Future of Condenser Bushing

Technology, concerns, and materials

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David Geibel, Technical Director, Alamo Components

Transformer failure modes

DOBLE Data:

Top transformer failures

- 43% winding/insulation
- **19% bushings**
- 16% tap changers

Transformer failure modes

Hartford Steam Boiler estimated:

2% annual failure rate of existing installed base in 2008

5% annual failure rate of existing installed base by 2013

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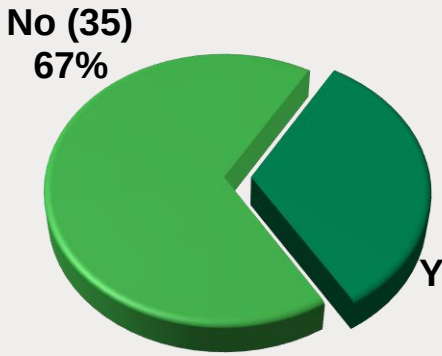
Condenser Bushing Concerns in North America

Have you experienced any events with deliberate damage with your condenser bushings?
(53 Respondents)



What happened and how often has this occurred?*

Issues

- Gun shots (13)
- Rock throwing (6)
- Item throwing (2)
- Copper theft (1)
- Porcelain chipping (1)
- Vandalism (1)

Frequency of Issues

- 15 years ago (1)
- 7 years ago (1)
- Once every 5 years (1)
- One time (1)
- Rarely (3)
- Once every couple of years (5)
- Once a year (2)
- A couple times a year (2)
- Once every couple of months (1)

*Findings from research conducted by independent organization AMG Research, sponsored by ABB

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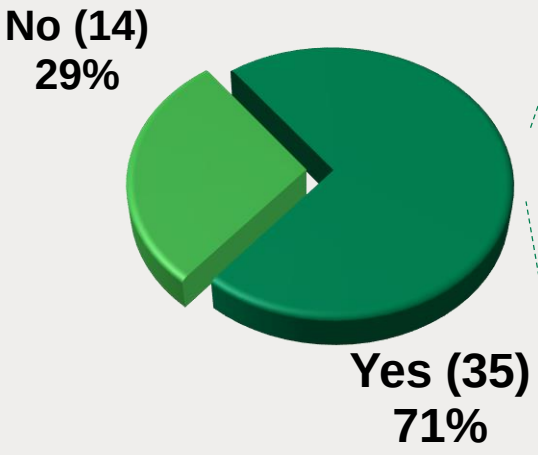
Condenser Bushing Concerns in North America

Do you ever experience outages as a result of your condenser bushings?
(53 Respondents)



Facility Type	No	Yes
IOU (35)	9%	91%
REC/Muni. (14)	58%	42%
Power Gen (4)	100%	-

How many times has this occurred?

- Every other year or longer (8)
- Once a year (5)
- Twice a year (6)
- Once a quarter (6)
- Every other month (3)
- Once a month (3)
- Twice a month (1)
- Don't know (3)

What was the cause?*

- Bushing failure (22)
- Animals (8)
- Leaks (6)
- Lightning (5)
- Bad test (4)
- Flashover (4)
- High temperatures (2)
- Moisture issues (2)
- Age of bushings (1)
- Don't know (2)

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Condenser Bushing Concerns in North America

Do you ever experience outages as a result of your condenser bushings?
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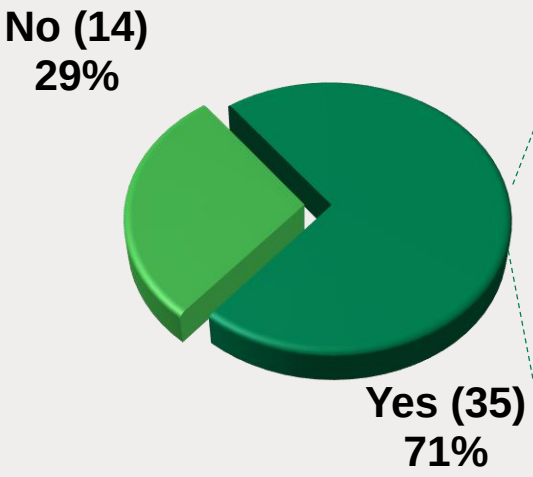

Facility Type	No	Yes
IOU (35)	9%	91%
REC/Muni. (14)	58%	42%
Power Gen (4)	100%	-

What were the costs associated with the outage?

- $500 (1)
- $6,000 (1)
- $7,000 (1)
- $10,000 (4)
- $20,000 (1)
- $50,000 (1)
- $1,000-$1 million (1)
- $10,000-$5 million (1)
- $15,000-$25,000 (1)
- $5,000-$500,000 (1)
- $50,000-$200,000 (1)
- $2.5 million (1)
- Depends on damage (4)
- Don’t know (16)

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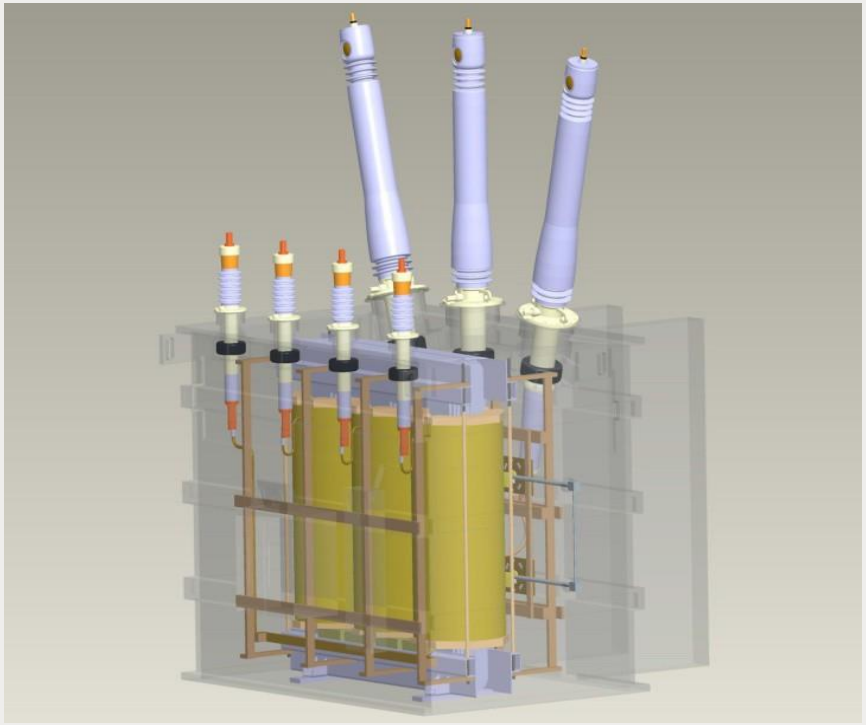
Presentation topics



- Types of bushings
  - Solid or “Bulk”
  - Condenser
    - Course graded
    - Fine graded
- Types of condenser cores
  - OIP/RBP/Epoxy/RIP/RIS
- Types of insulators
  - Porcelain/Epoxy/Silicones
  - HTV helical performance

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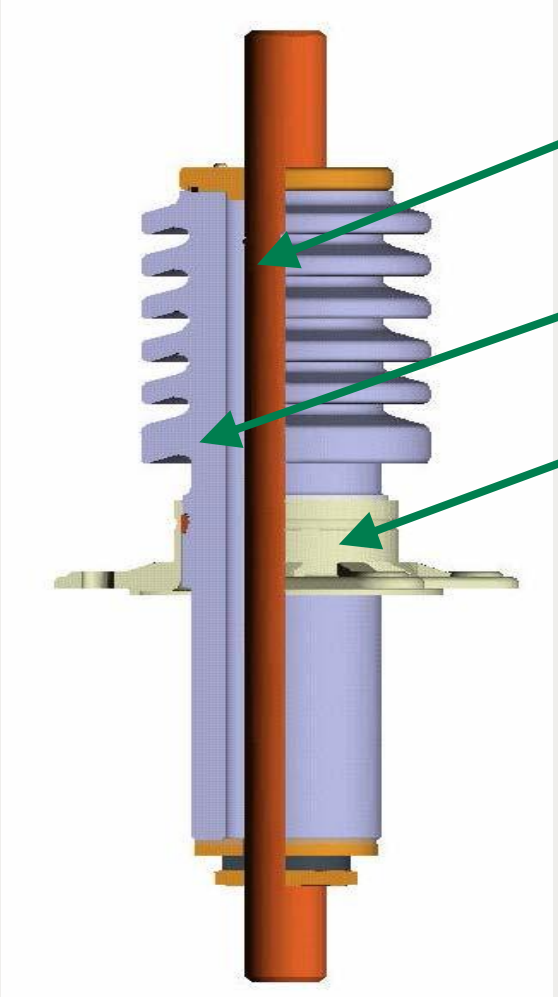
Bushing types



- Some solid or bulk type bushings contain their own oil or share oil with transformer such as Westinghouse Type RJ/LCRJ and GE Type A
- No test tap for measuring power factor nor capacitance

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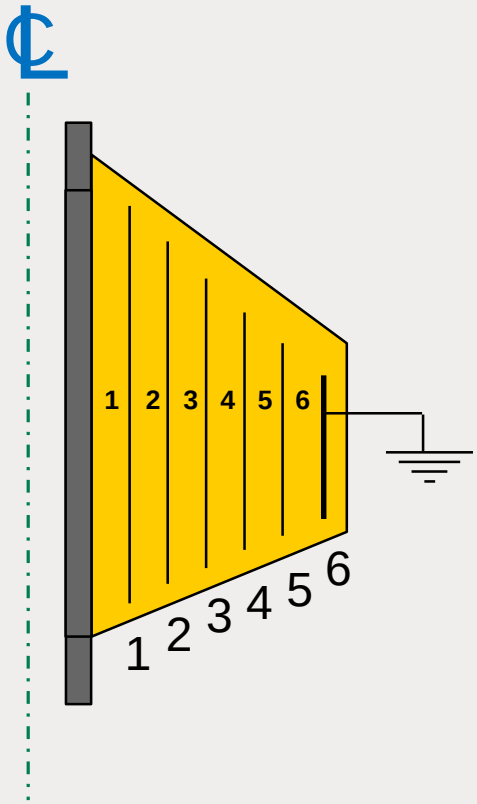
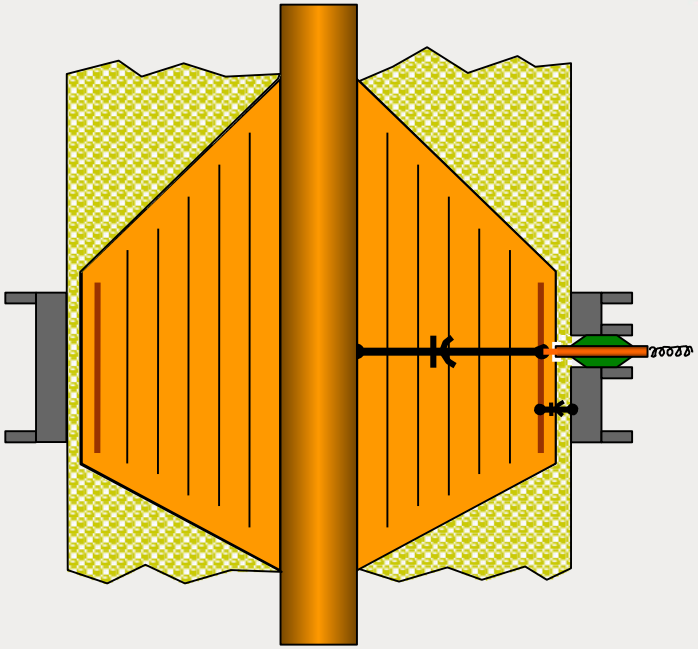
Bushing types
Capacitance Grading



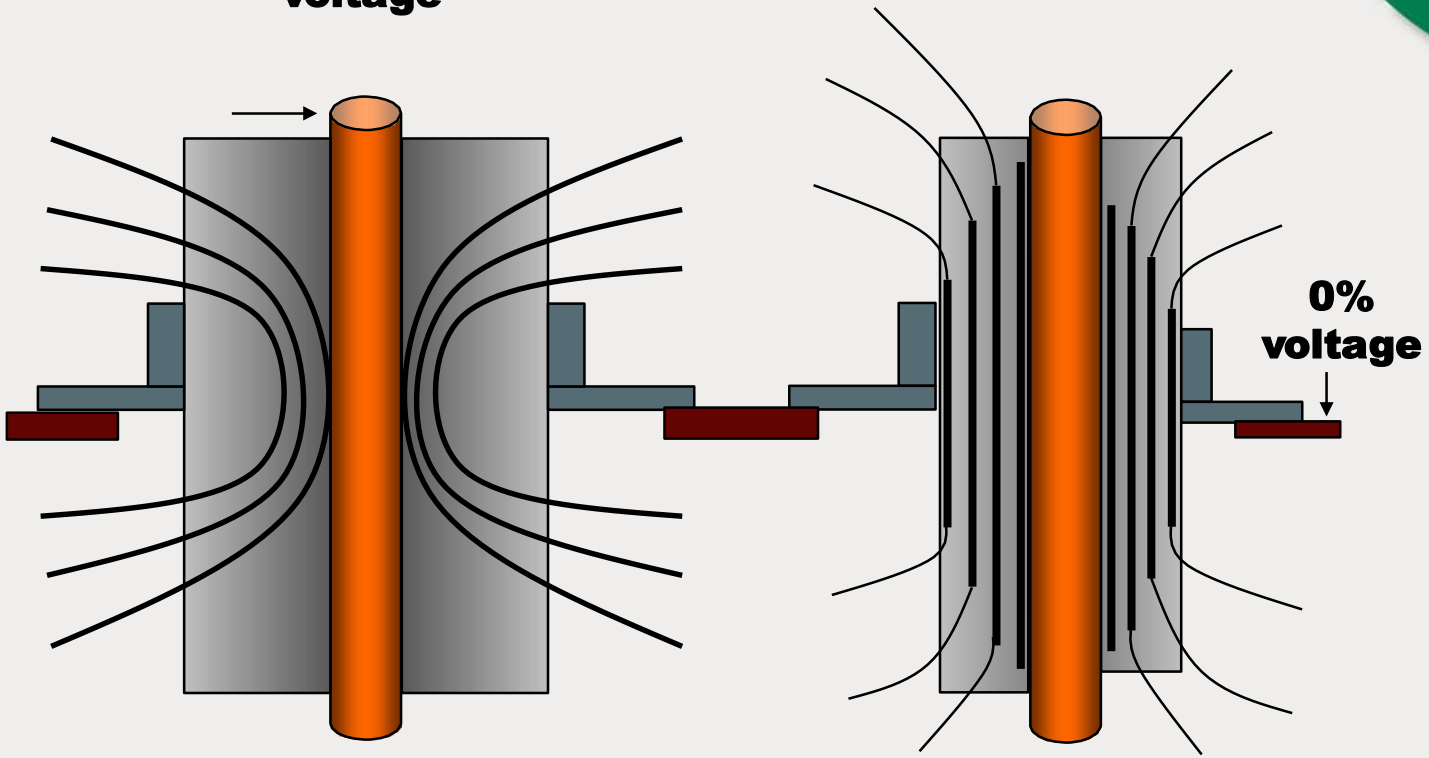


Solid bushing vs Condenser bushing

Uncontrolled (natural) electrical field

100% voltage

Capacity-controlled electrical field



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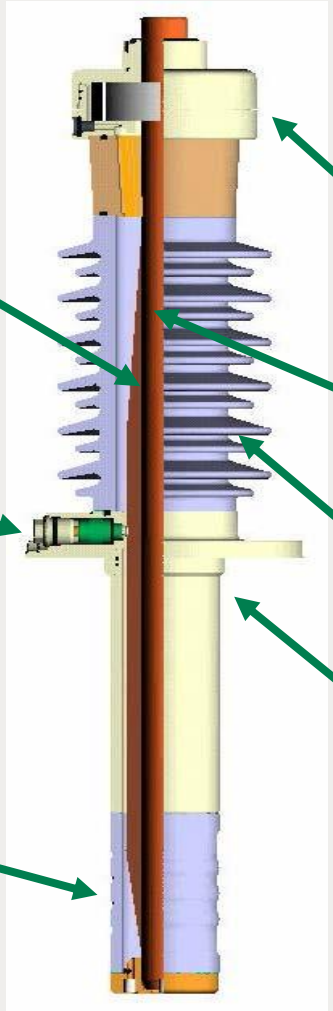
Bushing types
OIP Capacitance Graded (aka: Condenser) Bushing



Condenser body

Test tap or voltage tap provided for measuring power factor and capacitance

Lower insulator oil end

Spring housing

Center conductor

Upper insulator air end

Mounting flange

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Composite bushings

Definition of Composite

- A structure made up of different components

IEEE definition of Composite

- A fiber wound shell with polymer insulator

Industry perception definition of Composite

- Bushing made with polymer or resin materials

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Condenser core types

- Oil Impregnated Paper (OIP)
  - 15 kV to 800 kV
  - Plain paper condenser body
  - Core impregnated with hot oil under vacuum
  - Aluminum foil or ink print gradients
  - Partial discharge 10 pc at 1.5 times line to ground
  - Power factor requirements – less than .50%
- Resin Bonded Paper (RBP)
- Cast Epoxy
- Resin Impregnated Paper (RIP)
- Resin Impregnated Synthetic (RIS)

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Condenser core types

- Oil Impregnated Paper (OIP)
- Resin Bonded Paper (RBP)
  - 15 kV to 230 kV
  - Resin treated plain paper condenser body
  - Dry processed with varnish dipped core
  - Aluminum foil gradients
  - Partial discharge 100 pc at 1.5 times line to ground
  - Power factor requirements – less than 2.0%
- Cast Epoxy
- Resin Impregnated Paper (RIP)
- Resin Impregnated Synthetic (RIS)

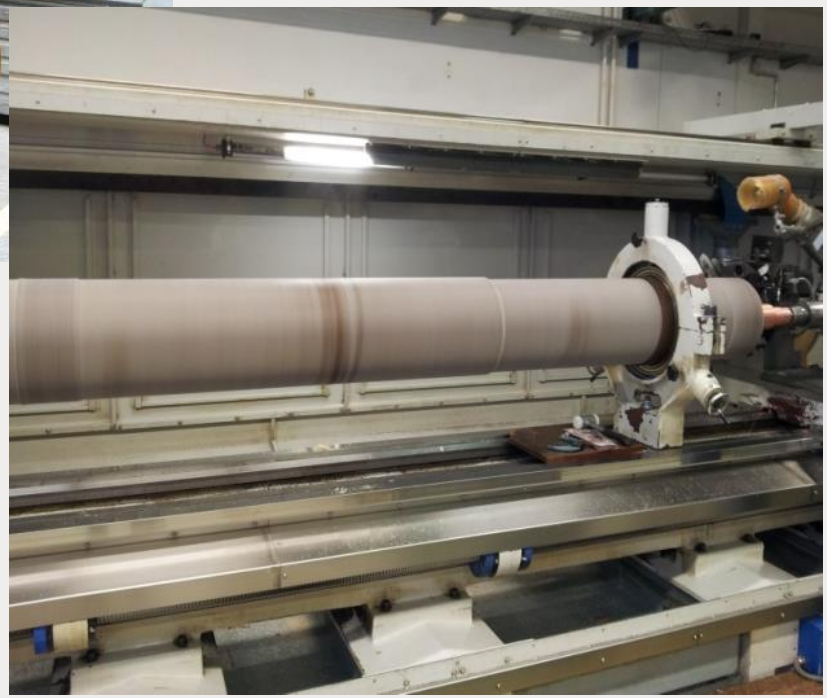
Condenser core types

- Oil Impregnated Paper (OIP)
- Resin Bonded Paper (RBP)
- Cast Epoxy
  - 15 kV – 138 kV
  - Metal screen mesh graded
  - Epoxy resin condenser body
  - Partial discharge 25 pc at 1.5 times line to ground
  - Power factor requirements – less than 1.0%
- Resin Impregnated Paper (RIP)
- Resin Impregnated Synthetic (RIS)

Condenser core types

- Oil Impregnated Paper (OIP)
- Resin Bonded Paper (RBP)
- Cast Epoxy
- Resin Impregnated Paper (RIP)
  - 15 kV to 800 kV
  - Crepe paper condenser body
  - Resin impregnated core under vacuum
  - Aluminum foil gradients
  - Partial discharge free although guideline of 10 pc
  - Power factor requirements – less than .85%
- Resin Impregnated Synthetic (RIS)

Condenser core type
Resin Impregnated Paper



Not Untested!!
35 yrs of manufacturing
~100,000 in service

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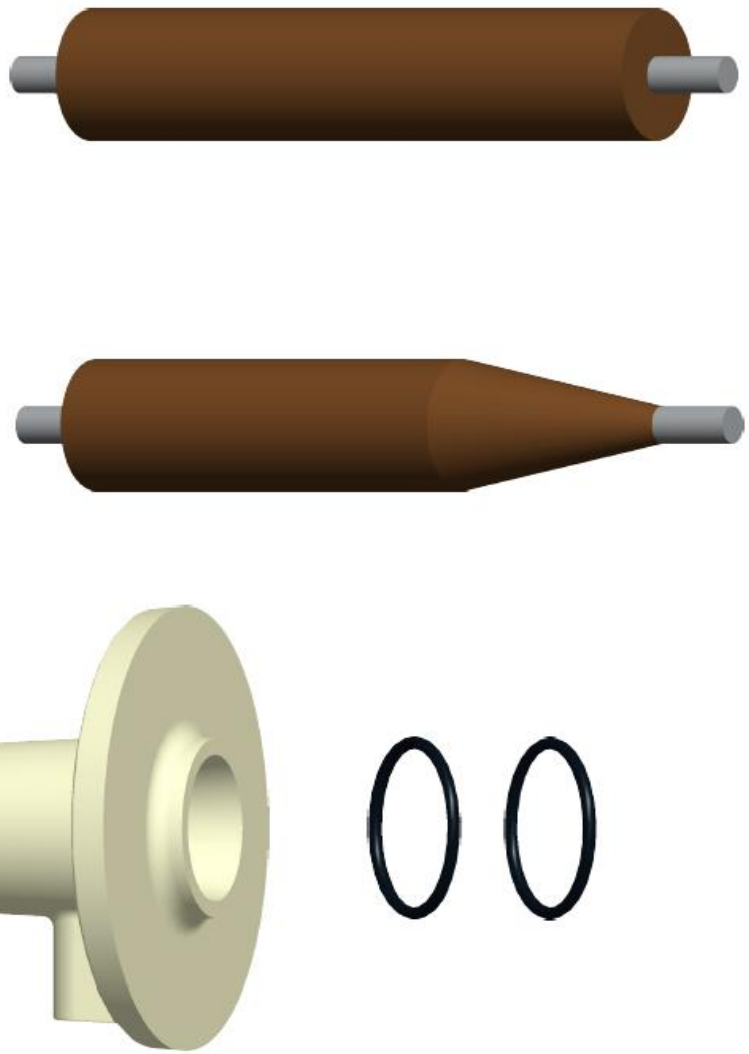
Condenser Core Types - RIP



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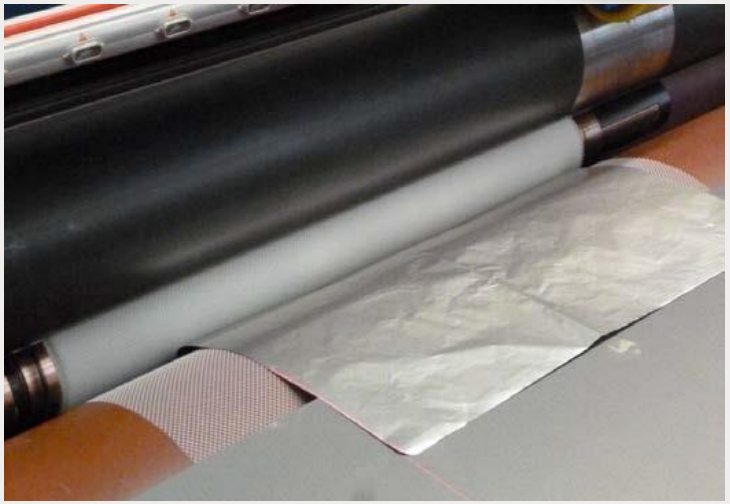
Condenser core types

- Oil Impregnated Paper (OIP)
- Resin Bonded Paper (RBP)
- Cast Epoxy
- Resin Impregnated Paper (RIP)
- Resin Impregnated Synthetic (RIS)
  - 25 kV to 161 kV
  - Synthetic mesh condenser body
  - Encapsulated with resin under vacuum
  - Aluminum foil gradients
  - Partial discharge free although guideline of 10 pc
  - Power factor requirements – less than .85%



Condenser core types

- Resin Impregnated Synthetic (RIS)
- Molded design condenser body

RIS Condenser Manufacturing

RIS condensers

25 kV
34.5 kV
115 kV
138 kV

230 kV

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Insulator material types

- Porcelain
  - No US manufacturers for HV porcelain
  - Poor yield rate
- Epoxy
- Room Temperature Vulcanized (RTV)
- Liquid Silicone Rubber (LSR)
- High Temperature Vulcanized (HTV)

Insulator material types

- Porcelain
- Epoxy
  - Casting including weather sheds
  - Not recommended for heavily contaminated applications
- Room Temperature Vulcanized (RTV)
- Liquid Silicone Rubber (LSR)
- High Temperature Vulcanized (HTV)

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Insulator material types

- Porcelain
- Epoxy
- Room Temperature Vulcanized (RTV)
  - Molded design
- Liquid Silicone Rubber (LSR)
  - Molded design
- High Temperature Vulcanized (HTV)
  - Extruded design
  - Hydrophobic
  - High performance in contaminated site applications and high UV

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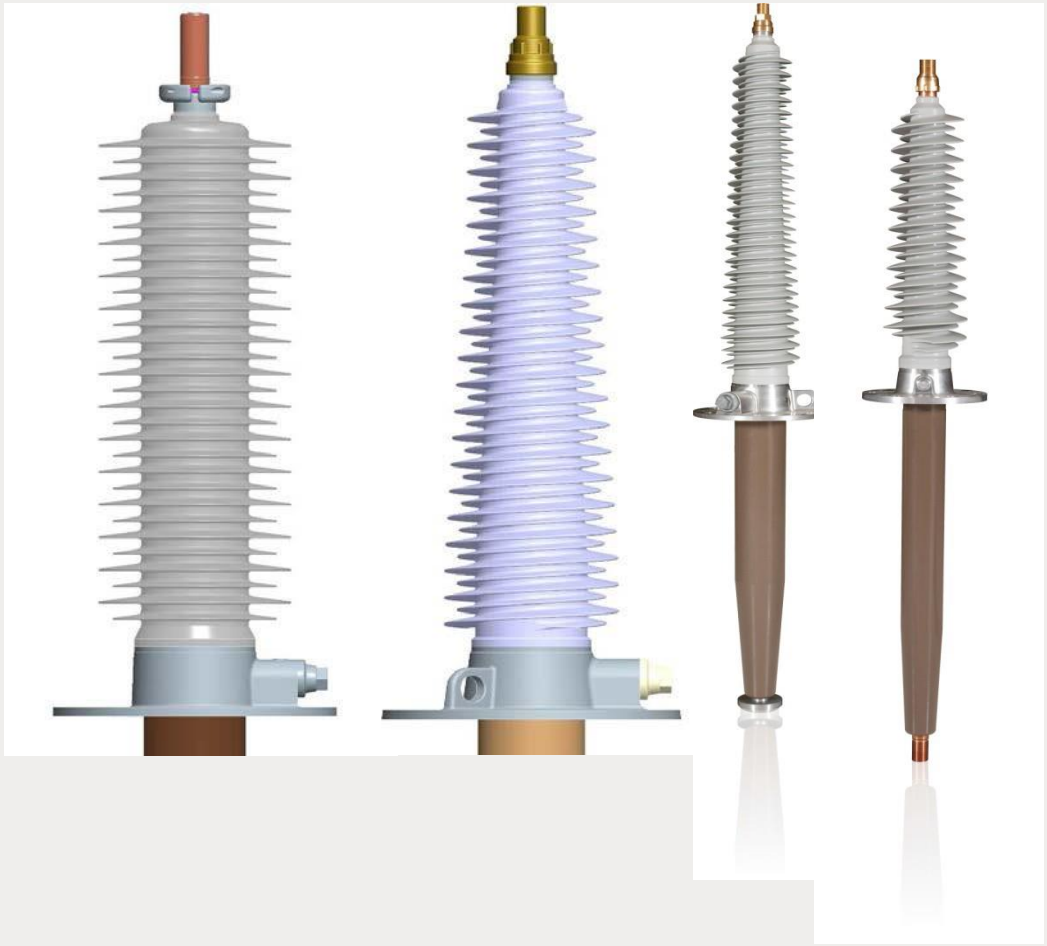
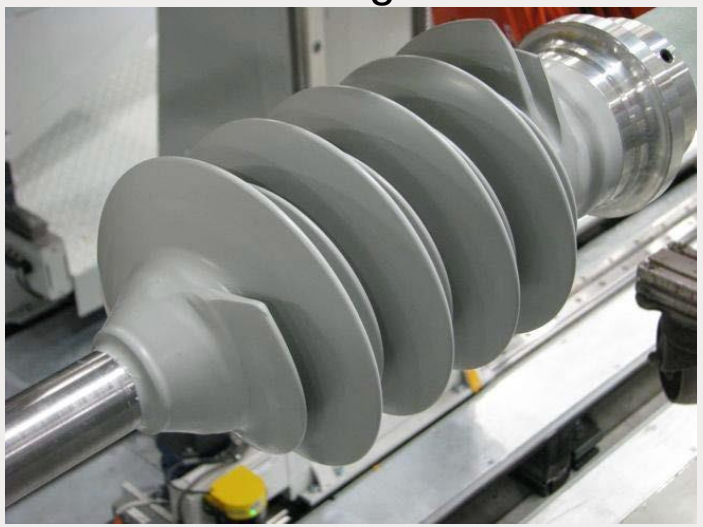
Silicone insulator shed design

Molded design

Extruded design



Extruding sheds



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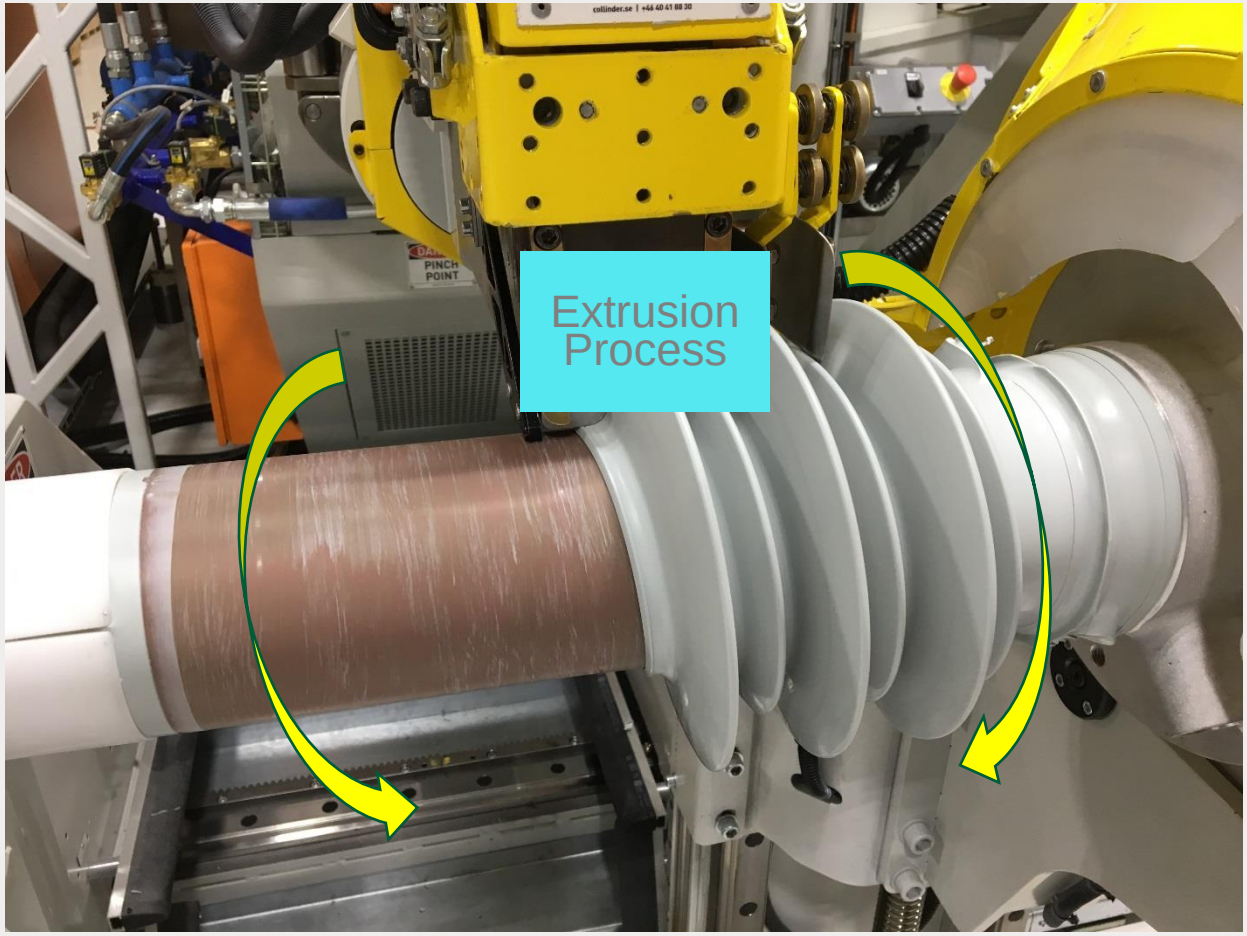
Applying the HTV weather sheds



Spray on Clean bushing

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Drizzle on clean bushing

Sheds heavily contaminated

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Yucky bushing
Drizzle stream

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Yucky Bushing Spray

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Hydrophobicity!!

IT WORKS!!!

See how drops capture clay and take it away and clean drops form.

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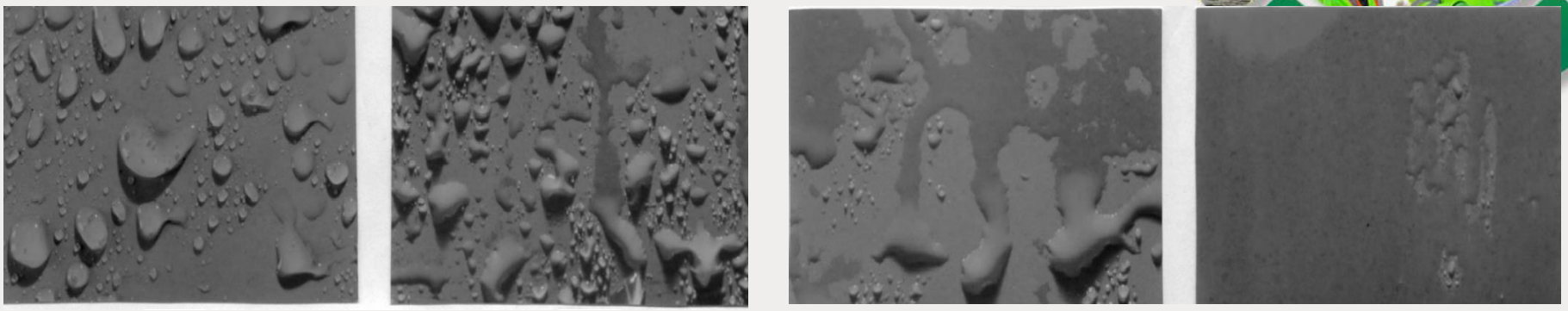
How Hydrophobic and for how long?
Insulator Material Types

Hydrophobic = Self-Cleaning



Good ← → Bad

Degrees of hydrophobic performance

Silicon oil continue to surface for at least the life of the bushings

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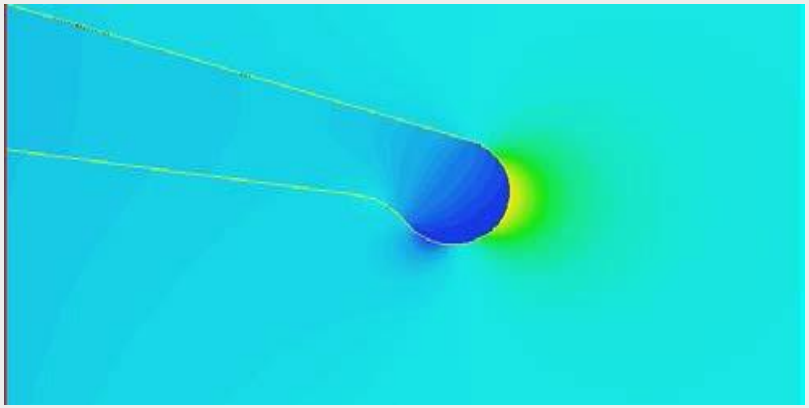
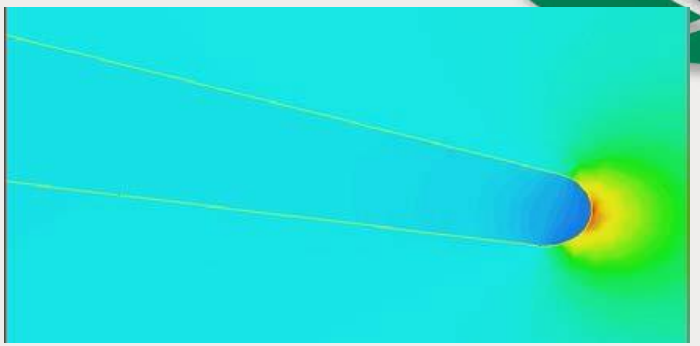
Silicone insulator shed profile design

ABB Helical extrusion

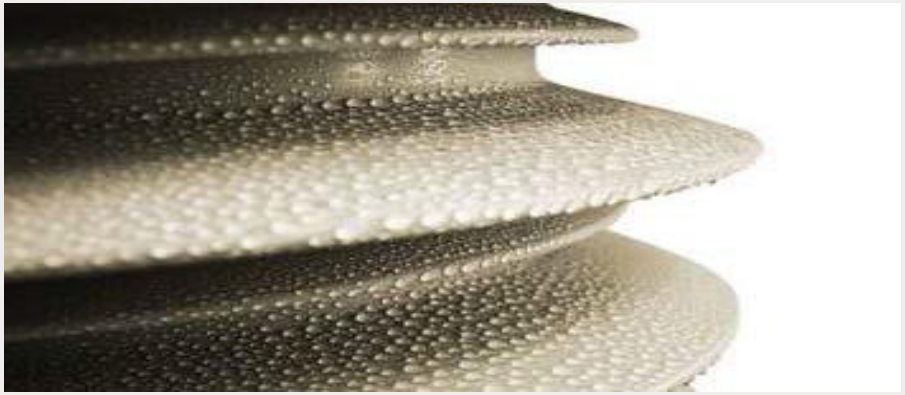


Low electrical field

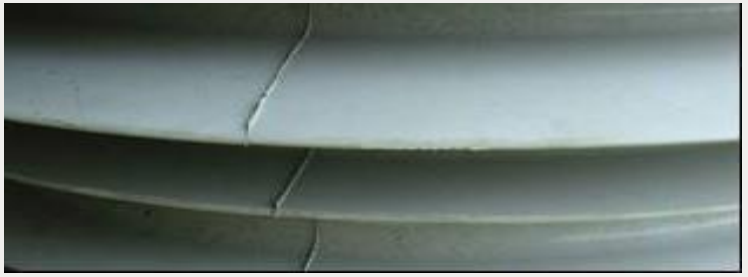
Injection molding



High electrical field



No mold lines



Mold lines

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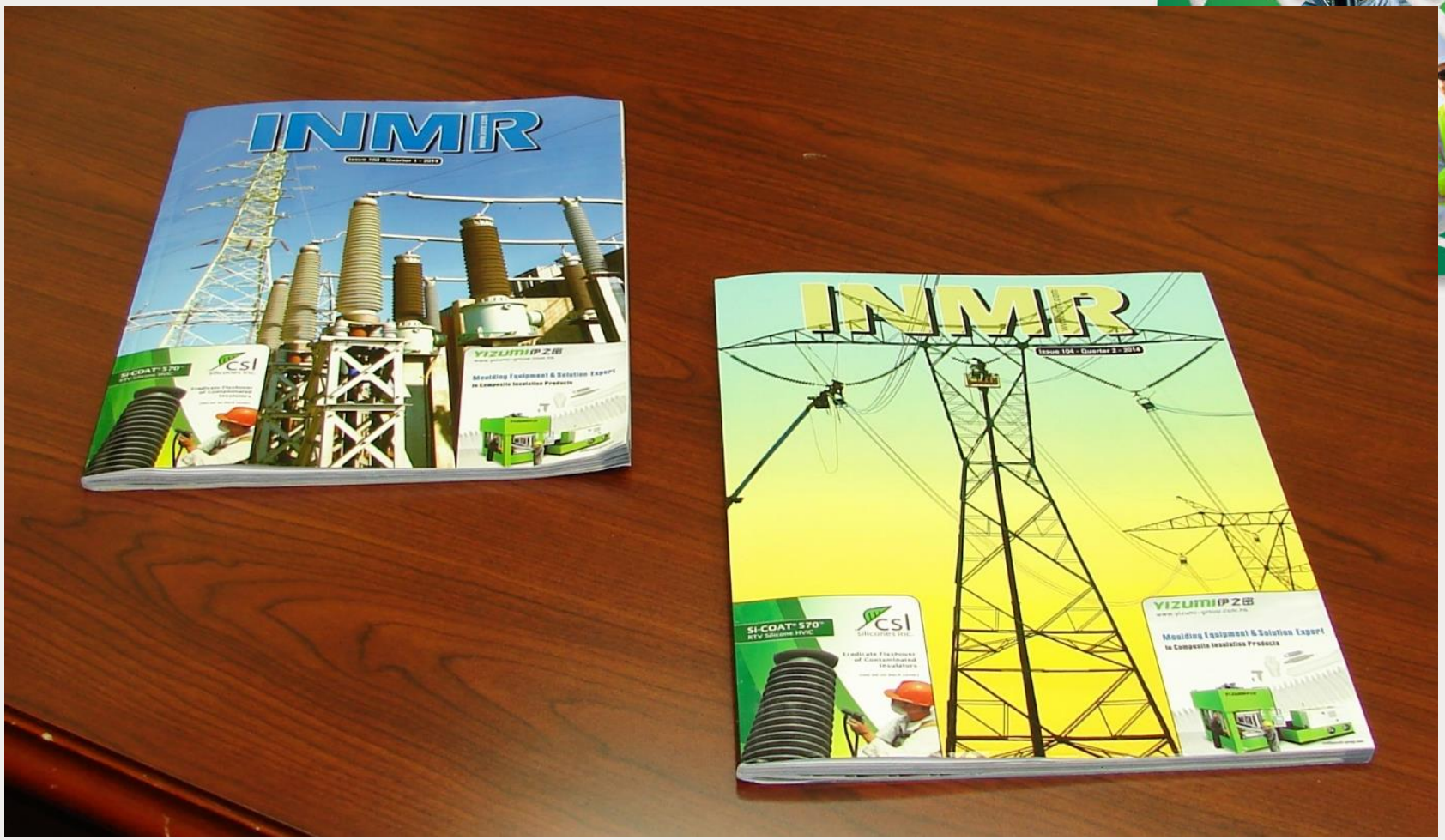
Applying Mature Weather Shed Technology Type O Plus Dry™



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Applying Mature Weather Shed Technology Type O Plus Dry™

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Applying Mature Weather Shed Technology Type O Plus Dry™

- Recent Cigre paper concludes life of HTV weather sheds good for life of bushing (copies available).
- This field study indicates “in service” insulators in good condition under various conditions.
- Holding up well even in the most severe environments.

Long-term service experience and inspection results of HV equipment made of silicone rubber insulators

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SUMMARY

KEYWORDS

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230 kV RIS shaker test

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Field issues – Managing the risk

- Has your company experienced field issues such as….
  - bushings catching on fire or supplemental to an existing fire?
  - porcelain shards external to transformer damaging other equipment or people?
  - porcelain shards damaging transformer internals?
  - seismic events?
  - bushings shortened life expectancy due moisture ingress?
  - bushings shortened life expectancy due to gas bubble evolution?
  - bushing failure due to external flashover due to high contamination?
  - bushings with oil leaks and create further concerns or costly environmental cleanup?
  - bushings damaged due to vandalism or terrorism?

RIP/RIS with Silicone insulator Advantages/benefits

- **RIP or RIS with Silicone Insulators**
  - **Safety**
  - **Apply at any angle 0 – 90 degrees**
  - **Fire retardant**
  - **Hydrophobic**
  - **Lighter**
  - **Less maintenance**
  - **No oil leaks**
  - **Environmental**
  - **Less collateral damage**
  - **Security**

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