LITERATURE

ISOLATOR/SURGE PROTECTOR

DAIRYLAND
ELECTRICAL INDUSTRIES
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INTRODUCTION

The Isolator/Surge Protector (ISP) is a solid-state decoupler. The ISP provides DC blocking and AC continuity that benefits grounding in cathodically protected systems. The ISP is appropriate for applications that require greater than 15 kARMS fault currents.

ISP lightning impulse protection levels are 75kA or 100kA - similar to other Dairyland decoupler products.

ISP Applications

Cathodically protected infrastructure systems that are not deliberately designed as part of a power system may experience large transient current or voltage due to nearby power systems; during these conditions, the ISP is active as an electrical short-circuit (grounds the protected structure.)

Note that the ISP only protects against hazardous voltage at its terminals, not the measured CP voltage from a structure to a reference cell.

For example, metallic pipelines that are adjacent to power lines are sensitive to electric and magnetic fields that change in amplitude over time. These induced fields deteriorate the pipeline: either long-term (e.g. due to steady-state AC currents) or short-term (e.g. due to transient conditions of AC fault currents, may be catastrophic). Other examples of applications include:

- High Voltage Cable
- Pipe Type Cable

Features and Benefits

Dairyland ISP has a proprietary design that maximizes the benefits of solid-state components and eliminates the trade-offs of solid-state components. Solid-state switching designs benefit from:

- High reliability, long life
- No spark or arc concerns
- Inherent fail-safe (fail short) design

Dairyland ISP has a logic-controlled circuit that eliminates:

- False triggers due to a wide variety of electrical disturbances
- Difficulty resetting (transition from active to DC blocking, AC continuity)

DC Isolation Benefits

Isolation is desirable because it prevents the flow of DC current from the structure being protected (DC current is by definition steady-state current.) There are several implied benefits:

- Reduces cathodic protection system costs (e.g. number of DC sources, lower power costs)
- Minimizes the effect of stray currents induced in an area far from the DC source

AC Continuity Benefits

AC continuity between ISP terminals allows flow of steady-state AC currents via grounding (a.k.a. bonding) between a protected structure and a grounded structure. These currents are supplied by nearby AC sources and either conduct or are induced into the protected structure and find a path to electrical ground. Any unintentional path to ground may affect the integrity of the protected structure.

ISP provides a very low resistance (preferential) path for these steady-state AC currents in order to direct their flow to the grounded structure (away from the protected structure.) Benefits include:

- Local control of undesirable AC corrosion effects of protected structures
- Prevents gradual accumulation of hazardous voltage that may harm humans or equipment

Systems That Experience AC Power Fault Transient Conditions

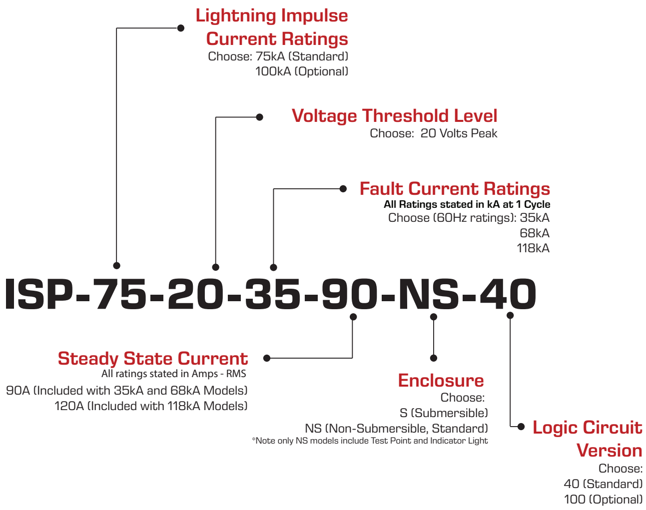
Unlike other Dairyland decoupler products, the ISP protects against the electrical fault hazards (transient conditions) often seen in pipe type cable protection that may be seen in transmission or distribution substations.

ISP continually monitors voltage across its terminals with logic-controlled circuitry. Upon detection of a transient condition that presents a hazard, its solid-state switch closes in an active state that creates a direct path to the grounded structure.

Systems Subject to Lightning Impulse Transient Conditions

Similar to other Dairyland decoupler products, ISP provides a short across its terminals for the duration of a lightning impulse current.

ISP MODEL SELECTION



Format for ISP Model Number: ISP-L-V-FC-AC-S-RC

L (Lightning Impulse) designation:

Lightning Impulse is specified as kilo-Amps maximum crest current during an 8x20 µs waveform (per IEC 62.2). ISP lightning impulse applies only to its terminals; additional voltage through ISP connection wires must be considered for structure voltage protection (see installation instructions.)

V (Trigger Voltage) designation:

ISP Trigger Voltage is 20V standard and is interpreted as the maximum blocking voltage across the ISP terminals. Testing ISP in an isolated condition, the ISP may become active (trigger) between 15V and 30V or more.

Once ISP is installed in its intended circuit (in-situ), steady-state AC current and the specific model of ISP will change observed trigger voltage (see AC Steady-State Current Designation and related graph in Figure 2).

When total voltage across the terminals of the ISP exceed this voltage threshold level, it transitions to active operation (short-circuit.)

FC (Fault Current) designation:

Dairyland ISP products are specified with 1-cycle fault current values in the Product Number (the -FC value). These 1-cycle fault current values have multi-cycle equivalent values that are calculated for convenience in Fig. 5. Comparing an application need often requires these multi-cycle equivalent values.

All values in k_{ARMS} (multiply by 1,000 for values in Amps RMS), all values 60Hz

-AC value (1-cycle)	35	68	118
3-cycle	28	55	96
10-cycle	21	40	75
30-cycle	11	14	54

Figure 1: Multi-Cycle I2T equivalent values for ISP (-FC designation)

For most applications, substation is the source of the estimated maximum fault current that may appear on a protected structure.

NOTE: in field conditions, the magnitude of the current during the first few cycles can be up to 1.7 times greater than an AC_{RMS} symmetrical value. To accommodate a transient fault condition with this excess current, Dairyland suggests choosing an ISP with a 10-cycle fault current rating greater than or equal to available symmetrical AC_{RMS} value from the power utility distribution or transmission system.

AC (Steady-State Current) designation:

The steady-state current rating (AC designation) of the ISP is the maximum steady-state AC current that can flow through the ISP while it is still blocking DC.

The ISP AC rating is determined by the DC voltage plus the peak AC voltage developed across the ISP terminals. As long as the sum of DC voltage plus peak AC voltage is below the appropriate line in Figure 2, the ISP blocks DC while conducting AC. If the sum rises above the appropriate line in Figure 2, the ISP becomes active (terminals are electrical short). That is, |VDC| + VPeak AC < 20V.

Note that two steady-state AC current ratings are available. If the ISP is installed where the steady-state current is above rating, the ISP is protected from failure, but is not blocking DC current. If this condition occurs on an ISP with a non-submersible enclosure, a red indicator mounted on the ISP cover will flash intermittently. This indicates the ISP may be applied above its steady state rating.

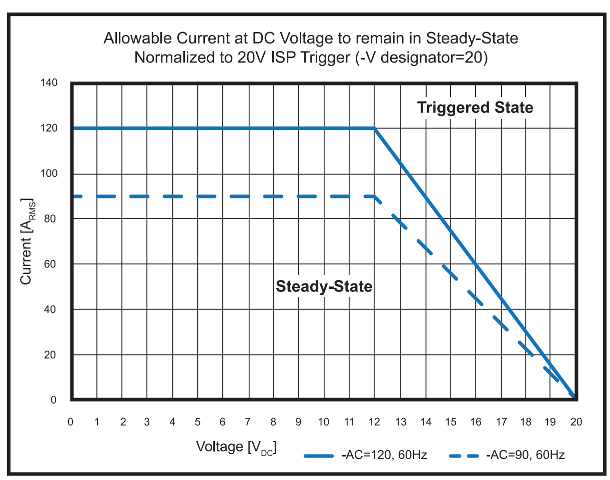


Figure 2: Trigger Voltage derating curve for Steady-State Current and Voltage parameters

If a specific application requires it, the DC leakage current may be measured and considered (see installation instructions.) For most ISP applications, DC leakage is insignificant.

S (Submersible or Non-Submersible Enclosure) designation:

All enclosures are 14 gauge #304L stainless steel, powder coat painted ANSI 61 light gray, non-bonded to either terminal.

The submersible enclosure designation (-S) indicates:

- 100% leak tested to NEMA 6P / IP67 equivalent
- indicator light and test point are not available

The non-submersible enclosure designation (-NS) indicates:

- rain tight to NEMA 4X / IP66 equivalent
- additional standard features include red indicator light and test point

The red indicator light illuminates upon triggering due to terminal voltage at or above the trigger voltage.

RC (DC Reset Current) designation:

This designation indicates the maximum DC current reset ability of ISP immediately following active / grounding operation.

As the ISP resets (ISP transitions back to DC blocking, AC continuous operation), if a DC current is present, the ISP Logic Circuit attempts to reset the ISP. Standard is 40A DC reset current and optional 100A DC reset current are available.

ISP THEORY OF OPERATION

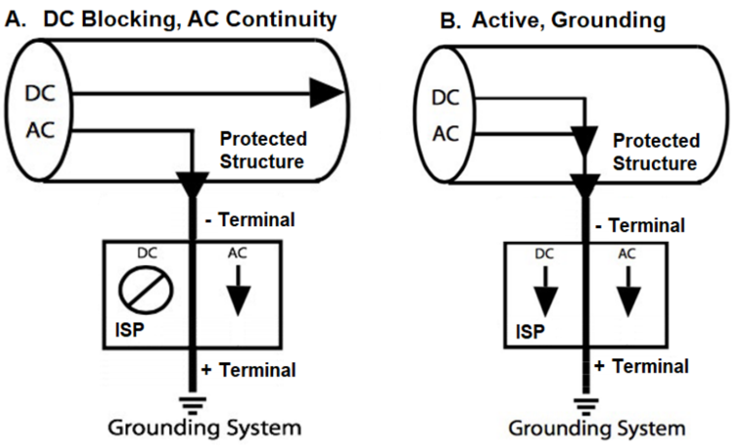


Figure 3: Visual Depiction of ISP operation

ISP OPERATION - VISUALIZATION

As illustrated in Fig. 3A, the **DC Blocking, AC Continuous** ISP presents high impedance to DC and low impedance to AC steady-state currents. This inactive mode continues while the voltage across the terminals is below the trigger voltage.

As illustrated in Fig. 3B, the **Active** ISP presents low impedance to all electrical current (both DC and AC). When a transient condition causes the terminal voltage to rise beyond the trigger voltage, ISP will activate with a very low-resistance short, reducing the voltage at the terminals to a fraction of its previous value in the DC Blocking, AC Continuous operation. Briefly after this change to active state, very large currents through this low resistance develop voltage that may exceed the trigger voltage.

The active ISP remains actively grounding until the logic-controlled circuitry detects the hazardous transient condition is no longer present. At this moment, the ISP will reset (return to the DC blocking, AC continuous operation. This reset (to DC blocking, AC continuous operation) may not succeed if DC current exceeding 40A is present; for this reason, an optional ISP with up to DC 100A reset capability is available.

ISP STATES — FUNCTIONAL DETAILS

Internal Components of a single ISP service different electrical conditions in either the untriggered or triggered state; see Fig. 4 below. (Note the 118kA ISP model is a combination of two of the below schematics with appropriately rated components.)

NOTE: Failure mode of all components within the ISP is short-circuit. In the event of electrical hazards in excess of specifications, please choose applications for ISP only where this fail-short mode of failure is safe and acceptable.

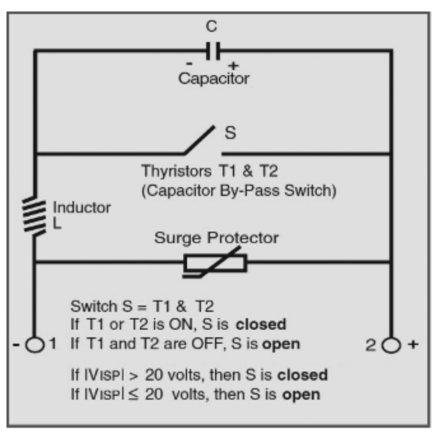


Figure 4: Simplified Internal Schematic of single ISP
(118kA ISP model is combines two single ISP models side-by-side.)

DC Blocking, AC Continuous Operation: Decoupling of DC and AC steady-state Currents

Fig. 5 depicts the path in which AC steady-state current will flow while blocking DC currents (I_1).

The switch (S) and the Surge Protector appear as high-impedance components while no hazardous voltage is present at the terminals. The capacitor (C) sets a primary impedance in this mode of operation. There is some negligible voltage drop due to the series inductor (L).

Negligible current flows in the other two current paths (I_2 and I_3 are both blocked.)

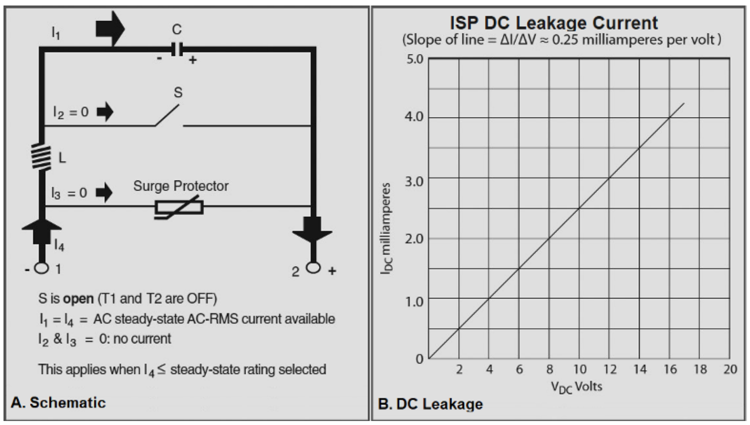


Figure 5A: Schematic showing primary AC steady-state current path through untriggered ISP

Figure 5B: DC Leakage current through ISP depends upon DC terminal voltage $|V_{ISP}|$

A relatively small DC leakage current is present during DC Blocking, AC Continuous operation. Fig. 5B provides an estimate of expected DC Leakage current that depends upon the DC voltage available at the terminals.

NOTE: Persistent triggering into active mode must be avoided when DC Blocking, AC Continuous operation is expected. Persistent triggering of ISP occurs when the current through the ISP is large enough to develop a voltage in excess of the trigger voltage for one minute or more. If this condition is present, it often indicates a problem within the facility or application.

Active Operation: Short-Circuit to all AC and DC signals

There are two kinds of triggered states which may occur in an ISP, due to either **AC Fault Current Hazards** or **Lightning Impulse Hazards**.

AC Fault Current Hazards are suppressed with switch (S), as shown in Fig. 6, which closes to conduct the fault current hazard I_4 through current path I_2.

This solid-state switch is composed of two anti-parallel solid-state thyristor components. The switch (S) trigger signal is controlled with a logic circuit that detects hazardous events at the ISP terminals and filters steady-state ISP events.

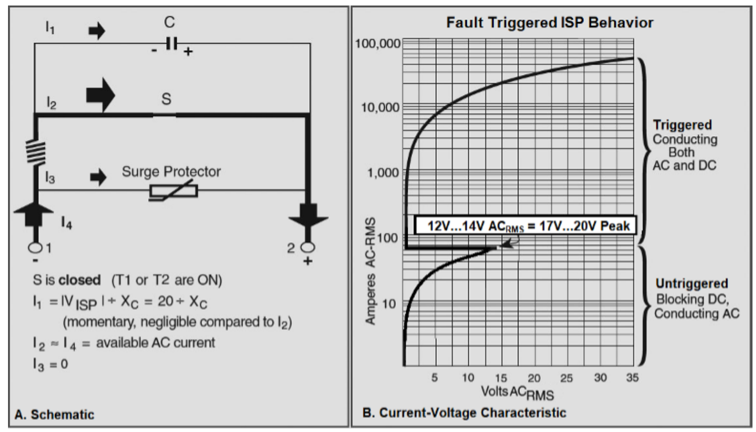


Figure 6A: Schematic showing primary fault-triggered current path.

Figure 6B: Current-Voltage Characteristics when ISP is fault-triggered.

The Volts ACRMS value of the X-axis may be converted to peak and interpreted $|V_{ISP}|$

Normally, thyristor switches reopen only when the input current commutes (changes polarity) each half-cycle of the input waveform (every 8.8ms for 60Hz, 10ms for 50Hz). This presents an undesirable behavior in cathodically protected systems, which always have a steady-state DC current present.

- This steady-state DC current prevents reset from active operation to DC blocking, AC continuous operation.
- In other words, switch S never re-opens, the ISP terminals appear "stuck" short-circuit even after the hazardous condition clears.

The presence of the inductor (L) further exacerbates this possibility, because it releases its stored energy to ensure current continues in the same direction internally (behind the ISP terminals.)

The Dairyland ISP solves this undesirable short-circuit "stuck" behavior by ensuring the switch (S) is reopened in the presence of DC current. Dairyland's logic-controlled circuit will both dissipate stored inductor energy following a hazardous event and force the thyristor open; this effectively resets the ISP to DC blocking, AC continuous operation.

Lightning Impulse Hazards are arrested primarily with the **Surge Protector** component, which is composed of Metal-Oxide Varistor (MOV) technology. As depicted in Fig. 7, the total lightning current I_4 (which is the specified current rating) divides between I_2 and I_3 current paths within the ISP.

The voltage at Terminal 1 in Fig. 7 increases or decreases (depending on the direction of current) very rapidly with respect to the other Terminal 2.

- The **Surge Protector** (MOVs) immediately responds to suppress this fast rise in terminal voltage.
- 85% of total input current I4 is directed through path I3.

The inductor (L) in the schematic slows current change through the switch (S) path and forces current I_4 primarily through I_3 path (Surge Protector path).

- Although the current is slowed in the I_2 path, it will eventually increase until the voltage exceeds the **ISP trigger voltage** and switch (S) will close.
- 15% of total input current I_4 is directed through path I_2

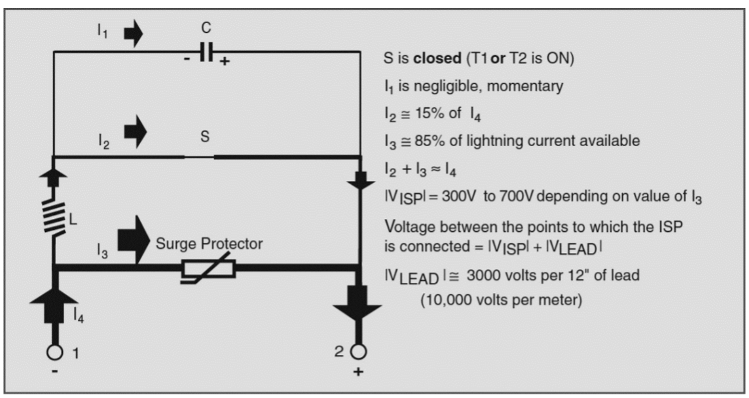


Fig. 7: Current paths through ISP during lightning impulse hazard

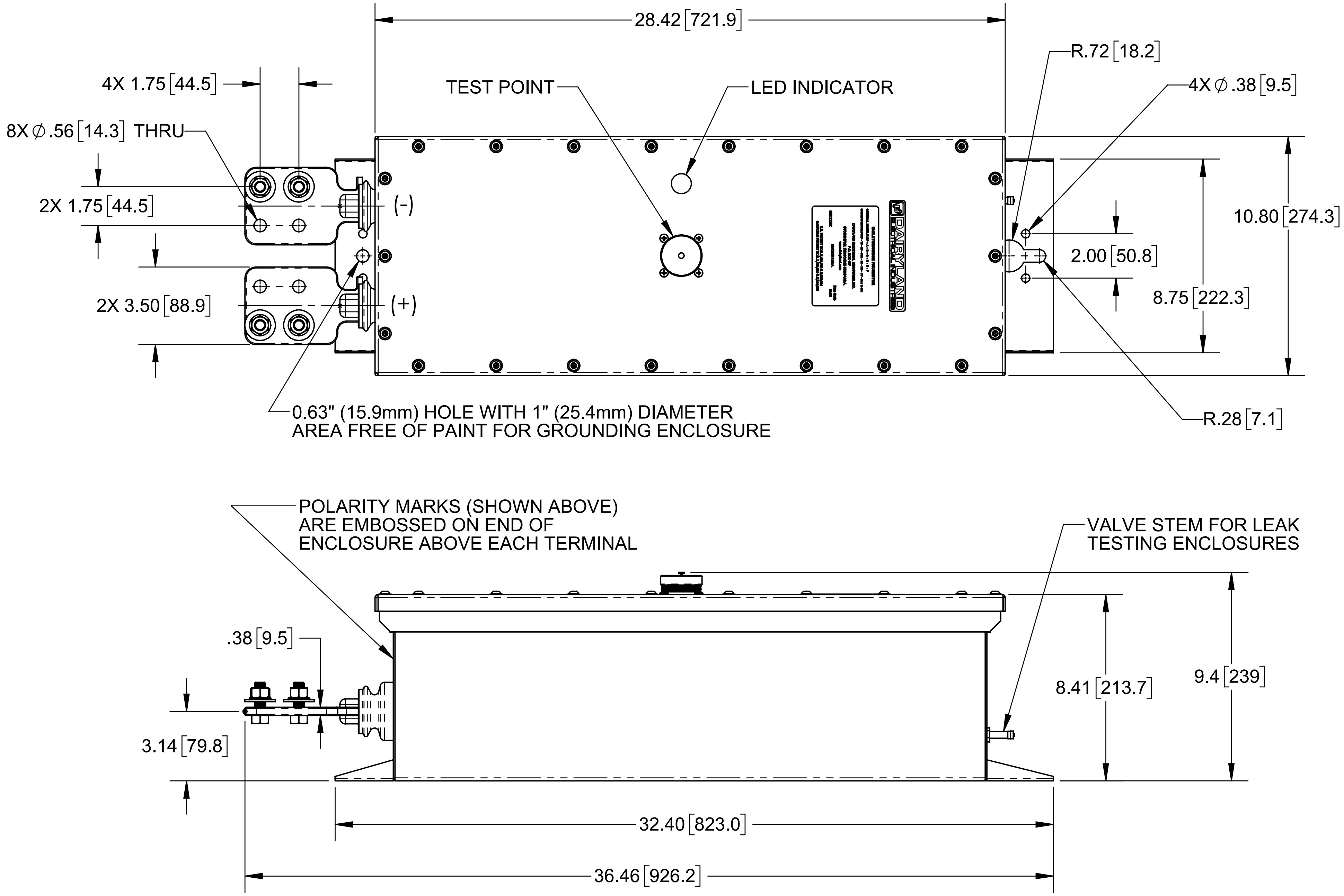
Total voltage from the protected structure to the grounded structure during this active operation due to lightning strike is equal to $|V_{ISP}| + |V_{LEAD}|$.

- **$|V_{ISP}|$ is the resulting voltage across the ISP terminals.** It is determined by voltage-to-current relationships of each active current path (I_2, I_3) mentioned previously. Typical values of $|V_{ISP}|$ are between 300V and 700V (depends mostly upon I_3).

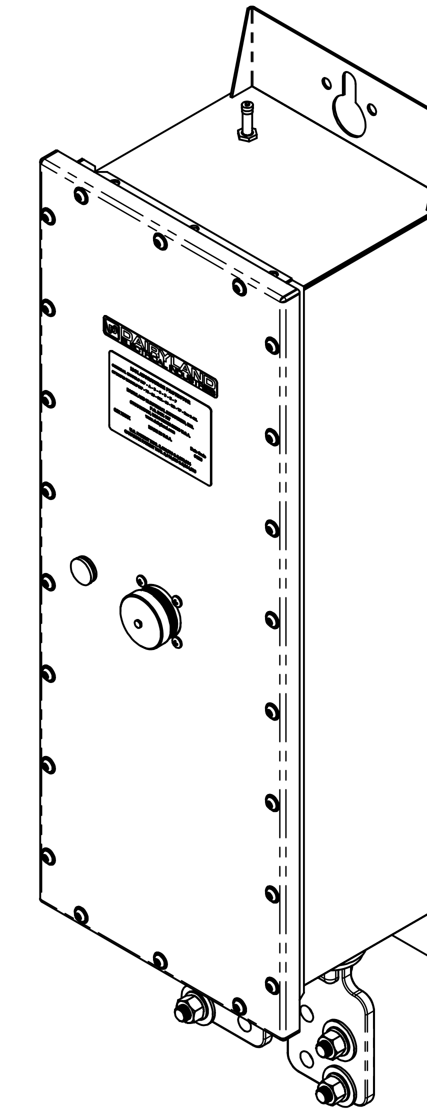
- **$|V_{LEAD}|$ is additional voltage across ISP wires.** During brief lightning hazards, inductance inherent in wires connected to the ISP causes additional voltage at the protected structure. Typical values are greater than 1,500V per foot of connecting wire for ISP installation.

Total voltage appears for a time inferred from the lightning impulse duration; as specified per standards and ISP specifications, 8 microseconds to crest (maximum), then 20 microseconds to decay to half value.

Similar to the AC Fault Current condition, the lightning impulse will close the semiconductor switch (S) and the Dairyland logic circuit control ensures it re-opens even in the presence of cathodically protection (in the presence of steady-state DC current.)



35kA/68kA ISP



ISOMETRIC VIEW

NOTE:

1. THE TEST POINT AND LED INDICATOR ARE ONLY AVAILABLE WITH A NON-SUBMERSIBLE ENCLOSURE AND ARE NOT AVAILABLE ON THE SUBMERSIBLE ENCLOSURE.

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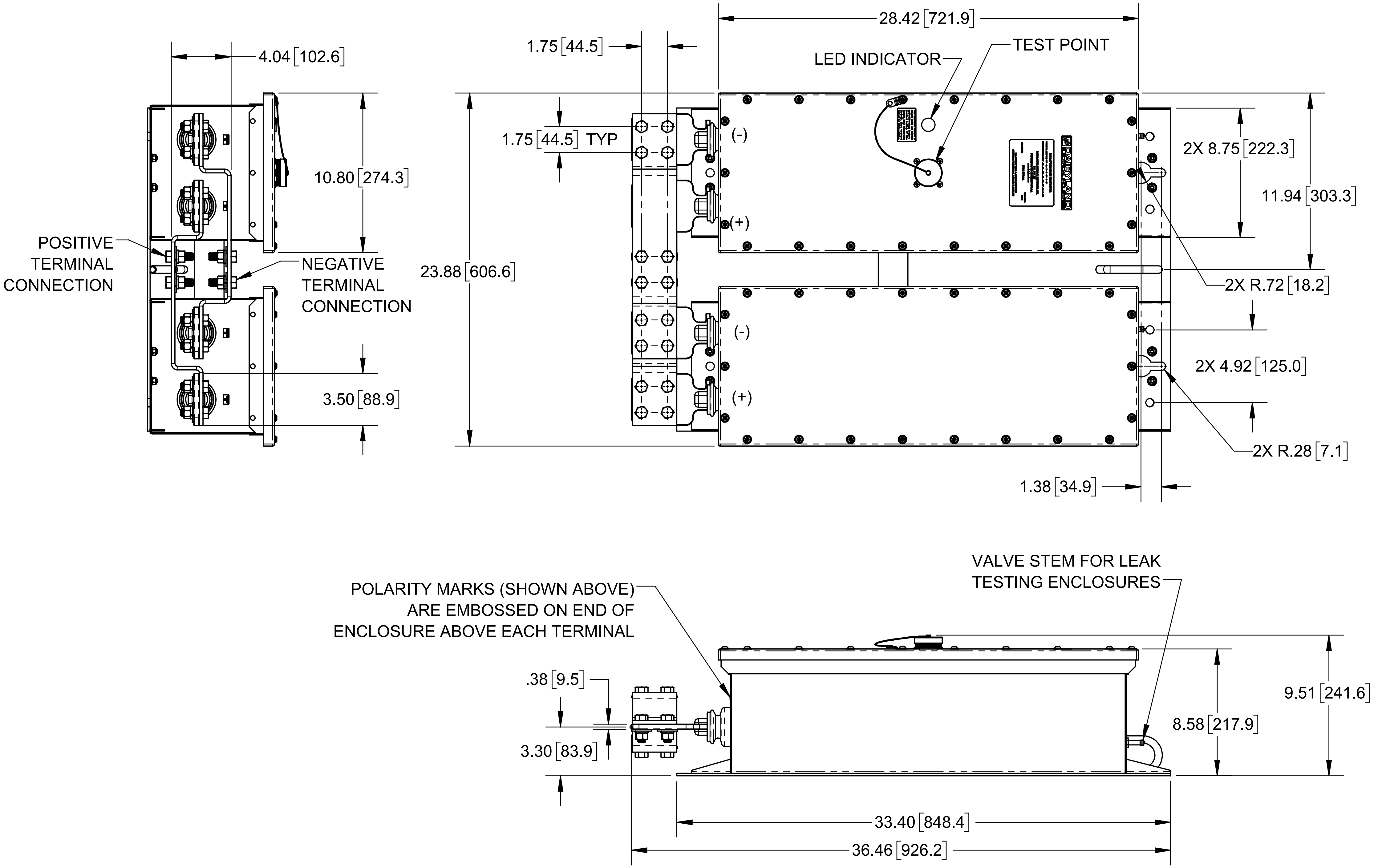

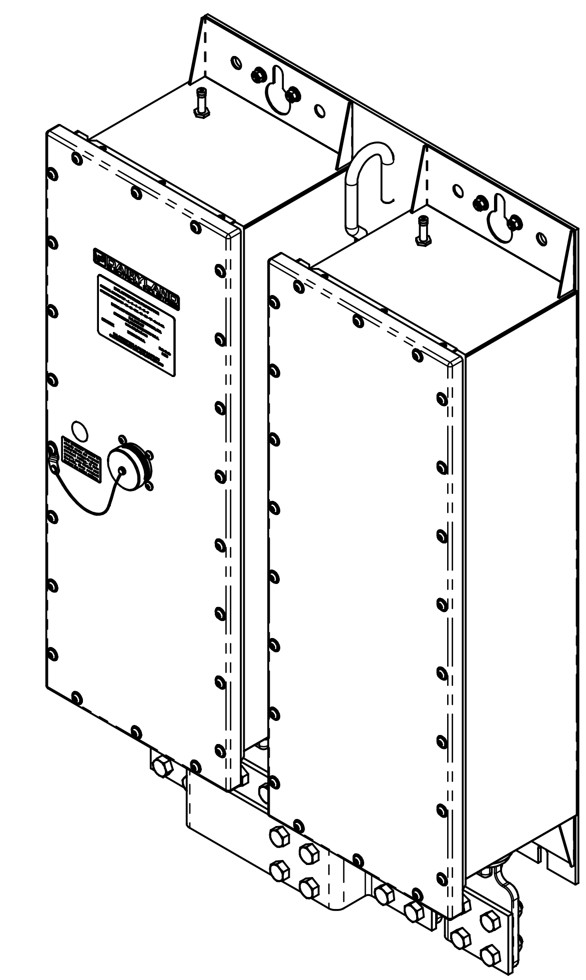

ISOMETRIC VIEW

118kA ISP

NOTE:

1. 118kA RATED ISP NOT AVAILABLE IN SUBMERSIBLE VERSION.

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