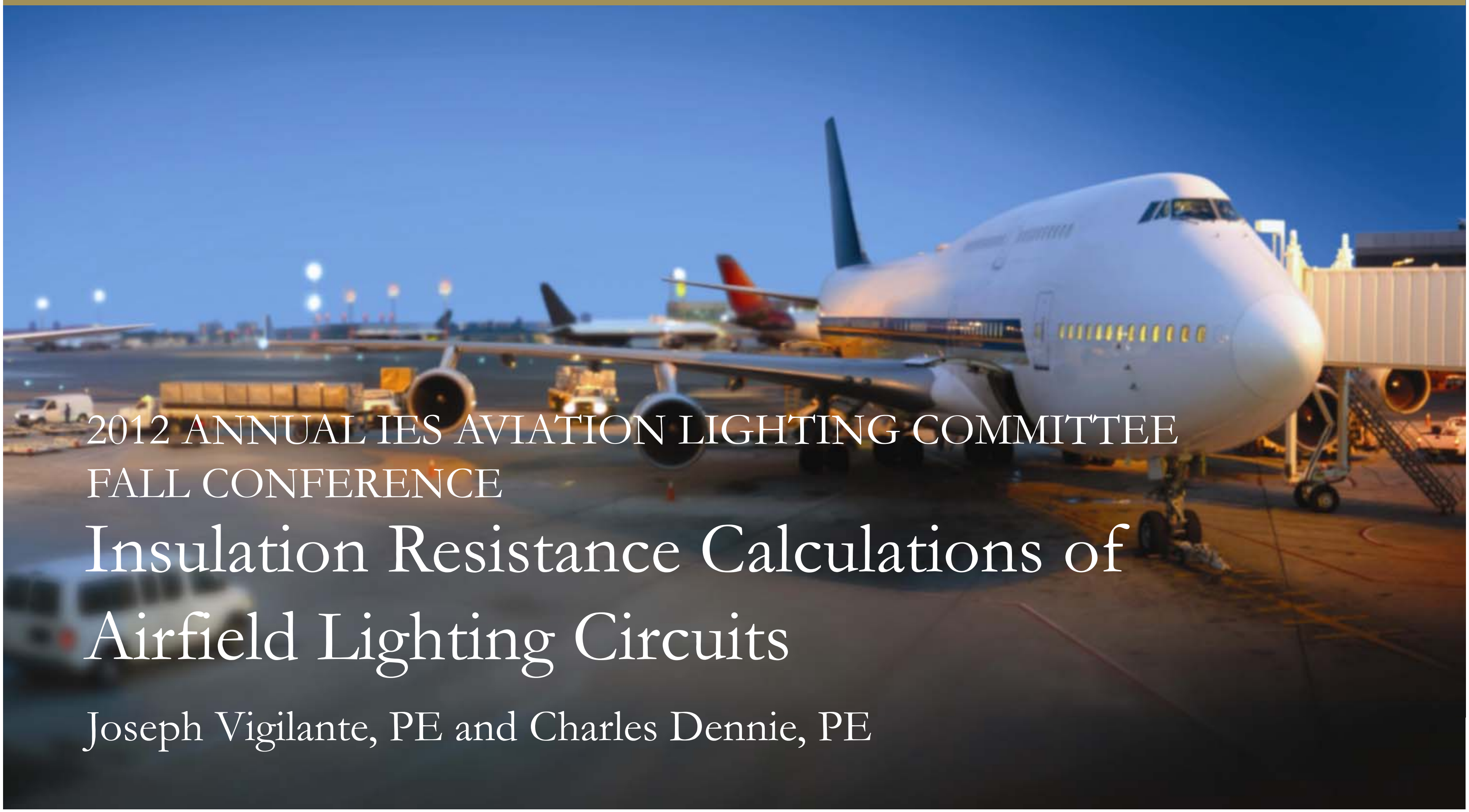
THE Burns GROUP ENGINEERING AND CONSTRUCTION



2012 ANNUAL IES AVIATION LIGHTING COMMITTEE
FALL CONFERENCE

Insulation Resistance Calculations of Airfield Lighting Circuits

Joseph Vigilante, PE and Charles Dennie, PE

Presentation Agenda

- Driving Factors
- Cable insulation resistance (IR) background
- FAA IR guideline recommendations
- Formula development
- Airfield lighting circuit calculations
- Presentation summary
- Why calculate circuit IR during design
- Open Q&A

Objective

To initiate a practice of analyzing AFL circuits during design utilizing both load and insulation resistance calculations to provide a minimum obtainable value for construction verification and maintenance practices.

Driving factors

- Circuit load is only half the story
- Disappointing field results
- Specifying a “given” is scary

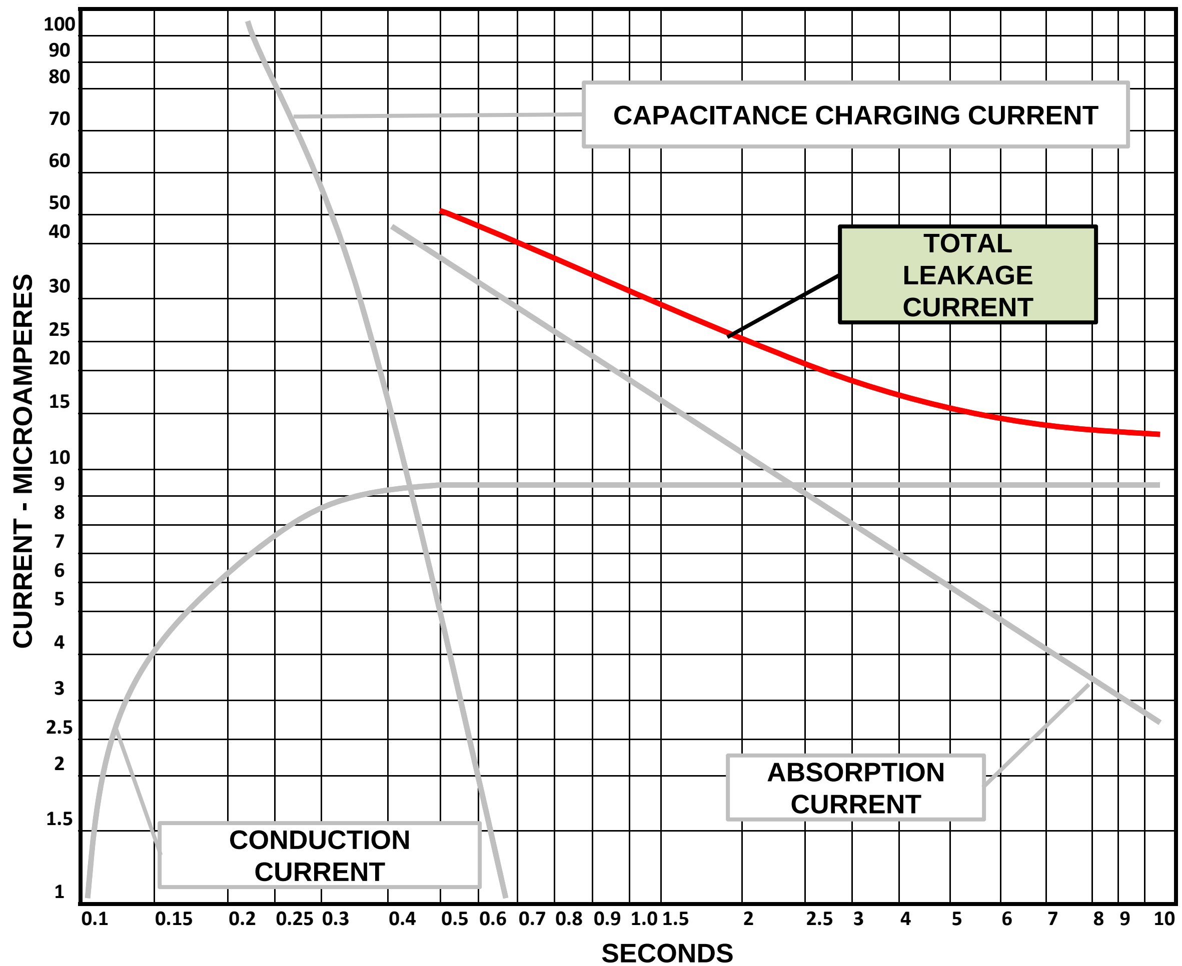
Insulation resistance background

- IR measured value
- Factor of applied voltage and leakage current
- Understand characteristics of leakage current

Anatomy of insulation current flow

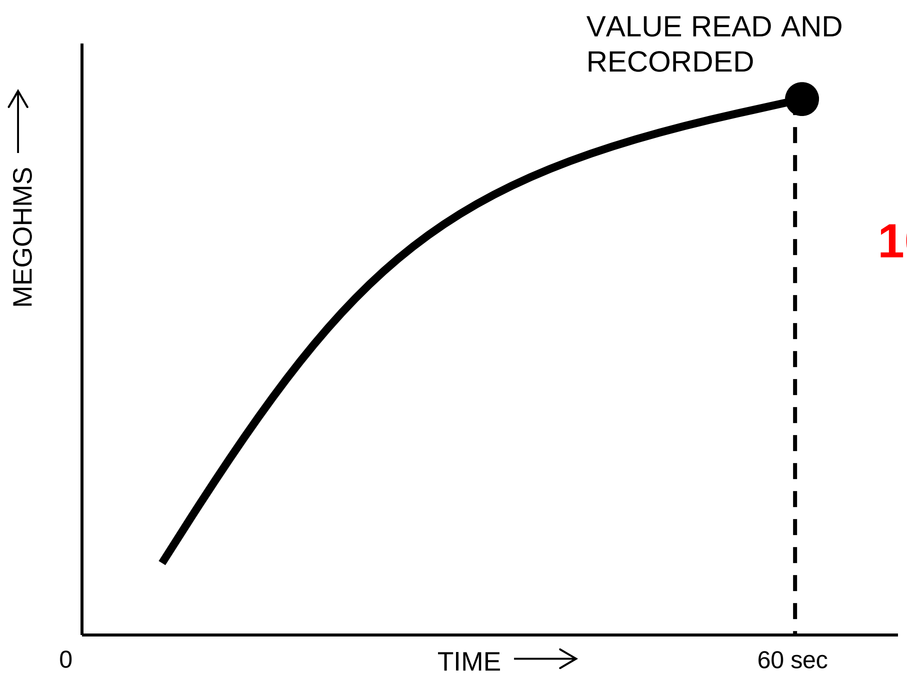
- Capacitance charging currents, ***C***
- Absorption current, ***AC***
- Conduction current, ***CC***

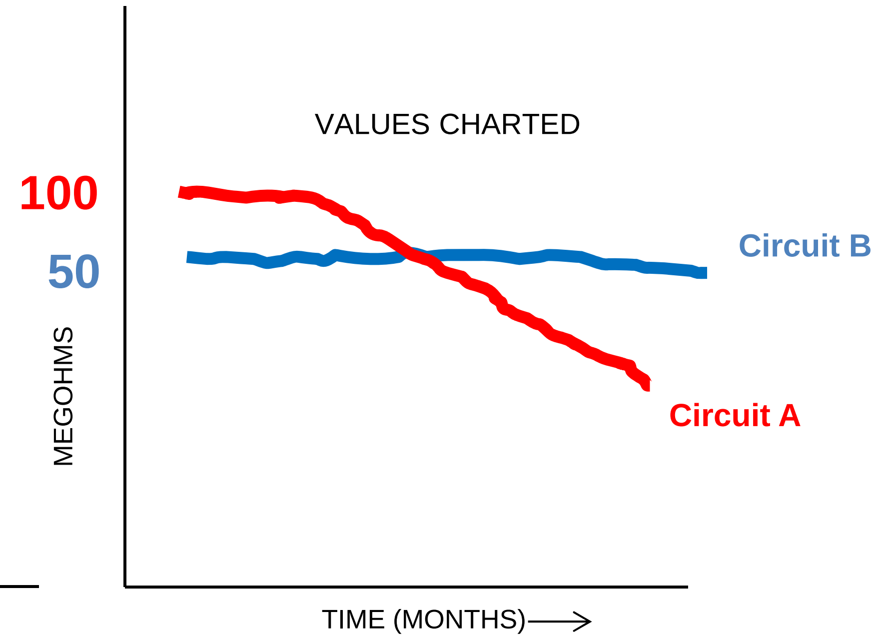
Anatomy of insulation current flow



Types of insulation resistance testing

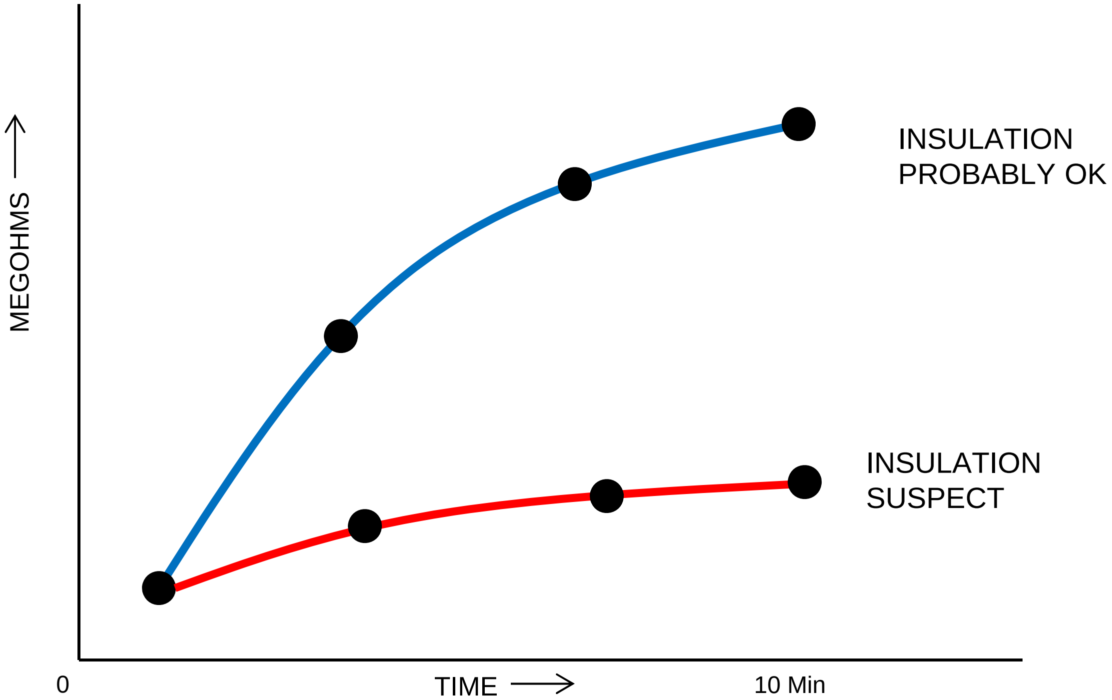
Short-time/spot reading





Types of insulation resistance testing

Time-resistance method



Testing airfield lighting circuits

- AC 150/5340-30G, *Design & Installation Details for Airport Visual Aids* - Chapter 12, Equipment & Material, Section 13, Testing
  - 50MΩ Non-grounded series circuits
  - FAA-C-1391, *Installation & Splicing of Underground Cable*

Resistance values for maintenance

- AC 150/5340-26B, *Maintenance of Airport Visual Aid Facilities*
  - Suggested minimum maintenance values
    - *10,000 ft. or less* - **50MΩ**
    - *10,001 ft. – 20,000 ft.* - **40MΩ**
    - *20,001+ ft.* - **30MΩ**

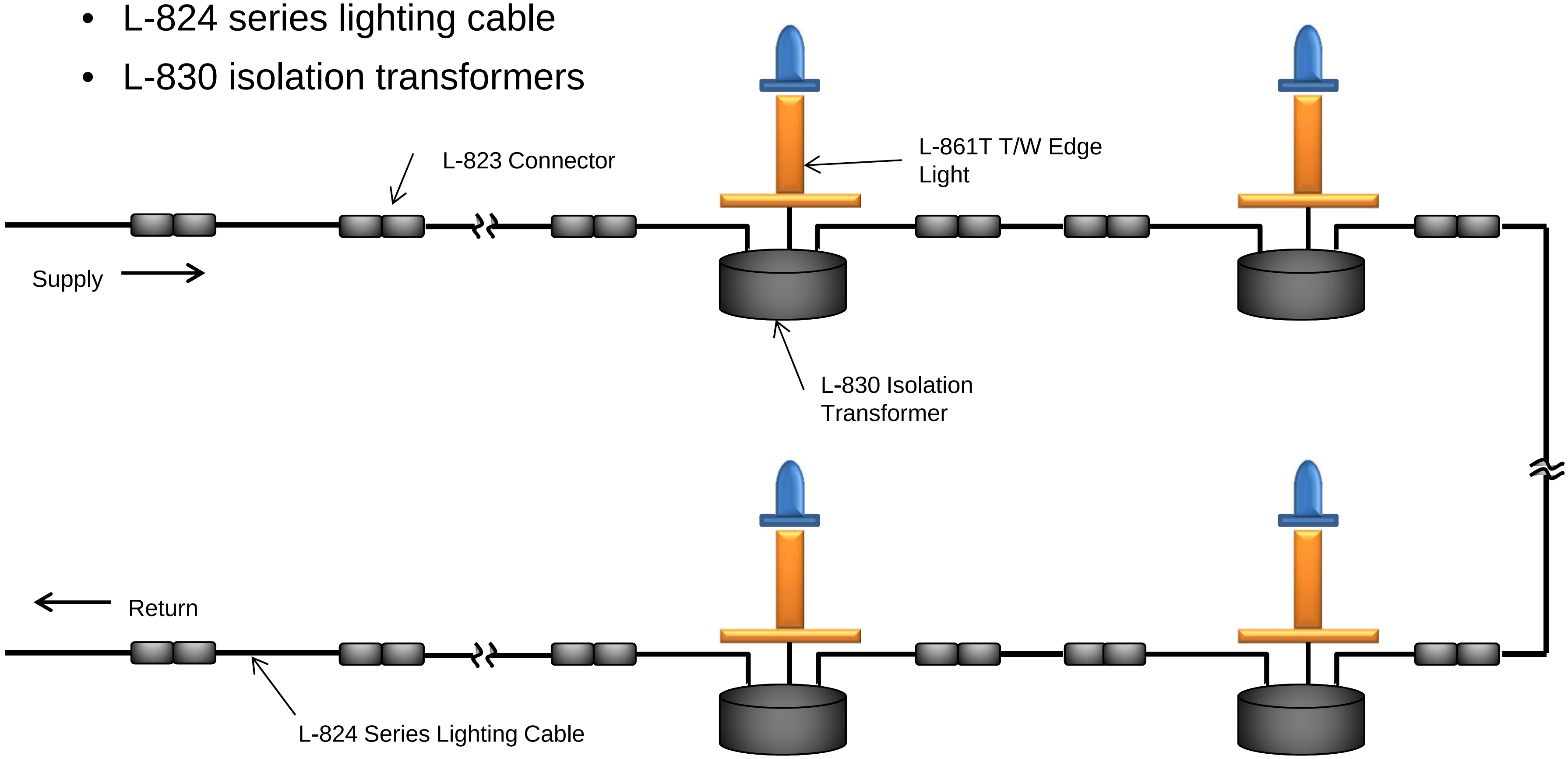
FAA-C-1391 Installation & Splicing of Underground Cables

- Spot Test – take readings no less than 1 minute after readings stabilized
- Cable IR values reduced to the length
- Circuit IR reduced due to parallel summation

Airfield circuit anatomy

Three circuit components

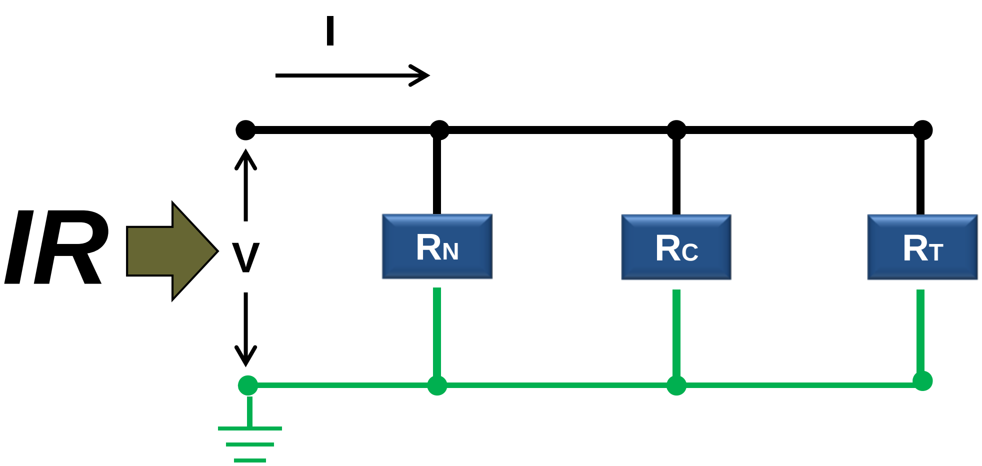
- L-823 cable connectors
- L-824 series lighting cable
- L-830 isolation transformers



Series circuit insulation resistance

Constant current series lighting circuit

- Combine similar components to reduce circuit
- Parallel summation from conductor to ground



$$IR = \frac{1}{\frac{1}{Rn} + \frac{1}{Rc} + \frac{1}{Rt}} M\Omega$$

FAA minimum IR value

L-824 airfield cable

AC 150/5345-7E, *Specification for L-824 Under ground Electrical Cable for Airport Lighting Circuits*

- Table 1, Test #9 > ICEA S-96-659, Section 7.11.2
- Corresponding to IR Constant 50,000 MΩ @ 1000 ft. @ 60°F

Cable expression

The insulation resistance of cable for a given length is expressed by the following formula:

$$RC = K * Log\left(\frac{D}{d}\right) * \left(\frac{1000}{L}\right)$$

Where:

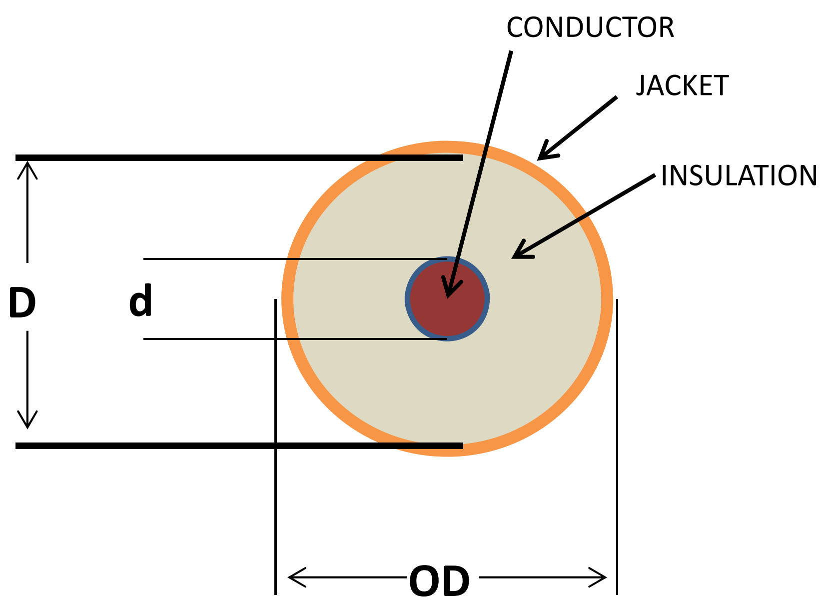
- RC = Insulation resistance in MΩ of cable
- K = Specific IR in MΩ @ 1000ft @ 60˚ F of insulation
- D = Outer diameter of insulation
- d = Outer diameter of bare copper wire
- L = Length of airfield cable in feet

Value of K for EPR insulation = 50,000 Megohms

Cable expression

FAA L-824 TYPE B AIRFIELD LIGHTING CABLE

Conductor Size	Stranding	Insulation Thickness mils (mm)	Jacket Thickness mils (mm)	Approximate Cable O.D. In (mm)
8 AWG	7	90 (2.3)	30 (0.76)	0.420 (10.7)
6 AWG	7	90 (2.3)	30 (0.76)	0.460 (11.7)
4 AWG	7	90 (2.3)	30 (0.76)	0.505 (12.8)



OD=10.7mm
D= 9.18 mm
d= 4.58 mm

Cable expression

$$RC = K * Log\left(\frac{D}{d}\right) * \left(\frac{1000}{L}\right)$$

RC = 50,000 * Log (9.18/4.58) * (1,000/L)

RC = 15,098,860 / L MΩ

FAA minimum IR value

L-823 cable connectors

AC 150/5345-26D, *FAA Specification for L-823 Plug and Receptacle, Cable Connectors*

- Section 5.1 – Type I Connectors 75,000 MΩ

Connector expression

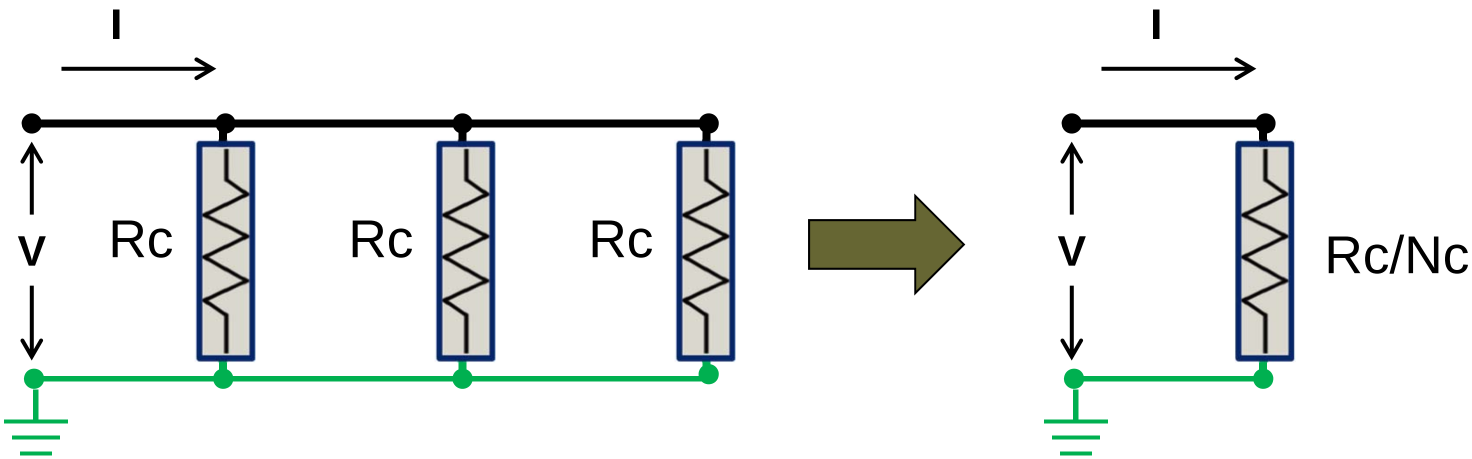
The insulation resistance of L-823 connector splices is expressed by the following formula:

$$RN = Rc/Nc$$

Where:

- RN = Insulation resistance in Megohms of all connectors
- Rc = IR of an individual L-823 connector splice
- Nc = Quantity of L-823 connector splices

Connector expression



Rc = 75,000 MΩ

RN = 75,000/Nc

FAA minimum IR value

L-830 isolation transformers

AC 150/5345-47C, *Specification for Series to Series Isolation Transformers for Airport Lighting Systems*

- Table 3 Insulation Resistance 7,500 MΩ

Table 3. Insulation Resistance

Winding under Test	Voltage Applied (kV DC)	Minimum Insulation Resistance (Megohms)	Maximum Leakage Current (Micro amps)
Hot/Cold Primary for transformers up to 150 W	15.0	7500	2.0
Hot/Cold Secondary for transformers up to 150 W	5.0	2500	2.0
Hot/Cold Primary for transformers over 150 W	15.0	3000	5
Hot/Cold Secondary for transformers over 150W	5.0	1000	5

Isolation transformer expression

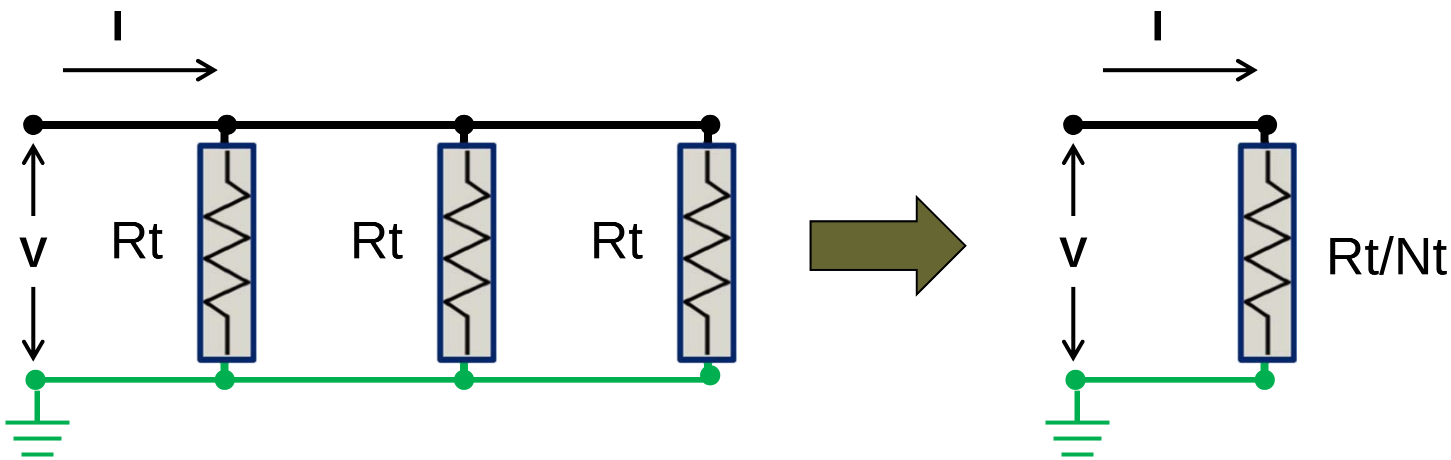
The insulation resistance of L-830 isolation transformers is expressed by the following formula:

$$RT = Rt/Nt$$

Where:

- RT = Insulation resistance in Megohms of all transformers
- Rt = IR of an individual L-830 isolation transformers
- Nt = Quantity of L-830 isolation transformers

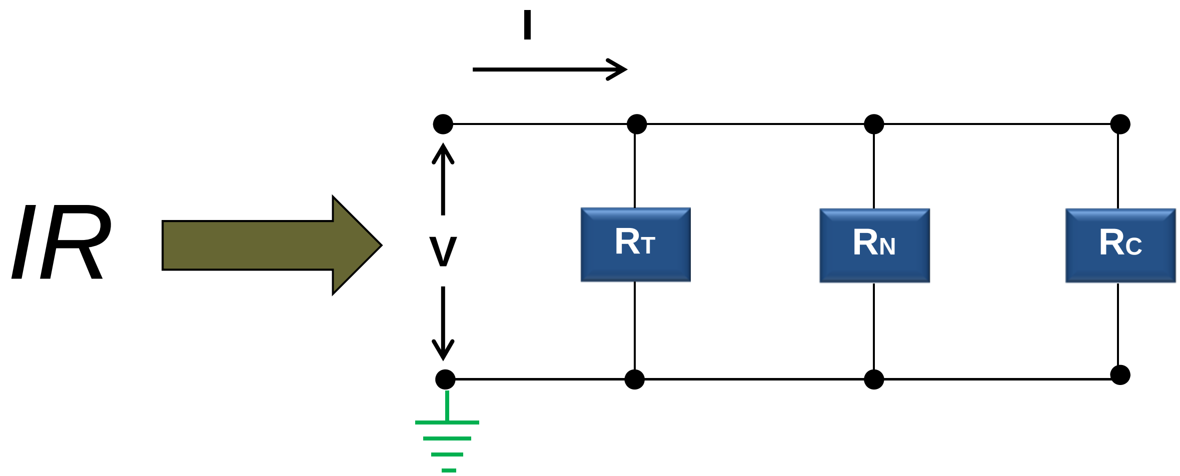
Isolation transformer expression



Rt = 7,500 MΩ

RT = 7,500/Nt

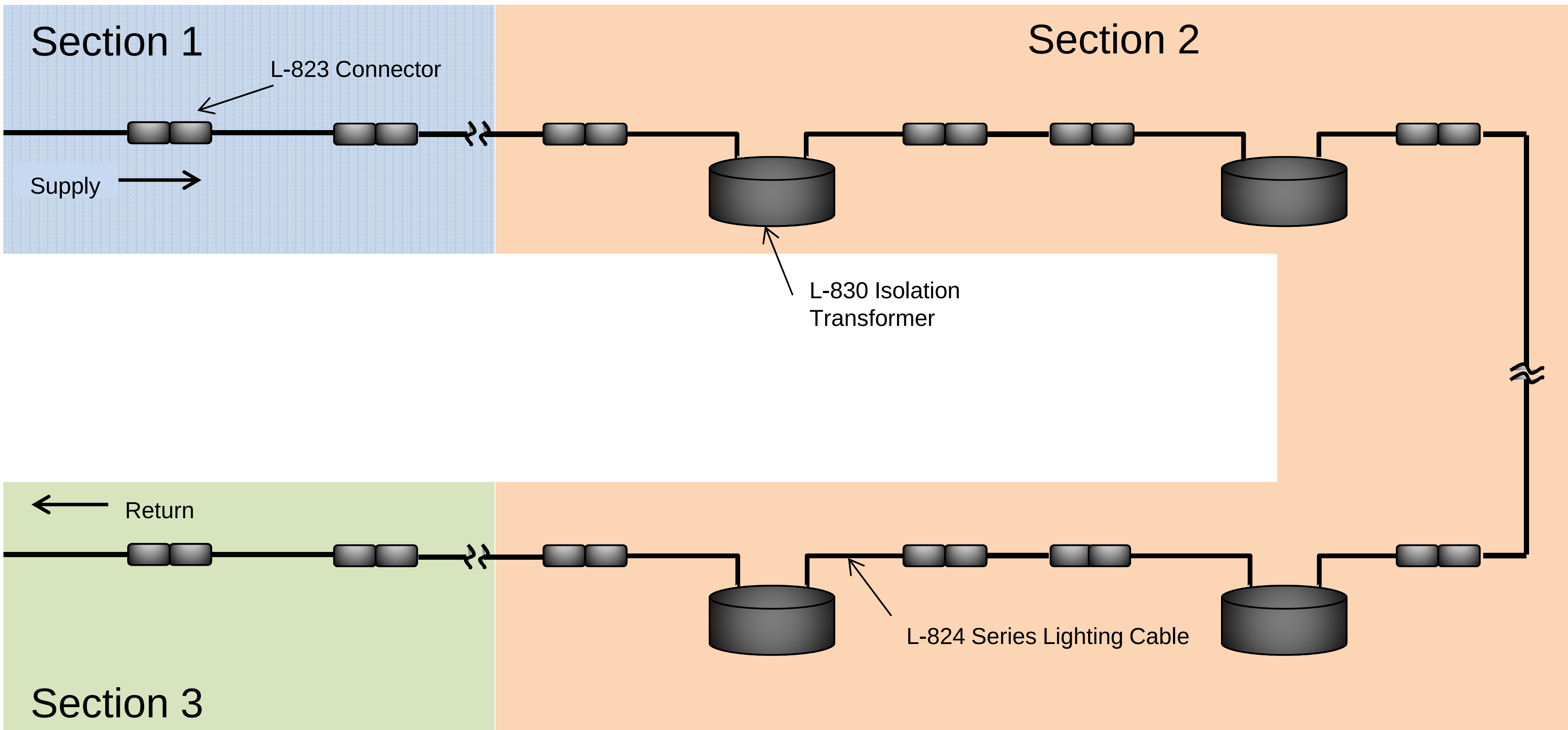
Root IR formula



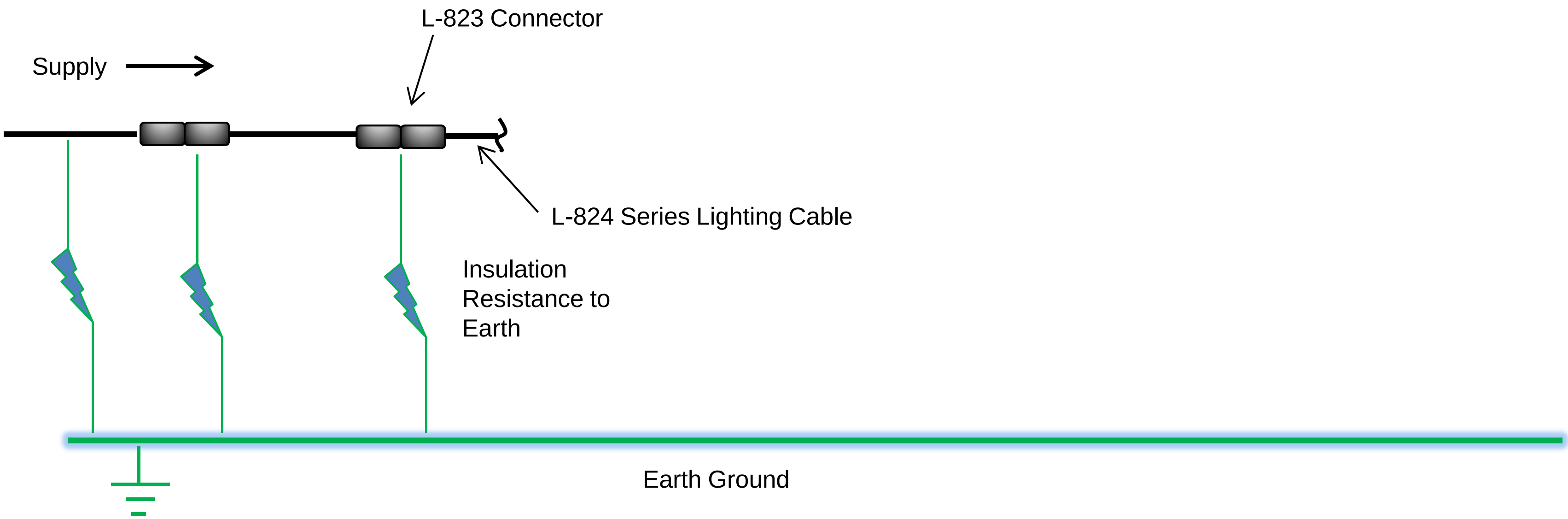
1/IR = 1/RC + 1/RN + 1/RT

$$IR = \frac{1}{\frac{L}{15{,}098{,}860} + \frac{Nc}{75{,}000} + \frac{Nt}{7{,}500}} M\Omega$$

Applying IR formula



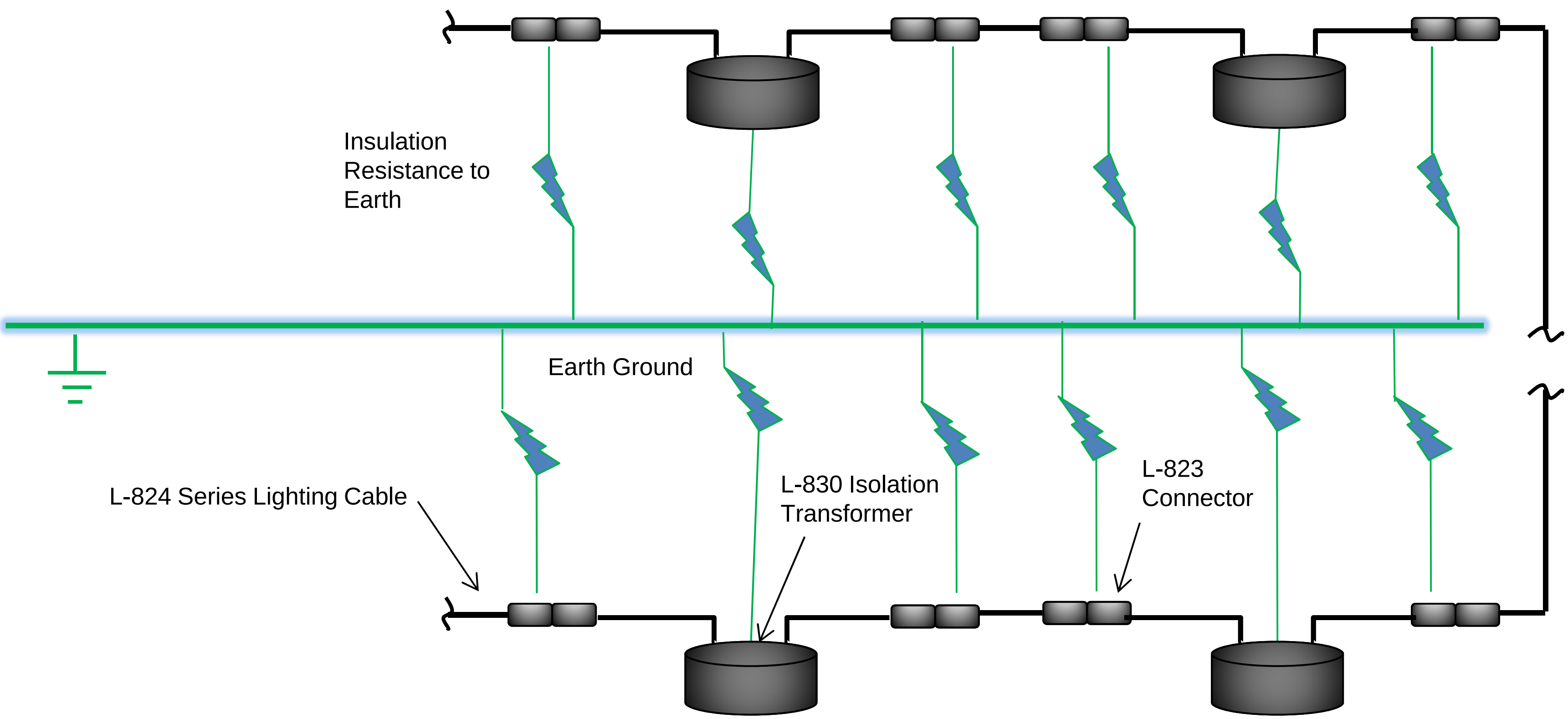
Developing IR calculation formula



$$\frac{1}{IRsection\ 1} = \frac{L}{15{,}098{,}860} + \frac{Nc}{75{,}000} \quad M\Omega^{-1}$$

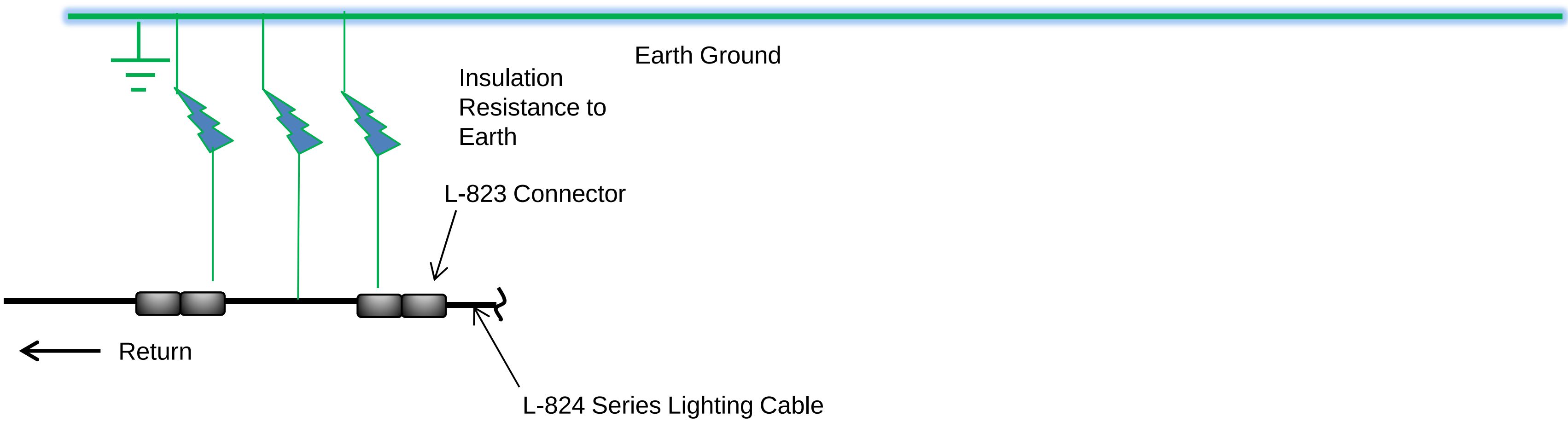
Developing IR calculation formula

$$\frac{1}{IRsection\ 2} = \frac{L}{15{,}098{,}860} + \frac{Nc}{75{,}000} + \frac{Nt}{7{,}500} \quad M\Omega^{-1}$$

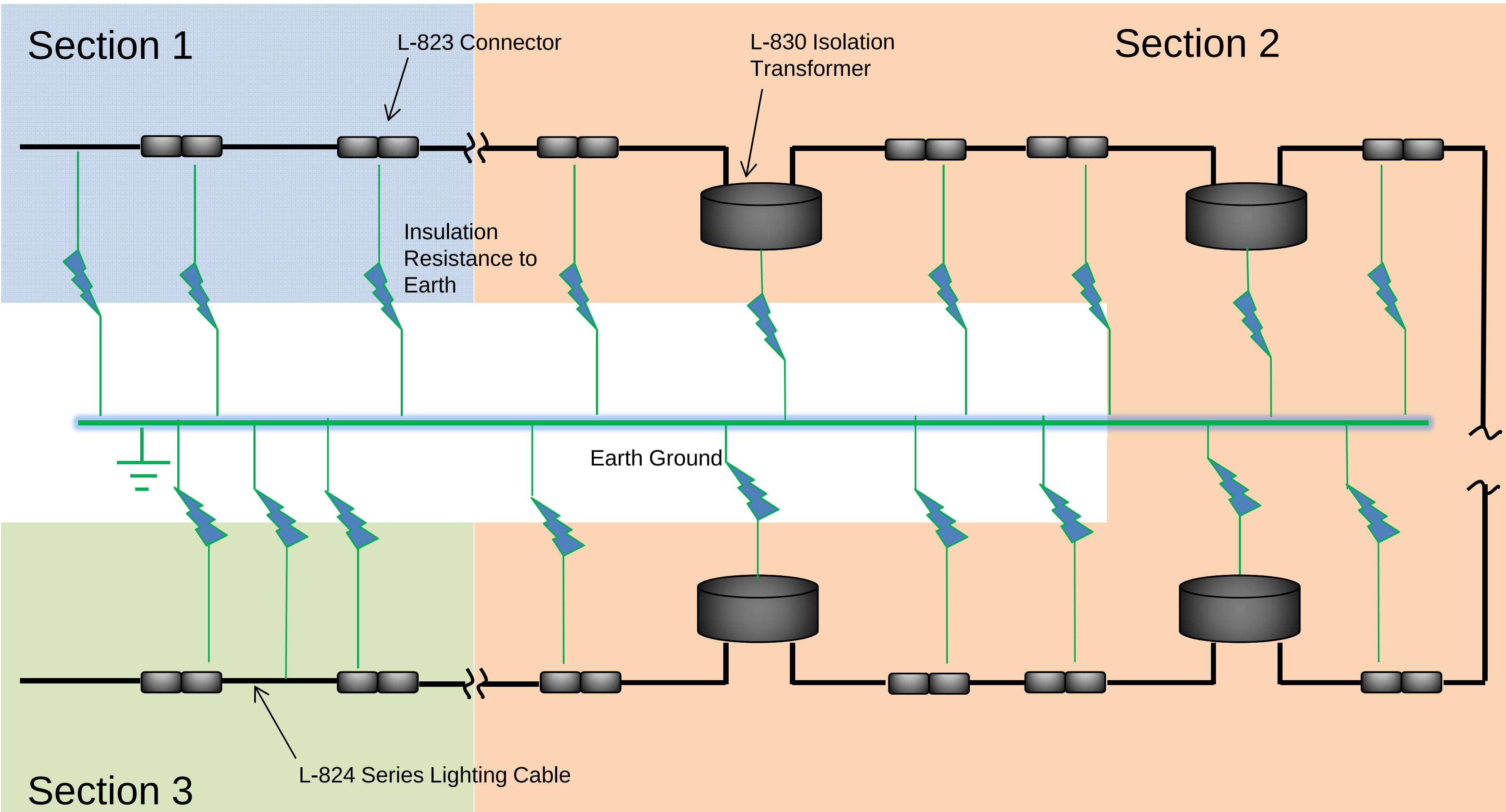


Developing IR calculation formula

$$\frac{1}{IRsection\ 3} = \frac{L}{15{,}098{,}860} + \frac{Nc}{75{,}000} \quad M\Omega^{-1}$$



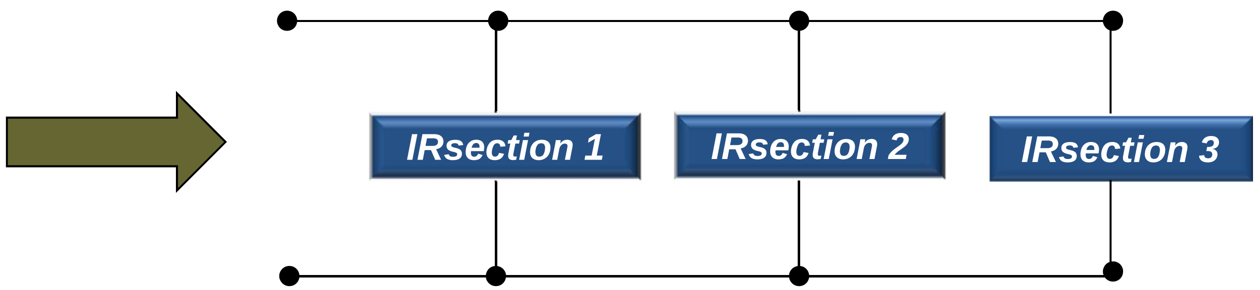
Developing IR calculation formula



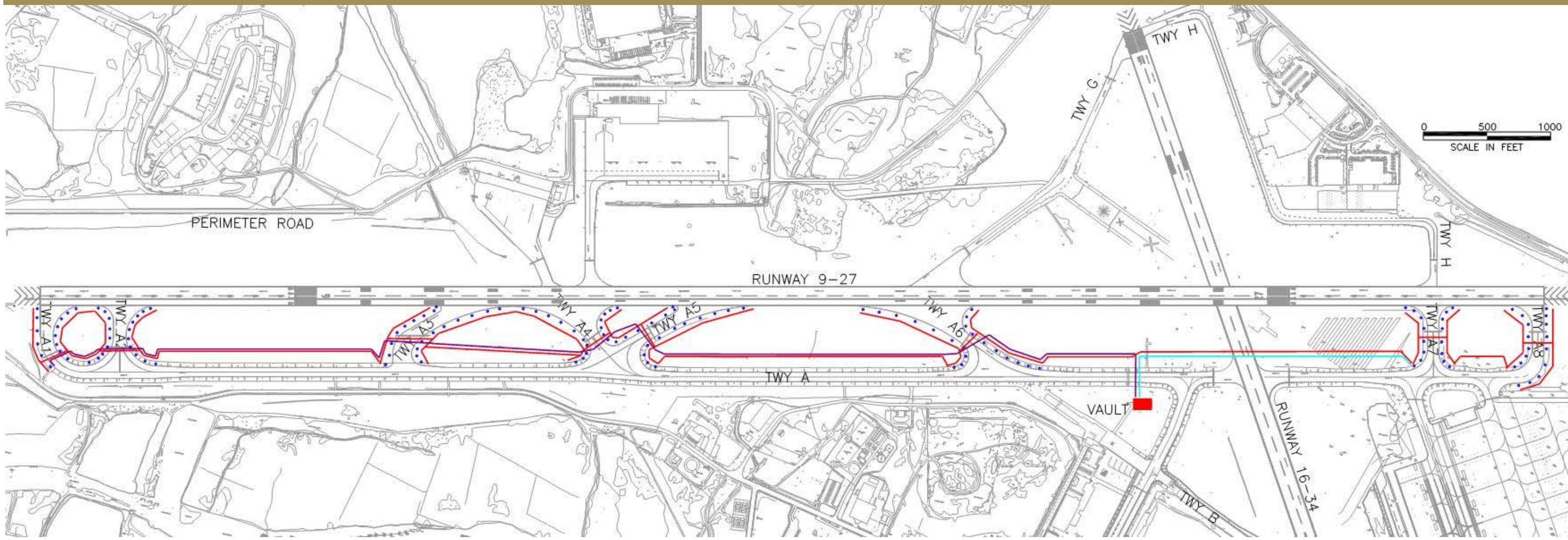
Developing IR calculation formula

$$IRtotal = \frac{1}{\frac{1}{IRsection\ 1} + \frac{1}{IRsection\ 2} + \frac{1}{IRsection\ 3}}\ \text{M}\Omega$$

IR total



Sample calculation



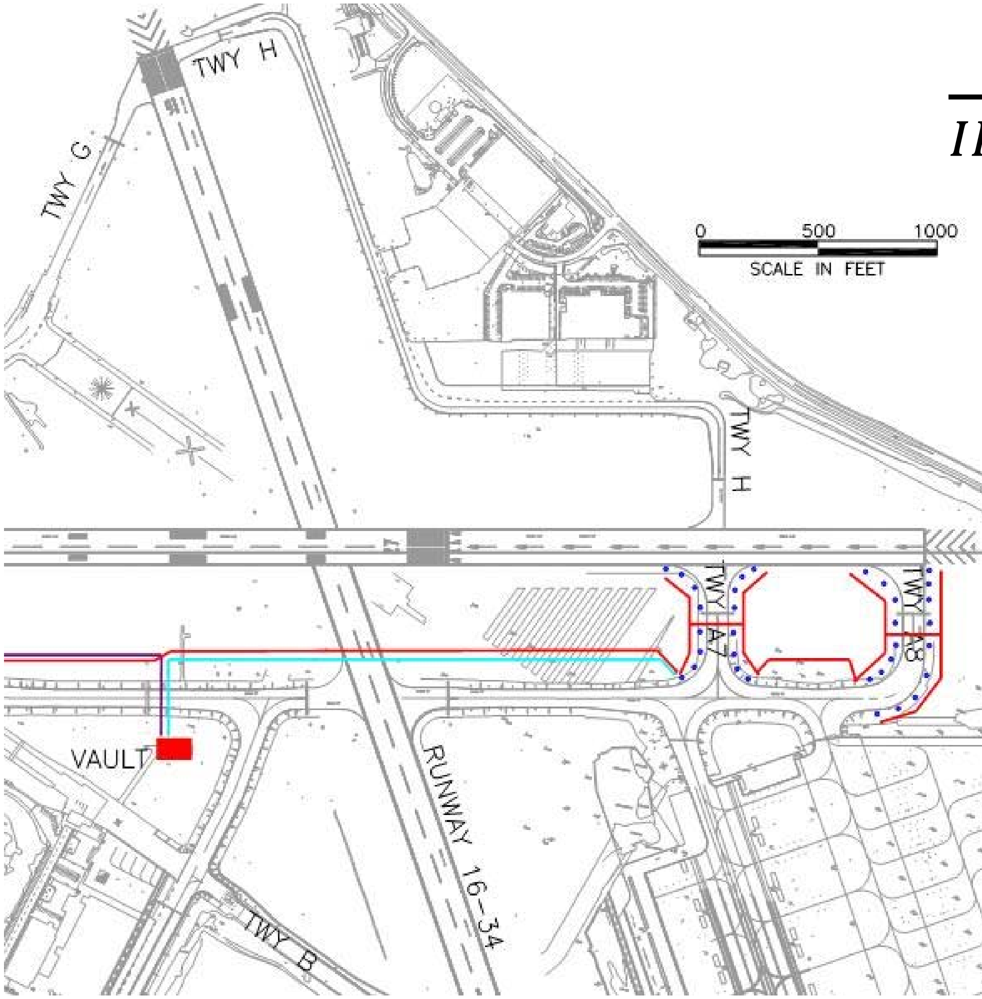
Section 1:
Cable = 4,000 feet
Connectors = 4
Isolation XFMRs = 0

Section 2:
Cable = 37,500 feet
Connectors = 400
Isolation XFMRs = 185

Section 3:
Cable = 10,500 feet
Connectors = 14
Isolation XFMRs = 0

Load Calc:
Cable = 52,000 feet
Fixtures = 140
Circuit Load = 9.34kW

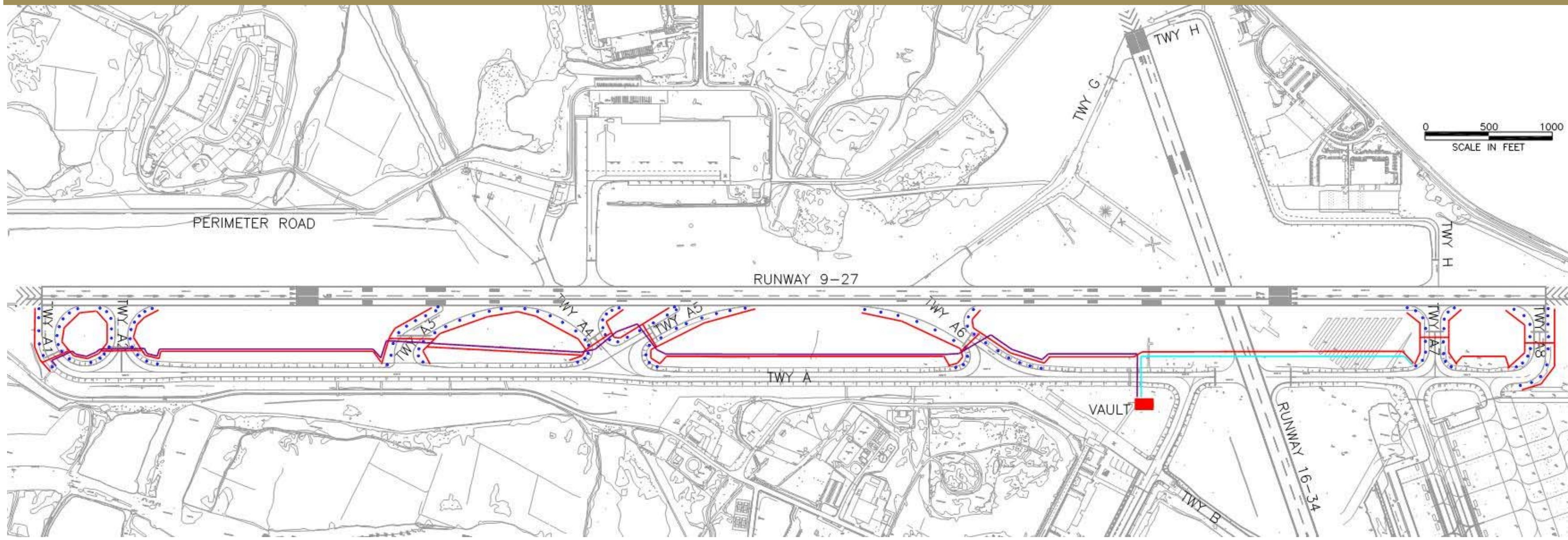
Sample calculation - section one



$$\frac{1}{IRsection\ 1} = \frac{4000}{15,098,860} + \frac{4}{75,000}$$

IRs1= $3,142\ M\Omega$

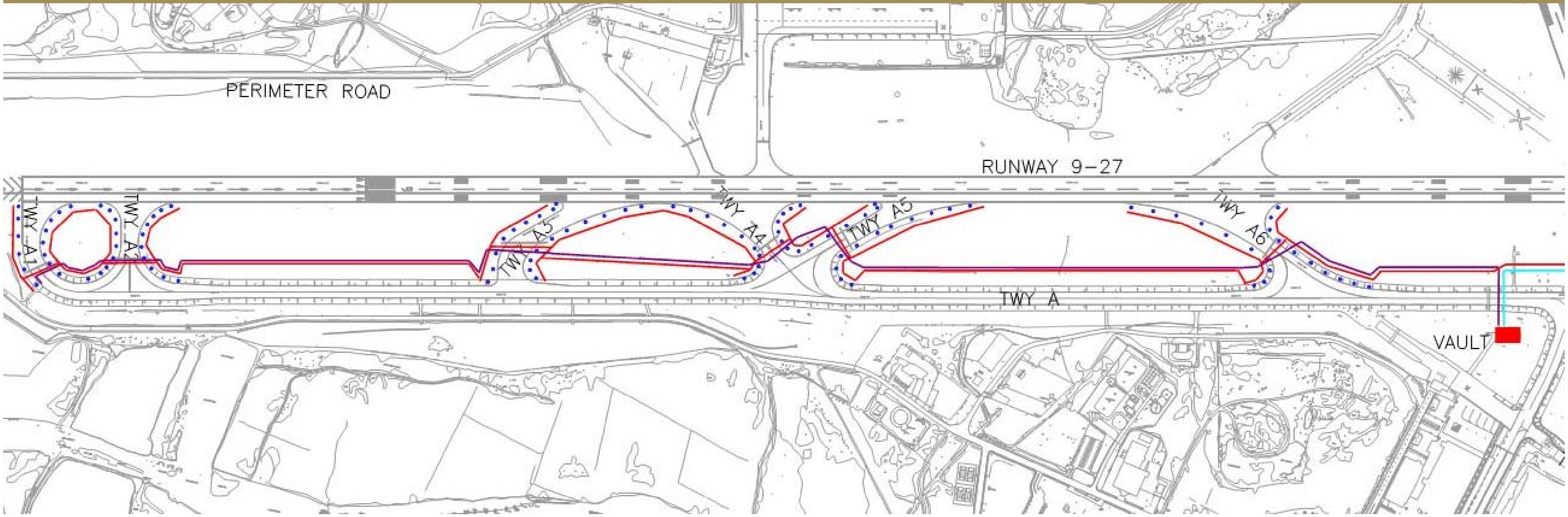
Sample calculation – section two



$$\frac{1}{IRsection\ 2} = \frac{37{,}500}{15{,}098{,}860} + \frac{400}{75{,}000} + \frac{185}{7{,}500}$$

IRs2= $30.8\ M\Omega$

Sample calculation – section three



$$\frac{1}{IRsection\ 3} = \frac{10{,}500}{15{,}098{,}860} + \frac{14}{75{,}000}$$

$$\mathrm{IRs3} = 1{,}134\ M\Omega$$

Calculation example

$$\frac{1}{IRsection\ 1} = \frac{4000}{15{,}098{,}860} + \frac{4}{75{,}000} = .00031825\ M\Omega^{-1}$$

$$\frac{1}{IRsection\ 2} = \frac{37{,}500}{15{,}098{,}860} + \frac{400}{75{,}000} + \frac{185}{7{,}500} = .032408\ M\Omega^{-1}$$

$$\frac{1}{IRsection\ 3} = \frac{10{,}500}{15{,}098{,}860} + \frac{14}{75{,}000} = .0008828\ M\Omega^{-1}$$

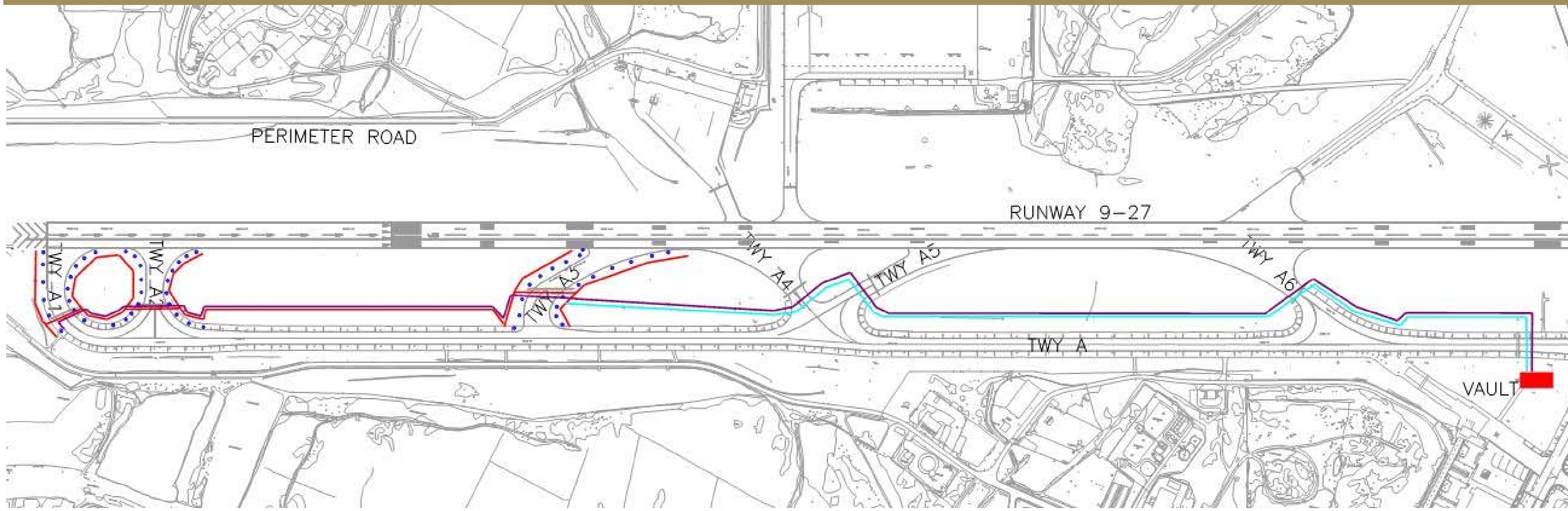
***IR total* = 29.7 MΩ**

AC 150/5340-30G : 50 MΩ

AC 150/5340-26B : 30 MΩ

Circuit design should be evaluated

Modified circuit



Section 1:
Cable = 6,000 feet
Connectors = 6
Isolation XFMRs = 0

Section 2:
Cable = 9000 feet
Connectors = 120
Isolation XFMRs = 52

Section 3:
Cable = 9,500 feet
Connectors = 14
Isolation XFMRs = 0

Load Calc:
Cable = 24,500 feet
Fixtures = 52
Circuit Load = 3.03kW

IR = 1/ (1/2,095 + 1/110 + 1/1,226)
IR = 95.9 MΩ

Presentation summary

- High initial field value – not necessarily indicate good circuit
- Standards provide recommended values - reductions are allowed
- Utilize parallel summation to calculate IR
- Check & verify transformer sizes and cable types for IR values
- Minimum allowable component values – higher factory test values
- Establish field test baseline and track results

Why calculate circuit IR during design?

- Mathematical model – eliminate unknown variables
- Good engineering practice – circuit load and insulation resistance calculations
- Establish the design baseline – expected results
- Helps understand the dynamics of the circuit & environment which it lives in

Open Q & A

Joe Vigilante, PE

jvigilante@burns-group.com / 215-979-7700, ext 7732

Chuck Dennie, PE, LC

cdennie@burns-group.com / 215-979-7700, ext 7762