANY OTHER PERSON, FIRM, OR CORPORATION TO ASSUME ANY LIABILITY OR OBLIGATION IN CONNECTION WITH THIS SALE OR LIMITED WARRANTY ON HIGH VOLTAGE'S BEHALF AND PURCHASER ACKNOWLEDGES THAT NO REPRESENTATION EXCEPT THOSE MADE HEREIN HAS BEEN MADE TO PURCHASER.

10. **RETURNS.** No goods may be returned to High Voltage without High Voltage's prior written permission, which permission may be withheld by High Voltage in its sole discretion. Any request for return authorization must be in writing and include, as applicable, model number, serial number, part number, reason for return, alleged defect, and apparent cause of alleged defect. Except as specifically provided in Section 9 Limited Warranty, if High Voltage consents to return of goods: (a) all return shipments are to be via prepaid freight and with all other charges prepaid, (b) if goods are returned to High Voltage within sixty (60) days from the date of original shipment for reasons other than an error by High Voltage in filling the Purchaser's order, Purchaser shall only be entitled to receive a credit in an amount equal to the payment received by High Voltage for the goods minus (i) handling charges, and (ii) a restocking fee determined solely by High Voltage which shall not exceed twenty five percent (25%) of the invoiced amount, and (c) if goods are returned to High Voltage after sixty (60) days from the date of original shipment for reasons other than an error by High Voltage in filling the Purchaser's order, Purchaser shall only be entitled to receive a credit in the amount equal to the payment received by High Voltage for the goods minus (x) a handling fee, and (y) a restocking fee in excess of twenty five percent (25%) which shall be determined by High Voltage.

11. **SECURITY INTEREST.** In order to induce High Voltage to ship goods without full payment, Purchaser grants a security interest to High Voltage in any and all of Purchaser's right, title and interest in the goods, and Purchaser agrees to comply with any reasonable request of High Voltage to perfect such security interest. Purchaser hereby further authorizes High Voltage to perfect High Voltage's security interest in said goods and consents to filing one or more financing statements without the signature of Purchaser.

12. **ARBITRATION.** Any controversy arising out of or relating to this document, or any breach thereof, including, without limitation, any claim that this document is voidable or void, shall be submitted to final and binding arbitration before, and in accordance with, the Commercial Rules of the American Arbitration Association then in effect, and judgment upon the award may be entered in any court have jurisdiction thereof; provided, however, that this clause shall not be construed to limit any rights which

High Voltage may have to apply to any court of competent jurisdiction for equitable, injunctive or provisional relief. This arbitration provision shall be deemed self-executing, and in the event that either party fails to appear at any properly noticed arbitration proceeding, an award may be entered against such party notwithstanding said failure to appear. Such arbitration shall be conducted before a single arbitrator under the aegis of the American Arbitration Association in Columbia County, State of New York. The arbitrator shall have the authority to award expenses to the successful party.

13. **LIMITATION OF LIABILITY.** TO THE MAXIMUM EXTENT PERMITTED UNDER APPLICABLE LAW, AND NOTWITHSTANDING ANYTHING ELSE IN THIS DOCUMENT OR OTHERWISE, INCLUDING THAT HIGH VOLTAGE WAS WARNED THAT DAMAGES WOULD OCCUR OR WERE LIKELY TO OCCUR, HIGH VOLTAGE SHALL NOT BE LIABLE WITH RESPECT TO ANY SUBJECT MATTER OF THIS DOCUMENT UNDER ANY CONTRACT, NEGLIGENCE, STRICT LIABILITY OR OTHER LEGAL OR EQUITABLE THEORY FOR (i) ANY AMOUNTS IN EXCESS IN THE AMOUNT PAID TO HIGH VOLTAGE FOR THE PARTICULAR GOODS OR PART THEREOF WHICH GAVE RISE TO THE APPLICABLE CAUSE OF ACTION OR CLAIM, OR (ii) ANY INDIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES, LOST PROFITS OR LOST OR CORRUPTED DATA, OR (iii) COST OF PROCUREMENT OF SUBSTITUTE GOODS, SOFTWARE, TECHNOLOGY OR SERVICES. HIGH VOLTAGE SHALL HAVE NO LIABILITY FOR ANY FAILURE OR DELAY DUE TO MATTERS BEYOND ITS REASONABLE CONTROL.

14. **SEVERABILITY.** These Terms and Conditions and Limited Warranty are the entire understanding between Purchaser and High Voltage with respect to the subject matter hereof and supersede all prior agreements, dealings and negotiations. No modification, alteration or amendment shall be effective unless made in writing and signed by a duly authorized representative of High Voltage. No waiver of any breach hereof shall be held to be a waiver of any other or subsequent breach. Nothing contained in this document shall be construed as requiring the commission of any act contrary to law. Whenever there is any conflict between any provision of this document and any present or future statute, ordinance or regulation contrary to which the parties have no legal right to contract, the latter shall prevail, but in such event the provision of this document thus affected shall be curtailed and limited only to the extent necessary to bring it within the requirements of the law. In the event that any part, article, section, paragraph, sentence or clause of this document shall be held to be indefinite, invalid or otherwise unenforceable, the entire document shall not fail on account thereof, and the balance of the document shall continue in full force and effect. If any arbitration tribunal or court of competent jurisdiction deems any provision hereof (other than for the payment of money) unreasonable, said arbitration tribunal or court may declare a reasonable modification thereof, and this document shall be valid and enforceable, and the parties hereto agree to be bound by and perform the same as thus modified.

15. **BASIS OF BARGAIN.** Each party recognizes and agrees that the warranty disclaimers and liability and remedy limitations in this document are material, bargained for bases of their agreement and that they have been taken into account and reflected in determining the respective obligations of the parties.

[End]

