UNIVERSIDAD NACIONAL DE INGENIERÍA
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"TERMINACIONES AUTOCONTRAÍBLES DE MEDIA TENSIÓN DE GOMA SILICONA"

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PARA OPTAR EL TÍTULO PROFESIONAL DE

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A mis padres por su apoyo incondicional, a mi esposa y a mis hijos quienes me estimulan a superarme día a día y a 3M PERÚ S.A. por haberme dado la oportunidad de desarrollar este tema.

TERMINACIONES AUTOCONTRAÍBLES DE MEDIA TENSIÓN DE GOMA SILICONA

SUMARIO

El descubrimiento de los materiales poliméricos y su uso como aislamiento en los cables de media tensión hicieron que los cables de aislamiento de papel se fueran dejando de lado. Actualmente los cables de polietileno reticulado tienen gran aceptación en nuestro mercado, debido a sus buenas características técnicas y precio asequible.

Paralelamente a los nuevos cables se desarrollaron también los accesorios (empalmes y terminaciones) adecuados para el buen funcionamiento de dichos cables en las redes de distribución.

De los diversos materiales que se utilizan para la fabricación de terminaciones, la goma silicona se destaca por su buen comportamiento frente a la humedad, los rayos UV y la contaminación ambiental

Si a estas ventajas añadimos la gran facilidad de montaje que representa el sistema autocontraíble, llegamos a la conclusión de que las terminaciones de goma silicona son la mejor alternativa como accesorio para terminar cables de energía de aislamiento seco.

ÍNDICE

PROLOGO

El presente Informe de Ingeniería ha sido elaborado con el objeto de mostrar las ventajas y beneficios que ha significado el desarrollo de la silicona como material para ser usado en terminaciones de media tensión instalados en cables de energía.

El diseño del accesorio está directamente relacionado con el cable en el cual se va a instalar, por lo que en el Capítulo I se detalla las características más importantes del cable con aislamiento de polietileno reticulado (XLPE).

En el Capítulo II se analiza las terminaciones de goma silicona autocontraíble tanto en sus funciones como accesorio para terminar los cables de energía como su comportamiento frente a las diversas condiciones ambientales de servicio. También se hace mención de las ventajas que representa la tecnología autocontraíble en cuanto a la facilidad de instalación, lo cual disminuye los costos de capacitación del personal.

El capítulo III trata sobre las especificaciones técnicas que deben cumplir estos accesorios, pudiendo hacerse pruebas adicionales de común acuerdo entre fabricante y usuario. Relacionado con este tema, en el Capítullo IV se describe los ensayos a que son sometidas las terminaciones para garantizar su performance en servicio durante su vida útil.

Finalmente, en el Capítulo V se analiza los costos de instalación de terminaciones, donde se menciona que el precio del accesorio no es significativo en comparación con los demás equipos y materiales usados en las redes de distribución primaria.

CAPÍTULO I

CABLES DE ENERGÍA DE MEDIA TENSIÓN, DE AISLAMIENTO POLIMÉRICO

1.1 Introducción.

Los cables de energía de media tensión empezaron a utilizarse a principios del siglo XX. Fueron del tipo NKY, con aislamiento de papel impregnado en aceite y funda de plomo para evitar el ingreso de humedad. En las redes de Lima aún podemos encontrar estos cables, con más de 50 años de servicio.

Con el descubrimiento de los materiales poliméricos se ha logrado fabricar cables de aislamiento "seco", los cuales son más livianos y maniobrables, con la consiguiente reducción de costos tanto en la fabricación y transporte de los cables como en la mano de obra de instalación.

Las propiedades dieléctricas del polietileno reticulado (XLPE) y su estabilidad térmica hacen que este tipo de cable sea de uso generalizado en redes aéreas autosoportadas y subterráneas.

1.2 Definición de términos técnicos.

Conductor (de un cable).- Alambre o conjunto de alambres, no aislados entre sí, destinados a conducir la corriente eléctrica.

Cable Unipolar.- Cable formado por un solo conductor.

Cable Tripolar.- Cable formado por 3 conductores.

Tensión Nominal.- Es la tensión de operación permanente del cable en condiciones normales de servicio.

Clase de Aislamiento (E).- Es la tensión nominal de operación entre fases para la cual está diseñado el cable.

Máxima Tensión de Diseño a Tierra (Eo).- Es la máxima tensión entre fase y pantalla o tierra, a la cual puede operar continuamente un cable, sin sufrir deterioro alguno en condiciones normales de operación.

Tensión de Impulso (BIL: Basic Insulation Level).- Es el valor de cresta de la tensión de impulso de forma de onda especificada.

Corriente Máxima Admisible.- Es el máximo valor que puede soportar permanentemente el cable y sus accesorios.

Corriente térmica nominal de Cortocircuito.- Es el valor medio eficaz de la componente asimétrica de la corriente de cortocircuito al producirse la falla, la cual debe ser liberada antes de que los conductores sufran un aumento peligroso de temperatura.

Corriente dinámica nominal de Cortocircuito.- Es el valor de cresta de la corriente de corta duración, que puede soportar la terminación sin sufrir daño mecánico, como consecuencia de los esfuerzos electrodinámicos a que está sometido.

Plástico.- Compuesto orgánico, polimerizado hasta lograr un alto peso molecular y puede ser moldeado en forma definida con la aplicación de calor o presión (o ambos), conservando esta forma cuando vuelve a las condiciones normales.

Termoplásticos.- Se reblandecen por medio del calor, endureciéndose nuevamente al enfriarse. El grado de reblandecimiento depende principalmente de la temperatura alcanzada y no de la duración del proceso. Ejemplo: policloruro de vinilo, polietileno.

Termoestables.- Material que en el proceso de fabricación es sometido a calor y presión, produciéndose un cambio químico y la obtención de enlaces entrecruzados. Como consecuencia de este cambio químico, el material no se reblandece al volver a aplicarle calor, pero se puede quemar si se calienta en exceso.

1.3 Materiales usados como aislamiento en cables de media tensión.

Los materiales que se emplean actualmente como aislamiento en la fabricación de cables de media tensión son:

a.- Policloruro de vinilo (PVC)

b.- Polietileno Lineal (PE)

c.- Polietileno Reticulado (XLPE)

d.- Goma de etileno propileno (EPR)

Cabe señalar que el cable de aislamiento de papel está prácticamente descontinuado en nuestro medio, ya que se fabrica sólo a pedido del cliente. El que más se utiliza es el de aislamiento de XLPE, que es termoestable, posee muy buena rigidez dieléctrica, bajo factor de pérdidas y excelente resistencia de aislamiento.

En el siguiente cuadro se muestra la capacidad térmica de los conductores para cables según su tipo de aislamiento:

Tensión Nominal E (kV)	Tipo de Aislamiento	Temperatura del Conductor (°C)	
		Servicio Normal	Cortocircuito
15 kV	PVC Polietileno Lineal Polietileno Reticulado Goma EPR	70 75 90 90	160 155 250 250

Tabla 1.1: Capacidad térmica según tipo de aislamiento.

1.4 Conformación de los cables.

Los cables de media tensión están constituidos por los elementos siguientes:

a.- Conductor de cobre rojo suave. Formada por varios hilos, es una cuerda redonda compacta para obtener así una superficie lisa y un diámetro reducido respecto a una cuerda normal, sin por ello reducir sus propiedades eléctricas o mecánicas a igualdad de sección nominal.

b.- Pantalla interna: Capa semiconductora. Impide la ionización del aire que, en el proceso de fabricación del cable, queda atrapado entre el conductor y el material aislante (efecto corona). La capa semiconductora forma cuerpo único con el aislante y no se separa de éste, constituyendo la verdadera superficie equipotencial del conductor.

También mejora la distribución del campo eléctrico en la superficie del conductor pues la convierte en cilíndrica y lisa, reduciendo así la solicitación eléctrica del aislante.

c.- Aislamiento. Está constituido por uno de los materiales que se indican en la tabla 1.1. La termoestabilidad del XLPE hace que este material tenga mejor comportamiento en caso de sobrecargas y cortocircuito; por lo tanto, se obtiene intensidades de corriente admisible superiores a la de otros aislantes para igual sección de conductor.

El espesor del aislamiento depende del nivel de tensión de diseño del cable, tal como se muestra en la tabla 1.2

Eo/E de Diseño	mm
3.6 / 6	2.5
6 / 10	3.4
8.7 / 15	4.5
12 / 20	5.5
18 / 30	8
60	17

Tabla 1.2: Espesor de aislamiento, según el nivel de tensión.

d.- Pantalla Externa: Está constituida por 2 elementos: una cubierta semiconductora (material extruído y/o cinta de tela) y una pantalla metálica (cintas y/o hilos de cobre o aluminio).

La cubierta semiconductora permite una distribución uniforme y radial del esfuerzo eléctrico en el aislamiento y evita la presencia de espacios vacíos ionizables entre el aislamiento y la pantalla metálica.

La pantalla exterior tiene las funciones siguientes:

- Confinar el campo eléctrico al interior del cable.
- Lograr una distribución simétrica y radial del esfuerzo eléctrico en el aislamiento.
- Limitar la influencia mutua entre cables próximos.
- Evitar el peligro de electrocución.

- La pantalla metálica adicionalmente permite el transporte de corrientes homopolares o corrientes de desbalance en sistemas de conexión en estrella con neutro corrido.

e.- Armadura. El cable puede o no llevar este componente. Es recomendable su uso como protección mecánica y seguridad eléctrica en el caso de instalación del cable directamente enterrado. Se coloca normalmente debajo de la cubierta exterior y está constituida por flejes de acero o alambres de acero galvanizado enrollados helicoidalmente.

f.- Cubierta o Chaqueta Exterior. Protege al cable del medio ambiente donde trabaja. Es recomendable el PVC para aplicaciones directamente enterradas y el polietileno para instalaciones aéreas por su mayor resistencia a los rayos ultravioletas.

1.5 Tipos de Cables de Media Tensión.

La nomenclatura de los cables de media tensión se basa en el orden de sus componentes (detallados en el acápite 1.4), los cuales son designados con letras del alfabeto. Cada letra indica un componente del cable.

Las letras normalizadas (VDE, ITINTEC) para la designación de los cables en nuestro medio son:

N Cable de energía con conductores de cobre.

NA = Cable de energía con conductores de aluminio.

Y = Aislamiento de PVC de media tensión.

2Y = Aislamiento de polietileno lineal.

2X = Aislamiento de polietileno reticulado (XLPE)

S = Pantalla de cinta de cobre.

SA = Pantalla de cinta de aluminio.

C = Pantalla de hilos de cobre.

E = Cable tripolar (pantalla en las tres fases).

Y = Chaqueta externa de PVC.

Para instalaciones subterráneas, los cables más conocidos son:

a.- NYSY: Cable formado por un conductor de cobre recocido, aislamiento de PVC, pantalla de cintas de cobre y chaqueta externa de PVC.

b.- N2YSY: Cable formado por un conductor de cobre recocido, aislamiento de PE, pantalla de cintas de cobre y chaqueta externa de PVC.

c.- N2XSY: Cable formado por un conductor de cobre recocido, aislamiento de XLPE, pantalla de cintas de cobre y chaqueta externa de PVC.

d.- N2XSEY: Cable formado por tres conductores de cobre recocido, aislamiento de XLPE, pantalla de cintas de cobre en cada fase y chaqueta externa de PVC.

Para instalaciones aéreas, los más conocidos son:

e.- N2XS2Y – S: Conjunto de tres cables unipolares reunidos en espiral alrededor de un elemento portante formado por una cuerda de acero galvanizado y forrado con polietileno.

Cada cable unipolar está formado por un conductor de cobre recocido, aislamiento de XLPE, pantalla de cintas de cobre y chaqueta externa de PE.

f.- NA2XSA2Y – S: Conjunto de tres cables unipolares reunidos en espiral alrededor de un elemento portante formado por una cuerda de acero galvanizado y forrado con polietileno.

Cada cable unipolar está formado por un conductor de aluminio, aislamiento de XLPE, pantalla de cintas de aluminio y chaqueta externa de PE.

Fig. 1.1a: Cable N2XSY

Fig. 1.1b: Cable N2XSEY

Fig. 1.1c: Cable N2XS2Y - S

Fig. 1.1d: Cable NA2XSA2Y - S

1.6 Especificación técnica del cable unipolar de XLPE, 8.7/15 kV.

Es el tipo de cable más utilizado en nuestro medio, especialmente en las empresas de electricidad, y tiene las características técnicas de construcción siguientes:

- Conductor de cobre rojo suave
- Pantalla interna: capa semiconductora
- Aislamiento de polietileno reticulado (XLPE)

- Pantalla externa:
  - Cinta semiconductora.
  - Cinta de Cobre.
- Cubierta exterior de PVC color rojo.

Sección Nominal mm2	Conductor	Aislamiento		Número de conductores	Cubierta
	Diám. Nominal mm	Espesor Nominal mm	Diám. Nominal mm		Diám. Nominal mm
25	6.1	4.5	17.3	1 3	23.0 47.0
35	7.1	4.5	18.3	1 3	24.5 53.0
50	8.2	4.5	19.4	1 3	26.0 55.0
70	9.9	4.5	21.1	1 3	27.5 60.0
95	11.6	4.5	22.8	1 3	29.0 64.0
120	13.0	4.5	24.2	1 3	31.0 67.0
150	14.5	4.5	25.7	1 3	33.0 71.0
185	16.2	4.5	27.4	1 3	35.0 75.0
240	18.5	4.5	29.8	1 3	37.0 77.0
300	20.8	4.5	32.0	1	40.0
400	23.5	4.5	34.7	1	43.0
500	26.4	4.5	37.6	1	46.0

Tabla 1.3: Características técnicas del cable N2XSY, 8.7/15 kV.

1.7 Teoría del cable de Media Tensión.

En este acápite se analiza el comportamiento del cable en presencia de una media tensión aplicada, siendo explicada de la manera siguiente:

a) ¿Qué pasa si a un cable que está compuesto únicamente por conductor de cobre y aislamiento, le aplicamos media tensión?. En la Fig. 1.2 se muestra este caso.

El conductor está compuesto por hilos (le da flexibilidad al cable) y al momento de aplicar el aislamiento en forma extruída sobre él, queda aire atrapado en los intersticios del conductor. Luego, al aplicarse media tensión, este aire se va a ionizar provocando actividad de descarga llamada ***descargas corona*** (esto es debido a la diferencia de potencial que existe entre la superficie de los hilos del conductor y el aislamiento)**.** Se irá, entonces, formando en el aislamiento un camino carbonoso hacia el exterior, provocándose finalmente la perforación del aislamiento y la descarga a tierra.

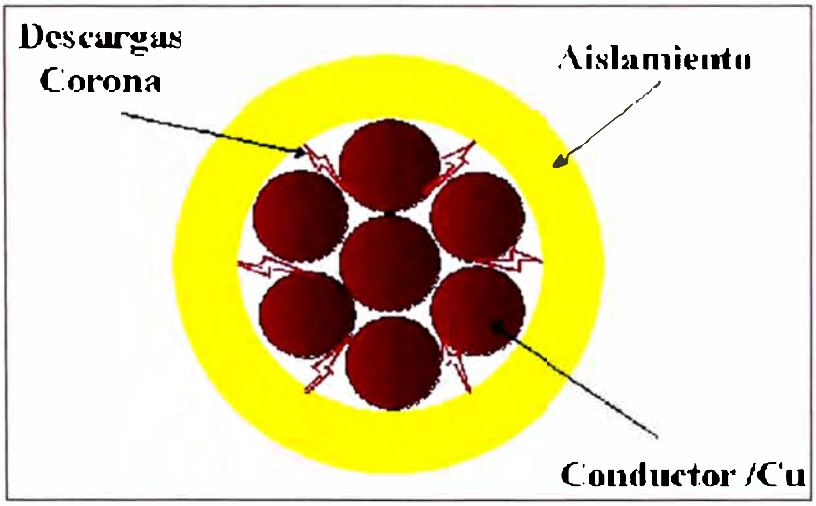

Fig. 1.2: Cable de energía sin pantalla semiconductora sobre el conductor.

Este problema se evita mediante la aplicación de la pantalla semiconductora sobre el conductor (ver Fig. 1.3). Con esto se logra poner al mismo potencial todos los puntos del conductor eliminando así la diferencia de potencial mencionado anteriormente. El aire atrapado no causará descargas corona.

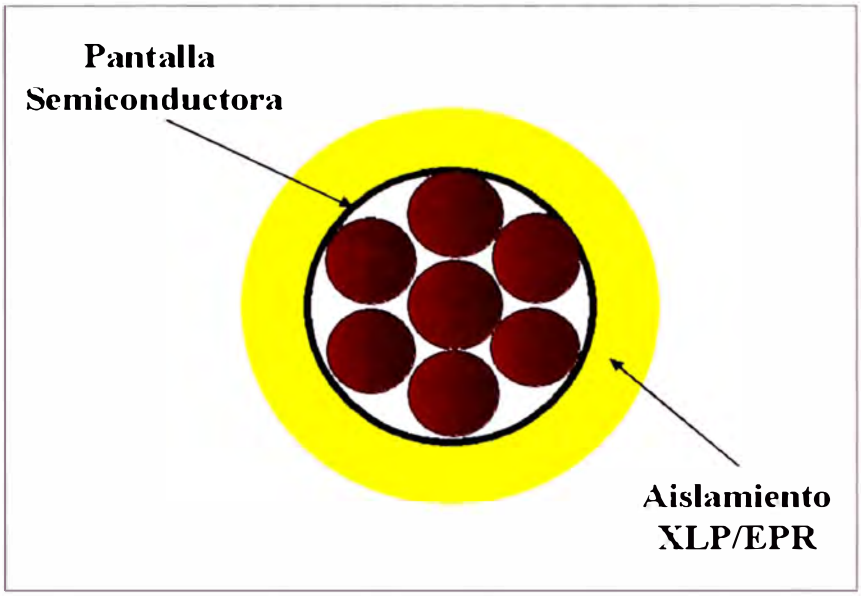

Fig. 1.3: Cable de energía con pantalla semiconductora sobre el conductor.

b) ¿Qué ocurre si a este cable lo colocamos dentro de un ducto, bajo tierra? En la Fig. 1.4 se muestra este caso.

Las líneas de campo eléctrico que salen del conductor no se distribuyen uniformemente, debido a que, en forma natural, busca el camino de menor impedancia ó “el camino más corto” a tierra. Vemos que se produce una gran concentración de campo en la zona inferior porque es más corta la distancia a tierra.

Esto produce un gran esfuerzo eléctrico en esa zona que posteriormente va a causar una falla a tierra.

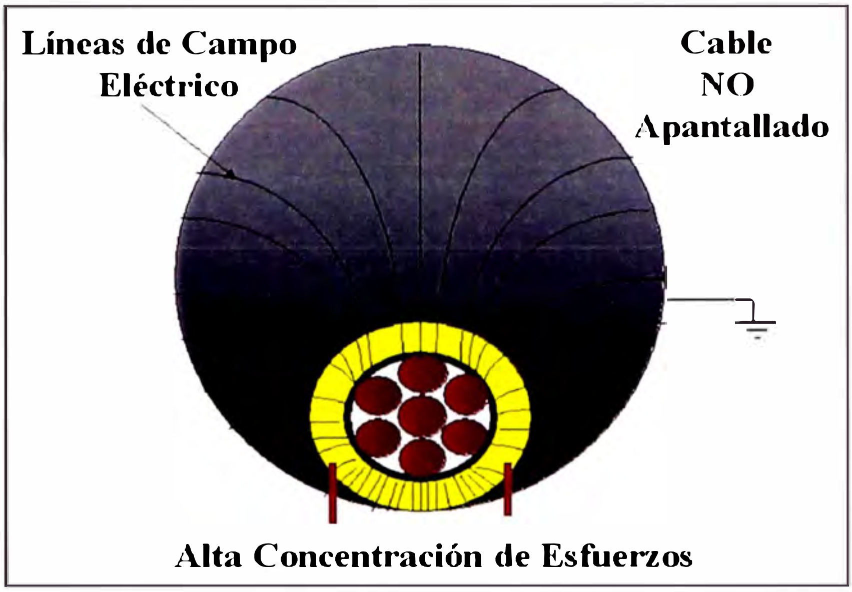

Fig. 1.4: Cable de energía sin pantalla semiconductora sobre el aislamiento.

Este problema se evita mediante la aplicación de la pantalla semiconductora sobre el aislamiento. Con esto se obtiene un campo eléctrico radial y uniforme. Ver Fig. 1.5, donde se aprecia la pantalla semiconductora más la pantalla de cinta de cobre.

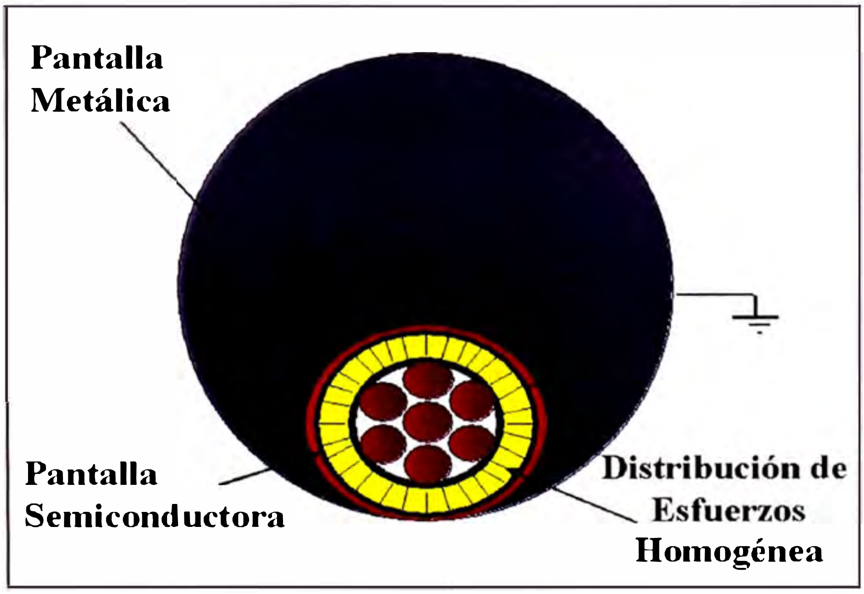

Fig. 1.5: Cable de energía con pantalla semiconductora sobre el aislamiento.

c) Finalmente, una vez resuelto los problemas de descargas corona y la concentración de esfuerzo eléctrico por la presencia de un campo no uniforme, en la Fig. 1.6 se tiene el cable tal cual se fabrica hoy en día.

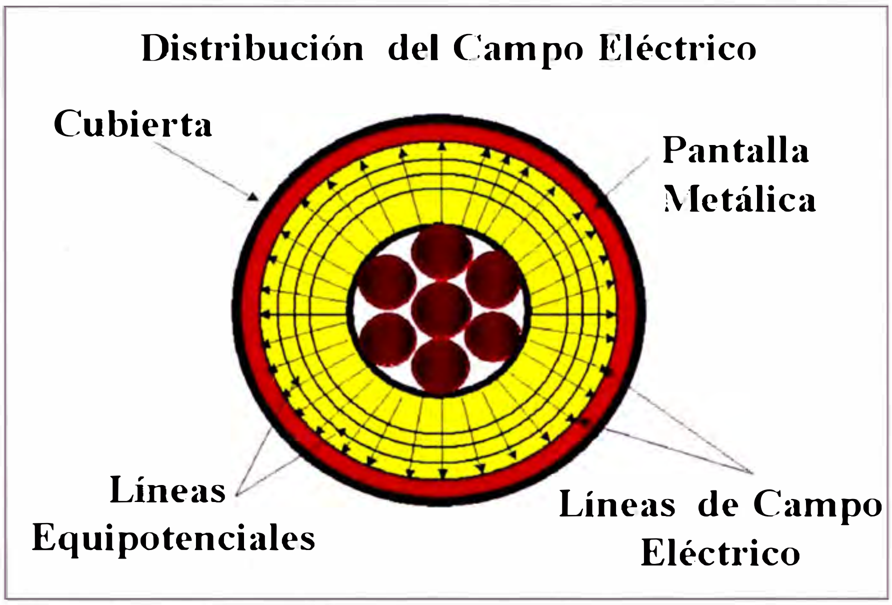

Fig. 1.6: Cable de media tensión. Conformación final.

CAPÍTULO II

TERMINACIONES PARA CABLES DE MEDIA TENSIÓN.

2.1 Introducción.

Las terminaciones, llamadas también como: mufas terminales, botellas terminales ó cabezas terminales, fueron desarrolladas por la necesidad de controlar tanto los efectos electromagnéticos producidos por el uso de la media tensión como los efectos que producen la humedad y los diversos contaminantes del medio ambiente, garantizando así la seguridad de las instalaciones eléctricas y de los usuarios.

Actualmente, existen diversos tipos de terminaciones diseñados para controlar los efectos mencionados anteriormente, usando para ellos distintos materiales y técnicas de montaje, entre los cuales se encuentran: el sistema de cintas, premoldeados (slip on), termocontraíbles y el sistema contraíble en frío o autocontraíble.

En el presente informe se analizan las terminaciones autocontraíbles de goma silicona, las cuales están especificadas para ser usadas en cables con pantalla y aislamiento sólido. Su diseño de una sola pieza hace que su instalación sea fácil, rápida y segura, no siendo necesario el uso de herramientas especiales.

2.2 Definición de términos técnicos.

Elastómeros.- Son aquellas resinas que al vulcanizarse con agentes químicos, como el azufre, producen materiales semejantes a la goma.

Monómero.- Es la unidad básica constituyente de un polímero. Así, el etileno es el monómero del polietileno.

Polímero.- Es una molécula de gran tamaño formada por la combinación de unidades químicas más pequeñas y simples llamadas monómeros.

Terminación.-Dispositivo para terminar cables de media tensión, de aislamiento laminado o extruído, para niveles de tensión de 2.5 kV ó más que se clasifican de la siguiente manera:

Clase 1: proveen control de esfuerzo en el corte de pantalla, aislamiento externo contra corrientes de fuga y sello contra ingreso de humedad.

Clase 2: proveen control de esfuerzo en el corte de pantalla y aislamiento contra corrientes de fuga.

Clase 3: proveen control de esfuerzo en el corte de pantalla.

Terminación para uso interior.- Es aquella diseñada para prestar servicio en instalaciones protegidas de la intemperie.

Terminación para uso exterior.- Es aquella diseñada para prestar servicio en instalaciones expuestas a la intemperie.

Tensión Nominal.- La tensión nominal de una terminación es aquella a la que puede funcionar permanentemente en condiciones normales de servicio. Se designa por la tensión expresada en kV entre cada uno de los conductores de fase y la pantalla metálica, Eo, y la tensión entre dos fases cualesquiera, E.

La tensión nominal de una terminación será como mínimo la misma que la del cable donde van instalados.

Tensión de Extinción de Descarga Parcial (Corona).- Es la tensión a la cual las descargas parciales no son detectables en los instrumentos (ajustados a sensibilidad y tensión específicas).

Intensidad de corriente máxima admisible en régimen permanente.- Es el valor máximo de la intensidad que puede soportar la terminación permanentemente, sin que la temperatura alcanzada sobrepase en ningún caso la máxima admitida por el cable.

Línea o distancia de fuga.- Es la menor distancia sobre la superficie aislante del terminal, entre la parte viva y la pantalla del cable de puesta a tierra.

Flashover.- Es la descarga disruptiva alrededor o sobre la superficie de un aislamiento, entre dos puntos de diferente potencial, producido por la aplicación de voltaje, donde el camino de descarga está suficientemente ionizado para mantener un arco eléctrico.

Cono de alivio o deflector.- Componente de la terminación que, unido a la pantalla metálica en el punto donde ésta termina, reduce el gradiente de potencial.

Tensión de Impulso (BIL: Basic Lightning Impulse Insulation Level).- Es el valor de cresta de la tensión de impulso de la forma de onda especificada.

Las terminaciones deben soportar las tensiones de impulso de maniobra y atmosféricas. De acuerdo a IEEE Std 48 – 1990, en la Tabla 2.1 se muestra el valor de BIL para cada clase de aislamiento.

Clase de Aislamiento (kV)	BIL (kV cresta)
5	75
8.7	95
15	110
25	150
34.5	200
46	250
69	350

Tabla 2.1: BIL de terminaciones de media tensión.

Constante dieléctrica K.- Es la medida de la capacidad de un material para almacenar carga eléctrica.

Material	K
Aire	1
Aislamiento del cable	3
Cinta de EPR	3
Material High - K	30

Tabla 2.2: Constante dieléctrica (K).

2.3 Materiales usados en terminaciones de media tensión.

Los materiales más utilizados para la fabricación de terminaciones de media tensión son:

- Porcelana
- Goma Silicona
- Goma EPDM
- EVA (termocontráctil)

2.4 La Goma Silicona.

Hace unos 30 años que se viene usando la goma silicona en terminaciones de media tensión. Para su desarrollo se hicieron muchos estudios de investigación con diferentes mezclas poliméricas hasta que se encontró una mezcla de silicona cuyas características permitieron obtener terminaciones no sólo fáciles de instalar, sino que presenta una buena performance en atmósferas húmedas y contaminadas.

2.4.1 La tecnología autocontraíble.

Los materiales que se usan son moldeados por inyección (uso exterior) o extruídos en forma tubular (uso interior), y luego son pre-ensanchados sobre un núcleo espiral de nylon. Cuando se retira el espiral, el tubo se contrae, ejerciendo una presión radial fuerte, uniforme y constante sobre el cable. Esta presión contráctil ofrece un sello contra la humedad y un buen contacto entre las superficies de la terminación y el cable, sin recurrir a la necesidad de utilizar adhesivos.

La facilidad de la aplicación son mostrados, esquemáticamente, en las Figs. 2.1a, 2.1b y 2.1c:

Fig. 2.1a: Se coloca el tubo pre-ensanchado

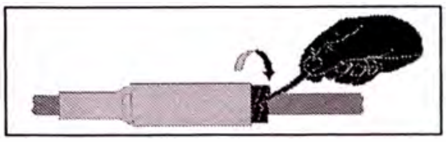

Fig. 2.1b: Se retira el tubo espiral de nylon.

Fig. 2.1c: El tubo se encuentra instalado.

Este sello se mantiene en el tiempo porque la goma tiene un enlace químico que le da al material una “memoria elástica”. Por esta misma razón, puede amoldarse a la expansión y contracción probable que pueda ocurrir en el cable durante las variaciones de carga.

2.4.2 Comportamiento de la silicona frente a la humedad.

La goma silicona, a diferencia de otros materiales como la porcelana, es hidrófuga, es decir, rechaza el agua. Cuando cae una gota de agua sobre la superficie de la silicona, no se esparce, conserva una forma casi esférica. Esto se puede apreciar en la Fig. 2.2.

Fig. 2.2: Gota de agua sobre la superficie de la silicona

Otra forma de expresar es que, los materiales *hidrófugos* como la silicona forman un ángulo de contacto grande, en cambio los materiales *hidrofílicos* forman ángulos de contacto mucho menores.

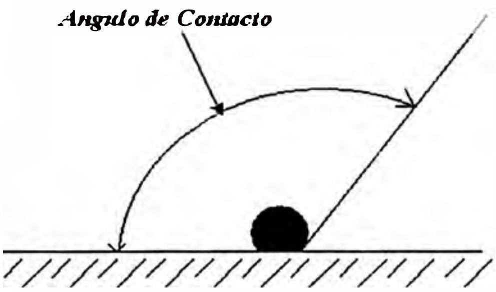

Fig. 2.3a: *Hidrófugo* Silicona

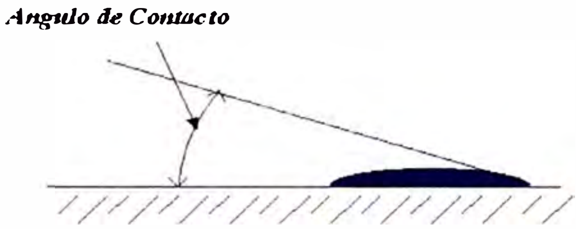

Fig. 2.3b: *Hidrofílico* Porcelana

2.4.3 Comportamiento de la silicona frente a los rayos UV.

La goma silicona es básicamente inorgánica, es decir, en su estructura molecular hay poca presencia de carbono. El enlace principal está formado por Silicio – Oxígeno (Si – O), el cual tiene una fuerza de enlace muy alta que difícilmente los rayos ultravioletas (UV) pueden romper, la estructura molecular son mostradas en las figuras siguientes:

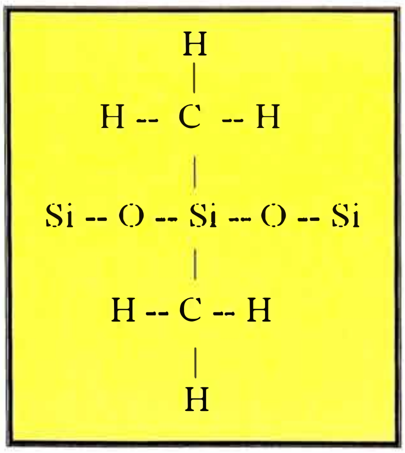

Fig. 2.4a: Fuerza del enlace Si-O

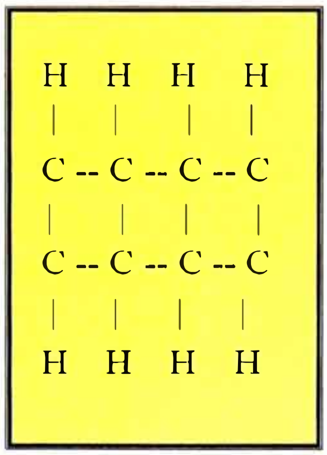

Fig 2.4b: Fuerza del enlace C-C

Como referencia, podemos ver en la Tabla 2.2, la magnitud de la fuerza de enlace de diversos elementos. Es necesario aplicar una energía mayor para romper dichos enlaces.

Energía de Enlace Polimérico	
Tipo de Enlace	**Fuerza de Enlace (kJ/M)**
Si – O (*)	445
C – O	360
C – C (**)	348
Si – C	318
C – S	275
Si - Si	222
UV (luz solr a 300 nm) (*) Silicona (**) EPDM, EVA, PE, etc	398

Tabla 2.2: Energía de Enlace Polimérico

2.4.4 Comportamiento de la silicona frente al tracking.

Se puede definir el tracking como el proceso que produce degradación de la superficie de la terminación, resultando en una pérdida progresiva del aislamiento por la formación de caminos conductivos.

Se produce tracking cuando tenemos presencia simultánea de:

- Contaminación: partículas en el ambiente, sustancias químicas, sal.
- Humedad: neblina, condensación, lluvia.
- Tensión eléctrica.

Estos elementos hacen que la resistencia superficial de la terminación disminuya, produciéndose corrientes de fuga. Es por ello que las terminaciones para uso exterior llevan campanas, los cuales evitan que se forme un camino continuo de humedad y contaminación.

2.5 Funciones de una terminación de media tensión.

De acuerdo a la norma IEEE 48 – 1990, las terminaciones están clasificadas según las funciones que cumplen:

Terminación Clase 1: Estas terminaciones proveen:

- Control de esfuerzo eléctrico en el corte de pantalla.
- Aislamiento contra corrientes de fuga (tracking).
- Sello de protección contra el medio ambiente.

Terminación Clase 2: Estas terminaciones proveen:

- Control de esfuerzo eléctrico en el corte de pantalla
- Aislamiento contra corrientes de fuga (tracking).

Terminación Clase 3: Estas terminaciones proveen:

- Control de esfuerzo eléctrico en el corte de pantalla.

Es importante mencionar:

- El control de esfuerzo es analizado en el acápite 2.6
- El aislamiento contra corrientes de fuga se indicó en el acápite 2.4
- El sello contra el medio ambiente debe ser tanto superior como inferior (se realiza mediante masillas aislantes y cinta de goma silicona).

2.6 Métodos de control de esfuerzo eléctrico.

El control del esfuerzo eléctrico en el corte de la pantalla semiconductora se resolvió inicialmente con el cono de alivio a base de cintas o premoldeados, luego se desarrolló la cinta de alta K y finalmente el tubo de alta K, que es el método que utiliza las terminaciones autocontraíbles de silicona.

Los cables apantallados están fabricados para soportar esfuerzos eléctricos uniformes a lo largo del cable. Tal como se indicó en el capítulo anterior (Fig, 1.6), las líneas de flujo se distribuyen en forma radial y uniforme, y las líneas equipotenciales son concéntricas.

Al efectuar la terminación de un cable, es necesario cortar y retirar la pantalla a una distancia dada del conductor según lo mostrado en la Fig. 2.5. Esto ocasiona una discontinuidad en la geometría axial del cable y un cambio brusco en el campo eléctrico, originando una concentración de esfuerzos en el lugar donde termina la pantalla.

Las líneas de campo, que parten perpendicularmente del conductor, convergen hacia el extremo del blindaje electrostático, y en consecuencia, el espaciamiento entre líneas equipotenciales es menor en esta zona, lo que significa que allí los gradientes de potencial resultan mayores. Estos gradientes son más elevados que los que existen en la zona cercana al conductor en tramos continuos de cable (zona de mayores gradientes).

Esta concentración, al no ser controlada, deteriora progresivamente el aislamiento con gran posibilidad de ocurrir una falla.

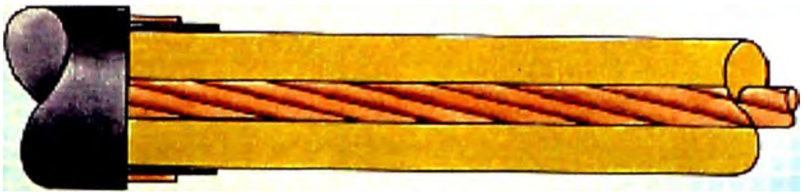

Fig. 2.5a: Corte y retiro de pantalla electrostática

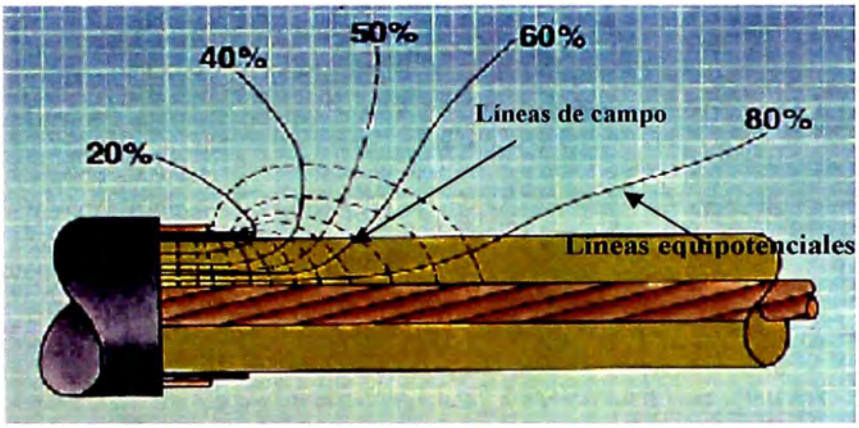

Fig. 2.5b: Líneas de campo eléctrico y líneas equipotenciales

2.6.1 Método geométrico (Cono de alivio).

Este método se conoce hace muchos años y consiste en expandir el diámetro del blindaje electrostático, con esto se logra que la superficie donde se concentra el campo eléctrico sea mayor, disminuyendo de esta manera el esfuerzo en dicha zona. En la Fig. 2.6 se observa la distribución del campo eléctrico y las líneas equipotenciales.

Inicialmente este aumento de diámetro se hacía utilizando cintas (goma aislante y luego cinta semiconductora) y posteriormente se desarrolló el cono premoldeado. Sin embargo, el terminal resulta de diámetro abultado en la zona del cono y su ejecución es lenta y tediosa, especialmente en el caso del cono encintado que depende mucho de la habilidad del montador.

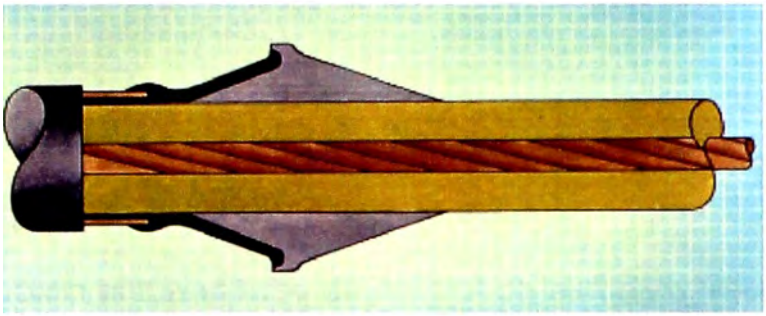

Fig. 2.6a: Cono de alivio

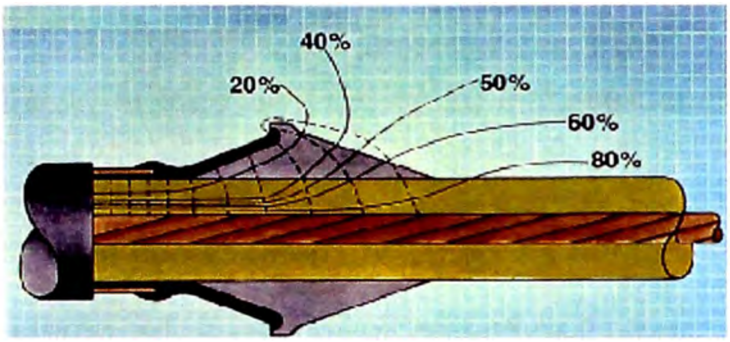

Fig. 2.6b: Nueva distribución de líneas de campo y líneas equipotenciales.

2.6.2 Método capacitivo (Alta K).

Este método consiste en el uso de un material de alta constante dieléctrica (K), generalmente en el rango de K30, colocado encima del aislamiento que tiene K3, como se observa en la Fig. 2.7a.

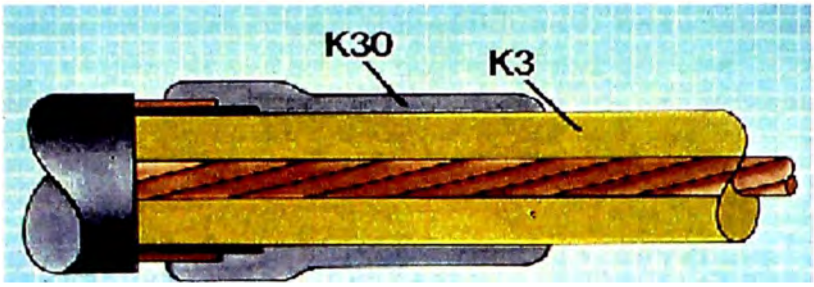

Fig. 2.7a: Tubo de control de esfuerzo High-K

Para entender como actúa el tubo de control de esfuerzo, recordemos el concepto de refracción de las ondas. Se basa en el hecho de que la velocidad de las ondas varía según el medio por donde atraviesan. Así, si insertamos oblicuamente un lápiz en un vaso con agua, parecerá que se "dobla" a la altura de la superficie del agua; esto se debe a que la luz pasa por dos medios de diferentes densidades.

El mismo efecto ocurre con el campo eléctrico, se refracta al pasar de un material de constante K1 a otro de constante K2. Esta refracción se muestra en la Fig. 2.7b y dependerá del ángulo de incidencia del campo eléctrico al pasar de un medio al otro y relación entre sus constantes dieléctricas.

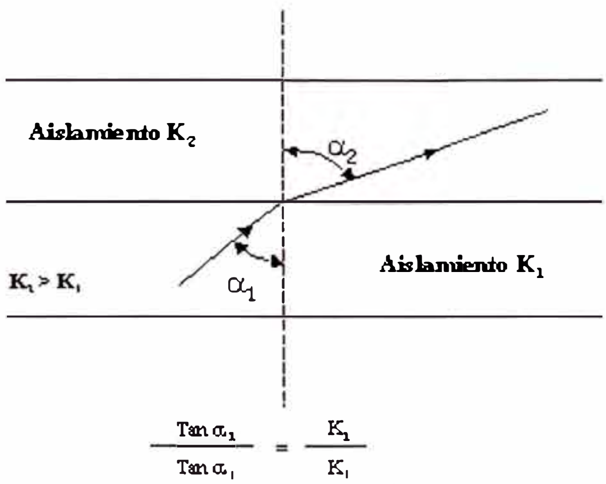

Fig. 2.7b: Refracción del campo eléctrico en la interfase

En nuestro caso, el campo sale del conductor, pasa por el aislamiento (K3) y se refracta en la interfase del aislamiento y el tubo de control de esfuerzo (K30), dirigiéndose por dentro del mismo hacia la pantalla. El resultado obtenido es que el esfuerzo eléctrico se reduce sustancialmente a lo largo del aislamiento, especialmente en la zona de corte de la pantalla. Esto se demuestra por el incremento de la separación de las líneas equipotenciales (ver Fig. 2.7c), es decir, a mayor relación de constantes dieléctricas, mayor será la magnitud de la refracción del campo eléctrico,

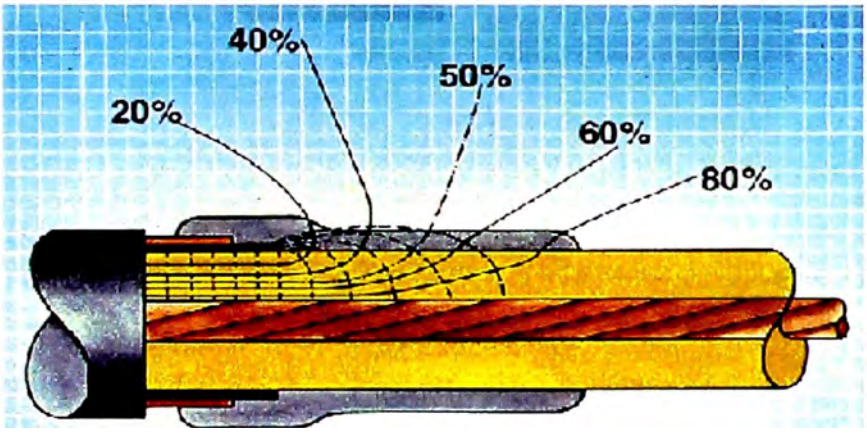

Fig. 2.7c: Nueva Distribución de líneas de campo y líneas equipotenciales.

En la Fig. 2.8 se comparan los dos métodos de control de esfuerzo. Con el uso de tubos de alta K se ha obtenido terminaciones más pequeñas y de más fácil instalación, ya que este tubo viene incorporado al tubo aislante de goma silicona, montándose ambos con la tecnología autocontraíble.

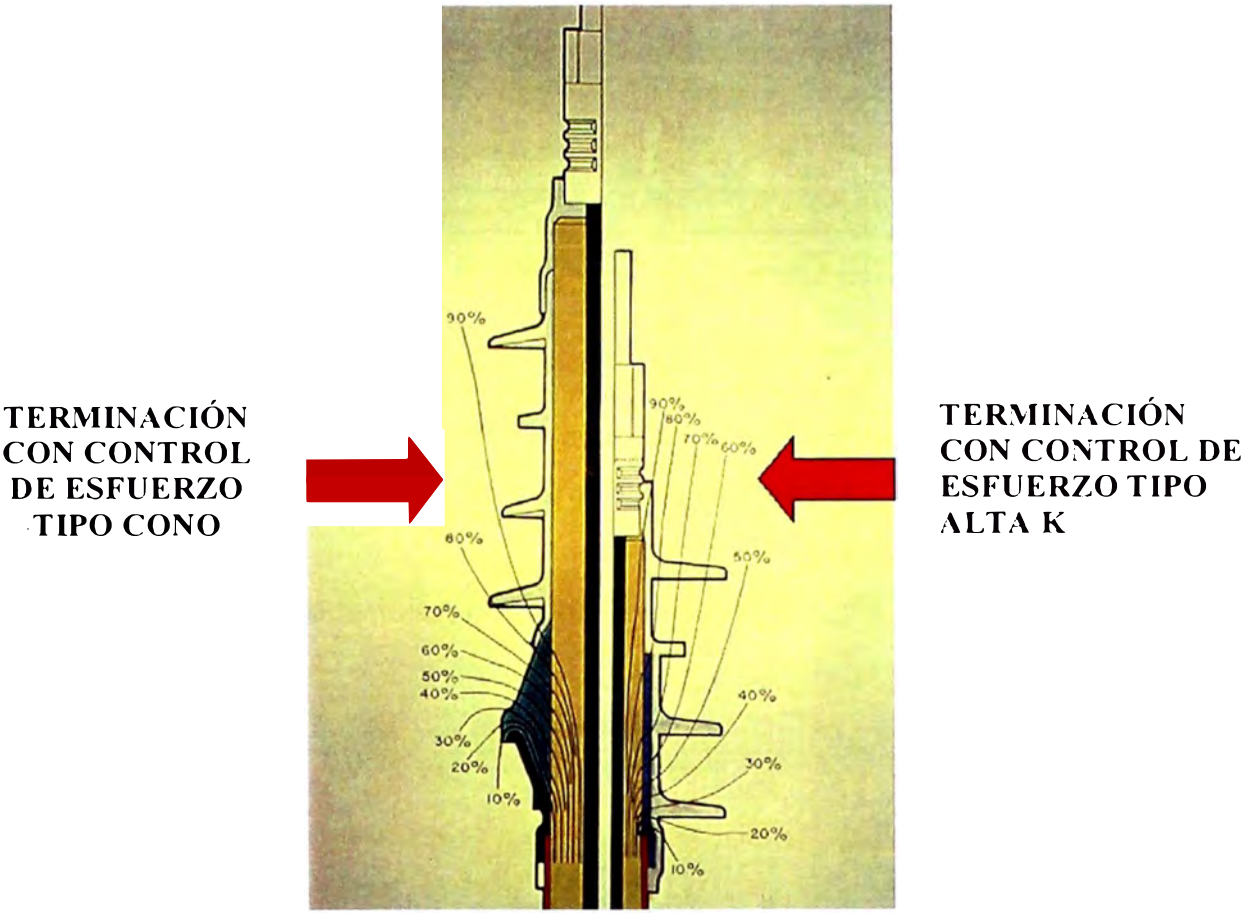

Fig. 2.8: Control de esfuerzo: Cono vs Tubo alta K

2.7 Corrección por altura.

Las terminaciones están especificadas para instalaciones de altitudes hasta 1000 metros sobre el nivel del mar. Para mayores alturas, se debe tener en cuenta que la densidad del aire es menor con respecto a la del nivel del mar y, en consecuencia, la rigidez dieléctrica del aire se reduce. La menor densidad del aire afectará también la ventilación natural de la terminación.

Por estas razones, para aplicaciones mayores a 1000 metros de altitud, se deberá derratear la Clase de tensión de la terminación usando el “factor de derrateo por altura” (ANSI / IEEE C57.12.00) de la tabla siguiente:

Altura (m)	Factor "k" de corrección de rigidez dieléctrica
1000	1.00
1500	0.95
2000	0.90
2500	0.85
3000	0.80
3500	0.76
4000	0.73
4500	0.67

Tabla 2.3: Factor de corrección por altura.

La corrección del nivel de tensión por altura esta expresada por:

$$V = \frac{\text{Voltaje Nominal}}{k} \qquad (2.1)$$

Se deberá usar terminaciones con rating igual o superior al valor así calculado.

2.8 Preparación del cable para instalar una terminación.

Tan importante como la buena instalación de una terminación es la buena preparación del cable, para lo cual debemos tener en cuenta las siguientes recomendaciones:

a.- Leer bien las instrucciones de montaje antes de iniciar el corte y retiro de las distintas capas que conforman el cable, verificando las dimensiones que se deben respetar.

b.- El operario deberá mantener las manos limpias y secas durante todo el proceso de montaje para no contaminar la zona de trabajo.

c.- Cortar el extremo del cable en caso de observar daño mecánico o presencia de contaminantes como polvo, arena, humedad y otros.

d.- Limpiar y lijar la zona adyacente al corte de la cubierta del cable, antes de retirar dicha cubierta (el lijado provee mayor adhesión de las gomas tipo mastic que se utilizan para el sello contra ingreso de humedad). No dejar este paso para el final de la preparación del cable, evitando así contaminar la parte expuesta del semiconductor y del aislamiento.

e.- La "regla de oro" de la preparación del cable es: *cortar y retirar cada capa del cable sin dañar la siguiente capa*.

f.- Si al retirar la pantalla semiconductora se hace un corte superficial en el aislamiento, debemos eliminarlo usando la lija no conductiva. Pero, si el corte es profundo, es preferible cortar el cable y empezar nuevamente. (Un corte profundo puede ocasionar que quede aire atrapado, el cual al ionizar producirá descargas corona y finalmente ocasionará la perforación del cable).

g.- El corte de la pantalla metálica debe ser limpio, recto y sin rebabas.

h.- En caso de requerir marcas provisionales en el semiconductor, se deberá usar cinta aislante con el adhesivo hacia afuera.

i.- La limpieza debe realizarse con el solvente que viene en el kit (no usar gasolina, kerosene o thinner). Debe evitarse el contacto del solvente con el semiconductor para evitar arrastrar partículas conductivas hacia el aislamiento.

j.- Usar bornes terminales de compresión o conectores tubulares tabicados para evitar el ingreso de humedad. El prensado debe hacerse con la prensa y dados apropiados, con el número de compresiones recomendados. En caso de rebabas deben ser eliminadas.

2.9 Procedimiento de montaje de una terminación autocontraíble de goma silicona.

Cada kit contiene materiales suficientes para hacer 3 terminaciones unipolares. Los componentes son:

3 tubos de goma silicona autocontraíble, con tubo de alta K incorporado.

3 sistemas de puesta a tierra (platina de Cu estañado y resorte de presión constante)

3 tiras de mastic.

1 rollo de cinta semiconductora.

1 rollo de cinta de goma silicona.

3 cojines de grasa de silicona.

1 kit de preparación de cable (lija no conductiva y 3 paños con solvente)

1 instructivo de montaje.

El procedimiento para hacer el montaje de una terminación autocontraíble de goma silicona están indicados en las figuras 2.9a, 2.9b y 2.9c.

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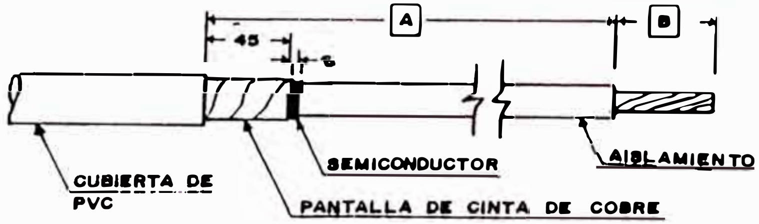
TÍTULO: TERMINACIÓN AUTOCONTRAÍBLE TIPO QTII EN CABLE SECO UNIPOLAR 15 kV USO EXTERIOR

DIB: JORGE HIDALGO
DIS: JORGE HIDALGO
REV:
APROBADO: V.C.C.
FIG: 2.9.a

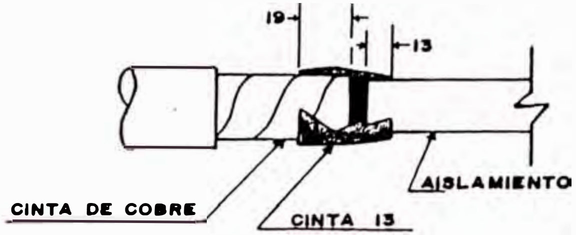
DIMENSIONES EN mm

DIMENSION	KIT Nº			
	5633K	5635K	5636K	5637K
A	241mm		254 mm	
B	PROFUNDIDAD DEL CONECTOR TERMINAL			



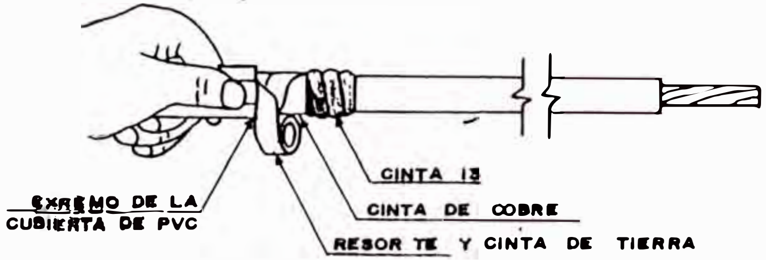
①

- RETIRAR LA CUBIERTA DE PVC, LA PANTALLA DE CINTA DE COBRE, LA CINTA SEMICONDUCTORA Y EL AISLAMIENTO COMO SE MUESTRA EN LA FIG. Y EN LA TABLA.
- LIMPIAR EL CABLE UTILIZANDO LOS PAÑITOS CON SOLVENTE DEL KIT CC-2. TENER CUIDADO DE QUE EL SOLVENTE NO TOQUE EL MATERIAL SEMICONDUCTOR.



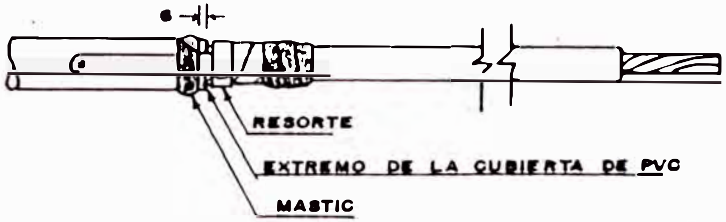
②

- APLICAR 2 CAPAS DE CINTA 13 A MEDIO TRASLAPE, ESTIRANDOLA FIRMEMENTE, SOBRE 19mm DE LA CINTA DE COBRE, EL SEMICONDUCTOR Y 13 mm. SOBRE EL AISLAMIENTO, COMO SE MUESTRA EN LA FIG.



③

- DESENROLLAR 25 A 50 mm EL RESORTE DE LA CINTA DE TIERRA.
- COLOCAR LA CINTA DE TIERRA A LO LARGO DEL CABLE.
- MANTENGA EL RESORTE EN SU LUGAR CON EL PULGAR.
- JALE EL RESORTE ALREDEDOR DE LA PANTALLA DE CINTA DE COBRE Y ENROLLELA SOBRE ELLA.



④

- ESCOGER UNA DE LAS TRES TIRAS DE MASTIC QUE SE INCLUYEN EN EL KIT. CORTAR DOS TROZOS DE 38mm DE LARGO Y QUITARLES SU ENVOLTURA PROTECTORA (LINER).
- COLOCAR UN TROZO DEBAJO DE LA CINTA DE TIERRA A 6 mm DEL EXTREMO DE LA CUBIERTA DE PVC, PRESIONE LA CINTA DE TIERRA CONTRA EL MASTIC Y COLOQUE EL SEGUNDO TROZO SOBRE LA CINTA DE TIERRA. VER FIG.

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DIB: JORGE HIDALGO
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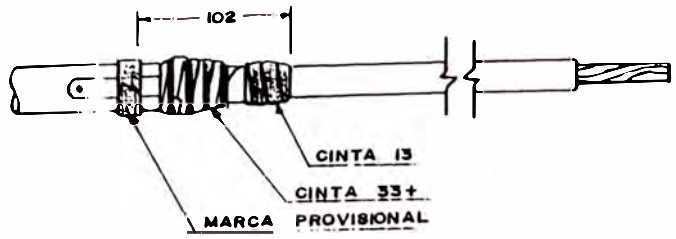
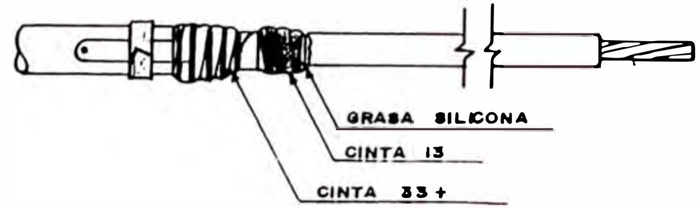
REV:
APROBADO: V.C.C.
FIG: 2.9.b



(5)

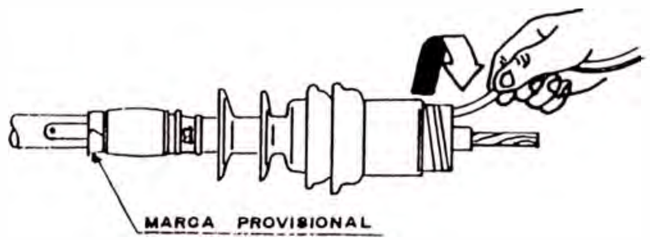
- APLICAR UNA CAPA A MEDIO TRASLAPE DE CINTA 33+ SOBRE EL MASTIC Y SOBRE EL RESORTE. NO CUBRIR LA CINTA 13
- HACER UNA MARCA PROVISIONAL A 102 mm DEL EXTREMO DE LA CINTA 13, COMO SE INDICA EN LA FIG.

NOTA: LA CINTA 33+ NO SE SUMINISTRA EN EL KIT.



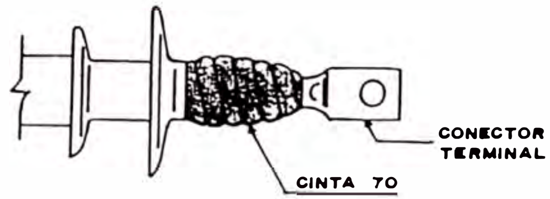
(6)

- APLICAR EN EL BORDE DE LA CINTA 13 UNA GENEROSA CAPA DE GRASA SILICONA.



(7)

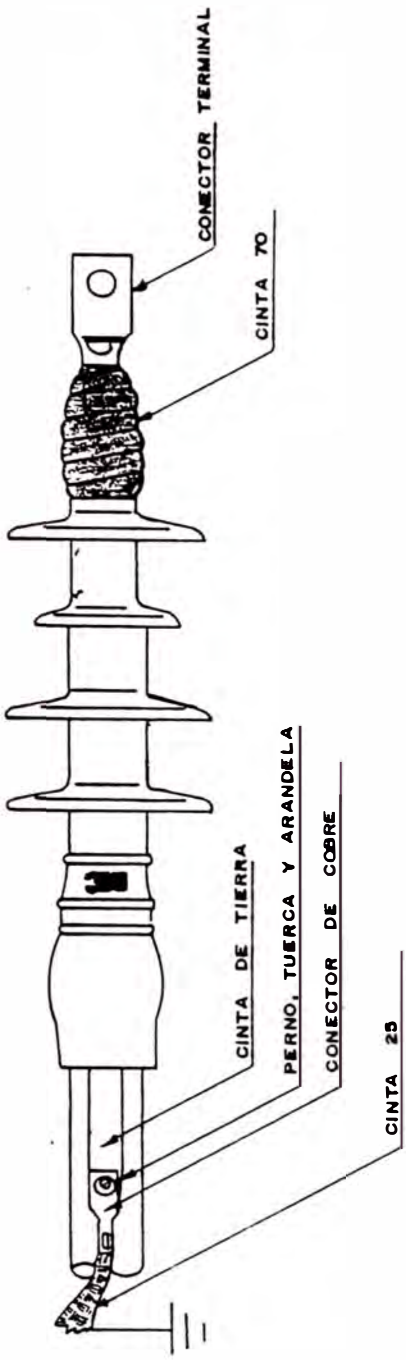
- INTRODUCIR EL AISLADOR EN EL CABLE HASTA EL BORDE DE LA MARCA PROVISIONAL. DESENROLLAR EL SOPORTE DE NYLON EN SENTIDO ANTIHORARIO.



(8)

- INSTALAR EL CONECTOR TERMINAL. PRENSAR EL CONECTOR APLICAR 4 CAPAS A MEDIO TRASLAPE DE CINTA 70 SOBRE EL CONECTOR Y SOBRE 25 mm DEL AISLADOR.

NOTA: LA CINTA 70 SE APLICA CON TENSION MODERADA.



(9) – CONECTAR LA TERMINACION A TIERRA COMO SE MUESTRA EN LA FIG.

UNIVERSIDAD NACIONAL DE INGENIERÍA FACULTAD DE INGENIERÍA ELÉCTRICA Y ELECTRÓNICA	TÍTULO: TERMINACIÓN AUTOCONTRAÍBLE TIPO QTII EN CABLE SECO UNIPOLAR 15 kV USO EXTERIOR	DIB: JORGE HIDALGO DIS: JORGE HIDALGO REV: APROBADO: V.C.C. FIG: 2.9.c	

CAPITULO III

ESPECIFICACIONES TÉCNICAS

3.1 Introducción.

En este capítulo se establecen las características técnicas que deben cumplir las terminaciones de media tensión, para efectos de ser utilizadas en las redes de distribución de una Empresa de Electricidad. Esta información es normalmente requerida en las licitaciones de obra, por lo que, para aclarar los conceptos que se deben especificar, se indican ejemplos de valores típicos, los cuales, en el caso de las terminaciones autocontraíbles de goma silicona, resultan ser iguales o mayores que los solicitados.

También se especifican otros elementos relacionados con las terminaciones como son: los cables de energía, las condiciones ambientales y de operación.

3.2 Normas de fabricación y pruebas.

Los accesorios considerados, deberán cumplir con la norma IEEE Std 48, “Standard Test Procedures and Requirements, for Alternating – Current Cable Terminations 2.5 kV Through 765 kV”

3.3 Condiciones ambientales.

Se establece las condiciones ambientales en las cuales trabajarán las terminaciones de media tensión. Las Empresas de Electricidad de Lima han clasificado las siguientes zonas de su área de concesión, según el nivel de corrosión:

3.3.1 Zona costera de "Corrosión severa, alta contaminación".

Altura sobre el nivel del mar	: hasta 300 m.
Humedad relativa	de 70% hasta 100%
Temperatura ambiente	15 °C a 35 °C

Neblina con suspensiones de sal, humos industriales y carencia de lluvias. Ambiente que presenta alta contaminación y corrosión.

3.3.2 Zona interior de "Corrosión moderada".

- Altura sobre el nivel del mar	: desde 300 m hasta 2000 m.
Humedad relativa	hasta 70 %
Temperatura ambiente	10°C a 35°C

Lluvias y neblinas durante los meses de Diciembre a Abril.

3.4 Condiciones de operación.

Con el objetivo de realizar una buena selección de las terminaciones de media tensión, es necesario conocer datos sobre el sistema eléctrico donde van a ser instaladas, siendo ellos:

- Tensión de servicio.
- Tensión máxima de operación.
- Nivel de cortocircuito.
- Tipo de conexión del neutro.

3.5 Condiciones generales de suministro.

Además de las características técnicas de las terminaciones, es necesario conocer los tipos de cables donde van a ser instaladas, por lo que se indican los datos de ambos materiales.

3.5.1 Características de los cables.

Para efectos de selección de la terminación adecuada para un cable determinado, es necesario conocer los datos siguientes:

- Tensión de diseño del cable.
- Tensión de servicio.
- Tipo de aislamiento del cable
- Conformación del cable.
- Diámetro sobre el aislamiento
- Calibre del conductor
- Tipo de instalación
- Altitud sobre el nivel del mar

3.5.2 Características de las terminaciones.

Las características técnicas básicas que las terminaciones deberán cumplir son:

- Las terminaciones serán Clase 1, es decir, proveerán control de esfuerzo eléctrico, aislamiento resistente al tracking y sello contra ingreso de humedad.
- Indicar la tecnología de montaje.

- Tipo de instalación, uso interior o exterior.
- Serán ofrecidos en kits de 3 juegos completos.
- Incluirán el conector de puesta a tierra.
- El borne terminal será estanco y tendrá un baño de estaño para protección contra la corrosión.
- El instructivo de montaje, preferentemente en español, será incluido en el kit.
- La caja de cada kit llevará los datos siguientes:

Terminación interior (o exterior).	
Tensión nominal de diseño (Eo/E)	: Ej. 8.7/15 kV
Tipo de cable	: Ej. Unipolar (o tripolar)
Sección	: Ej. 1 x 120 mm2
Diámetro sobre el aislamiento	: Ej. 16.3 – 22.9 mm
Número de catálogo	: Ej. QTII 5633K
Código de stock	

3.6 Garantía de Calidad Técnica.

La garantía técnica otorgada es de 2 años, a partir de la entrega del material y consiste en la obligación de reponer el producto que presente fallas atribuibles al diseño o al proceso de fabricación.

3.7 Especificaciones técnicas de suministro.

Las especificaciones técnicas deben ser abiertas, es decir, no deben estar direccionadas a determinado fabricante o tecnología. En la Tabla 3.1

se da un ejemplo de especificaciones en la cual los datos requeridos están dados por normas internacionales.

CARACTERÍSTICA	UNIDAD	SOLICITADO	OFRECIDO
Marca			
Modelo			QTII
Número de catálogo			5633KC-70
Tipo			Autocontraíble
Norma de diseño y pruebas		IEEE Std 48	IEEE Std 48
Sección del conductor	mm2	1 x 70	1 x 70
Diámetro sobre el aislamiento	mm		16.3 – 22.9
Tensión de servicio	kV	10	Clase 15 kV
Tensión de prueba, descarga parcial (< 3pC)	kV	13	28
Tensión alterna sostenida, en seco, 1 min.	kV	50	85
Tensión alterna sostenida, en seco, 6 hr.	kV	35	80
Tensión alterna sostenida, en húmedo, 10 seg.	kV	45	65
Tensión directa sostenida, 15 min.	kV	75	75
Tensión de impulso	kV	110	150
Línea de fuga mínima	mm	400	438

Tabla 3.1: Especificaciones técnicas de terminación polimérica unipolar, uso exterior, para cable N2XSY, 10 kV

CAPITULO IV

PRUEBAS APLICADAS A TERMINACIÓN DE MEDIA TENSIÓN

4.1 Introducción.

En nuestro medio, para realizar las pruebas de terminaciones de media tensión, se considera como referencia las normas IEEE Std 48.

Las pruebas se consideran pruebas tipo, es decir, son realizadas por el fabricante durante el desarrollo de un nuevo producto o modelo de terminación, y serán tales que después de haber sido superadas, no deberán repetirse, a excepción que dicho modelo sufra modificaciones en su concepción o en alguno de los materiales utilizados.

Estas pruebas, garantizan la buena performance a largo plazo de los accesorios. En general los accesorios deben tener una expectativa de vida similar al cable.

Debido a la variedad de materiales usados y modelos de estos accesorios, el fabricante tiene la potestad de diseñar sus propios métodos de calificación de sus productos, por lo que no se puede establecer pruebas de rutina. Sin embargo, las pruebas mínimas a ser a las terminaciones serán convenidas entre el fabricante y el usuario.

4.2 Pruebas de la goma silicona como materia prima.

La goma silicona tiene buenas propiedades físicas, que la hacen apta para ser usada como materia prima para la fabricación de terminaciones de media tensión. En el Anexo B se muestran características como: factor de disipación, constante dieléctrica, elongación, carga de rotura y otros.

4.3 Pruebas de diseño y producto terminado.

4.3.1 Organismos Internacionales:

Los principales Organismos Internacionales que se consideran como referencias para realizar las pruebas de diseño y producto son:

- ABNT - Brasil
- BSI – Inglaterra
- CENELEC – Europeo
- EDF – Francia
- IEEE – USA
- JCAA – Japón
- VDE – Alemania

4.3.2 Pruebas estandarizadas

De acuerdo a la norma IEEE Std 48 (ver Anexo D), las terminaciones deben pasar satisfactoriamente las pruebas siguientes:

a.- Prueba de tensión sostenida a frecuencia industrial, 60 seg. en seco.

b.- Prueba de tensión sostenida a frecuencia industrial, 10 seg. en húmedo.

c.- Prueba de tensión sostenida a frecuencia industrial, 6 hrs. en seco.

d.- Prueba de descargas parciales (corona).

e.- Prueba de tensión de impulso (BIL).

g.- Prueba de carga cíclica.

4.3.3 Secuencia típica de pruebas:

Las pruebas mencionadas no se realizan separadamente, sino que deberán seguir una secuencia de pruebas. Una secuencia típica es la mostrada en la tabla siguiente:

1° Descarga parcial.	7° Descarga Parcial
2° Tensión sostenida AC – 1 min..	8° Ciclos térmicos.
3° Tensión sostenida AC – 6 hr.	9° Descarga parcial.
4° Tensión sostenida AC – 10 seg. (lluvia).	10° Impulso (BIL)
5° Tensión sostenida DC – 15 min.	11° Prueba de presión (detectar fugas)
6° Impulso (BIL)	

Tabla 4.1: Secuencia típica de pruebas de diseño de terminaciones.

4.3.4 Pruebas adicionales:

Adicionalmente a las pruebas estandarizadas, el fabricante puede diseñar sus propias pruebas de producto en coordinación con el usuario. Entre ellas mencionamos las siguientes:

a.- Prueba salina: Las terminaciones son expuestas a una mezcla vaporizada de agua y sal, y energizadas a 1 x Eo de tensión (8.7 kV para Clase 15 kV). El nivel de conductividad de la solución salina es de 1000 µS/cm.

b.- Prueba de contaminantes sólidos: Simula zonas industriales, de alta humedad y costeras. Las terminaciones son cubiertas con una mezcla de contaminantes sólidos (ASTM-D-2132) que incluyen:

Piedra silicia	85 partes
Arcilla	9 partes
Sal	3 partes
Pulpa de papel	3 partes
Agua	100 partes

Tabla 4.2: Composición de contaminantes para prueba de laboratorio

Son constantemente rociadas por agua y energizadas a un valor de 150% de la tensión nominal.

c.- Prueba francesa de humedad: Se utiliza para terminaciones de uso interior, en ambientes de humedad relativa 95% y temperatura de 30 a 45 °C. Se aplica una tensión de 2 x Eo durante 350 horas.

4.3.5 Descripción de las principales pruebas de terminaciones de media tensión:

Previamente a la realización de las pruebas, las muestras deberán estar preparadas teniendo en cuenta lo siguiente:

- Deben estar limpias
- Deben estar secas o húmedas (según el tipo de prueba)
- Deben estar montadas sobre el cable de mayor calibre para el cual están diseñadas.

- Deben ser montadas siguiendo las instrucciones del fabricante, incluyendo el control de esfuerzo y el sello contra ingreso de humedad.
- Deben estar conectadas a los equipos de prueba utilizando elementos similares a los que se usan en una instalación estándard

a.- ***Prueba de tensión sostenida a frecuencia industrial:*** La tensión de prueba se aplicará entre el conductor y la pantalla puesta a tierra para el caso de cables unipolares y entre un solo conductor y los otros dos unidos entre sí y a las pantallas puestas a tierra, para el caso de cables tripolares.

Si la muestra soporta la tensión de prueba especificada, durante los tiempos que se indican en las columnas 3, 4 y 5 de la Tabla 4.3, se considerará que la muestra ha pasado la prueba. Si ocurre descarga disruptiva ó perforación, se deberá repetir la prueba. Si en la repetición de la prueba se presenta nuevamente una descarga disruptiva o perforación, se considerará que la muestra no pasó la prueba y será rechazada; en cambio, si en la repetición no hay presencia de descarga ni otro tipo de falla, entonces se considera que la muestra sí pasó la prueba.

Cabe mencionar que la prueba de tensión sostenida durante 10 segundos, en húmedo, solo es requerido para los modelos de uso exterior.

b.- ***Prueba de descargas parciales (corona) – Tensión de extinción:*** El instrumento detector de descargas parciales debe estar ajustado para medir pulsos de descarga del orden de 3 pC. La tensión de prueba debe ser elevada por lo menos hasta 120% del valor indicado en al columna 8 de la Table 4.3. Si la descarga parcial excede de 3 pC la tensión será disminuida hasta el valor indicado en la columna 8 y deberá mantener este nivel mínimo 3 seg. y máximo 60 seg. La muestra pasará la prueba si el nivel de descarga parcial no excede de 3 pC durante el periodo indicado.

c.- ***Prueba de tensión de impulso (BIL):*** Se realiza con la tensión normalizada de 1.2/50 μs, con los valores de cresta que se indican en la columna 9 de la Tabla 4.3. Se deben aplicar 10 impulsos positivos y 10 impulsos negativos entre conductor y pantalla puesta a tierra para el caso de cables unipolares y entre un solo conductor y los otros dos unidos entre sí y las pantallas puestas a tierra, para el caso de cables tripolares.

Se considera el resultado como satisfactorio si no se producen descargas externas ni perforaciones. Se admite que durante los ensayos de un terminal se produzca una descarga externa, en cuyo caso deberán aplicarse 10 nuevos impulsos de la misma polaridad. Si no se produce ninguna descarga externa ni perforación, se considerará que la muestra pasó la prueba.

d.- ***Prueba de tensión sostenida en corriente continua:*** La muestra será sometida a la tensión continua indicada en la columna 11 de la Tabla 4.3 durante 15 minutos. Si ocurre una descarga o perforación, se repite la prueba. Si vuelve a producirse descarga o perforación, se considera que la muestra no pasó la prueba.

e.- ***Prueba de ciclo de carga (envejecimiento acelerado):*** Para terminaciones en cable unipolar y clase de aislamiento hasta 46 kV, se prepararán 4 muestras montadas en los extremos de 2 tramos de cables. Estos tramos de cable tendrán una longitud de 2.0 m como mínimo cada uno y estarán conectados en paralelo con ambas pantallas conectadas a tierra.

La prueba consta de 3 etapas:

Primera etapa: En la columna 6 de la Tabla 4.3, se indica la tensión que será aplicada sin interrupción durante un periodo de 30 días. La fase de calentamiento se inicia haciendo circular por los conductores una corriente tal que la temperatura en el cable se encuentre a unos 5 °C de su temperatura máxima de operación en emergencia y por un periodo de 6 horas. La fase de enfriamiento se realiza sin corriente pero con tensión aplicada, durante un tiempo tal que la temperatura del cable se enuentre a unos 5 °C de la temperatura ambiente.

Un ciclo de carga aproximadamente se logra en 24 horas dependiendo del tiempo que tome llegar a las temperaturas requeridas de calentamiento y enfriamiento. Se debe completar 30 ciclos de carga.

Segunda etapa: Luego de los 30 ciclos de carga mencionados, las 4 muestras serán sometidas a la prueba de descargas parciales (corona).

Tercera etapa: Finalmente, las 4 muestras serán sometidas a la prueba de tensión de impulso aplicando una tensión normalizada de 1.2 / 50 μs.

Luego de haber realizado las tres etapas, se verifica el estado físico de las muestras y si se comprueba que se haya producido perforación o daños en el dieléctrico en una de las muestras, se considerará como falladas todas las muestras.

f.- ***Prueba de presión (detección de fugas):*** La muestra será sometida a una presión de 200 kPa (30 lb/pulg2) en el extremo del cable, por 1 hora. Si se usa gas a presión, la muestra debe ser sumergida en un recipiente de agua con solución jabonosa a no menos de 5 cm debajo de la superficie. Si se usa un líquido a presión, la muestra deberá ser espolvoreada con tiza en las zonas de los sellos y se aplicará una presión de 100 kPa (15 lb/pulg2) durante 2 horas ó 50 kPa (7 lb/pulg2) durante 6 horas.

La muestra pasará la prueba si no se presentan fugas ni roturas, luego de haber realizado el ensayo.

Clase de aislamiento (KV) Columna 1	Tensión máx a tierra (kV) Columna 2	Tensión alterna					Descarga parcial tensión extinción corona (kVrms) Columna 8	Tensión Impulso (Bil) seco (kVcresta) Columna 9	Tensión Impulso Maniobra (BSL) (kV cresta) Columna 10	Tensión continua 15min, seco (kVavg) Columna 11
		1min, seco (kVrms) Columna 3	10 seg, húmedo (kVrms) Columna 4	6 h, seco (kVrms) Columna 5	Ciclo de carga, seco (kVrms) Columna 6	Radio Interferencia (µV) Columna 7				
2.5	1.6	20	20	10	4.5	50	2.0	60	---	40
5	3.2	25	25	15	9	50	4.5	75	---	50
8.7	5.5	35	30	25	15	50	7.5	95	---	65
15	9.5	50	45	35	26	50	13	110	---	75
25	16.0	65	60	55	43	100	21.5	150	---	105
34.5	22.0	90	80	75	60	150	30	200	---	140
46	19.5	120	100	100	53	200	40	250	---	170

Tabla 4.3: Pruebas dieléctricas para terminaciones instaladas en cables de media tensión de aislamiento extruído.

4.4 Resultado de las pruebas realizadas en terminaciones autocontraíbles.

En la Tabla 4.4 se muestra los resultados obtenidos al realizar las pruebas de diseño, para una terminación autocontraíble de goma silicona de 4 campanas, Clase 15 kV, tomando como referencia los valores indicados por la norma IEEE Std 48-1990.

Datos adicionales para mayor número de campanas y/o clase de aislamiento se muestran en el Anexo B.

IEEE Std. 48	Clase 15 kV	
	Requerido	Resultado
AC 60 seg, seco	50 kV	85 kV(*)
AC 10 seg, húmedo	45 kV	55 kV(*)
AC 6 hr, seco	35 kV	80 kV(*)
Corona 3 pC, CSV (inicio) CEV (extinción)	-- 13 kV	33 kV 28 kV
DC 15min, seco	75 kV	Pasó 75 kV
Impulso	110 kV	+165 kV(*) -150 kV(*)
Ciclo de carga, 30 días AC, 130°C • Corona 3 pC, CEV • Impulso 10+ 10-	 28.5 kV 13 kV +110 kV -110 kV	 Pasó Pasó Pasó Pasó

Tabla 4.4: Resultados típicos de pruebas de diseño, modelo QTII de 4 campanas.

4.5 Protocolo de pruebas típico de terminaciones autocontraíbles para uso exterior.

En el Anexo C se muestra el protocolo de pruebas de una terminación autocontraíble de goma silicona para uso exterior, en la cual se observa que los resultados de las pruebas exceden los valores requeridos por la norma IEEE Std 48

CAPITULO V

COSTOS Y PRESUPUESTOS

5.1 Introducción.

Las terminaciones fabricadas con materiales elastoméricos son cada día menos costosos, razón por la cual no tienen mayor ingerencia dentro del presupuesto de una obra. Los materiales y equipos, tales como: transformadores, celdas de transformación, cables de energía y otros, son más significativos en la estructura de costos de obras en redes de distribución primaria. Sin embargo, en forma referencial, se indican en este capítulo precios de terminaciones de goma silicona y el costo de la mano de obra para el montaje en obra.

5.2 Tiempos de instalación.

El tiempo total de instalación de una terminación está dado por la suma del tiempo de preparación del cable más el tiempo de montaje del kit.

En la tabla 5.1 se muestran los tiempos referenciales que toma la instalación de terminaciones en un cable seco unipolar de 35 mm2, 15 kV, según el tipo de tecnología que emplea para su montaje.

Tiempo	**Autocontraíble**	Termocontraíble	Porcelana	EPDM
Preparación del cable	1.5	2.0	1.5	1.5
Montaje de terminación	0.5	1.2	2.2	0.8
Tiempo de Instalación	2.0	3.2	3.7	2.3

Tabla 5.1: Tiempos de instalación de terminaciones con diferentes tecnologías de montaje.

Vemos que la tecnología autocontraíble es la que emplea menos tiempo para instalar un kit de terminaciones, por lo tanto el costo de mano de obra también será menor.

5.3 Precios referenciales de terminaciones autocontraíbles.

En la tabla 5.2 se muestran los precios de mercado de kits de terminaciones unipolares, clase 15 kV, tanto para uso interior como exterior.

Calibre	Modelo	Precio del kit (US$)	Mano de Obra (US$)
Unipolar, uso interior: 25 – 70 mm2 95 – 240 mm2 300 – 500 mm2	 QTII 5623K QTII 5624K QTII 5625K	 140.00 180.00 220.00	 70.00 80.00 100.00
Unipolar, uso exterior: 25 – 70 mm2 95 – 240 mm2 300 – 500 mm2	 QTII 5633K QTII 5635K QTII 5636K	 270.00 295.00 340.00	 70.00 80.00 100.00

Tabla 5.2: Precio de kits de terminaciones autocontraíbles

Cabe mencionar que cada kit contiene 3 terminaciones unipolares y 3 bornes terminales de cobre estañado.

CONCLUSIONES

- La silicona, por sus características eléctricas y mecánicas y sus ventajas frente a otras alternativas, han demostrado en los últimos 30 años ser un buen material para la fabricación de terminaciones de media tensión. Estas características y ventajas son:

  Es hidrófuga, es decir, rechaza el agua.

  Tiene gran estabilidad frente a los rayos ultravioleta.

  Tiene una superficie lisa que minimiza la adhesión de contaminación.

  Es, en su mayor parte, inorgánica, por lo que las erosiones producidas por descargas eléctricas, no forman caminos conductivos de carbono.

- Las terminaciones de silicona, frente a otros materiales como el termocontraíble, EPDM, y la porcelana, tiene las ventajas siguientes:

  Es fácil de instalar.

  No requiere el uso de herramientas especiales.

  Pocos componentes por cada kit.

  Con pocos tamaños se abarca todos los calibres de cable.

- Las terminaciones autocontraíbles son las más fáciles de instalar pues la elasticidad de la goma de silicona permite ensanchar el tubo aislador y su "memoria elástica" permite que recupere su diámetro original al retirar el soporte de plástico que lo mantiene ensanchado.

- El diseño de la terminación, de una sola pieza, reduce la cantidad de componentes del kit de terminación. Esto disminuye la posibilidad de error humano y el tiempo de ejecución de la terminación.
- Las terminaciones autocontraíbles utilizan tubo de alta K para controlar el esfuerzo eléctrico en la zona de corte de la pantalla semiconductora. Este método es más eficiente y el tamaño final de la terminación es menor que en el caso donde se usa el método de cono de alivio de esfuerzos.
- El precio de los kits de terminaciones autocontraíbles no es significativo dentro de un presupuesto de obra. El factor determinante para la selección del usuario es la gran facilidad de montaje y el hecho de no tener que utilizar herramientas especiales.
- Las terminaciones de goma silicona exceden las exigencias de las normas técnicas internacionales.

ANEXO A

ESPECIFICACIONES TÉCNICAS DE CABLES DE ENERGÍA DE MEDIA TENSIÓN, DE 3.6/6 kV A 12/20 kV.

CEPER PIRELLI

Cables de Energía
Polietileno Reticulado

CEX-3

VOLTENAX® 3,6/6 kv.

CONSTRUCCION:

1. Conductor de cobre rojo suave
2. Pantalla Interna: capa semiconductora
3. Aislamiento de polietileno reticulado (XLPE)
4. Pantalla externa
    4.1. Capa semi conductora
    4.2. Alambres o cinta de cobre
5. Cubierta exterior de Policloruro de Vinilo (PVC) color rojo.

NORMAS DE FABRICACION

ITINTEC 370.050
IEC-502

TENSION DE DISEÑO

E_o/E = 3,6/6 kv.

CARACTERISTICAS DIMENSIONALES

Sección Nominal mm²	Conductor Ø Nominal mm	Aislamiento Espesor Nominal mm	Aislamiento Ø Nominal mm	Número de Conductores	Cubierta Espesor Nominal mm	Cubierta Ø exterior Nominal mm	Peso Neto Nominal kg/km
10	3,6	2,5	10,8	1 3	1,8 1,9	17,0 35,0	390 1490
16	4,8	2,5	12,0	1 3	1,8 2,0	18,5 38,0	480 1865
25	6,1	2,5	13,3	1 3	1,8 2,1	19,5 41,0	595 2310
35	7.1	2,5	14,3	1 3	1,8 2,1	20,5 43,0	710 2725
50	8,2	2,5	15,4	1 3	1,8 2,2	22,0 46,0	850 3245
70	9,9	2,5	17,1	1 3	1,8 2,3	23,5 50,0	1085 4140
95	11,6	2,5	18,8	1 3	1,8 2,5	25,0 54,0	1370 5190
120	13,0	2,5	20,2	1 3	1,8 2,6	26,5 57,0	1630 6130
150	14,5	2,5	21,7	1 3	1,8 2,7	28,0 61,0	1915 7210
185	16,2	2.5	23,4	1 3	1,8 2,8	30,0 65,0	2300 8580
240	18,5	2,6	25,9	1 3	1,9 3,0	33,0 71,0	2910 10730
300	20.8	2.8	28.6	1	2,0	36,0	3595
400	23.5	3,0	31.7	1	2,1	39,0	4480
500	26,4	3,2	35,0	1	2,2	43,0	5520

Valores nominales sujetos a tolerancias normales de manufactura
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CEPER PIRELLI

Cables de Energía
Polietileno Reticulado

CEX-4

VOLTENAX® 6/10 kv.

CONSTRUCCION:

1. Conductor de cobre rojo suave
2. Pantalla interna: capa semiconductora
3. Aislamiento de polietileno reticulado (XLPE)
4. Pantalla externa
   4.1. Capa semi conductora
   4.2. Alambres o cinta de cobre
5. Cubierta exterior de Policloruro de Vinilo (PVC) color rojo

NORMAS DE FABRICACION

ITINTEC 370, 050
IEC - 502

TENSION DE DISEÑO

E_o/E = 6/10 kv

CARACTERISTICAS DIMENSIONALES

Sección Nominal mm²	Conductor Ø Nominal mm	Aislamiento Espesor Nominal mm	Aislamiento Ø Nominal mm	Número de Conductores	Cubierta Espesor Nominal mm	Cubierta Ø exterior Nominal mm	Peso Neto Nominal kg/km.
16	4,8	3,4	13,8	1 3	1,8 2,1	20.0 42,0	550 2220
25	6,1	3,4	15,1	1 3	1,8 2,2	21,5 45,0	670 2720
35	7,1	3,4	16,1	1 3	1,8 2,3	22,5 48,0	800 3180
50	8,2	3,4	17,2	1 3	1,8 2,4	23,5 50,0	940 3730
70	9,9	3,4	18,9	1 3	1,8 2,5	25,0 55,0	1190 4690
95	11,6	3,4	20,6	1 3	1,8 2,7	27,0 59,0	1490 5810
120	13,0	3,4	22,0	1 3	1,8 2,8	28,5 62,0	1770 6790
150	14,5	3,4	23,5	1 3	1,9 2,9	30,0 65,0	2080 7890
185	16,2	3,4	25,2	1 3	1,9 3,0	32,0 69,0	2480 9320
240	18,5	3,4	27,5	1 3	2,0 3,1	34,0 75,0	3130 11610
300	20,8	3,4	29,8	1	2,1	37,0	3810
400	23,5	3,4	32,5	1	2,2	40.0	4700
500	26,4	3,4	35,4	1	2,3	43,0	5760

Valores nominales sujetos a tolerancias normales de manufactura
CEPER PIRELLI se reserva el derecho a modificar, cuando lo crea necesario, los datos que figuran en el presente catálogo.

VOLTENAX 6/10 kv.
CAPACIDAD DE CONDUCCION DE CORRIENTE

Sección Nominal mm²	Aire (A)			Directamente enterrado (A)		
	3 Cables Unipolar en plano	3 Cables Unipolar sin Espaciam.	1 Cable Tripolar	3 Cables Unipolar en plano	3 Cables Unipolar sin Espaciam.	1 Cable Tripolar
16	144	128	118	145	126	121
25	188	168	155	186	162	156
35	229	204	189	222	194	187
50	274	244	226	261	228	221
70	341	305	281	317	279	270
95	417	372	341	377	333	322
120	479	429	391	425	377	365
150	545	486	444	473	423	409
185	621	559	506	522	475	460
240	734	662	595	597	549	531
300	840	757	---	664	617	---
400	945	863	---	708	688	---
500	1081	987	---	783	768	---

Temperatura ambiente: 30° C al aire libre
25° C directamente enterrado

Resistividad termica del terreno: 0,9 k.m/w

VOLTENAX 6/10 kv.
PARAMETROS ELECTRICOS

Sección Nominal mm²	Res. Ohmica máxima en C.C. a 20° C ohm/km	Resistencia en C.A. ohm/km.	REACTANCIA XL (ohm/km)		
			En plano	En triángulo	Tripolar
16	1,15	1,47	0,244	0,174	0,162
25	0,727	0,928	0,232	0,162	0,150
35	0,524	0,670	0,223	0,154	0,142
50	0,387	0,495	0,216	0,147	0,136
70	0,268	0,343	0,208	0,139	0,128
95	0,193	0,248	0,201	0,132	0,122
120	0,153	0,197	0,197	0,128	0,118
150	0,124	0,161	0,193	0,124	0,114
185	0,0991	0,130	0,189	0,120	0,111
240	0,0754	0,100	0,185	0,115	0,106
300	0,0601	0,0818	0,181	0,112	---
400	0,0470	0,0662	0,178	0,109	---
500	0,0366	0,0542	0,175	0,106	---

CEPER PIRELLI

Cables de Energía
Polietileno Reticulado

CEX-5

VOLTENAX® 8,7/15 kv.

CONSTRUCCION:

1. Conductor de cobre rojo suave
2. Pantalla interna: capa semiconductora
3. Aislamiento de polietileno reticulado (XLPE)
4. Pantalla externa
   4.1. Capa semi conductora
   4.2. Alambres o cinta de cobre
5. Cubierta exterior de Policloruro de vinilo (PVC) color rojo

NORMAS DE FABRICACION

ITINTEC 370.050
IEC-502

TENSION DE DISEÑO

E_o/E = 8,7/15 kv.

CARACTERISTICAS DIMENSIONALES

Sección Nominal mm²	Conductor	Aislamiento		Número de Conduc-tores	Cubierta		Peso Neto Nominal kg km
	Ø Nominal mm	Espesor Nominal mm	Ø Nominal mm		Espesor Nominal mm	Ø exterior Nominal mm	
25	6,1	4,5	17,3	1 3	1,8 2,4	23,0 47,0	760 2780
35	7,1	4,5	18,3	1 3	1,8 2,4	24,5 53,0	870 3600
50	8,2	4,5	19,4	1 3	1,8 2,5	26,0 55,0	1020 4170
70	9,9	4,5	21,1	1 3	1,8 2,7	27,5 60,0	1270 5170
95	11,6	4,5	22,8	1 3	1,8 2,8	29,0 64,0	1560 6270
120	13,0	4,5	24,2	1 3	1,9 2,9	31,0 67,0	1840 7260
150	14,5	4,5	25,7	1 3	1,9 3,0	33,0 71,0	2140 8320
185	16,2	4,5	27,4	1 3	2,0 3,1	35,0 75,0	2580 10800
240	18,5	4,5	29,8	1 3	2,0 3,3	37,0 77,0	3180 11500
300	20,8	4,5	32,0	1	2,1	40,0	3820
400	23,5	4,5	34,7	1	2,2	43,0	4700
500	26,4	4,5	37,6	1	2,3	46,0	5730

Valores nominales sujetos a tolerancias normales de manufactura

VOLTENAX 8,7/15 kv.
CAPACIDAD DE CONDUCCION DE CORRIENTE

Sección Nominal mm²	Aire (A)			Directamente enterrado (A)		
	3 Cables Unipolar en plano	3 Cables Unipolar sin Espaciam.	1 Cable Tripolar	3 Cables Unipolar en plano	3 Cables Unipolar sin Espaciam.	1 Cable Tripolar
25	188	169	156	184	161	155
35	229	207	191	219	193	186
50	274	247	229	258	227	221
70	342	309	284	314	278	269
95	417	377	344	374	332	322
120	478	433	395	417	375	364
150	543	493	447	465	421	408
185	620	564	510	519	474	460
240	734	668	599	595	549	531
300	827	760	---	639	611	---
400	944	869	---	708	688	---
500	1079	995	---	785	770	---

Temperatura ambiente: 30° C al aire libre
25° C directamente enterrado

Resistividad termica del terreno: 0,9 k.m/w

VOLTENAX 8,7/15 kv.
PARAMETROS ELECTRICOS

Sección Nominal mm²	Res. ohmica máxima en C.C. A 20° C ohm/km	Resistencia en C.A. ohm/km	REACTANCIA XL (ohm/km)		
			En plano	En triángulo	Tripolar
25	0,727	0,928	0.239	0,170	0,159
35	0,524	0,670	0,231	0,162	0,151
50	0,387	0,495	0.224	0,155	0,144
70	0,268	0,343	0,215	0,145	0,136
95	0,193	0,248	0,208	0,138	0,129
120	0,153	0,197	0,204	0,134	0,125
150	0,124	0,161	0,199	0,130	0,121
185	0,0991	0,130	0,195	0,126	0,117
240	0,0754	0,103	0,189	0,120	0,112
300	0,0601	0,0819	0,186	0,117	---
400	0,0470	0,0662	0,183	0,113	---
500	0,0366	0,0542	0,179	0,110	---

CEPER PIRELLI

Cables de Energía
Polietileno Reticulado

CEX - 6

VOLTENAX® 12/20 kv.

CONSTRUCCION:

1. Conductor de cobre rojo suave
2. Pantalla interna: capa semiconductora
3. Aislamiento de polietileno reticulado (XLPE)
4. Pantalla externa
   4.1. Capa semi conductora
   4.2. Alambres o cinta de cobre
5. Cubierta exterior de Policloruro de Vinilo (PVC) color rojo

NORMAS DE FABRICACION

ITINTEC 370.050
IEC - 502

TENSION DE DISEÑO

E_o/E = 12/20 kv.

CARACTERISTICAS DIMENSIONALES

Sección Nominal mm²	Conductor Ø Nominal mm	Aislamiento Espesor Nominal mm	Aislamiento Ø Nominal mm	Número de Conduc-tores	Cubierta Espesor Nominal mm	Cubierta Ø exterior Nominal mm	Peso Neto Nominal kg/km
35	7,1	5.5	20,3	1	1,8	26,5	960
				3	2,6	57,0	4085
50	8,2	5,5	21,4	1	1,8	28,0	1110
				3	2,7	60,0	4735
70	9,9	5,5	23,1	1	1,8	29,5	1360
				3	2,8	64,0	5685
95	11,6	5,5	24,8	1	1,9	32,0	1675
				3	2,9	68,0	6815
120	13,0	5,5	26,2	1	1,9	34,0	1975
				3	3,0	73,0	7985
150	14,5	5,5	27,7	1	2,0	35,0	2290
				3	3,1	76,0	9105
185	16,2	5,5	29,4	1	2,0	37,0	2695
				3	3,2	80,0	10645
240	18,5	5,5	31,7	1	2,1	39,0	3320
				3	3,4	86,0	12885
300	20,8	5,5	34,0	1	2,2	42,0	3975
400	23,5	5,5	36,7	1	2,3	45,0	4860
500	26,4	5,5	39,6	1	2,4	48,0	5945

Valores nominales sujetos a tolerancias normales de manufactura
CEPER PIRELLI se reserva el derecho a modificar, cuando lo crea necesario, los datos que figuran en el presente catálogo.

VOLTENAX 12/20 kv
CAPACIDAD DE CONDUCCION DE CORRIENTE

Sección Nominal mm²	Aire (A)			Directamente enterrado (A)		
	3 Cables Unipolar en plano	3 Cables Unipolar sin Espaciam.	1 Cable Tripolar	3 Cables Unipolar en plano	3 Cables Unipolar sin Espaciam.	1 Cable Tripolar
35	230	209	193	217	192	185
50	275	250	231	255	226	220
70	342	311	286	311	277	269
95	416	379	347	368	331	321
120	478	436	397	415	375	364
150	542	495	450	462	420	408
185	620	567	513	517	473	460
240	732	671	603	592	548	531
300	825	763	---	638	611	---
400	942	873	---	708	688	---
500	1058	991	---	757	764	---

Temperatura ambiente: 30° C al aire libre
25° C directamente enterrado

Resistividad termica del terreno: 0,9 k.m/w

VOLTENAX 12/20 kv
PARAMETROS ELECTRICOS

Sección Nominal mm²	Res. ohmica máxima en C.C. A 20° C ohm/km	Resistencia en C.A. ohm/km	REACTANCIA XL (ohm/km)		
			En plano	En triángulo	Tripolar
35	0,524	0,670	0,238	0,168	0,158
50	0,387	0,495	0,231	0,161	0,151
70	0,268	0,343	0,221	0,152	0,142
95	0,193	0,248	0,214	0,144	0,135
120	0,153	0,197	0,208	0,139	0,130
150	0,124	0,161	0,204	0,135	0,126
185	0,0991	0,130	0,200	0,130	0,122
240	0,0754	0,100	0,194	0,125	0,116
300	0,0601	0,0819	0,190	0,121	---
400	0,0470	0,0662	0,187	0,117	---
500	0,0366	0,0544	0,182	0,114	---

VOLTENAX 3,6/6 kv. CAPACIDAD DE CONDUCCION DE CORRIENTE

Sección Nominal mm²	Aire (A)			Directamente enterrado (A)		
	3 Cables Unipolar en plano	3 Cables Unipolar sin Espaciam.	1 Cable Tripolar	3 Cables Unipolar en plano	3 Cables Unipolar sin Espaciam.	1 Cable Tripolar
10	107	95	88	107	94	90
16	143	127	118	145	126	121
25	188	167	154	187	162	156
35	228	203	188	223	194	187
50	273	242	225	262	228	221
70	341	303	279	319	279	270
95	417	371	340	378	333	323
120	480	428	389	427	378	365
150	545	487	442	475	423	409
185	621	557	504	523	475	460
240	735	661	593	598	550	531
300	840	756	---	664	617	---
400	963	866	---	740	694	---
500	1081	986	---	783	768	---

Temperatura ambiente: 30° C al aire libre
25° C directamente enterrado

Resistividad termica del terreno: 0,9 k.m/w

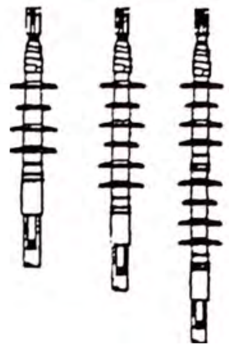
VOLTENAX 3,6/6 kv. PARAMETROS ELECTRICOS

Sección Nominal mm²	Res. ohmica máxima en C.C. A 20° C ohm/km	Resistencia en C.A. ohm/km	REACTANCIA XL (ohm/km)		
			En plano	En triángulo	Tripolar
10	1,83	2,34	0,259	0,185	0,171
16	1,15	1,47	0,240	0,171	0,158
25	0,727	0,928	0,228	0,159	0,147
35	0,524	0,670	0,220	0,151	0,139
50	0,387	0,495	0,214	0,144	0,133
70	0,268	0,343	0,205	0,136	0,125
95	0,193	0,248	0,199	0,129	0,119
120	0,153	0,197	0,194	0,125	0,115
150	0,124	0,161	0,191	0,121	0,112
185	0,0991	0,130	0,187	0,118	0,109
240	0,0754	0,100	0,182	0,113	0,104
300	0,0601	0,0817	0,179	0,110	---
400	0,0470	0,0661	0,177	0,107	---
500	0,0366	0,0541	0,174	0,105	---

ANEXO B

ESPECIFICACIONES TÉCNICAS DETERMINACIONES AUTOCONTRAÍBLES DE GOMA SILICONA, PARA USO EXTERIOR, DE 15 – 34.5 kV.

Data Sheet



Quick Term II
Silicone Rubber Termination Kits
5630K and 5690K Series 15 kV–34.5 kV

1. Product Description

3M 5630K and 5690K Series Quick Term II Silicone Rubber Termination Kits are one-piece Cold Shrink terminations for Tape Shield, Wire-Shield and Uni-Shield® power cables. **They meet the requirements of IEEE standard 48-1990, for class 1 terminations.** In addition they meet German standard VDE 0278 parts 5 & 100, British standard BS C-89, Spanish standard UNE 21-115-75 and Brazilian standard A·B·N·T· 9314. Similar terminations using Quick Term II technology meet French EdF standards HN 33-E-01 and HN 41-E-01. Data on foreign standards are available upon request. The 3M Quick Term II consists of a high dielectric constant (High-K) stress control tube insulated with a molded silicone skirted insulator. There is a four skirt design rated 15 kV, a six skirt design rated 25/28 kV and an eight skirt design rated 34.5 kV. Each insulator design incorporates an extended base feature which when combined with mastic ensures a seal at the cable jacket end where the termination ground strap is brought out. Quick Term II terminations are provided in an expanded state, mounted on a removable inner supporting plastic core. As supplied in this pre-stretched condition the termination is ready for field installation. During installation the core is unwound, allowing termination to shrink and form a tight seal. Collectively, these termination kits cover cables with primary insulation O.D. from 0.33" to 1.95" (0.85 to 49.5 mm) and with cable jacket O.D. from 0.55" to 2.40" (14.0 to 61.0 mm).

These kits can be used to terminate Tape Shield, Wire-Shield and Uni-Shield power cables from:

#8 AWG to 2000 kcmil at 5 kV,
#8 AWG to 2000 kcmil at 8 kV,
#4 AWG to 1750 kcmil at 15 kV,
#2 AWG to 1250 kcmil at 25.0 kV and
#2 AWG to 1000 kcmil at 34.5 kV.

Stress Control

The 3M Quick Term II controls the electric field surrounding the terminated cable insulation shield end, by use of a special high dielectric constant (High-K) material which is an integral part of the termination. The High-K material has a dielectric constant of about 25. By controlling the electrical field, the stress concentration in the applied termination materials and at the air interface is less than 15 volts/mil at rated voltage. In the shielded portion of 15 kV cable, the stress concentrations typically vary from 50 volts/mil at the shield to about 70 volts/mil at the conductor. When terminated with the Quick Term II, the stress in the cable underneath this unit is less than it is in the shielded portion of the cable.

Figure 1 shows an actual computerized stress plot of the Quick Term II.

Cold Shrink Insulators

The 3M Quick Term II Skirted Insulators are constructed of non-tracking silicone rubber which minimizes leakage currents in wetted conditions for three reasons:

1. The smooth surface of the silicone rubber insures that a minimum amount of contamination will adhere to the termination.
2. Silicone rubber has a hydrophobic surface: When water comes in contact with the silicone it beads up and runs off the skirts rather than completely wetting these surfaces. Thus a less conductive path is formed on the silicone and leakage currents are lowered.
3. When leakage currents do increase and arcing occurs on the surface, the ash formed by erosion of the silicone insulator is non-organic or nonconductive. Continued degradation is thereby deterred.

Under heavy rain conditions, conventional skirted terminations with even-skirt diameter insulators tend to form drip paths or continuous water paths from insulator skirt tip to skirt tip. By comparison, 3M Quick Term II insulators are designed with unique, uneven skirt diameters. This feature allows water dripping from the upper skirt to fall free, avoiding the skirt to skirt conductive path that can develop with even-skirt diameter insulators. This design of the 3M Quick Term II termination optimizes performance under heavy rain conditions.

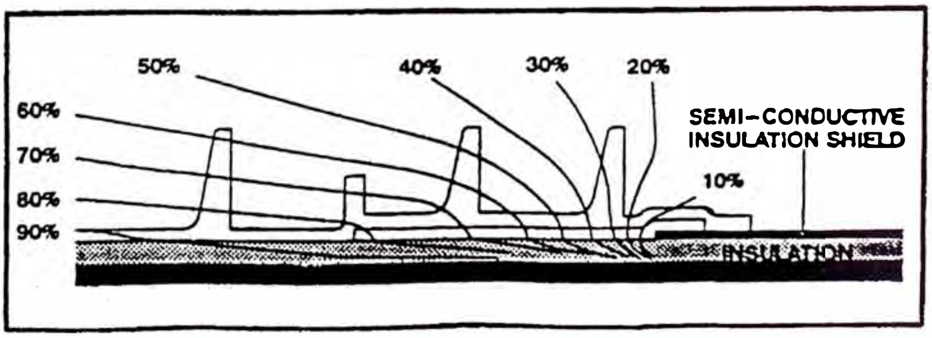


Figure 1

Kit Contents

Each kit contains sufficient quantities of the following materials to make three terminations:

- — 3 Hi-K Silicone Rubber Terminations
- — 3 Mechanical Ground Strap Assemblies
- — 3 Strips of Mastic
- — 1 Roll of Scotch™ 13 Semi-Con Tape
- — 1 Roll of Scotch 70 Silicone Tape
- — 3 Packs of Silicone Grease
- — 1 Scotch Cable Preparation Kit
- — 1 Instruction Sheet

2. Applications

The 5630K and 5690K Series Quick Term II Silicone Cold Shrink Terminations are used to terminate Tape Shield, Wire Shield and Uni-Shield power cable rated 15 kV, 25/28 kV and 34.5 kV having extruded solid dielectric insulation as follows: Polyethylene (high and low density), cross-linked polyethylene (XLP) and ethylene propylene rubber (EPR). The terminations are light weight for either free-hanging or bracket-mounting arrangements. They can be used in both protected and weather exposed contaminated areas. The amount of airborne contamination determines the operating environment. Operating environments are described as areas having varying degree of airborne contaminant or pollution severity that may, or may not effect the long term performance of terminations. These operating environments are defined as light, medium, heavy and extremely heavy variations of pollution severity. The appropriate termination selection depends on the system voltage and operating environment. (See tables to right)

3. Data: Physical and Electrical Properties

The 5630K and 5690K Series Quick Term II terminations can be used on cables with a rated operating temperature of 90°C and an emergency overload rating of 130°C, (reference: AEIC CS5 and AEIC CS6). These kits meet requirements for a 15 kV, 25 kV and 34.5 kV, Class 1 termination in IEEE Standard Test Procedures and Requirements for High-Voltage Cable Terminations (IEEE Standard 48-1990). (See Section 5, "Performance Tests"). The current rating of Quick Term II terminations meets and exceeds the current rating of the cables.

Recommended Application Guide

Termination Kit	System Voltage	Operating Environment: Light	Medium	Heavy	Extremely Heavy
(Four Skirt) 5632K – 5637K	5 & 8 kV	✔	✔	✔	
(Four Skirt) 5632K – 5637K	15 kV	✔	✔	✔	
(Six Skirt) 5691K – 5694K	15 kV		✔	✔	✔
(Eight Skirt) 5696K – 5698K	15 kV			✔	✔
(Four Skirt) 5633K – 5637K	25/28 kV	✔			
(Six Skirt) 5691K – 5694K	25/28 kV	✔	✔	✔	
(Eight Skirt) 5696K – 5698K	25/28 kV		✔	✔	✔
(Four Skirt) 5633K – 5637K	34.5 kV				
(Six Skirt) 5691K – 5694K	34.5 kV	✔			
(Eight Skirt) 5696K – 5698K	34.5 kV	✔	✔	✔	★

Recommended operating environments are marked with a check (✔)

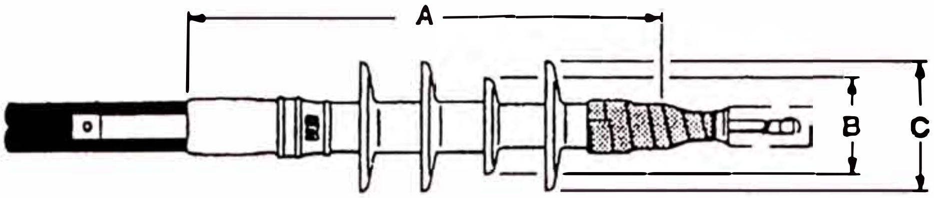
★ Consult 3M sales representative.

Pollution Severity Level Guide

Light	Heavy
• Areas without industry and with low density housing. • Areas subjected to frequent winds and/or rain fall with low density industry and housing. • Agricultural areas. ☆ • Mountainous areas. All of these regions should be situated at least 7 to 15 miles from the coast and should not be exposed to coastal winds. ✱	• High density industrial areas and some urban areas with high density housing, especially those with infrequent rain fall. • Areas subjected to a moderate concentration of conductive dust, particularly industrial smoke producing deposits. • Areas generally close to the coast and exposed to coastal spray or to strong winds carrying sand and salt, and subjected to regular condensation.
Medium	**Extremely Heavy**
• Non polluting industrial areas subject to infrequent rain fall and with average density housing. • Areas subjected to frequent winds and/or rainfall with high density industry and housing. • Areas exposed to wind from the coast but generally over two miles from the coast.	• Usually very limited areas having extremely heavy pollutants from industrial sites especially those located near oceans and subjected to prevailing winds from the sea. • Very small isolated areas where terminations are located immediately adjacent to a pollutant source, especially downwind (cement plants, paper mills, etc.).

☆ Use of fertilizers by spraying, or the burning of crop residues, can lead to a higher pollution level due to dispersal by wind.

✱ Distances from coast depend on the topography of the coastal area and on the extreme wind conditions.



FOUR–SKIRT TERMINATION

A. Typical Dimensions

Product Number	A	B	C	Creepage Distance	Arcing Distance
5632K	13.25" (max) (337 mm)	1.62" (41,1 mm)	2.60" (66,0 mm)	18.0" (max) (457 mm)	13.75" (max) (349 mm)
5633K	12.0" (max) (305 mm)	1.67" (42,4 mm)	2.68" (68,1 mm)	17.25" (max) (438 mm)	12.5" (max) (317 mm)
5635K	12.0" (max) (305 mm)	1.82" (46,2 mm)	2.75" (69,8 mm)	17.25" (max) (438 mm)	12.5" (max) (317 mm)
5636K	13.5" (max) (343 mm)	2.00" (50,8 mm)	3.25" (82,5 mm)	19.25" (max) (489 mm)	14.0" (max) (356 mm)
5637K	13.75" (max) (349 mm)	2.00" (50,8 mm)	3.55" (90,2 mm)	19.50" (max) (495 mm)	14.25" (max) (362 mm)

B. Termination Selection Table

Kit No.	Cable Insulation O. D. Range	Cable Jacket O. D. Range	Conductor Size Range (AWG kcmil)					
			5 kV (100%)	8 kV* (100%)	8 kV (133%)	15 kV (100%)	15 kV (133%)	25 kV**
5632K	0.33–0.69 in. (8,4–17,5 mm)	0.55–0.92 in. (14,0–23,4 mm)	8–2/0	8–1/0	8–1	8–4	8–6	
5633K	0.64–0.90 in. (16,3–22,9 mm)	0.80–1.20 in. (20,3–30,5 mm)	3/0–300	2/0–250	1/0–4/0	2–3/0	4–1/0	2–1
5635K	0.84–1.33 in. (21,3–33,8 mm)	1.00–1.60 in. (25,4–40,6 mm)	350–750	300–750	250–600	3/0–500	2/0–350	1/0–250
5636K	1.10–1.65 in. (27,9–41,9 mm)	1.30–1.90 in. (33,0–48,3 mm)	750–1500	750–1250	600–1000	500–1000	350–750	300–500
5637K	1.30–1.95 in. (33,0–49,5 mm)	1.50–2.40 in. (38,1–61,0 mm)	1000–2000	1000–2000	800–1750	750–1750	600–1500	600–1250

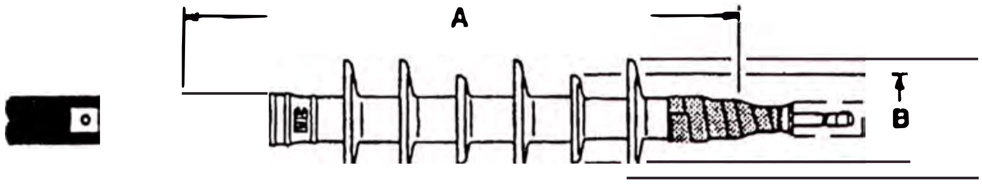
* Also appropriate for 5 kV (133%).

** See Recommended Application Guide, on page 2.

C. Typical Results per IEEE STD. 48–1990 Tests

IEEE STD. 48 Test	5 kV Class		8 kV Class		15 kV Class		25 kV Class	
	Requirement	Results	Requirment	Results	Requirement	Results	Requirement	Results
60 sec. w/s ac	25 kV	75 kV*	35 kV	80 kV*	50 kV	85 kV*	65 kV	90 kV*
10 sec. w/s wet ac	25 kV	55 kV*	30 kV	60 kV*	45 kV	65 kV*	60 kV	75 kV*
6 hours w/s ac	15 kV	70 kV*	25 kV	75 kV*	35 kV	80 kV*	55 kV	85 kV*
Corona @ 3 pc. CSV CEV	— 4.5 kV	9.0 kV 8.5 kV	— 7.5 kV	12 kV 11 kV	— 13 kV	33 kV 28 kV	— 21.5 kV	36 kV 32 kV
15 min. w/s dc	50 kV	Pass 50 kV	65 kV	Pass 65 kV	75 kV	Pass 75 kV	105 kV	pass 105 kV
Impulse w/s	75 kV	+125 kV* –115 kV*	95 kV	+130 kV* –125 kV*	110 kV	+165 kV* –150 kV*	150 kV	+180 kV* –165 kV*
30 day Cyclic Aging @ 130°C w/s ac Corona @ 3 pc. CEV> Impulse +10 – 10	9 kV 4.5 kV +75 kV – 75 kV	Pass Pass Pass Pass	15 kV 7.5 kV +95 kV –95 kV	Pass Pass Pass Pass	28.5 kV 13 kV +110 kV –110 kV	Pass Pass Pass Pass	48 kV 21.5 kV +150 kV –150 kV	Pass Pass Pass Pass

*At higher voltage flashovers occur.



SIX–SKIRT TERMINATION

A. Typical Dimensions

Product Number	A	B	C	Creepage Distance	Arcing Distance
5691K	15.0″ (max) (381 mm)	1.67″ (42,4 mm)	2.68″ (68,1 mm)	23.0″ (max) (584 mm)	15.5″ (max) (394 mm)
5692K	15.0″ (max) (381 mm)	1.82″ (46,2 mm)	2.75″ (69,8 mm)	23.0″ (max) (584 mm)	15.5″ (max) (394 mm)
5693K	16.5″ (max) (419 mm)	2.00″ (50,8 mm)	3.25″ (82,5 mm)	25.75″ (max) (654 mm)	17.0″ (max) (432 mm)
5694K	16.75″ (max) (425 mm)	2.00″ (50,8 mm)	3.55″ (90,2 mm)	26.0″ (max) (660 mm)	17.25″ (max) (438 mm)

B. Termination Selection Table

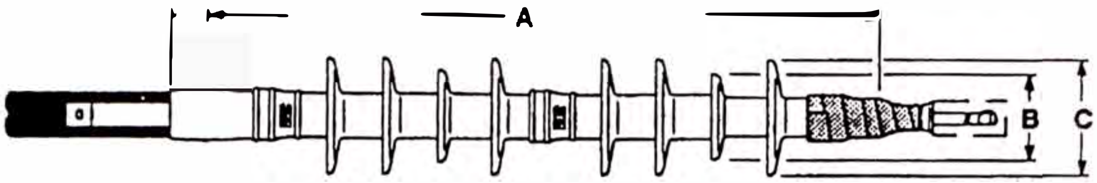
Kit No.	Cable Insulation O. D. Range	Cable Jacket O. D. Range	Conductor Size Range (AWG kcmil)		
			15 kV (100%)**	15 kV (133%)**	25 kV
5691K	0.64–0.90 in. (16,3–22,9 mm)	0.80–1.20 in. (20,3–30,5 mm)	#2–3/0	#4–1/0	2–1
5692K	0.84–1.33 in. (21,3–33,8 mm)	1.00–1.60 in. (25,4–40,6 mm)	3/0–400	2/0–350	1/0–250
5693K	1.10–1.65 in. (27,9–41,9 mm)	1.30–1.90 in. (33,0–48,3 mm)	500–750	400–750	300–500
5694K	1.30–1.95 in. (33,0–49,5 mm)	1.50–2.40 in. (38,1–61,0 mm)	800–1750	800–1500	600–1250

** See Recommended Application Guide, on page 2.

C. Typical Results per IEEE STD. 48–1990 Tests

IEEE STD. 48 Test	15 kV Class		25 kV Class†		34.5 kV Class†	
	Requirement	Results	Requirement	Results	Requirement	Results
60 sec. w/s ac	50 kV	100 kV*	65 kV	110 kV*	90 kV	115 kV*
10 sec. w/s wet ac	45 kV	70 kV*	60 kV	80 kV*	80 kV	90 kV*
6 hours w/s ac	35 kV	95 kV*	55 kV	105 kV*	75 kV	110 kV*
Corona @ 3 pc. CSV CEV	 13 kV	33 kV 28 kV	 21.5 kV	36 kV 32 kV	 30 kV	41 kV 39 kV
15 min. w/s dc	75 kV	Pass 75 kV	105 kV	Pass 105 kV	140 kV	Pass 140 kV
Impulse w/s	110 kV	+195 kV* −180 kV*	150 kV	+210 kV* −195 kV*	200 kV	+225 kV* −210 kV*
30 day Cyclic Aging @ 130°C w/s ac Corona @ 3 pc. CEV> Impulse +10 − 10	28.5 kV 13 kV +110 kV − 110 kV	Pass Pass Pass Pass	48 kV 21.5 kV +150 kV −150 kV	Pass Pass Pass Pass	66 kV 30 kV +200 kV −200 kV	Pass Pass Pass Pass

†25 kV class Quick Term II terminations will also meet prorated values for 28 kV rated systems.
*At higher voltage flashovers occur.



EIGHT–SKIRT TERMINATION

A. Typical Dimensions

Product Number	A	B	C	Creepage Distance	Arcing Distance
5696K	19.5" (max) (495 mm)	1.82" (46,2 mm)	2.75" (69,8 mm)	30.0" (max) (762 mm)	20.0" (max) (508 mm)
5697K	21.5" (max) (546 mm)	2.00" (50,8 mm)	3.25" (82,5 mm)	33.0" (max) (832 mm)	22.0" (max) (559 mm)
5698K	21.75" (max) (552 mm)	2.00" (50,8 mm)	3.55" (90,1 mm)	33.25" (max) (845 mm)	22.25" (max) (565 mm)

B. Termination Selection Table

Kit No.	Cable Insulation O. D. Range	Cable Jacket O. D. Range	Conductor Size Range (AWG kcmil)		
			15 kV** (100%)	25 kV**	34.5 kV
5696K	0.84–1.33 in. (21,3–33,8 mm)	1.00–1.60 in. (25,4–40,6 mm)	3/0–400	1/0–250	#2–3/0
5697K	1.10–1.65 in. (27,9–41,9 mm)	1.30–1.90 in. (33,0–48,3 mm)	500–750	300–500	4/0–400
5698K	1.30–1.95 in. (33,0–49,5 mm)	1.50–2.40 in. (38,1–61,0 mm)	800–1750	600–1250	500–1000

** See Recommended Application Guide, on page 2.

C. Typical Results per IEEE STD. 48–1990 Tests

IEEE STD. 48 Test	15 kV Class		25 kV Class		34.5 kV Class	
	Requirement	Results	Requirement	Results	Requirement	Results
60 sec. w/s ac	50 kV	115 kV*	65 kV	125 kV*	90 kV	135 kV*
10 sec. w/s wet ac	45 kV	75 kV*	60 kV	85 kV*	80 kV	95 kV*
6 hours w/s ac	35 kV	100 kV*	55 kV	110 kV*	75 kV	120 kV*
Corona@3pc. CSV CEV	— 13 kV	33 kV 28 kV	— 21.5 kV	38 kV 32 kV	— 30 kV	41 kV 39 kV
15 min. w/s dc	75 kV	Pass 75 kV	105 kV	Pass 105 kV	140 kV	Pass 140 kV
Impulse w/s	110 kV	+215 kV* –200 kV*	150 kV	+235 kV* –220 kV*	200 kV	+255 kV* –240 kV*
30 day Cyclic Aging @ 130°C w/s ac Corona@3 pc. CEV> Impulse +10 – 10	28.5 kV 13 kV +110 kV – 110 kV	Pass Pass Pass Pass	48 kV 21.5 kV +150 kV –150 kV	Pass Pass Pass Pass	68 kV 30 kV +200 kV –200 kV	Pass Pass Pass Pass

*At higher voltage flashovers occur.

D. Typical Physical & Electrical Properties

Silicone Rubber Insulator

Physical Properties

Test Method	Typical Value*
• Color	Munsel Gray
• Permanent Set 22 hours @ 100°C (212°F) 100% elongation 5 minute recovery	8%
• Ultimate Tensile Strength (ASTM D412-68)	1200 psi (8.28 MPa)

Electrical Properties

Test Method	Typical Value*
• Dielectric Constant (K) (ASTM D150-70)	
23°C (73°F)	3.4
90°C (194°F)	3.0
130°C (266°F)	2.7
• Dissipation Factor (ASTM D150-70)	
23°C (73°F)	0.4%
90°C (194°F)	1.3%
130°C (266°F)	1.2%
• Dielectric Strength (ASTM D149-70) 075" gap (1,90 mm)	507 volts/mil (20 kV/mm)
• Track Resistance (ASTM 2303-68) 2.5 kV, 10 k Ohms	10 hrs.

EPDM Rubber High-K Stress Control Tube

Physical Properties

Test Method	Typical Value*
• Ultimate Tensile Strength (ASTM 412-68)	1394 psi (9.6 MPa
• Permanent Set 22 hours @ 100°C (212°F) 100% elongation 5 minute recovery	18%

Electrical Properties

• Dielectric Constant (K)
(ASTM D150-70)
60 Hz; @ 60% strain

	@400 V	@3 kV
23°C (73°F)	25.7	28.8
65°C (149°F)	24.5	27.2
90°C (194°F)	25.2	27.7
vs. frequency @ 23°C (73°F)		
150 Hz		35
1,000 Hz		29
10,000 Hz		24
100,000 Hz		20

• Dissipation Factor
(ASTM D150-70)
60 Hz; @ 60% strain

	@400 V	@3 kV
23°C (73°F)	0.096	0.166
65°C (149°F)	0.093	0.165
90°C (194°F)	0.132	0.161
vs. frequency @ 23°C (73°F)		
150 Hz		0.16
1,000 Hz		0.15
10,000 Hz		0.14
100,000 Hz		0.12

*Average values, not intended for specification purposes.

4. Specification Guide

Open Specification

The cable termination must be a one-piece Cold Shrink 15 kV, 25 kV or 34.5 kV Class device and meet all 15 kV, 25 kV or 34.5 kV requirements for Class 1 termination as recorded in IEEE Standard 48-1990. The termination must be a molded rubber unit ~~where the built~~ in stress relief mechanism uses the concept of high dielectric constant capacitive stress grading. The molded rubber insulator must be made from silicone rubber.

Closed Specification

Terminate all 15 kV, 25 kV and 34.5 kV Class Tape Shield, Wire Shield, and Uni-Shield Cables in accordance with the instructions in the 3M Brand 5630K and 5690K series Qu: Term II Silicone Rubber Termination Kits.

5. Performance Tests

A. Corona Tests

The purpose of the corona tests is to insure th all properly installed terminations opera corona-free at a minimum of 150% of the operating voltage. In this test, phase to grou voltage is gradually increased until hig frequency discharges are displayed on a oscilloscope.

The voltage at which these discharges reac three picocoulombs is recorded as the coror starting voltage (CSV). The voltage is the lowered until the discharges are less than thr picocoulombs. This voltage is recorded as t: corona extinction voltage (CEV). All Quic Term II terminations conform with the IPCE recommended minimum corona extinctic (CEV) level of 150% of operating voltag. Samples installed on 15 kV class cable a: typically corona-free at 30 kV. Sample installed on 34.5 kV class cable are typical corona-free at 40 kV.

B. Impulse Tests (BIL)

In this test a nominal 1.2 x 50 microsecor wave, both positive and negative, is used. Te consecutive impulses at each polarity ar applied. All Quick Term II terminations mee the BIL requirements as recorded in IEE Standard 48-1990 with a considerable amour of safety margin.

C. Alternating Current Withstand Tests

All terminations meet ac withstand tests a specified in IEEE Standard 48-1990. See ap plicable tables **"Typical Results per IEE STD. 48-1990 Tests."**

The average value of voltage which will ar over the termination surface in air, from th cable connecting lug to the ground strap at th termination base, is shown in table below.

To determine dielectric strength, terminatior are immersed in SF_6 gas. The SF_6 gas, havin a higher dielectric strength than air, preven termination flashover. The ac breakdown va! ues are shown in table below.

Product Number	AC Flashover					AC Breakdown in SF_6				
	5 kV Class	8 kV Class	15 kV Class	25 kV Class	34.5 kV Class	5 kV Class	8 kV Class	15 kV Class	25 kV Class	34.5 kV Class
5632K–5637K	80 kV	85 kV	85 kV	95 kV		95 kV	100 kV	130 kV	155 kV	
5691K–5694K			105 kV	115 kV	125 kV			130 kV	155 kV	197 kV
5696K–4598K			125 kV	135 kV	145 kV			130 kV	155 kV	197 kV

D. Environmental Performance

When airborne contaminants are deposited on a termination surface destructive leakage currents can be initiated when the surface becomes wet. Fog and drizzle are worse than rain. Rain tends to wash the pollutants off the termination while fog will wet the pollutants making the surface conductive to varying degrees promoting leakage current formation. This is most typical of hydrophillic surfaces typified by porcelain (Figure 2). The surface of 3M Quick Term II silicone insulator is hydrophobic which makes it less likely to erode or track because the surface does not wet readily. (Figure 3). This either prevents or minimizes leakage current formation. On occasion severe environmental conditions can be sustained for long time periods and cause any polymeric surface to lose its hydrophobicity. Because of this, EPDM polymers tend to lose their hydrophobicity over time, and porcelain surfaces become increasingly hydrophillic with time, which will result in premature failure or flashover. However, the silicone surface will re-establish its hydrophobic surface within 24 hours (Figure 4). This unique ability of the Quick Term II silicone is a major factor to insure long service life.

References

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H. C. Hervig*, "Splices and Terminations for Solid Dielectric Cables — A Comparison of Alternatives", T and D Committee, Electric Council of New England, 1989.

R. W. Gorur, L. A. Johnson* and H. C. Hervig* "Accelerated Aging of Silicone Rubber Cable Terminations", T and D Conference on Electrical Insulation and Dielectric Phenomena, Leesburg Virginia, 1989.

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L. A. Johnson*, "Polymeric Terminations Present and Future — Cold Shrink Silicone Terminations", IEEE/PES T and D Conference, 1989.

R. S. Gorur, L. A. Johnson* and H. C. Hervig*, "Contamination Performance of Silicone Rubber Cable Terminations", IEEE Winter Power Meeting, Feb. 1990.

*Member of the 3M Electrical Products Division Technical Community.

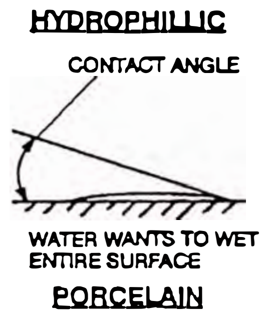


FIGURE 2

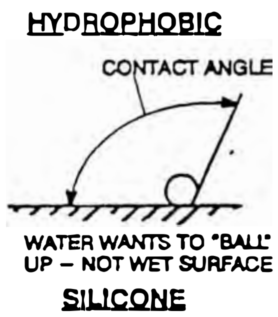


FIGURE 3

E. Sealing Tests

The bottom seal on shielded power cable formed with mastic placed under and over t flat ground strap, which is then over-wrapp with vinyl tape. The tape wrap compresses t mastic to provide a moisture seal around t ground strap. The elongated base of a 563C or 5690K Series Quick Term II Cold Shri insulator covers the cable jacket end and tap mastic region to complete the seal. The to seal on the lug is provided by the use of Scot 70 Silicone Rubber Electrical Tape.

The seals are tested by immersing the lug e in water and applying air pressure to t conductor. Both seals will withstand intern air pressure test per IEEE Standard 48-199

F. Ultraviolet Resistance

After 1,000 hours of testing in a Weather-C Meter according to Specifications AST D750 and ASTM G23, the silicone insulat exhibited no crazing, cracking or change surface appearance. Silicone rubber, unli carbon based elastomers, is inherently stab under exposure to sunlight. This is because c the silicone molecular back bone (the silico oxygen bond) has a bond strength greater tha the ultraviolet energy of sunlight while th carbon-carbon bond of an EPDM elastomer less than sunlight.

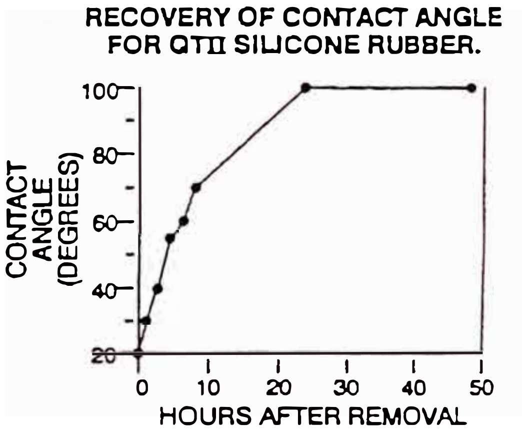


FIGURE 4

6. Installation Techniques

A detailed instruction sheet regarding proper installation is included in each kit. A brief summary of these procedures is as follows:

A. Prepare cable according to standard procedure. (Figure 1)

B. Install solderless ground strap and mastic seal. (Figure 2)

C. Overwrap mastic with protective vinyl tape layer. (Figure 3)

D. Apply a liberal coating of silicone grease to the edge of the cable semi-conductive insulation shield (or 13-Tape). (Figure 3)

E. Place termination over cable and unwind the core allowing the termination to shrink into place. (Figure 4)

F. Install terminal lug and apply 70-Tape Top Seal. (Figure 5)

7. Field Maintenance

Hypotting

These terminations can be tested according to the instructions given in IEEE Standard 400-1980, "Guide for Making High Direct Voltage Tests in the Field."

Surface Cleaning

It is not uncommon in areas of extreme contamination for users to periodically clean terminations and other insulators. Energized or deenergized, established techniques for cleaning cable terminations can be used, e. g. high pressure water and pulverized corn cobs.

8. Availability

3M 5630K and 5690K Series Quick Term II Molded Silicone Rubber Termination Kits can be purchased through your local authorized 3M electrical distributor.

9. Shelf Life

3M 5630K and 5690K Series Quick Term II Silicone Rubber Termination Kits are packaged three terminations per carton. As provided in the expanded state, terminations have an on-shelf storage life of five years.

Maximum recommended storage temperature is 110°F (43°C). They are not effected by freezing storage temperatures. The year and quarter of manufacture is molded into the base of each Quick Term II termination. Stock rotation practice is recommended.

FIGURE 1

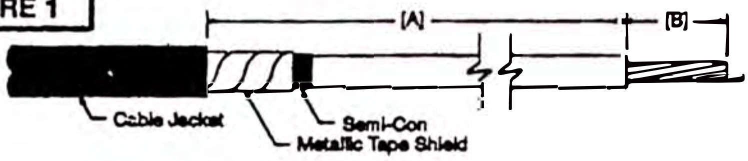


FIGURE 2

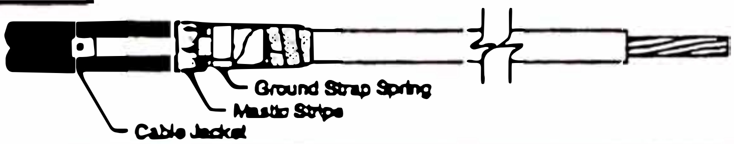


FIGURE 3

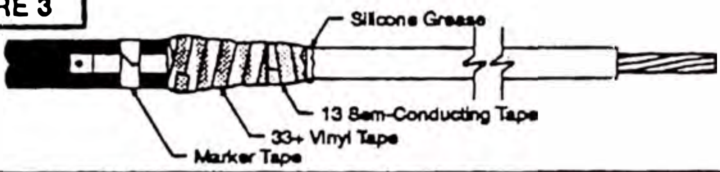


FIGURE 4

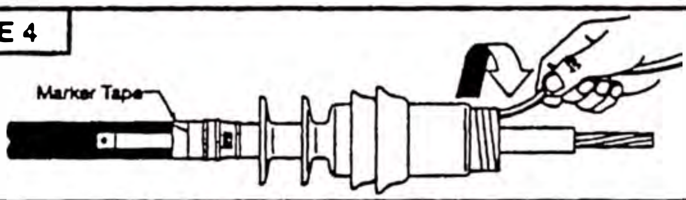
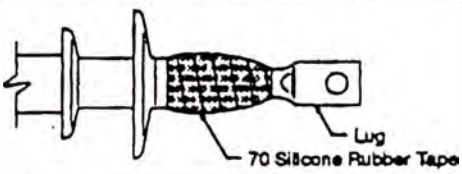


FIGURE 5



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3M

ANEXO C

PROTOCOLO DE PRUEBAS DE TERMINACIONES AUTOCONTRAÍBLES DE GOMA SILICONA

3M

Cold Shrink™ 7695-S-4 QT-III Termination

Certified Test Report

This report details the evaluation of the 7695-S-4 Cold-Shrink Termination to IEEE Std 48-1996 and 3M design tests. The 7695-S-4 terminations met or exceeded requirements as per IEEE Std 48-1996. The design testing verified performance well in excess of IEEE test requirements. This qualification testing was done to 25 kV test levels and 130° centigrade conductor temperature for current cycling.

I hereby certify that this Test Report is a true and correct record of tests conducted under my direction.

John T. Larson
Testing and Services Group

Notary Public:
Sworn and subscribed before me this: 8th, day of Jan, 1997

M. L. Smith, Travis County, Austin TX

MARY L. SMITH
MY COMMISSION EXPIRES
October 10, 2000

Approved By:

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Dr. James E. Sax
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3M Report Number: CR7695-S-4

Testing period covered by this report: October 1996 to January 1997

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Contents

Revision 0

Summary

This report details the evaluation of the 7695-S-4 (production units) Cold-Shrink Termination to IEEE Std 48-1996 and 3M design tests. The 7695-S-4 terminations met or exceeded requirements as per IEEE Std 48-1996. The design testing verified performance well in excess of IEEE test requirements. This qualification testing was done to 25 kV test levels and 130° centigrade conductor temperature for current cycling. The results obtained are characteristic of all other 25 kV class terminations in the 7690 series of the QT-III line.

Purpose

Evaluate 3M Cold Shrink 7695-S-4 Silicone Rubber QT-III Termination on both the largest and smallest cable they are designed to accommodate. The evaluation was run according to the following standards and some additional internal tests used by 3M to verify product performance:

IEEE Std 48-1996 *"IEEE Standard Test Procedures and Requirements for High-Voltage Alternating-Current Cable Terminations"*

IEEE Std 4-1995 *"IEEE Standard Techniques for High-Voltage Testing"*

Test Specimens

Each of the test specimens was assigned a specimen number as it was constructed. This is the description of each of the test specimens:

85115 and 85116 Each of these specimens had two 7695-S-4 QT-III Terminations installed on an 8 foot length of 1000 kcmil stranded aluminum conductor, 260 mil XLPE 100% insulation level, ribbon shielded cable. These specimens are for the maximum cable size the 7695-S-4 QT-III Terminations are designed to accommodate.

85122 and 85123 Each of these specimens had two 7695-S-4 QT-III Terminations installed on an 8 foot length of 4/0 stranded conductor, 260 mil XLPE 100% insulation level, ribbon shielded cable. These specimens are for the minimum cable size the 7695-S-4 QT-III Terminations are designed to accommodate.

85214 had one 7695-S-4 QT-III Termination installed on a 3 foot length of the 4/0 kcmil stranded copper conductor, 260 mil XLPE 100% insulation level, ribbon shielded cable. This specimen is for the minimum cable size the 7695-S-4 QT-III Terminations are designed to accommodate.

85215 had one 7695-S-4 QT-III Termination installed on a 3 foot length of the 1000 kcmil stranded aluminum conductor, 260 mil XLPE 100% insulation level, ribbon shielded cabie. This specimen is for the maximum cable size the 7695-S-4 QT-III Terminations are designed to accommodate.

Test Deviations

- 3M chooses to report actual Partial Discharge Levels obtained during testing in lieu of pass or fail at a specified level as required by IEEE Std 48-1996.

- The standard Wet Test Procedure, according to IEEE Std 4-1995, calls for a 60 second withstand, table 3 on page 72. That standard and table also refer to "practice in USA" calling for a 10 second wet withstand. IEEE Std 48-1996 calls for the 10 second withstand even though IEEE Std 4-1995 refers to this as "an earlier test method". 3M uses the more stringent 60 second withstand for wet testing.

- 3M also reports Partial Discharge Results initially and after completing the test sequences (Short term voltage withstands and 30 day current cycling).

- 3M uses one set of specimens for both the short term and 30 day current cycle tests. According to IEEE Std 48-1996 the manufacturer is allowed to use a separate set of test specimens for the short term electrical tests, and the 30 day current cycle.

- According to IEEE Std 48-1996 paragraph 8.1.c the terminations be installed on the largest cable the termination is designed to accommodate. When possible, 3M will electrically test on both the largest and smallest cable the termination is designed to accommodate. In some instances, this may take some additional time, and will be covered in a future revision of the report.

- In addition to the IEEE Std 48 test sequence, 3M engineers ran additional tests to verify the overall performance of this termination product. These additional test results are included as a part of this report. All of the tests performed on each of the six specimens are reported in chronological order. It must be pointed out that the values obtained during these tests are for the specific specimen tested. Testing another specimen with the same terminations could result in identical, higher, or lower test levels.

Test Results On Specimen Number 85115, 1000 kcmil Conductor

Tests In Chronological Order:	Value:	Result:
Partial Discharge (Corona) Extinction Voltage Covering IEEE Std 48-1996 8.4.1.5 (Deviation cited)		
Direct Calibration, Haefely	2.0 pC	Verified Test Circuit
Partial Discharge Inception Voltage	46.0 kV-RMS	
Magnitude	30.0 pC	
Partial Discharge Extinction Voltage	42.7 kV-RMS @ <3 pC	Exceeds IEEE requirements
Power Frequency Voltage One Minute Dry Withstand Test According To IEEE Std 48-1996 8.4.1.1		
One Minute Withstand	65 kV-RMS	Meets IEEE requirements
Power Frequency Voltage Six Hour Dry Withstand Test According To IEEE Std 48-1996 8.4.1.3		
Six Hour AC Withstand	55 kV-RMS	Meets IEEE requirements
Power Frequency Voltage Ten Second Wet Withstand Test According To IEEE Std 48-1996 8.4.1.2 (Deviation cited)		
Termination "A" Sixty Second Withstand	60 kV-RMS	Exceeds IEEE requirements
Termination "B" Sixty Second Withstand	60 kV-RMS	Exceeds IEEE requirements
Direct Voltage Fifteen Minute Dry Withstand Test According To IEEE Std 48-1996 8.4.1.9		
Fifteen Minute DC Withstand	- 105 kV-DC	Meets IEEE requirements
Lightning Impulse Voltage Withstand Test According To IEEE Std 48-1996 8.4.1.7		
Test Surges, 10 Surges At Each Polarity	± 150 kV-Crest	Meets IEEE requirements
Actual Impulse Wave Shape Applied	1.44μsec. front/49.5 μsec. tail	Within required tolerance
Partial Discharge (Corona) Extinction Voltage Covering IEEE Std 48-1996 8.4.1.5 (Deviation cited)		
Direct Calibration, Haefely	2.0	Verified Test Circuit
Partial Discharge Inception Voltage	47.5 kV-RMS	
Magnitude	43.8 pC	
Partial Discharge Extinction Voltage	43.9 kV-RMS @ <3 pC	Exceeds IEEE requirements
Cyclic Aging Test According To IEEE Std 48-1996 8.4.2		
Jacket Temperature For 130° C Conductor Temp.	70.75° Centigrade	Verified Test Circuit
Current Required For 130° C Conductor Temp.	1220 Amperes	Information
Cycle Used	10 Hours On, 14 Hours Off	Information
Voltage Applied (100% On Time, Not Cycled)	43 kV-RMS	Meets IEEE requirements
Total Number Of Days At Voltage	30 Days	Meets IEEE requirements
Total Number Of Current Cycles	31 Cycles	Exceeds IEEE requirements
Partial Discharge (Corona) Extinction Voltage Covering IEEE Std 48-1996 8.4.1.5 (Deviation cited)		
Direct Calibration, Haefely	3.0 pC	Verified Test Circuit
Partial Discharge Inception Voltage	48.8 kV-RMS	
Magnitude	18.4 pC	
Partial Discharge Extinction Voltage	44.9 kV-RMS @ <3 pC	Exceeds IEEE requirements
Lightning Impulse Voltage Withstand Test According To IEEE Std 48-1996 8.4.1.7		
Test Surges, 10 Surges At Each Polarity	± 150 kV-Crest	Meets IEEE requirements
Actual Impulse Wave Shape Applied	1.46 μsec. front/48.7 μsec. tail	Within required tolerance

Test Results On Specimen Number 85115, 1000 kcmil Conductor

The following tests are not part of the IEEE Std 48-1996 Test Sequence. They were performed in order to help define the design parameters of these particular Terminations.

Partial Discharge (Corona) Extinction Voltage Covering IEEE Std 48-1996 8.4.1.5 (Deviation cited)

Direct Calibration. Haefely	2.0 pC	Verified Test Circuit
Partial Discharge Inception Voltage	44.0 kV-RMS	
Magnitude	4.0 pC	
Partial Discharge Extinction Voltage	41.5 kV-RMS @ <3 pC	Exceeds IEEE requirements

AC Step Test. 3M Design Test

This specimen was taken to 55 kV-RMS and held at that voltage for 1 hour. After the hour withstand was completed the voltage was increased 5 kV-RMS and held for another hour. This cycle of voltage increases and 1 hour withstands was continued to flashover or breakdown. This specimen went to 85 kV-RMS and failed after 38 minutes into the 60 minute withstand.

Test Results On Specimen Number 85116, 1000 kcmil Conductor

Tests In Chronological Order:	Value:	Result:
Partial Discharge (Corona) Extinction Voltage Covering IEEE Std 48-1996 8.4.1.5 (Deviation cited)		
Direct Calibration, Haefely	2.0 pC	Verified Test Circuit
Partial Discharge Inception Voltage	29.1 kV-RMS	
Magnitude	7.0 pC	
Partial Discharge Extinction Voltage	27.3 kV-RMS @ <3 pC	Exceeds IEEE requirements
Power Frequency Voltage One Minute Dry Withstand Test According To IEEE Std 48-1996 8.4.1.1		
One Minute Withstand	65 kV-RMS	Meets IEEE requirements
Power Frequency Voltage Six Hour Dry Withstand Test According To IEEE Std 48-1996 8.4.1.3		
Six Hour AC Withstand	55 kV-RMS	Meets IEEE requirements
Power Frequency Voltage Ten Second Wet Withstand Test According To IEEE Std 48-1996 8.4.1.2 (Deviation cited)		
Termination "A" Sixty Second Withstand	60 kV-RMS	Exceeds IEEE requirements
Termination "B" Sixty Second Withstand	60 kV-RMS	Exceeds IEEE requirements
Direct Voltage Fifteen Minute Dry Withstand Test According To IEEE Std 48-1996 8.4.1.9		
Fifteen Minute DC Withstand	- 105 kV-DC	Meets IEEE requirements
Lightning Impulse Voltage Withstand Test According To IEEE Std 48-1996 8.4.1.7		
Test Surges, 10 Surges At Each Polarity	± 150 kV-Crest	Meets IEEE requirements
Wave shape applied will be the same as specimen 85115		Within required tolerance
Partial Discharge (Corona) Extinction Voltage Covering IEEE Std 48-1996 8.4.1.5 (Deviation cited)		
Direct Calibration, Haefely	2.0	Verified Test Circuit
Partial Discharge Inception Voltage	46.6 kV-RMS	
Magnitude	8.3 pC	
Partial Discharge Extinction Voltage	43.8 kV-RMS @ <3 pC	Exceeds IEEE requirements
Cyclic Aging Test According To IEEE Std 48-1996 8.4.2		
Jacket Temperature For 130° C Conductor Temp.	72.25° Centigrade	Verified Test Circuit
Current Required For 130° C Conductor Temp.	1220 Amperes	Information
Cycle Used	10 Hours On, 14 Hours Off	Information
Voltage Applied (100% On Time, Not Cycled)	43.0 kV-RMS	Meets IEEE requirements
Total Number Of Days At Voltage	30 Days	Meets IEEE requirements
Total Number Of Current Cycles	31 Cycles	Exceeds IEEE requirements
Partial Discharge (Corona) Extinction Voltage Covering IEEE Std 48-1996 8.4.1.5 (Deviation cited)		
Direct Calibration, Haefely	3.0 pC	Verified Test Circuit
Partial Discharge Inception Voltage	46.6 kV-RMS	
Magnitude	5.4 pC	
Partial Discharge Extinction Voltage	44.2 kV-RMS @ <3 pC	Exceeds IEEE requirements
Lightning Impulse Voltage Withstand Test According To IEEE Std 48-1996 8.4.1.7		
Test Surges, 10 Surges At Each Polarity	± 150 kV-Crest	Meets IEEE requirements
Wave shape applied will be the same as specimen 85115		Within required tolerance

Test Results On Specimen Number 85116, 1000 kcmil Conductor

The following tests are not part of the IEEE Std 48-1996 Test Sequence. They were performed in order to help define the design parameters of these particular Terminations.

Partial Discharge (Corona) Extinction Voltage Covering IEEE Std 48-1996 8.4.1.5 (Deviation cited)

Direct Calibration, Haefely	2.0 pC	Verified Test Circuit
Partial Discharge Inception Voltage	44.2 kV-RMS	
Magnitude	4.5 pC	
Partial Discharge Extinction Voltage	42.5 kV-RMS @ <3 pC	Exceeds IEEE requirements

AC Step Test. 3M Design Test
This specimen was taken to 55 kV-RMS and held for 60 minutes. After 60 minutes the voltage was increased 5 kV-RMS and held for another 60 minutes. This cycle of voltage increases and 1 hour withstands was continued to flashover or breakdown. This specimen went to 95 kV-RMS and flashed over at 14 minutes into the 60 minute withstand.

Maximum Impulse. 3M Design Test
For this test three surges were applied at each impulse level starting at +150 kV-Crest and increasing the crest voltage up to +220 kV-Crest in approximately 10 kV-Crest increments. At +220 kV-Crest there were 3 flashovers. The same was done on the negative polarity, when the termination got to -170 kV-Crest there was 1 withstand followed by 3 flashovers.

Test Results On Specimen Number 85122, 4/0 AWG Conductor

Tests In Chronological Order:	Value:	Result:
Partial Discharge (Corona) Extinction Voltage Covering IEEE Std 48-1996 8.4.1.5 (Deviation cited)		
Direct Calibration, Haefely	2.0 pC	Verified Test Circuit
Partial Discharge Inception Voltage	49.7 kV-RMS	
Magnitude	5.8 pC	
Partial Discharge Extinction Voltage	42.4 kV-RMS @ <3 pC	Exceeds IEEE requirements
Power Frequency Voltage One Minute Dry Withstand Test According To IEEE Std 48-1996 8.4.1.1		
One Minute Withstand	65 kV-RMS	Meets IEEE requirements
Power Frequency Voltage Six Hour Dry Withstand Test According To IEEE Std 48-1996 8.4.1.3		
Six Hour AC Withstand	55 kV-RMS	Meets IEEE requirements
Power Frequency Voltage Ten Second Wet Withstand Test According To IEEE Std 48-1996 8.4.1.2 (Deviation cited)		
Termination "A" Sixty Second Withstand	60 kV-RMS	Exceeds IEEE requirements
Termination "B" Sixty Second Withstand	60 kV-RMS	Exceeds IEEE requirements
Direct Voltage Fifteen Minute Dry Withstand Test According To IEEE Std 48-1996 8.4.1.9		
Fifteen Minute DC Withstand	- 105 kV-DC	Meets IEEE requirements
Lightning Impulse Voltage Withstand Test According To IEEE Std 48-1996 8.4.1.7		
Test Surges, 10 Surges At Each Polarity	± 150 kV-Crest	Meets IEEE requirements
Actual Impulse Wave Shape Applied	1.19µsec. front/48.9 µsec. tail	Within required tolerance
Partial Discharge (Corona) Extinction Voltage Covering IEEE Std 48-1996 8.4.1.5 (Deviation cited)		
Direct Calibration, Haefely	2.0	Verified Test Circuit
Partial Discharge Inception Voltage	32.4 kV-RMS	
Magnitude	41.5 pC	
Partial Discharge Extinction Voltage	30.8 kV-RMS @ <3 pC	Exceeds IEEE requirements
Cyclic Aging Test According To IEEE Std 48-1996 8.4.2		
Jacket Temperature For 130° C Conductor Temp.	74° Centigrade	Verified Test Circuit
Current Required For 130° C Conductor Temp.	598 Amperes	Information
Cycle Used	8 Hours On, 16 Hours Off	Information
Voltage Applied (100% On Time, Not Cycled)	43.0 kV-RMS	Meets IEEE requirements
Total Number Of Days At Voltage	31.7 Days	Exceeds IEEE requirements
Total Number Of Current Cycles	32 Cycles	Exceeds IEEE requirements
Partial Discharge (Corona) Extinction Voltage Covering IEEE Std 48-1996 8.4.1.5 (Deviation cited)		
Direct Calibration, Haefely	2.0 pC	Verified Test Circuit
Partial Discharge Inception Voltage	65.0 kV-RMS	
Magnitude	<3 pC	Discharge free at the one minute withstand level.
Lightning Impulse Voltage Withstand Test According To IEEE Std 48-1996 8.4.1.7		
Test Surges, 10 Surges At Each Polarity	± 150 kV-Crest	Meets IEEE requirements
Actual Impulse Wave Shape Applied	1.19µsec. front/49.5 µsec. tail	Within required tolerance

Test Results On Specimen Number 85122, 4/0 AWG Conductor

The following tests are not part of the IEEE Std 48-1996 Test Sequence. They were performed in order to help define the design parameters of these particular Terminations.

Partial Discharge (Corona) Extinction Voltage Covering IEEE Std 48-1996 8.4.1.5 (Deviation cited)

Direct Calibration, Haefely	2.0 pC	Verified Test Circuit
Partial Discharge Inception Voltage	58.9 kV-RMS	
Magnitude	11.0 pC	
Partial Discharge Extinction Voltage	57.4	Exceeds IEEE requirements

AC Step Test, 3M Design Test

This specimen was taken to 55 kV-RMS and held at that voltage for 1 hour. After the hour withstand was completed the voltage was increased 5 kV-RMS and held for another hour. This cycle of voltage increases and 1 hour withstands was continued to flashover or breakdown. This specimen went to 115 kV-RMS and flashed over at 1 minute into the 60 minute withstand.

Maximum Impulse, 3M Design Test

For this test three surges were applied at each impulse level starting at +150 kV-Crest and increasing the crest voltage up to +230 kV-Crest in approximately 10 kV-Crest increments. At +230 kV-Crest there were 3 flashovers. Test was repeated on the negative polarity, at -210 kV-Crest there were 2 withstands followed by 3 flashovers.

Test Results On Specimen Number 85123, 4/0 AWG Conductor

Tests In Chronological Order:	Value:	Result:
Partial Discharge (Corona) Extinction Voltage Covering IEEE Std 48-1996 8.4.1.5 (Deviation cited)		
Direct Calibration, Haefely	2.0 pC	Verified Test Circuit
Partial Discharge Inception Voltage	41.0 kV-RMS	
Magnitude	7.9 pC	
Partial Discharge Extinction Voltage	40.1 kV-RMS @ <3 pC	Exceeds IEEE requirements
Power Frequency Voltage One Minute Dry Withstand Test According To IEEE Std 48-1996 8.4.1.1		
One Minute Withstand	65 kV-RMS	Meets IEEE requirements
Power Frequency Voltage Six Hour Dry Withstand Test According To IEEE Std 48-1996 8.4.1.3		
Six Hour AC Withstand	55 kV-RMS	Meets IEEE requirements
Power Frequency Voltage Ten Second Wet Withstand Test According To IEEE Std 48-1996 8.4.1.2 (Deviation cited)		
Termination "A" Sixty Second Withstand	60 kV-RMS	Exceeds IEEE requirements
Termination "B" Sixty Second Withstand	60 kV-RMS	Exceeds IEEE requirements
Direct Voltage Fifteen Minute Dry Withstand Test According To IEEE Std 48-1996 8.4.1.9		
Fifteen Minute DC Withstand	- 105 kV-DC	Meets IEEE requirements
Lightning Impulse Voltage Withstand Test According To IEEE Std 48-1996 8.4.1.7		
Test Surges, 10 Surges At Each Polarity	± 150 kV-Crest	Meets IEEE requirements
Wave shape applied will be the same as specimen 85122		Within required tolerance
Partial Discharge (Corona) Extinction Voltage Covering IEEE Std 48-1996 8.4.1.5 (Deviation cited)		
Direct Calibration, Haefely	2.0	Verified Test Circuit
Partial Discharge Inception Voltage	58.6 kV-RMS	
Magnitude	44.0 pC	
Partial Discharge Extinction Voltage	55.5 kV-RMS @ <3 pC	Exceeds IEEE requirements
Cyclic Aging Test According To IEEE Std 48-1996 8.4.2		
Jacket Temperature For 130° C Conductor Temp.	69.0° Centigrade	Verified Test Circuit
Current Required For 130° C Conductor Temp.	598 Amperes	Information
Cycle Used	8 Hours On, 16 Hours Off	Information
Voltage Applied (100% On Time, Not Cycled)	43.0 kV-RMS	Meets IEEE requirements
Total Number Of Days At Voltage	31.7 Days	Exceeds IEEE requirements
Total Number Of Current Cycles	32 Cycles	Exceeds IEEE requirements
Partial Discharge (Corona) Extinction Voltage Covering IEEE Std 48-1996 8.4.1.5 (Deviation cited)		
Direct Calibration, Haefely	2.0 pC	Verified Test Circuit
Partial Discharge Inception Voltage	59.2 kV-RMS	
Magnitude	4.0 pC	
Partial Discharge Extinction Voltage	48.9 kV-RMS @ <3 pC	Exceeds IEEE requirements
Lightning Impulse Voltage Withstand Test According To IEEE Std 48-1996 8.4.1.7		
Test Surges, 10 Surges At Each Polarity	± 150 kV-Crest	Meets IEEE requirements
Wave shape applied will be the same as specimen 85115		Within required tolerance

Test Results On Specimen Number 85123, 4/0 AWG Conductor

The following tests are not part of the IEEE Std 48-1996 Test Sequence. They were performed in order to help define the design parameters of these particular Terminations.

Partial Discharge (Corona) Extinction Voltage Covering IEEE Std 48-1996 8.4.1.5 (Deviation cited)

Direct Calibration. Haefely	2.0 pC	Verified Test Circuit
Partial Discharge Inception Voltage	44.5 kV-RMS	
Magnitude	12 pC	
Partial Discharge Extinction Voltage	40.7 kV-RMS @ <3 pC	Exceeds IEEE Requirements

AC Step Test. 3M Design Test

This specimen was taken to 55 kV-RMS and held at that voltage for 1 hour. After the hour withstand was completed the voltage was increased 5 kV-RMS and held for another hour. This cycle of voltage increases and 1 hour withstands was continued to flashover or breakdown. This specimen went to 115 kV-RMS and flashed over at 21 minutes into the 60 minute withstand.

Maximum Impulse. 3M Design Test

For this test three surges were applied at each impulse level starting at +150 kV-Crest and increasing the crest voltage up to +200 kV-Crest in approximately 10 kV-Crest increments. At +200 kV-Crest there was 1 withstand followed by 3 flashovers. Test was repeated on the negative polarity, at -190 kV-Crest there was 2 flashovers followed by 3 withstands. At -200 kV-Crest there were 3 flashovers.

Test Results on Specimen Numbers 85214 (1000 kcmil Conductor) and 85215 (4/0 Conductor)

Specimen 85214 and 85215 were both pressure tested according to *IEEE Std 48-1996 7.1.2 Class 1A* Specimens were constructed according to 8.1.a, b, d, and g (deviation cited concerning minimum and maximum cables used for testing.)

(1) Both of the terminated ends of the specimens, 85214 and 85215, were submersed in a water bath. The cable ends of both specimens were fitted with air fittings and the specimens were pressurized to 7.0 psi. There were no indications of any leaks during or at the end of the six hour pressurization. ***Meets IEEE Std 48-1996 8.4.3 (a) Requirements.***

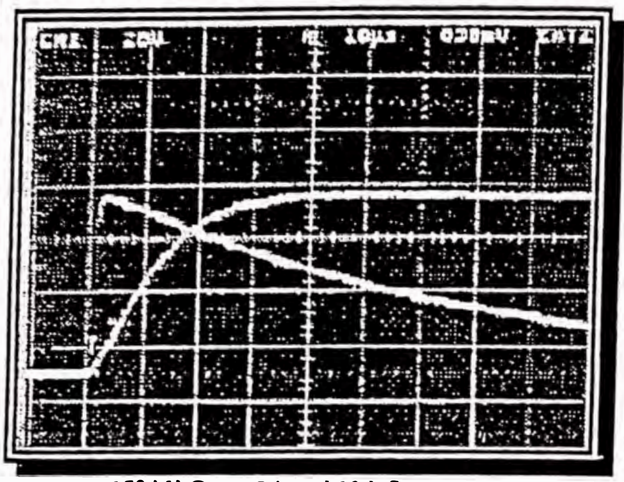
(2) Both of the specimens 85214 and 85215, were installed on a vacuum line with a isolation valve and vacuum gauge on the specimen side of the valve. The specimens were evacuated to 67 Pa (0.5 torr.). The vacuum source and specimen was isolated by closing the valve. After 30 minutes there was no loss in vacuum. ***Meets IEEE 48-1996 8.4.3 (b) Requirements.***

Impulse Test Oscillograms:

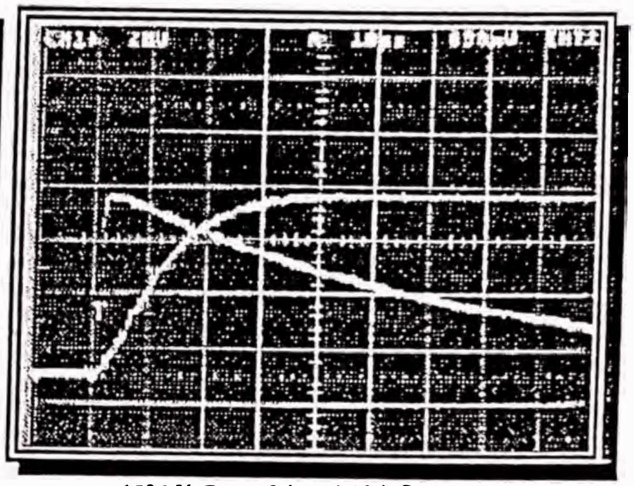
Common Settings To All Oscillograms:

Deflection = 20 Volts Per Division
Sweep = 0.5 and 10 µseconds Per Division
Measuring Ratio = 2.141 kV/Volt Corrected To The Prevailing Atmospheric Conditions At Test Time.

Specimen 885115 Oscillograms Taken Before Current Cycling

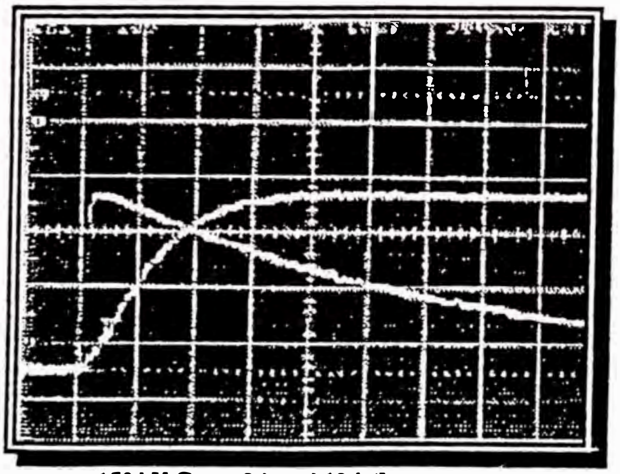


+150 kV-Crest, 9th and 10th Surges

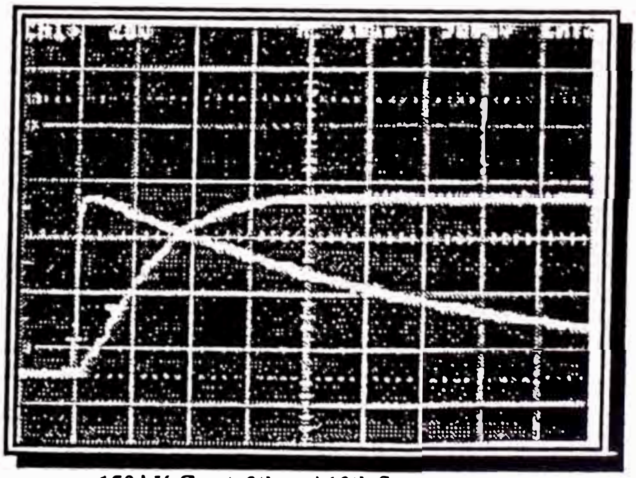


150 kV-Crest, 9th and 10th Surges

Specimen 85115 Oscillograms Taken After Current Cycling



150 kV-Crest, 9th and 10th Surges



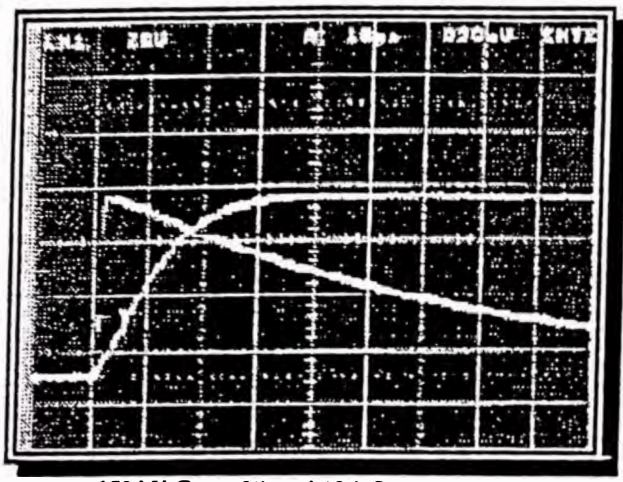
150 kV-Crest, 9th and 10th Surges

Impulse Test Oscillograms:

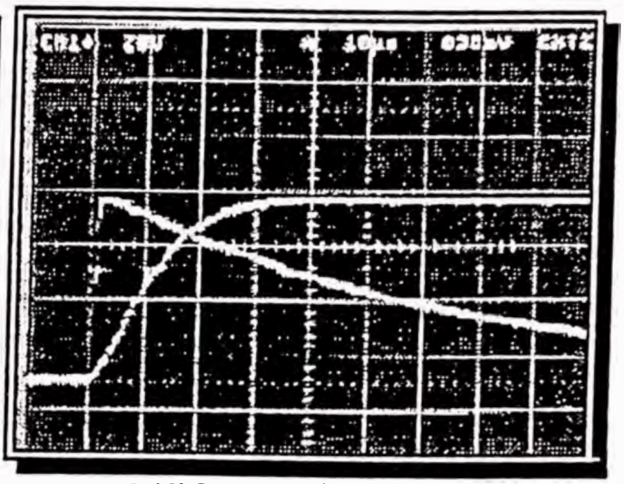
Common Settings To All Oscillograms:

Deflection = 20 Volts Per Division
Sweep = 0.5 and 10 μseconds Per Division
Measuring Ratio = 2.141 kV/Volt Corrected To The Prevailing Atmospheric Conditions At Test Time.

Specimen 85116 Oscillograms Taken Before Current Cycling

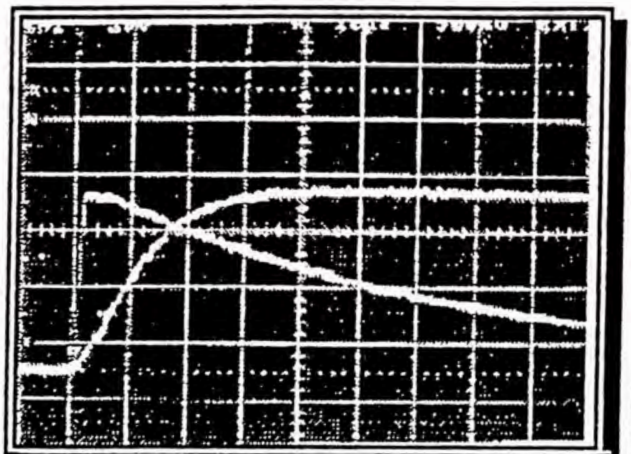


150 kV-Crest, 9th and 10th Surges

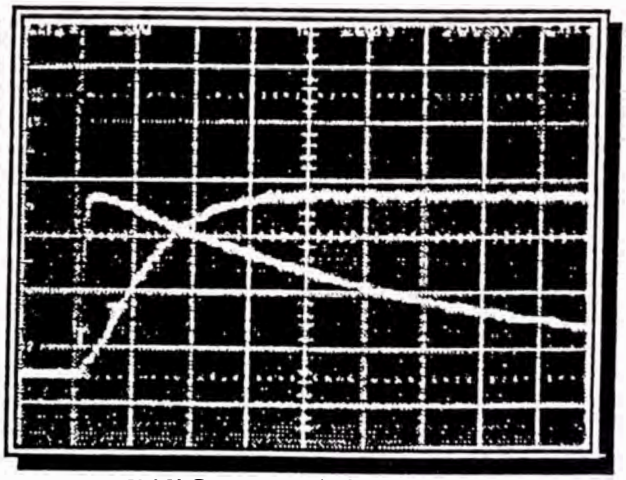


150 kV-Crest 9th and 10th Surges

Specimen 85116 Oscillograms Taken After Current Cycling



150 kV-Crest, 9th and 10th Surges



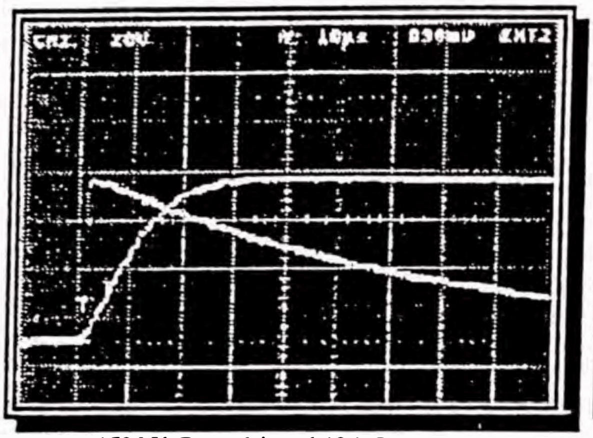
150 kV-Crest 9th and 10th Surges

Impulse Test Oscillograms:

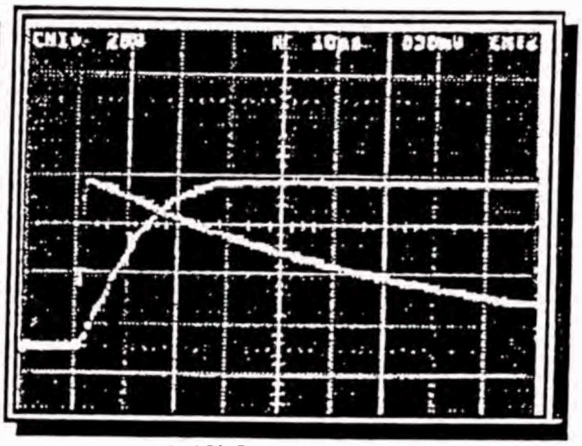
Common Settings To All Oscillograms:

Deflection = 20 Volts Per Division
Sweep = 0.5 and 10 µseconds Per Division
Measuring Ratio = 2.141 kV/Volt Corrected To The Prevailing Atmospheric Conditions At Test Time.

Specimen 85122 Oscillograms Taken Before Current Cycling

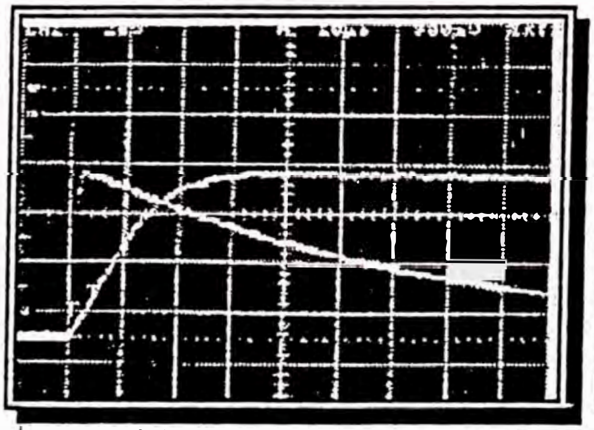


150 kV-Crest, 9th and 10th Surges

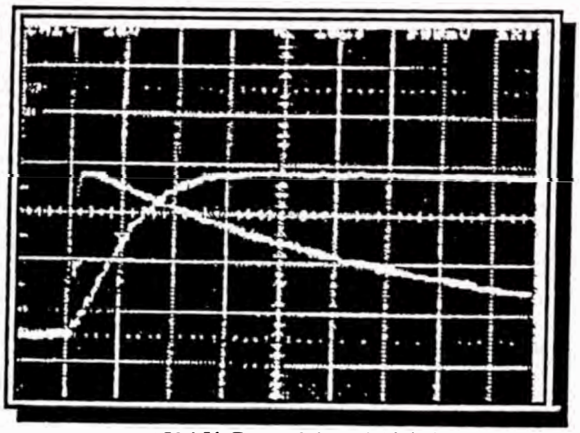


150 kV-Crest, 9th and 10th Surges

Specimen 85122 Oscillograms Taken After Current Cycling



150 kV-Crest, 9th and 10th Surges



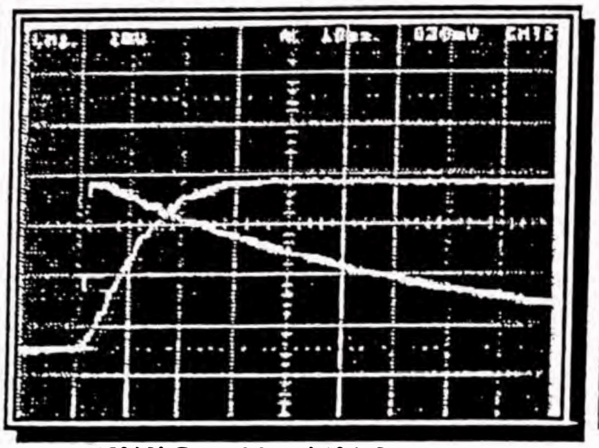
150 kV-Crest, 9th and 10th Surges

Impulse Test Oscillograms:

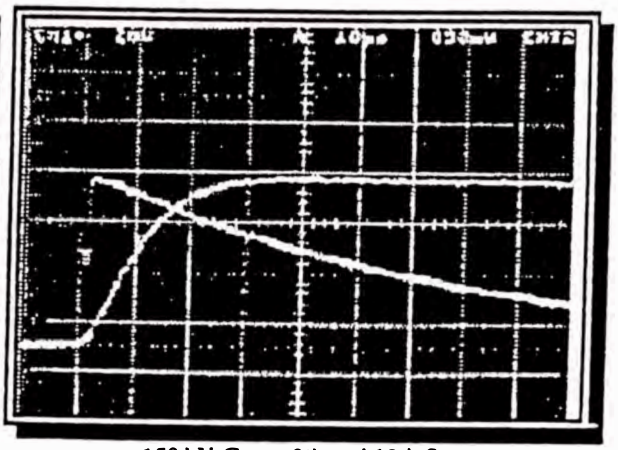
Common Settings To All Oscillograms:

Deflection = 20 Volts Per Division
Sweep = 0.5 and 10 μseconds Per Division
Measuring Ratio = 2.141 kV/Volt Corrected To The Prevailing Atmospheric Conditions At Test Time.

Specimen 85123 Oscillograms Taken Before Current Cycling

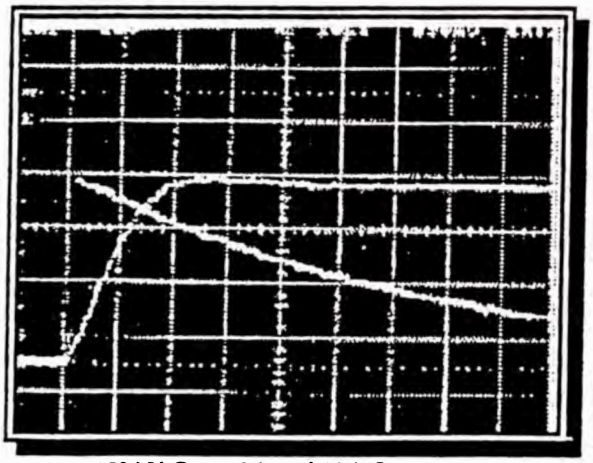


150 kV-Crest, 9th and 10th Surges

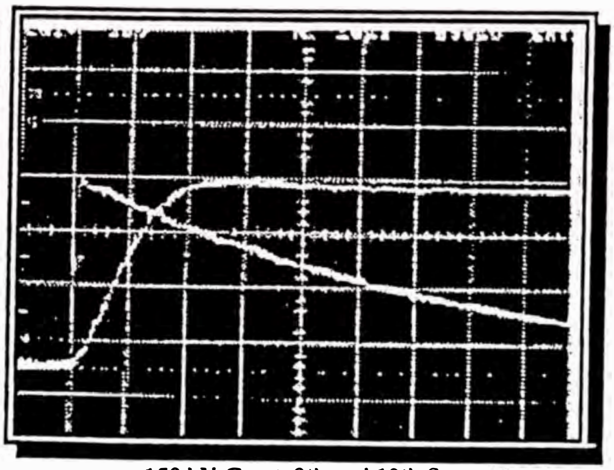


150 kV-Crest, 9th and 10th Surges

Specimen 85123 Oscillograms Taken After Current Cycling

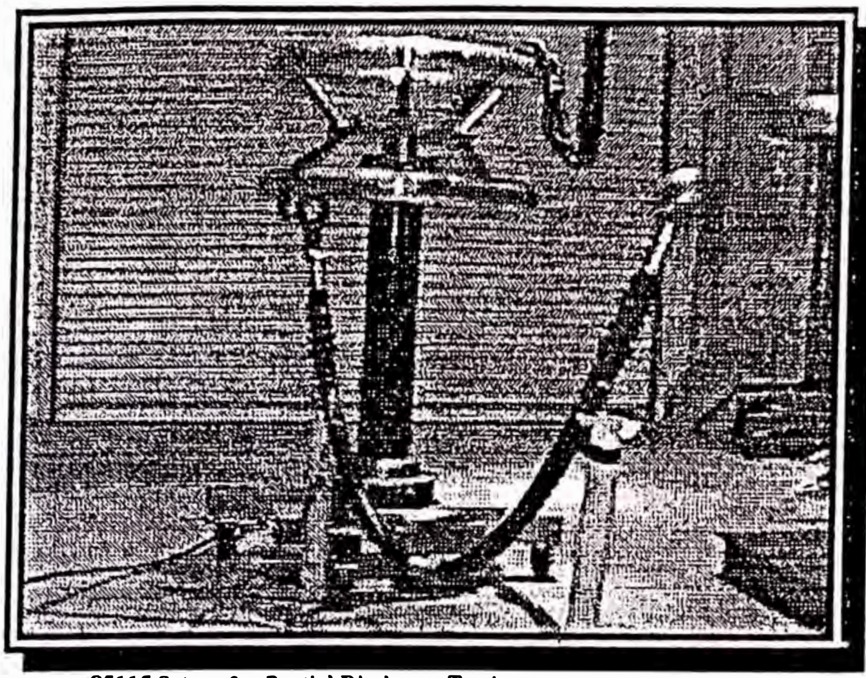


150 kV-Crest, 9th and 10th Surges

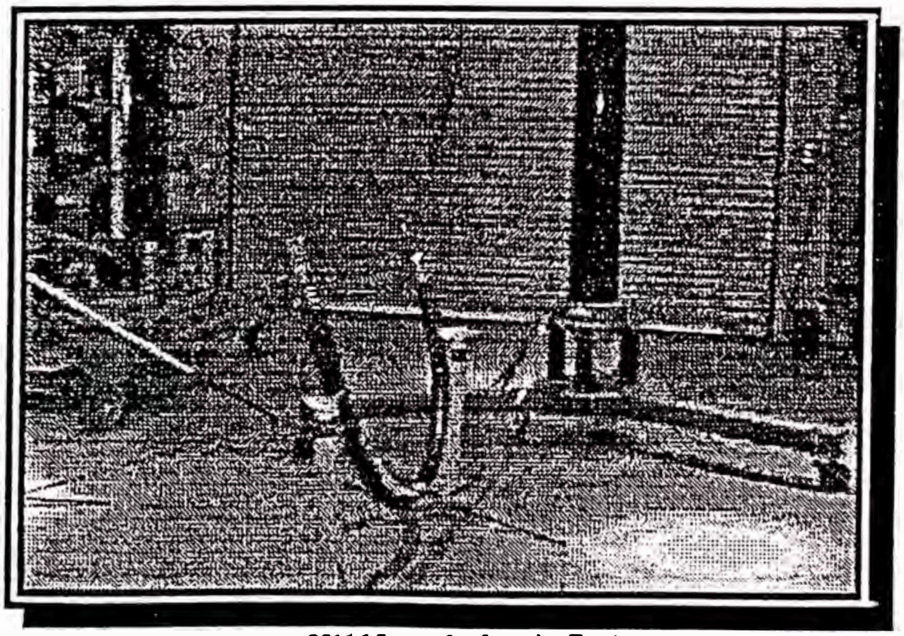


150 kV-Crest, 9th and 10th Surges

Specimen Photographs

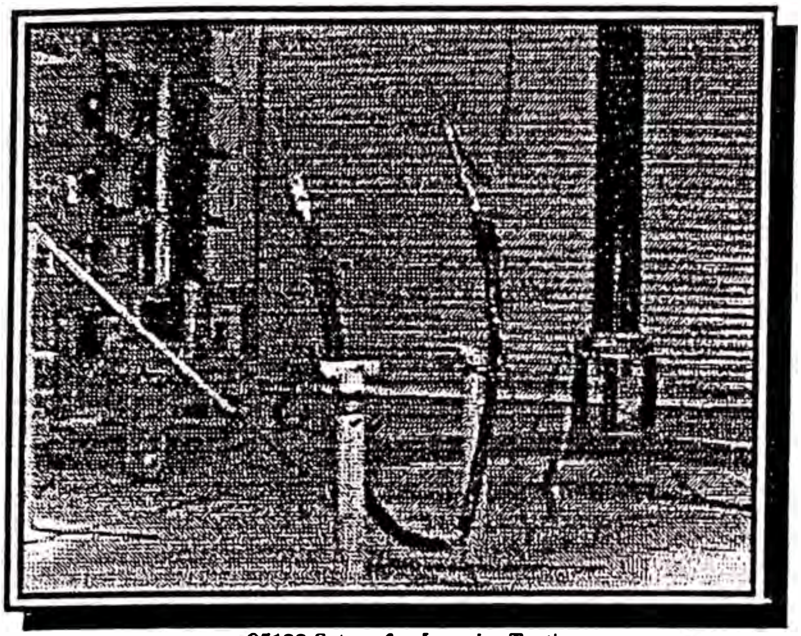


85115 Set up for Partial Discharge Testing

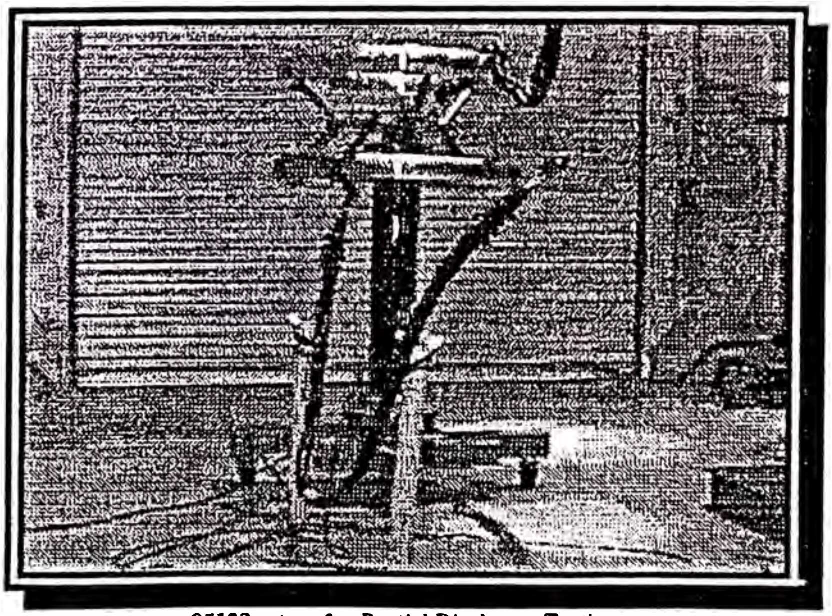


85116 Set up for Impulse Testing

Specimen Photographs

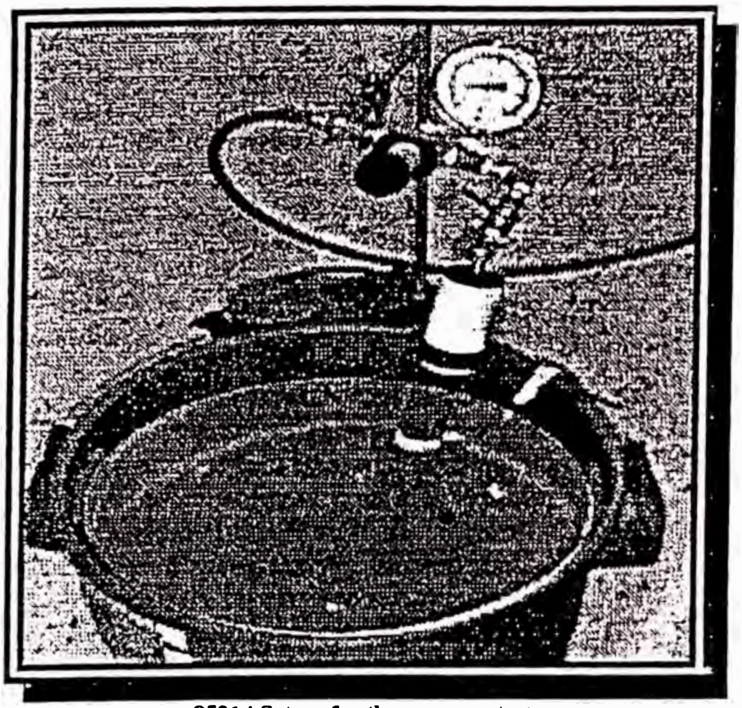


85122 Set up for Impulse Testing

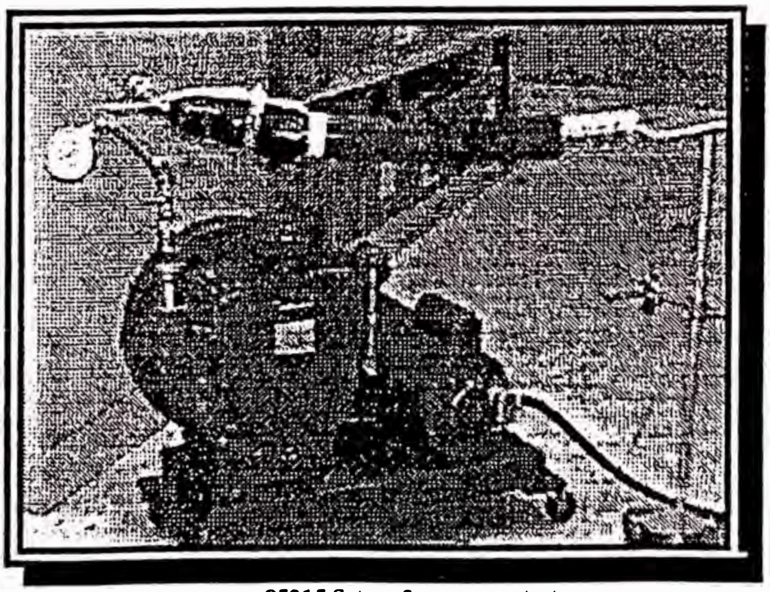


85123 set up for Partial Discharge Testing

Specimen Photographs

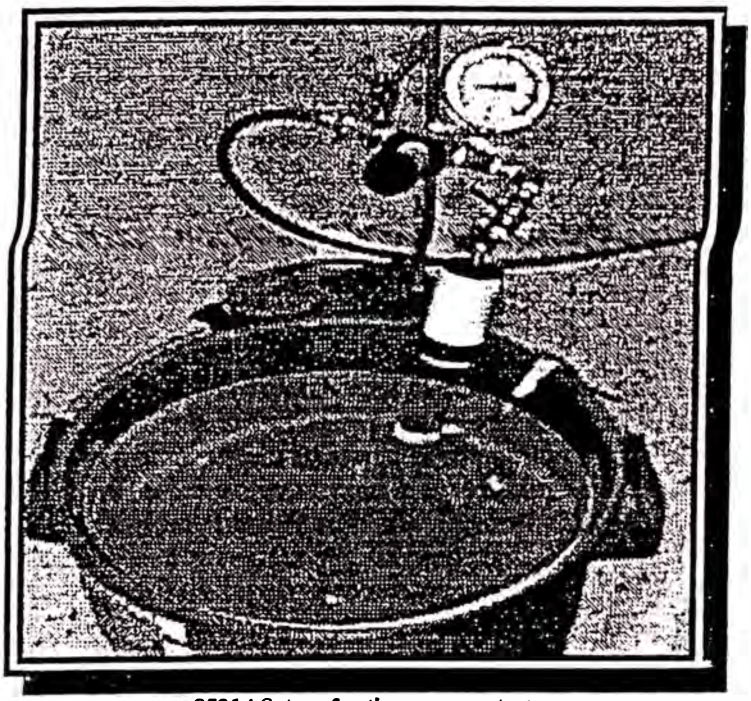


85214 Set up for the pressure test.

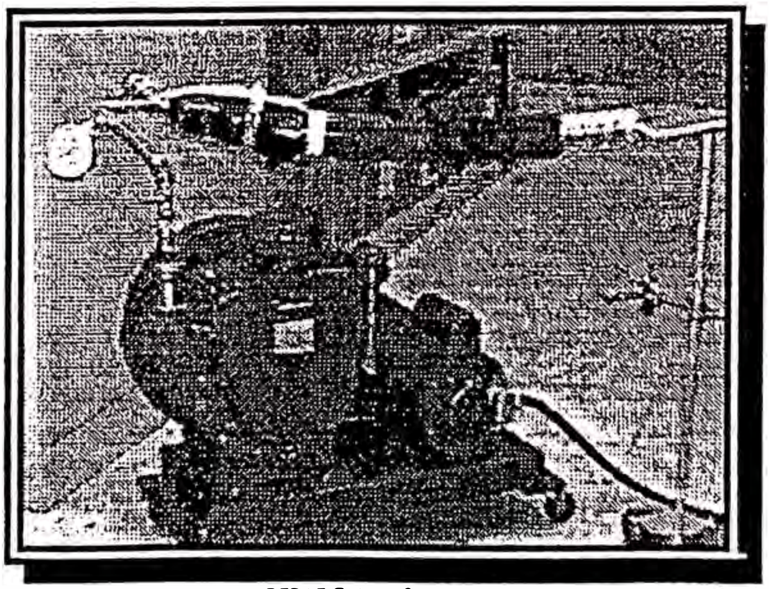


85215 Set up for vacuum test

Specimen Photographs



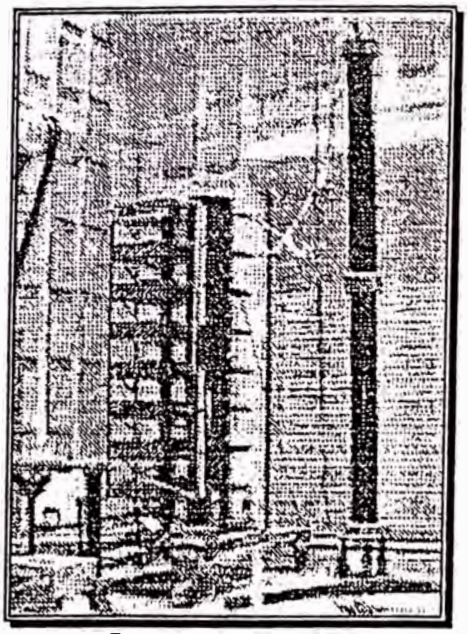
85214 Set up for the pressure test.



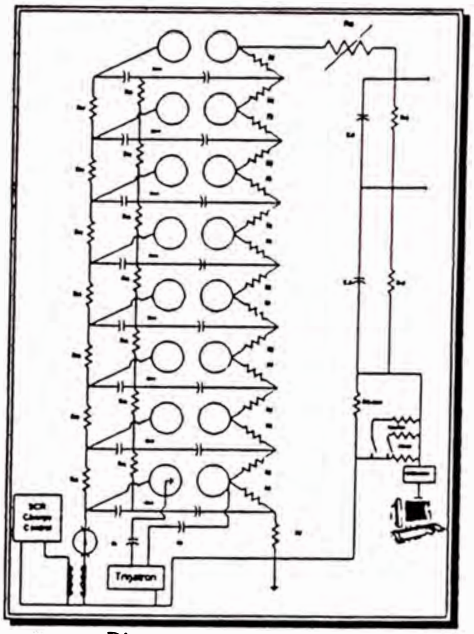
85215 Set up for vacuum test

Impulse Generator

Manufacturer	= Emile Haefely & Co. LTD, Basel-Switzerland
Model	= Series "E" Generator
Number Of Stages	= 8
Maximum Voltage Per Stage	= 100kV
Maximum Output Voltage	= 800 kV
Energy At Maximum Voltage	= 40 kJ
Capacitance Per Stage	= 100 nF
Impulse Voltage Divider	= 1.2 MeV
Commission Dates	= Divider 1967, Control Desk/Trigatron 1986, Generator 1988
Calibration Cycle	= Yearly, suspect, or after repair or maintenance, which-ever comes first.
Measuring System	= Tektronix Digital Storage Oscilloscope Model 468



Generator



Diagram

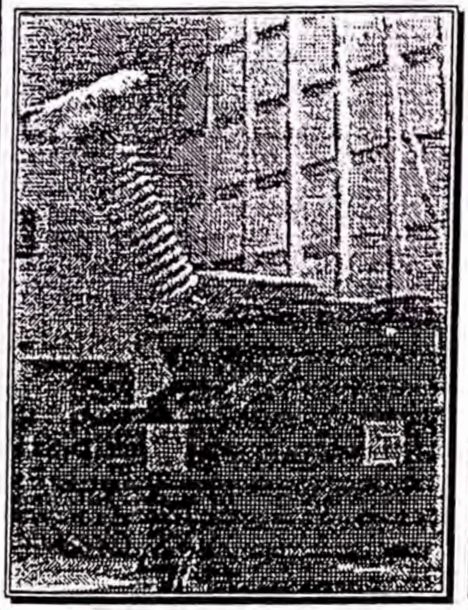
Circuit Variables Utilized For Test:

Measuring Ratio (kV/Volt On DSO)	= 2.1335/1 Further corrected to prevailing atmospheric conditions at test time
R_{series}	= 148.1 Ω
Input Attenuation	= 6:1
CRO Volts/Division	= 20
Surge Dwell Time	= 22 Seconds
Number Of Stages And Configuration	= Four Stages In Series, Top Four Stages Shorted Out.

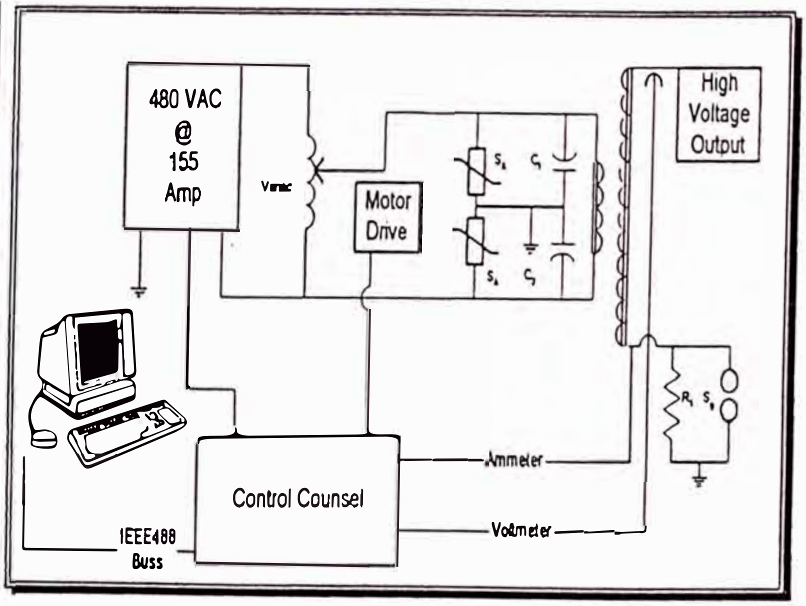
This configuration was used for all four specimens covered in this report.

AC Dielectric Test Set

Manufacturer	Phenix Technologies (Formerly American High Voltage Test Systems)
Output Rating	250 kV @ 500 MA, Partial Discharge Free Winding (<2 pC)
High Voltage Metering	Capacitive Tapped High Voltage Bushing
Duty Cycle	1 hour on/1 hour off rating 125 kVA, Continuous Rating 100 kVA
Calibration Cycle	Yearly, suspect, or after repair or maintenance, which-ever comes first
Guaranteed Discharge Level	< 2 pC at 250 kV
Actual Discharge Level	< 0.75 at 250 kV
Distortion	< 5%
Impedance	< 15% at rated current
Options	4 1/2 Digit Panel Meters, accurate to 2% of full scale Multiple function timer circuit IEEE 488 GPIB for control, meter reading functions, and automated testing Input power RF filtering Software for Computer Controlled Testing
Commission Date	August 1988



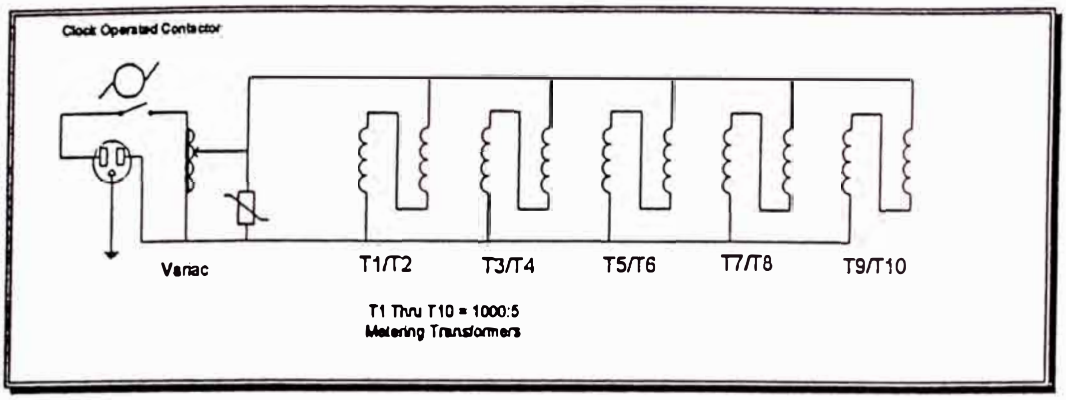
Transformer



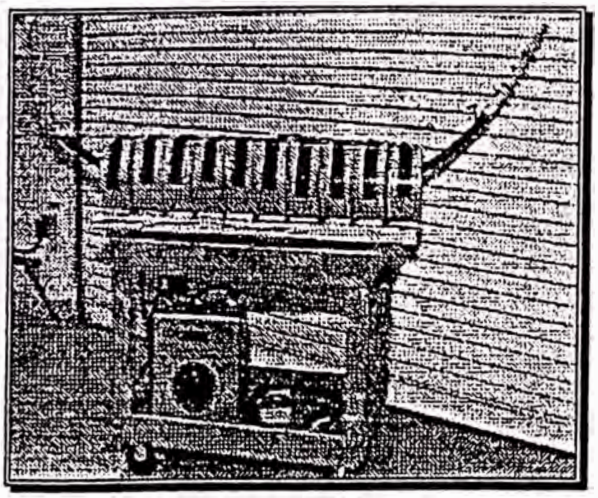
Diagram

Current Source

Power Source:	Variable Auto-Transformer (Variac).
Current Source:	Specimen with a jumper connected in a loop configuration through 1000:5 Window Type Metering Transformers.
Configuration:	Multiple, whatever combination of series/parallel transformers required to drive the current needed.
High Voltage Source:	AC Test Set.



Typical hook-up of five parallel banks of two transformers in series was used. Series/Parallel combinations were selected according to the load being presented by the test specimen. We have several power sources we routinely use from 115VAC/5Amp to 480VAC/60Amp. Loop current measurements are taken with a digital ammeter.



Typical Current Source.—There are a number of different sets and configurations used in the laboratory.

Equipment Utilization List:

Equipment:	3M Instrument Number:	Calibration Due:
Haefely Partial Discharge Detector	85762	9/30/97
Biddle Partial Discharge Detector	67327	3/15/97
AC Test Set, American High Voltage, 250 kV-RMS	67567	11/27/97
AC Test Set, Phenix	123495	7/23/97
AC Test Set, Phenix	67468	7/2/97
AC Test Set, Phenix	67469	7/2/97
AC Test Set, Biddle	81604	12/3/97
DC Test Set, Biddle	81553	3/26/97
Impulse Generator, Haefely	598901	3/26/97
Omega Psychrometer	123497	3/5/97
Tektronix DSO	76811	8/7/97
Ashcroft Pressure Gauge	123420	10/18/97
Ametek Vacuum/Pressure Gauge	123569	4/15/97
Ammeter, AW Sperry	123463	3/18/97
Ammeter	117490	9/10/97
Omega Temperature Meter	123693	3/18/97
Fluke 87 DVM	123316	11/14/97

Instrument calibrations are done in the 3M Metrology Laboratory or by Haefely Test Systems Inc., or Rothe Development. Calibrations are traceable to NIST. The High Voltage Laboratory equipment is calibrated yearly, after a repair, if suspect, or found to be off during a random spot check.

All original data, and Oscillograms are filed in the 3M Electrical Products, U&I Sector, Testing & Services Group Master File. Some original data may be in the form of an electronic files as some tests are computer driven.

Revision History

Revision:	Change:
0	Original report, no changes, additions, or deletions.

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ANEXO D

NORMA IEEE Std. 48-1996

IEEE Std 48-1996
(Revision of IEEE Std 48-1990)

IEEE Standard Test Procedures and Requirements for Alternating-Current Cable Terminations 2.5 kV Through 765 kV

Circuits and Devices

Communications Technology

Computer

Electromagnetics and Radiation

IEEE Power Engineering Society

Sponsored by the
Insulated Conductors Committee

IEEE Std 48-1996

IEEE

Published by the Institute of Electrical and Electronics Engineers, Inc., 345 East 47th Street, New York, NY 10017, USA.

20 June 1996 *SH94389*

IEEE Std 48-1996
(Revision of IEEE Std 48-1990)

IEEE Standard Test Procedures and Requirements for Alternating-Current Cable Terminations 2.5 kV Through 765 kV

Sponsor

Insulated Conductors Committee of the IEEE Power Engineering Society

Approved 2 May 1996

IEEE Standards Board

Abstract: All indoor and outdoor cable terminations used on alternating-current cables having laminated or extruded insulation rated 2.5 kV through 765 kV are covered, except for separable insulated connectors, which are covered by IEEE Std 386-1995.
Keywords: accelerated contamination testing, correction factors, dielectric field tests, environmental exposure, nons..ndard service conditions, rating, solar radiation, standard service conditions, test requirements, ultraviolet light

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The Institute of Electrical and Electronics Engineers, Inc.
345 East 47th Street, New York, NY 10017-2394, USA

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Introduction

(This introduction is not part of IEEE Std 48-1996, IEEE Standard Test Procedures and Requirements for Alternating-Current Cable Terminations 2.5 kV Through 765 kV.)

This standard supersedes IEEE Std 48-1990, IEEE Standard Test Procedures and Requirements for High-Voltage Alternating-Current Cable Terminations.

Several definitions have been added to reflect use of polymeric designs and to differentiate between various environments encountered. To clarify test procedures, Class 1 terminations have been divided into three classes: Class 1A for extruded dielectric cable, Class 1B for laminated dielectric cable, and Class 1C for pressure-type systems.

Partial discharge requirements for laminated cable terminations have been replaced by ionization test requirements, which are more applicable for laminated cable constructions. Retesting is not intended now as the partial discharge is more difficult. Reflecting cable voltage trends, table 1 contains test requirements up to 765 kV for laminated dielectric terminations and 230 kV for solid dielectric cable terminations.

Clause 9 has been expanded to include a pollution severity guide to assist the user to define a particular environment and help determine type and creepage length needed. Effects of solar radiation are addressed and test methods are recommended. The user is also advised to refer to the manufacturer for contamination testing, particularly if difficult environments are encountered.

At the time this standard was approved, Working Group 10-40 of the Accessories Subcommittee 10 of the Insulated Conductors Committee had the following membership:

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When the IEEE Standards Board approved this standard on 2 May 1996, it had the following membership:

Contents

IEEE Standard Test Procedures and Requirements for Alternating-Current Cable Terminations 2.5 kV Through 765 kV

1. Scope

This standard covers all indoor and outdoor cable terminations used on alternating-current cables having laminated or extruded insulation rated 2.5 kV through 765 kV, except separable insulated connectors, which are covered by IEEE Std 386-1995, IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600 V [B16].[1]

Cable terminations and component parts shall be capable of withstanding the tests specified in this standard.

2. References

This standard shall be used in conjunction with the following standards. When the following standards are superseded by an approved revision, the revision shall apply.

IEC 270-1981, Partial Discharge Measurements.[2]

IEEE Std 4-1995, IEEE Standard Techniques for High-Voltage Testing (ANSI).[3]

IEEE Std 82-1994, IEEE Standard Test Procedure for Impulse Voltage Tests on Insulated Conductors (ANSI).

IEEE Std 835-1994, IEEE Standard Power Cable Ampacity Tables (ANSI).

[1]The numbers in brackets correspond to those of the bibliography in clause 10.

[2]IEC publications are available from IEC Sales Department, Case Postale 131, 3, rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse. IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

[3]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

3. Definitions

The definitions and terminology used herein apply specifically to cable terminations treated in this standard. For additional definitions, see [B15].

3.1 apparatus termination: A termination designed for use in sealed enclosures where the external dielectric strength is dependent upon liquid or special gaseous dielectric and where the ambient temperature of the medium immediately surrounding the termination may reach 55 °C.

3.2 breakdown: A disruptive discharge occurring through a dielectric.

3.3 chalking: The powdered surface on the polymeric insulator consisting of particles of filler resulting from ultraviolet exposure or leakage current activity.

3.4 cracking: Rupture of the polymeric insulator material to depths equal to or greater than 0.1 mm.

3.5 crazing: Surface microfractures of the insulator material to depths less than 0.1 mm resulting from ultraviolet exposure.

3.6 design tests: Tests made by the manufacturer to obtain data for design or application, or to obtain information on the performance of each type of high-voltage cable termination.

3.7 external connector (aerial lug): A connector that joins the external conductor to the current-carrying parts of a cable termination.

3.8 field tests: Tests that may be made on a cable system (including the high-voltage cable terminations) by the user after installation, as an acceptance or proof test.

3.9 flashover: A disruptive discharge around or over the surface of an insulating member, between parts of different potential or polarity, produced by the application of voltage wherein the breakdown path becomes sufficiently ionized to maintain an electric arc.

3.10 high-voltage cable termination: A device used for terminating alternating-current power cables having laminated or extruded insulation rated 2.5 kV and above, which are classified according to the following:

a) Class 1 termination: Provides electric stress control for the cable insulation shield terminus; provides complete external leakage insulation between the cable conductor(s) and ground; and provides a seal to the end of the cable against the entrance of the external environment and maintains the operating design pressure, if any, of the cable system. This class is divided into three types:
   - Class 1A: For use on extruded dielectric cable
   - Class 1B: For use on laminated dielectric cable
   - Class 1C: Expressly for pressure-type cable systems

b) Class 2 termination: Provides electric stress control for the cable insulation shield terminus, and provides complete external leakage insulation between the cable conductor(s) and ground.

c) Class 3 termination: Provides electric stress control for the cable insulation shield terminus.

NOTE—Some cables below 15 kV do not have an insulation shield. Terminations for such cables would not be required to provide electric stress control. In such cases, this provision would not be part of the definition.

3.11 indoor termination—dry: A termination intended for use where it is protected from solar radiation and precipitation and not subject to periodic condensation, or other excessive humidity (90% RH or more). May be installed in air conditioned or heated areas.

3.12 indoor termination—wet: A termination intended for use where it is protected from direct exposure to both solar radiation and precipitation, but is subjected to climatic conditions that can cause condensation onto the termination surfaces.

3.13 outdoor termination: A termination intended for use where it is not protected from direct exposure to either solar radiation or precipitation. These are Class 1A, 1B, or 1C terminations. Class 2 terminations may also qualify.

3.14 outdoor termination—polluted: A termination intended for use where it is not protected from direct exposure to either solar radiation or precipitation, and is exposed to nonstandard (unusual) service conditions such as extreme seacoast salt deposits, solid precipitates, etc. Often requires extra maintenance such as washing or extra creepage length.

3.15 partial discharge (corona) extinction voltage: The voltage at which partial discharge (corona) is no longer detectable on instrumentation adjusted to a specified sensitivity, following the application of a specified higher voltage.

3.16 pressure-type termination: A Class 1C termination intended for use on positive pressure cable systems.

Single pressure zone termination: A pressure-type termination intended to operate with one pressure zone.

Multipressure zone termination: A pressure-type termination intended to operate with two or more pressure zones.

3.17 radio influence voltage (RIV): The radio noise appearing on conductors of electric equipment or circuits, as measured using a radio-noise meter as a two-terminal voltmeter in accordance with specified methods.

3.18 routine tests: Tests made on each high-voltage cable termination or upon a representative number of devices, or parts thereof, during production for purposes of quality control.

3.19 termination insulator: An insulator used to protect each cable conductor passing through the device and provide complete external leakage insulation between the cable conductor(s) and ground.

3.20 weathersheds: The external part of the termination insulator that protects the core and provides the wet electrical strength and leakage distance.

3.21 withstand test voltage: The voltage that the device must withstand without flashover, disruptive discharge, puncture, or other electrical failure when voltage is applied under specified conditions.

NOTE—For power frequency voltages, the values specified are RMS values and for a specified time. For lightning or switching impulse voltages, the values specified are crest values of a specified wave. For direct voltages, the values specified are average values and for a specified time.

4. Service conditions

4.1 Standard service conditions

Devices conforming to this standard shall be capable of successful operation under the following service conditions. Refer to [B14] for more information.

4.1.1 Physical conditions

a) Temperature
   1) The temperature of the medium in direct contact with the termination shall not be less than –30 °C, nor more than +40 °C.
   2) For apparatus terminations, the temperature of the medium in direct contact with the termination (ambient inside enclosure) shall not exceed 55 °C. The devices designed for this service will be connected to the equipment bus which may, at full load, reach a maximum temperature of 85 °C.

b) The altitude shall not exceed 1000 m (3300 ft) where atmospheric air is part of the thermal or dielectric system or both.

4.1.2 System conditions

The nominal power system frequency is not less than 48 Hz nor more than 62 Hz.

4.2 Nonstandard service conditions

The following service conditions may require special consideration in design or application of the cable terminations, and should be called to the attention of the manufacturer.

4.2.1 Physical conditions

a) Temperature of the surrounding medium (ambient temperature) less than –30 °C and more than +40 °C
b) Altitude exceeding 1000 m (3300 ft) where atmospheric air is part of the thermal or dielectric system or both (see clause 9)
c) Damaging fumes or vapors, excessive or abrasive dust, explosive mixtures of dust or gases, steam, salt spray, excessive moisture or dripping water, salt on roadways, etc.
d) Unusual mechanical conditions such as vibration, shock, cantilever loading, wind loading, icing, etc.
e) Unusual transportation or storage conditions
f) Unusual space limitations
g) Unusual internal pressures
h) Unusual maintenance difficulties

4.2.2 Electrical conditions

— Power frequencies less than 48 Hz or greater than 62 Hz

5. Rating

The rating of a high-voltage cable termination shall include the following items, where applicable:

a) *BIL (basic lightning impulse insulation level).* The crest value of a lightning impulse voltage of a specified wave shape, which the high-voltage cable termination is required to withstand under specified conditions.

b) *BSL (basic switching impulse insulation level).* The crest value of a switching impulse voltage of a specified wave shape, which the high-voltage cable termination is required to withstand under specified conditions.

c) *Insulation class.* The nominal phase-to-phase operating voltage of a three-phase cable system where the device may be applied, which reflects the associated design tests and impulse insulation levels.

NOTE—High-voltage cable terminations may be applied on other than three-phase circuits if the rated maximum design voltage to ground is not exceeded.

d) *Maximum and minimum cable conductor diameter.* The largest and smallest cable conductor diameters that the high-voltage cable termination is designed to accommodate without special modifications.

e) *Maximum and minimum cable insulation diameter.* The largest and smallest diameters over the insulation of round conductor cables, as measured by a circumferential tape, that the high-voltage cable termination is designed to accommodate without special modifications.

f) *Maximum design voltage to ground.* The maximum voltage at which the high-voltage cable termination is designed to operate continuously under normal conditions.

NOTE—It is not intended that this maximum voltage limit be applied to transient overvoltages or unusual service operating conditions where the system voltage may exceed those values for only short periods of time.

g) *Rated internal pressure.* The nominal internal pressure for which the termination is designed to operate when this pressure is greater than one atmosphere absolute under standard conditions.

NOTE—Regarding continuous current rating (ampacity), the application of various types of cable terminations requires engineering consideration as to the ampacity of the completed installation. A cable termination by itself cannot be assigned a design or nominal current or ampacity rating since this parameter is completely dependent upon the type and material of the cable conductor, the thickness and type of cable insulation, the maximum allowable cable conductor temperature for the type of cable insulation involved, and the anticipated maximum ambient temperature of the medium surrounding the cable termination.

IEEE Std 835-1994[4] will indicate the wide range of ampacities permitted under the various conditions anticipated in service with different voltage ratings and maximum cable conductor temperature limitations.

The termination of high-voltage cables generally requires the addition of insulating materials for dielectric purposes, which usually increase the thermal resistance to heat flow from the cable conductor to the surrounding air or other medium. The types and amounts of dielectric or other materials are generally a function of the type of cable being terminated, the insulation class, the range of cable sizes that can be accommodated, and operating service conditions.

The supplier of cable terminating devices or material should be consulted for the ampacity of the design for the intended application with a specific type and size of cable.

It is recommended that the ampacity of the cable termination be limited (barring any other terminating material limitation) by a hot spot cable conductor temperature within the termination zone equal to the cable conductor temperatures established for the particular cable insulation involved.

[4]Information on references can be found in clause 2.

6. Product markings

The following information is suggested for Class 1, 2, and 3 termination labels, where required or specified by the user:

a) Manufacturer's name, type, designation number, manufacturing date, or date code
b) IEEE termination class number
c) Insulation class
d) Maximum design voltage to ground
e) Maximum and minimum cable conductor size
f) Maximum and minimum cable insulation diameter
g) BIL
h) Rated internal pressure (gauge), when applicable.

NOTE—Any information not included on the product shall be included in product installation instructions.

7. Test requirements

7.1 Design tests

To comply with this standard, high-voltage cable terminations shall successfully pass the following tests as noted.

7.1.1 Dielectric tests

See note 10 of table 1, or 4.1.

a) Power frequency voltage 1 min dry withstand test in accordance with column 3 of table 1 or 2 and 8.4.1.1 (all classes).
b) Power frequency voltage 10 s wet withstand test in accordance with column 4 of table 1 or 2 and 8.4.1.2. This test is made on outdoor terminations only (Classes 1 and 2 when applicable).
c) Power frequency voltage 6 h dry withstand test in accordance with column 5 of table 1 or 2 and 8.4.1.3 (all classes).
d) Power frequency partial discharge (corona) extinction voltage test in accordance with column 8 of table 2 and 8.4.1.5 for extruded dielectric cable terminations.

   Ionization factor measurements are to be used for laminated dielectric cable terminations in accordance with column 8 of table 1, 8.4.1.6, and table 6.

   Power frequency RIV testing in accordance with column 7 of table 1 or 2 and 8.4.1.4 if the termination is for use on other cable (all classes) or if there is a question on external metallic hardware affecting the radio influence voltage if the termination is for use on any other cable (all classes).
e) Lightning impulse voltage withstand test in accordance with column 9 of table 1 or 2 and 8.4.1.7 (all classes).
f) Switching impulse voltage wet withstand test (if applicable) in accordance with column 10 of table 1 and 8.4.1.8 (all classes).
g) Direct voltage 15 min dry withstand test in accordance with column 11 of table 1 or 2 and 8.4.1.9 (all classes).
h) Cyclic aging test in accordance with 8.4.2 (all classes).

NOTE—Some Class 3 terminations, especially above 15 kV, may not meet impulse requirements in column 9 of table 1 or 2, usually because of inadequate creepage length. If so, actual values shall be agreed upon by manufacturer and user, but must meet the BIL of the equipment connected to the termination.

Table 1—Standard dielectric tests for high-voltage laminated dielectric cable terminations assembled and ready for service

Insulation class (kV) (12) Column 1	Max design voltage to ground (kV) (13) Column 2	1 min Dry withstand (kV RMS) Column 3	10 s Wet withstand (3) (kV RMS) Column 4	6 h Dry withstand (kV RMS) Column 5	Cyclic aging dry (kV RMS) Column 6	Radio influence voltage dry (μV) Column 7	Max ionization factor % all voltage classes Column 8	Lightning impulse (BIL) dry withstand (kV crest) Column 9	Switching impulse (BSL) (3) wet (dry) withstand (kV crest) Column 10	Direct voltage test (9) 15 min dry withstand (kV avg) Column 11
2.5	1.6	20	20	10	3	50	See table 5 and 8.4.1.6	60	—	40
5	3.2	25	25	15	6	50		75	—	50
8.7	5.5	35	30	25	10	50		95	—	65
15	9.5	50	45	35	17	50		110	—	75
25	16	65	60	55	29	100		150	—	105
34.5	22	90	80	75	40	150		200	—	140
46	29.5	120	100	100	53	200		250	—	170
69	44	175	145	120	80	300		350	—	245
115	73	205	190	160	133	400		450	—	275
120	73	260	230	190	140	450		550	—	320
138	88	310	275	210	160	500		650	—	355
161	102	365	315	250	186	500		750	—	395
230	146	390	380	320	265	500		900	—	450
230	146	460	445	320	265	500		1050	—	510
345	220	520	—	440	300	500		1175	(900)	555
345	220	575	—	440	300	500		1300	825	600
345	220	575	—	440	300	500		1300	900	600
500	318	575	—	440	435	500		1300	(1100)	600
500	318	690	—	440	435	500		1550	1050	700
500	318	750	—	575	435	500		1675	1110	745
500	318	750	—	575	435	500		1675	1175	745
765	486	1300	—	755	663	500		2075	1435	965
765	486	1300	—	755	663	—		2175	1505	965

NOTES TO TABLE 1
1—Power frequency includes any frequency from 48 Hz to 62 Hz.
2—All withstand values are test voltages without negative tolerance but may include an atmospheric correction factor.
3—Indoor cable terminations are not subjected to the wet test. Indoor terminations rated 345 kV and higher shall withstand dry switching impulse voltage tests as noted in brackets in column 10.
4—The required lightning and switching impulse values shall be met with both positive and negative polarity tests.
5—On assembled multiple conductor cable terminations, the tests shall be made between each conductor and ground with the terminals on adjacent conductors grounded.
6—The values in this table are for general use. It is recognized that cable terminations of higher or lower insulation class or BIL may be used where conditions warrant and when specified and agreed upon.
7—When the dielectric strength of the cable termination is dependent upon taping or the use of auxiliary insulation, such insulation shall be used when any design tests are made.
8—When a cable termination is assembled with cable for its dielectric test in the equipment or in the apparatus in which it will operate, the applied test voltage shall be determined by the tests required for the equipment or apparatus if these voltages are lower than the values listed in the table.
9—The direct voltage test shall be made with negative polarity on the conductor. Refer to 7.3 of this standard for comments regarding the direct voltage test values.
10—Certain types of resistance or capacitance graded cable terminations are sensitive to prolonged overvoltage testing and may not be able to withstand some of the power frequency and direct voltage tests, although they are perfectly satisfactory for service. In such cases, the manufacturer shall so specify and shall perform such other special tests as agreed upon by the user.
11—For grounded systems.

7.1.2 Pressure leak tests

All Class 1 terminations shall be pressure leak tested in accordance with 8.4.3 as follows:

Class 1A test procedures a) and b)
Class 1B test procedures a) [30 lbf/in^2 only] and b)
Class 1C test procedures b) and c)

7.2 Routine tests

NOTE—Because of the variety of termination designs and materials, especially with polymeric terminations, each manufacturer generally specifies and performs its own particular routine and quality assurance tests. It is impractical to establish standard routine tests that will be applicable to every situation. Therefore, other routine tests may be performed as agreed upon by the manufacturer and user in addition to those listed herewith.

a) *Dielectric tests.* See note 10 of table 1 or 2. A dielectric test on the termination insulator in accordance with 8.5.1 (all classes).

b) *Partial discharge tests.* As an option, partial discharge tests in accordance with 7.1.1 item d) can be used.

NOTE—This applies only to factory-manufactured termination insulators. Termination insulators fabricated on the cable in the field cannot be given this test.

c) *Pressure leak tests.* A pressure leak test on all pressure-tight parts and factory-assembled seals in accordance with 8.5.2 (Class 1C).

Table 2—Standard dielectric tests for high-voltage extruded dielectric cable terminations assembled and ready for service

Insulation class (kV) (12) Column 1	Max design voltage to ground (kV) (13) Column 2	1 min Dry withstand (kV RMS) Column 3	10 s Wet withstand (3) (kV RMS) Column 4	6 h Dry withstand (kV RMS) Column 5	Cyclic aging dry (kV RMS) Column 6	Radio influence voltage dry (μV) Column 7	Partial discharge (corona) extinction voltage (11) (kV RMS) Column 8	Lightning impulse (BIL) dry withstand (kV crest) Column 9	Switching impulse (BSL) (3) wet (dry) withstand (kV crest) Column 10	Direct voltage test (9) 15 min dry withstand (kV avg) Column 11
2.5	1.6	20	20	10	4.5	50	2	60	—	40
5	3.2	25	25	15	9	50	4.5	75	—	50
8.7	5.5	35	30	25	15	50	7.5	95	—	65
15	9.5	50	45	35	26	50	13	110	—	75
25	16	65	60	55	43	100	21.5	150	—	105
34.5	22	90	80	75	60	150	30	200	—	140
46	29.5	120	100	100	60	200	40	250	—	170
69	44	175	145	120	80	300	60	350	—	245
115	73	205	190	160	133	400	80	450	—	275
120	73	260	230	190	140	450	100	550	—	320
138	88	310	275	210	160	500	120	650	—	355
161	102	365	315	250	186	500	140	750	—	395
230	146	460	445	330	265	—	200	1050	—	510

NOTES

1—Power frequency includes any frequency from 48 Hz to 62 Hz.

2—All withstand values are test voltages without negative tolerance but may include an atmospheric correction factor.

3—Indoor cable terminations are not subjected to the wet test. Indoor wet terminations to be tested at three times phase-to-ground voltage.

4—The required lightning and switching impulse values shall be met with both positive and negative polarity tests.

5—On assembled multiple conductor cable terminations, the tests shall be made between each conductor and ground with the terminals on adjacent conductors grounded.

6—The values in this table are for general use. It is recognized that cable terminations of higher or lower insulation class or BIL may be used where conditions warrant and when specified and agreed upon.

7—When the dielectric strength of the cable terminat ..i is dependent upon taping or the use of auxiliary insulation, such insulation shall be used when any design tests are made.

8—When a cable termination is assembled with cable for its dielectric test in the equipment or in the apparatus in which it will operate, the applied test voltage shall be determined by the tests required for the equipment or apparatus if these voltages are lower than the values listed in the table.

9—The direct voltage test shall be made with negative polarity on the conductor. Refer to 7.3 of this standard for comments regarding the direct voltage test values.

10—Certain types of resistance or capacitance graded cable terminations are sensitive to prolonged overvoltage testing and may not be able to withstand some of the power frequency and direct voltage tests, although they are perfectly satisfactory for service. In such cases, the manufacturer shall so specify and shall perform such other special tests as agreed upon by the user.

11—The minimum detector sensitivity shall be 5.0 pC.

12—For use with 100% insulation cable as defined in AEIC CS5-87 or CS6-87. To obtain test values for voltage classes that are not listed, use linear interpolation between the two closest listed values and round off to the nearest whole kilovolt.

13—For grounded systems.

7.3 Dielectric field tests

See note 10 of table 1 or 2. Field tests are tests that may be made in accordance with 8.6 on the completely installed cable system (including the cable terminations) by the user as an installation acceptance or proof test (all classes).

The values listed in column 11 of table 1 or 2 are not intended to be the test voltages for a given rated voltage cable system, but are only to serve as a guide for the maximum voltage that the cable termination may be expected to withstand under normal conditions without flashover or without affecting its dielectric characteristics.

The magnitude of the actual test voltage to be used for the installed cable system shall be determined by reference to applicable AEIC or ICEA cable specifications. The cable termination manufacturer shall be consulted before conducting any field tests that exceed the values listed in table 1 or 2.

NOTE—Some cable insulation may be damaged by direct voltage field tests. The cable manufacturer should be consulted before testing.

Transformers, regulators, and other equipment that cannot be disconnected from the cable system while conducting the field test should be investigated to be sure that the withstand voltage strength of this equipment is not exceeded.

8. Test procedures

8.1 Preparation of test specimen

The test specimen shall comply with the following requirements as specified in 8.4 through 8.6:

a) It shall be clean.

b) It shall be dry and clean.

c) It shall be assembled with cable of the type and maximum conductor size for which the high-voltage cable termination is designed, and filled (as applicable) with the grade and quantity of materials specified by the manufacturer and assembled with any electric stress-controlling features such as stress-relief cones, etc., in the manner specified by the manufacturer. For dielectric tests, a mandrel with insulation having the same physical and electrical characteristics as that used on the cable may be substituted for cable, and the test assembly shall include the standard types of external connectors (aerial lugs).

   NOTE—It is recommended that pre-molded terminations that depend on maximum and minimum cable insulation diameters for sizing should be tested using the minimum cable insulation diameter and maximum conductor size.

d) It shall be completely assembled and the entrances sealed. High-voltage cable terminations incorporating gland-type entrances shall be assembled with a mandrel so that the cable seal is made by compressing the gland-searing material against the mandrel.

e) It shall be mounted in a manner determined by the manufacturer, who shall consider typical service conditions. All details of the test mounting shall be recorded and shall be available upon request.

f) It shall have the high-voltage test connection leave the terminal of the high-voltage cable termination in a direction approximately parallel to the axis of the device for a distance of not less than the dry arcing distance over the insulator. No other object except the supporting structure shall be close enough to the device to appreciably affect the test results.

g) It shall be completely assembled with its own metal parts and have provision for admitting air or other medium to the interior (if liquid medium is used, fill completely) and provisions for measuring internal pressure during the test. Units that are intended to operate with internal pressure, whether such pressure is from the cable system or a separate source, shall be tested at the minimum pressure under which the cable system or terminal would be expected to operate in actual service.

8.2 Standard test conditions

8.2.1 Atmospheric and precipitation conditions

The standard atmospheric and precipitation conditions are given in table 3.

Table 3—Standard atmospheric and precipitation conditions

Air temperature	20 °C	20 °C	68 °F
Barometric pressure	101.3 kPa	760 mmHg	29.92 inHg
Humidity	11 g/m^3	11 g/m^3	6.867 × 10^{-4} lb/ft^3
Average precipitation rate for all measurements (vertical and horizontal components)	1.0–1.5 mm/min		
Limits for any individual measurement (vertical or horizontal component)	0.5–2.0 mm/min		
Temperature of collected water	ambient temperature ± 15 °C		
Resistivity of collected water corrected to 20 °C[a]	100 ± 15 Ω·m		

[a]For switching impulses, if the prescribed water resistivity cannot be obtained, a lower value may be used but the actual value must be stated in the test report. For correction of water resistivity to 20 °C, refer to IEEE Std 4-1995.

Where test conditions differ from those above, suitable corrections shall be made as outlined in 8.3.

8.2.2 Rate of voltage application for power frequency and direct voltage tests

The initial voltage shall not be greater than 20% of the test voltage. The applied voltage may be quickly raised to 75% of the test value. The continued rate of voltage increase shall be such that the time to reach the expected test voltage shall be between 15 s and 30 s after the 75% value has been reached.

8.2.3 Duration of voltage application for power frequency and direct voltage withstand tests

The required voltage shall be held for the specified time (table 1 or 2) after the full value has been reached.

8.2.4 Testing equipment and voltage measurements

The character of the test equipment and the method of measuring voltage shall conform to IEEE Std 4-1995.

8.3 Correction factors

a) Correction D for variation in relative air density and H for variation in humidity shall be made when the conditions under which the tests are conducted vary from the standard test conditions given in 8.2.1. Correction factors shall be used for only the following tests:

1) *Power frequency voltage 10 s wet withstand test.* The applied test voltage shall be the specified test voltage multiplied by D as determined by item c) below.

2) *Lightning impulse voltage wet withstand test.* The applied test voltage shall be the specified test voltage multiplied by D/H as determined by items c) and d) below, respectively.

3) *Switching impulse voltage wet withstand test.* The applied test voltage shall be the specified test voltage multiplied by D as determined by item c) below.

b) The air temperature at the time of the test shall be between 10 °C and 40 °C (50 °F and 104 °F).

c) The relative air density, D, at the time of the test should preferably be between 0.95 and 1.05 and shall be determined as follows:

$$D = (A)\left[\frac{P}{t_0 \pm t}\right]$$

where

D = relative air density
A = 2.89 for P in kilopascals
A = 0.386 for P in millimeters of mercury
or 17.61 for P in inches of mercury
t_0 = 273 for t in degrees Celsius
or 459 for t in degrees Fahrenheit

d) The humidity correction factor, H, for variation in humidity is given in figure 1. The vapor pressure at the time of the test should preferably be between 7.6 mmHg and 15.2 mmHg (1000 Pa and 2000 Pa) (0.3 inHg and 0.6 inHg).

e) All data used in determining any correction factors shall be recorded.

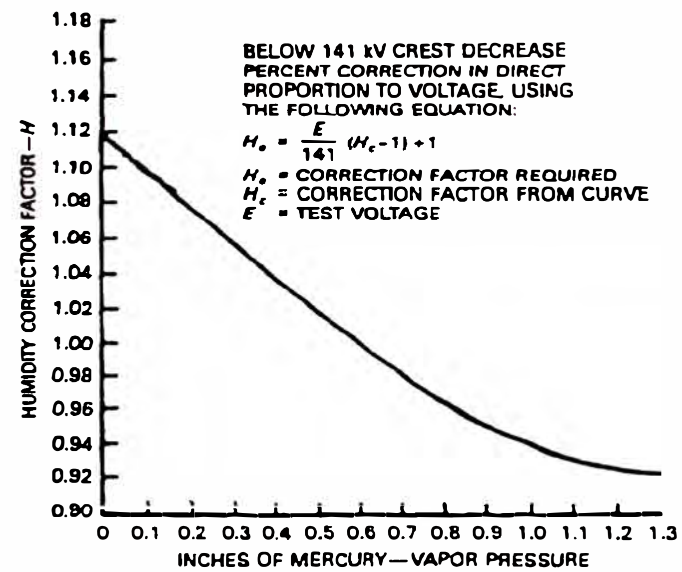


Figure 1—Humidity correction factor, 1.2 × 50 μs impulse

8.4 Design tests

Tests for extruded dielectric cable terminations are summarized in table 4. Termination tests are summarized in table 5.

Table 4—Design tests and sequence for extruded cable terminations

Design test	Subclause	Minimum number of samples		
		4	4 (2[a])	2
Partial discharge (corona) extinction voltage	8.4.1.5	❑ ⇓ ⇓		
Power frequency voltage 1 min dry withstand	8.4.1.1	❑ ⇓ ⇓		
Power frequency voltage 6 h dry withstand	8.4.1.3	❑ ⇓ ⇓		
Power frequency voltage 10 s wet withstand (outdoor terminations)	8.4.1.2	❑ ⇓ ⇓ ⇓ ⇓		
Direct voltage 15 min dry withstand	8.4.1.9	❑ ⇓ ⇓		
Lightning impulse voltage withstand	8.4.1.7	❑ ⇓		
Partial discharge (corona) extinction voltage	8.4.1.5		❑ ⇓	❑ ⇓
Cyclic aging	8.4.2 item c)		❑ ⇓	❑ ⇓
Lightning impulse voltage withstand	8.4.1.7		❑ ⇓	❑ ⇓
Partial discharge (corona) extinction voltage	8.4.1.5		❑ ⇓	❑ ⇓
Pressure leak test (Class 1 terminations only)	8.4.3			❑

[a]Four samples for single-phase terminations in insulation classes up to and including 46 kV, and two samples for single-phase terminations in insulation classes above 46 kV according to 8.4.2 item b). Two samples for one-piece, three-phase terminations according to 8.4.2 item b).

NOTES—
❑ = test
⇓ = specimen, proceed to following test

Table 5—Design tests and sequence for laminated dielectric cable terminations—Class 1B and 1C

Design test	Subclause	Minimum number of samples		
		4	4 (2[a])	2
Ionization factor	8.4.1.6	❑ ⇓		
Power frequency voltage 1 min dry withstand	8.4.1.1	❑ ⇓ ⇓		
Power frequency voltage 6 h dry withstand	8.4.1.3	❑ ⇓ ⇓		
Power frequency voltage 10 s wet withstand (outdoor terminations)	8.4.1.2	❑ ⇓ ⇓		
Direct voltage 15 min dry withstand	8.4.1.9	❑ ⇓ ⇓		
Impulse withstand voltage	8.4.1.7	❑ ⇓		
Ionization factor	8.4.1.6	❑	❑ ⇓	
Cyclic aging	8.4.2 item c)		❑ ⇓	
Ionization factor	8.4.1.6		❑	
Impulse withstand voltage	8.4.1.7			
Pressure leak test	8.4.3			❑

[a]Four samples for single-phase terminations in insulation classes up to and including 46 kV, and two samples for single-phase terminations in insulation classes above 46 kV according to 8.4.2 item b). Two samples for one-piece, three-phase terminations according to 8.4.2 item b).

Switching impulse voltage wet withstand test, 8.4.1.8, shall be used at 345 kV and above in lieu of the power frequency voltage 10 s wet test.

8.4.1 Dielectric tests

8.4.1.1 Power frequency voltage 1 min dry withstand test

The test specimen shall be prepared for test in accordance with 8.1 items b), c), e), and f) and tested in accordance with 8.2 and column 3 of table 1 or 2. If the test specimen withstands the specified test voltage for the specified time, it shall be considered as having passed the test. If flashover occurs, the test shall be repeated. If the repeat test also results in flashover or other dielectric breakdown, the test specimen shall be considered as having failed. If the specimen passes the repeat test, the test specimen shall be considered as having passed the test.

8.4.1.2 Power frequency voltage 10 s wet withstand test

The test specimen shall be prepared for test in accordance with 8.1 items a), b), c), e), and f) and tested in accordance with 8.2 and column 4 of table 1 or 2. This test is required on outdoor terminations only. Wet tests shall be made in accordance with IEEE Std 4-1995.

If the test specimen withstands the specified test voltage for the specified time, it shall be considered as having passed the test. If flashover occurs, the test shall be repeated. If the repeat test also results in flashover or other dielectric breakdown, the test specimen shall be considered as having failed. If the specimen passes the repeat test, the test specimen shall be considered as having passed the test.

8.4.1.3 Power frequency voltage 6 h dry withstand test

The test specimen shall be prepared for test in accordance with 8.1 items b), c), e), and f) and tested in accordance with 8.2 and column 5 of table 1 or 2. If the test specimen withstands the specified test voltage for 6 h, it shall be considered as having passed the test. If the test is interrupted, the total duration of voltage application shall be increased by twice the duration of each interruption.

8.4.1.4 Radio influence voltage (RIV) test

The test specimen shall be prepared for test in accordance with 8.1 items a), b), c), e), and f) and tested in accordance with 8.2 and IEC 270-1981.

The applied test voltage shall be the maximum design voltage to ground indicated in column 2 of table or 2. The test specimen shall have successfully passed the test if the RIV does not exceed the value indicated in column 7 of table 1 or 2 measured at 1 MHz.

NOTE—Some cables may develop higher influence voltage levels than specified in column 7. In such cases, another type of cable or equivalent insulated test mandrel may be substituted for the noisy cable to determine the true characteristics of the termination under test.

8.4.1.5 Partial discharge (corona) extinction voltage test

The test specimen shall be prepared for test in accordance with 8.1 items a), b), c), e), and f) and tested in accordance with 8.2 and IEC 270-1981.

The partial discharge detecting apparatus shall be adjusted to have a sensitivity that will permit detection of discharge pulses of at least 5.0 pC. The test voltage shall be raised to at least 120% of the value listed in column 8 of table 2. If partial discharge exceeds 5.0 pC, the test voltage shall be lowered to the value listed in column 8 and shall be maintained at this level for at least 3 s but not more than 60 s. The test specimen shall have successfully passed the test if the partial discharge level does not exceed 5.0 pC during this period.

NOTE—Some cables may indicate a partial discharge extinction voltage lower than that specified in column 8. In such cases, another type of cable or equivalent insulated test mandrel may be substituted for noisy cable to determine the true characteristics of the termination under test.

8.4.1.6 Ionization factor test

The test specimen shall be prepared for test in accordance with 8.1 items a), b), c), e), and f) and tested in accordance with 8.2 and table 6.

The ionization factor is the difference, at 60 Hz, between the percent dielectric power factor measured at an average stress of 100 V/mil and the percent dielectric power factor measured at an average stress of 20 V/mil. The measurement voltage is based on the insulation thickness of the laminated cable. The measurement shall be made at 25 °C ± 5 °C.

8.4.1.7 Lightning impulse voltage withstand test

The test specimen shall be prepared for test in accordance with 8.1 items a), b), c), e), and f) and tested in accordance with 8.2 and column 9 of table 1 or 2.

Table 6—Maximum allowable ionization factor values for laminated dielectric cable terminations

Class 1B terminations Impregnated-paper-insulated cables—Solid-type %	
Rated voltage (kV)	**Maximum ionization factor (%)**
10–200	0.6
21–350	0.4
35–460	0.2
46–690	0.2

Class 1C terminations		
Cable type	**Rated voltage (kV)**	**Maximum ionization factor (%)**
High-pressure	69–161 162–765	0.1 0.05
Low pressure, Gas-filled (at 10 lb/in^2 gage)	10–29 30–46	0.4 0.2
Low and medium pressure, Liquid-filled	15–161 230 345–500	0.1 0.1 0.1

a) A nominal 1.2 × 50 μs wave, both positive and negative, shall be used. The characteristics of the impulse wave shall conform to the requirements contained in IEEE Std 4-1995, except that the virtual front time shall not exceed 5 μs in the cases where the capacitance of the test piece is such as to prevent attainment of requirement.

b) Ten consecutive impulses at each polarity shall be applied to the test specimen. If a flashover or other dielectric breakdown does not occur, the test specimen shall be considered as having passed the test. If two or more of the applied impulse waves cause flashover, the specimen shall be considered as having failed. If one of the applied impulses causes flashover, ten additional impulses shall be applied. If flashover or other dielectric breakdown does not occur, the specimen shall be considered as having passed the test.

NOTE—When a specimen is tested with a unidirectional impulse, the insulation under test sometimes becomes polarized. It is suggested, therefore, that each set of impulses with a given polarity be preceded by impulses of that polarity at approximately 50%, 65%, and 80% of the required value in table 1 or 2. This procedure will neutralize the polarization effects of any previous tests. Refer to IEEE Std 82-1994.

8.4.1.8 Switching impulse voltage wet withstand test

The test specimen shall be prepared for test in accordance with 8.1 items a), c), e), and f) and tested in accordance with 8.2 and column 10 of table 1. This test is required on certain classes of terminations only (see note below), under standard wet test conditions as defined in IEEE Std 4-1995.

a) A nominal 250 × 2500 µs wave, both positive and negative, shall be used.

b) Ten consecutive impulses at each polarity shall be applied to the test specimen. If a flashover or other dielectric breakdown does not occur, the test specimen shall be considered as having passed the test. If two or more of the applied impulse waves cause flashover, the specimen shall be considered as having failed. If one of the applied impulses causes flashover, ten additional impulses shall be applied. If flashover or other dielectric breakdown does not occur, the specimen shall be considered as having passed the test.

NOTE—This test applies to cable terminations rated 345 kV and higher only, and is used in lieu of the power frequency voltage 10 s wet withstand test (see table 1). In the case where the cable termination is classified as an indoor type (see clause 3), a switching impulse test must be made, dry. The test values are referred to in column 10 of table 1 in brackets.

8.4.1.9 Direct voltage 15 min dry withstand test

The test specimen shall be prepared for test in accordance with 8.1 items a), c), e), and f) and tested in accordance with 8.2 and column 11 of table 1 or 2.

a) A direct voltage of negative polarity, having a ripple of less than 3% at the required test value, shall be used.

b) The test voltage shall be applied for the specified duration starting after the required test voltage has been reached. If the test specimen withstands the required test voltage for 15 min, it shall be considered as having passed the test. If a flashover occurs, the test shall be repeated. If the repeat test also results in flashover or other dielectric breakdown, the test specimen shall be considered as having failed.

8.4.2 Cyclic aging test

a) The test specimen shall be prepared for test in accordance with 8.1 items a), b), c), e), and f).

b) Each test specimen shall be assembled as follows:

   1) For single-phase terminations in insulation and classes up to and including 46 kV, a total of four terminations shall be tested with two on one length of power cable and two on another. For single-phase terminations in insulation classes above 46 kV, a minimum of two terminations shall be tested with one on each end of a power cable. A minimum of 2 m (6 ft) of cable shall be used between terminations.

   NOTE—A typical load cycle test circuit for single-phase terminations is shown in figure 2. In this test setup, the loading current and the high voltage are applied with separate, independent power supplies. The metallic shield of each power cable is connected to a single grounding point to prevent current from circulating in the metallic shield of either cable.

   2) For one piece, three-phase terminations, a total of two samples shall be tested on one length of power cable. A minimum of 2 m (6 ft) of cable shall be used between terminations.

   NOTE—A typical load cycle test circuit for three-phase terminations is shown in figure 3. In this test setup, the phases are connected in a series loop to easily facilitate the circulation of current through the conductors. The loading current and the high voltage are applied with separate, independent power supplies. A test setup using three-phase power is also acceptable. The cable connecting the terminations may be three single-conductor cables or one three-conductor cable. In either case, the metallic shield(s) must be interrupted and single-point grounding must be utilized to prevent circulating shield currents.

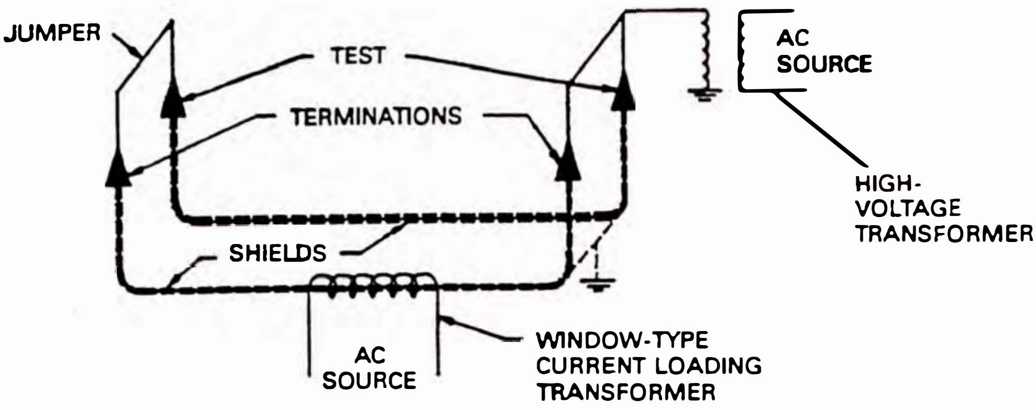
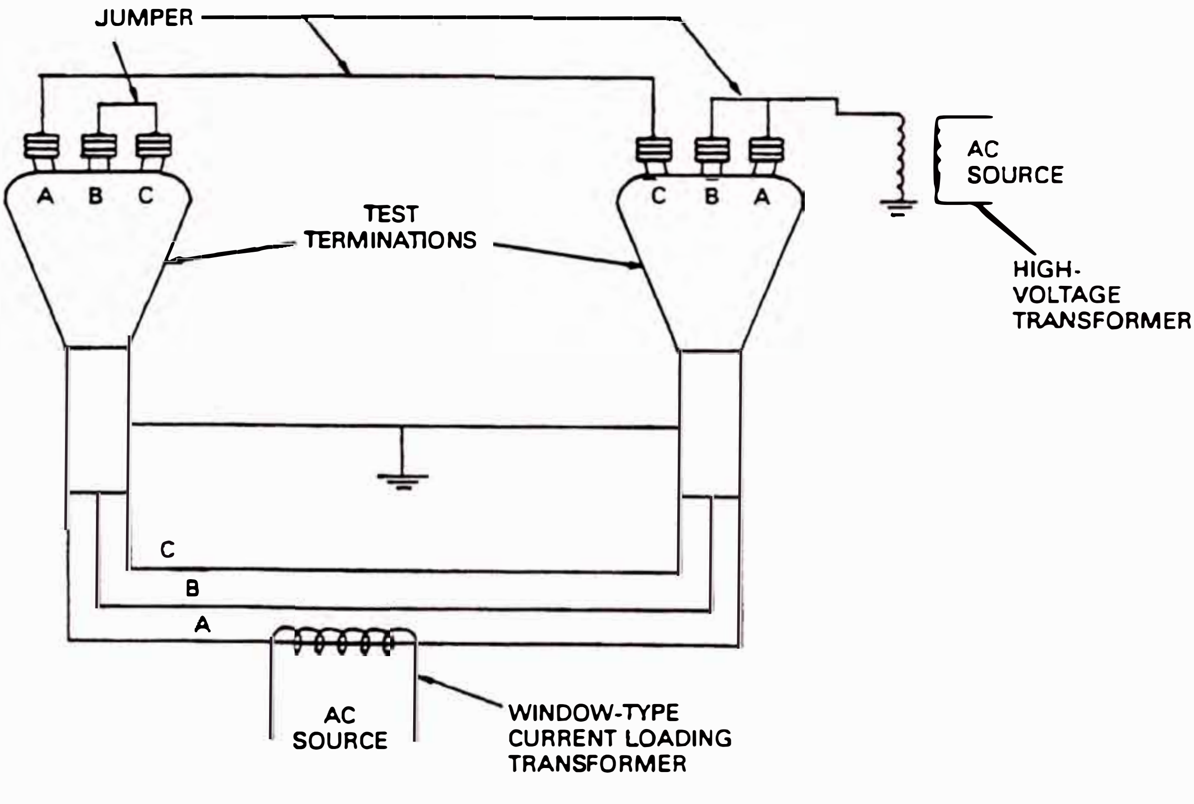


Figure 2—Single-phase terminations



NOTE: This method of cyclic aging requires only single-phase voltage and current power supplies. Test setups using three-phase power supplies are also acceptable.

Figure 3—One-piece three-phase terminations

In both the single- and three-phase test setups, the window-type current transformer may be installed on one of the jumper leads to help minimize circulating currents in the cable metallic shield(s). The jumper leads may be an uninsulated wire or bus, an unshielded power cable, or a shielded power cable.

The test configurations shown in figures 2 and 3 are only examples of how the test may be performed. Other test setups may be used to obtain the same goal.

For large, higher voltage cables, more than 2 m of cable may be required to prevent the conductor temperature midway between the terminations from being influenced by the terminations. Up to 5 m (approximately 15 ft) may be required.

c) Testing shall be in accordance with 8.2 and the following:

   1) Applied test voltage for Class 1A extruded dielectric cable terminations shall be in accordance with column 6 of table 2.

   2) Applied test voltage for Class 1B and 1C laminated dielectric cable terminations shall be in accordance with column 6 of table 1.

   3) Voltage shall be applied continuously to the test specimens for a 30-day period. See 7.4.2, item c) 1) or item c) 2).

   4) Load current, in addition to voltage [item c) 3) above], shall be applied to the test specimens. During the current-on period, the cable conductor temperature midway between the terminations shall be within 5 °C of the cable's maximum rated emergency operating temperature for a period of 6 h. During the current-off period, the conductor temperature midway between the terminations shall drop to within 5 °C of the ambient air temperature.

If this condition cannot be met, then every five cycles the current (and voltage) shall remain off for 48 h. The load cycle shall be resumed at the end of the 48 h period. (This procedure may be followed even if the 5 °C condition can be met if a test facility prefers not to run the tests during the weekend.)

The test specimens shall complete 30 load cycles. If the 48 h off period is used, it is not considered in the test cycles.

NOTE— One load cycle is 24 h long with a current-on period and a current-off period. The duration of the current-on and current-off periods is governed by the amount of time it takes a given test specimen to achieve the desired temperature.

The cable's emergency rating temperature should be determined by reference to applicable AEIC or ICEA cable specifications or to the cable manufacturer in the case of special use cables.

Temperature can be determined by reading the jacket temperature midway between terminations and comparing it to a "dummy" cable equivalent, where both jacket and conductor temperature have been determined. Equivalent current loadings can also be useful.

   5) Partial discharge (corona) extinction voltage test level shall be determined for each specimen before the 30 load cycle test period is started and after completion of the 30 load cycle test period. Partial discharge levels shall be determined in accordance with 8.4.1.5.

   6) After completion of the cyclic aging test and partial discharge (corona) extinction voltage test level, each specimen shall be tested with lightning impulse voltage (10 shots at each polarity) in accordance with 8.2, 8.4.1.7, and column 9 of table 1 or 2.

NOTE—For laminated dielectric cable terminations (Class 1B and 1C), the ionization factor test shall be used in place of partial discharge in accordance with table 6 and 8.4.1.6.

d) Class 1 B and 1 C terminations shall show no visual indications of fluid leakage at the completion of the cyclic aging test.

If the two specimens (one specimen for 46 kV and above or for a three-phase specimen) withstand all of the above specified test conditions for the specified time, they shall be considered as having passed the test.

If the test is interrupted or otherwise affected, the cycle(s) affected shall be repeated. If dielectric breakdown occurs in any test specimen, all test specimens shall be considered as having failed.

NOTE—The cyclic aging test is not intended to establish current rating for a termination (see clause 5).

8.4.3 Pressure leak tests

The test specimen shall be prepared at room temperature in accordance with 8.1 items a), b), d), and g) and tested in accordance with items a) and b), or b) and c) below. See 7.1.2 for determining which tests to use. The test specimen shall have successfully passed if no leak or rupture occurs.

NOTE—The following pressures are gauge except in item b) below.

a) Apply 200 kPa (30 lbf/in^2) for 1 h at room temperature. If gas pressure is used, the test specimen shall be immersed at a depth of not less than 5 cm in a liquid bath or the exterior surface shall be coated with soap solution. If liquid pressure is used, the liquid shall have a viscosity no greater than 125 s (Saybolt Universal) at 25 °C. Seal areas are to be coated with a white chalk that will stain if there is a leak. The test may be made at 100 kPa (15 lbf/in^2) for 2 h or 50 kPa (7 lbf/in^2) for 6 h when specified and agreed upon.

b) For Class 1C terminations (components) with the test specimen at a temperature not higher than 25 °C, evacuate to a pressure of not more than 67 Pa (0.5 torr or 0.01 lb/in^2 absolute), after which the valve shall be closed, separating the test specimen from the pump. During the next 30 min, the rise in pressure shall not exceed 67 Pa (0.5 torr or 0.01 lbf/in^2). For Class 1 A and 1 B terminations, the test pressure shall be not more than 670 Pa (5 torr or 0.1 lbf/in^2) using the same procedure.

c) Fill the test specimen with a liquid that has a viscosity no greater than 125 s (Saybolt Universal) at 25 °C. Apply 2.5 times rated internal pressure or 267 kPa (40 lbf/in^2), whichever is highest, for terminations up to 2000 kPa (300 lbf/in^2) [consult manufacturer for test on terminations with rated internal pressure greater than 2000 kPa (300 lbf/in^2)]. The internal pressure (or pressures) shall be observed and maintained at the test pressure until the temperature of the test specimen and filling fluid have stabilized. The temperature-pressure test shall then be continued 1 h for single-pressure zone terminations and 24 h for multipressure zone terminations. Leakage shall be detected at the end of this period by visual examination of chalk on the exterior surfaces of the test specimen and by pressure drop in the high-pressure zone or pressure rise in the low-pressure zone of a multipressure zone termination.

8.5 Routine tests

8.5.1 Dielectric tests

Dielectric tests shall be made on termination insulators prepared in accordance with 8.1 items a) and b) and tested in accordance with 8.2. Any of the following procedures may be used at the manufacturer's option:

a) Using parts simulating external metal parts for the fully assembled cable termination, apply power frequency voltage for 1 min using the value shown in column 3 of table 1 or 2 for the specified insulation classification. If flashover occurs, the test may be repeated. If puncture occurs, or if flashover occurs on the repeat test, the insulator shall be rejected.

b) Using parts simulating external metal parts of the fully assembled cable termination, maintain power frequency flashover for at least 3 min. The insulator shall be rejected if the flashover causes puncture.

c) Using a conducting member passing through the insulator (see note below) and a conducting ring surrounding the insulator at the approximate midpoint, maintain power frequency flashover for at least 3 min. Any insulator that is punctured shall be rejected. Good insulators for cable terminations rated 69 kV and higher might be punctured by this method and, therefore, these insulators should be tested as prescribed in item d) below.

NOTE—Several insulators may be tested in parallel and, when so tested, the voltage control shall be such that a continual flashover occurs and divides uniformly over the insulators under test. To meet this condition it may be necessary to insert additional impedance in the testing circuit. High-frequency test voltage may be used for these tests, in which case the test duration shall be at least 3 s. The high frequency shall be of the order of 200 000 Hz in damped trains, but not less than 100 000 Hz.

d) Using a conducting surface on the entire internal surface of the termination insulator and a series of conducting rings surrounding the insulator at each minimum diameter of corrugation or petticoat, apply a power frequency voltage for 1 min using an average puncture gradient of 28 kV/cm (70 kV/in). Any punctured insulator shall be rejected.

NOTE—Most polymeric termination designs do not lend themselves to the above tests. Consult the manufacturer(s) for specific procedures to determine insulator integrity.

8.5.2 Pressure leak tests

NOTE—The pressures indicated below are gauge.

Routine pressure leak tests on parts and on factory-assembled seals shall be made in accordance with the practice developed by the manufacturer. Class 1C components having a rated internal pressure greater than 100 kPa (15 lbf/in^2) shall be subjected to an internal pressure of 2.5 times the nominal rating for terminations rated up to 2000 kPa (300 lbf/in^2) in accordance with the following:

a) One hour on single-pressure zone terminations where the outer surface of the parts subjected to leakage are exposed for visual examination.

b) Twenty-four hours on multipressure zone terminations where the outer surface of the parts subject to leakage are not exposed for visual examination, and leakage detection must be determined by pressure drop in the high-pressure zone or pressure rise in the low-pressure zone.

c) For terminations with an internal pressure rating greater than 2000 kPa (300 lbf/in^2), the test procedure should be agreed upon by the purchaser and manufacturer.

8.6 Dielectric field tests

The tests are to be conducted in accordance with 8.1 items b) and f).

Direct voltage test values up to the maximums listed in table 1 or 2 may be used with the test set connected for negative polarity. Refer to 7.3 for comment regarding the direct voltage test values.

The field test voltage has been established for phase-to-ground tests only.

9. Application guide

9.1 Application at altitudes greater than 1000 m (3300 ft)

9.1.1 Effect on ampacity

A high-voltage cable termination that depends an air for its cooling medium and is designed for standard temperature rise may be used at altitudes greater than 1000 m (3300 ft) provided that the ampacity is reduced by the correction factors listed in table 7.

The temperature of the cooling air is not likely to exceed the values for the respective altitudes given in table 7.

Table 7—Altitude-ampacity correction factors

Altitude		Altitude ampacity correction factor	Maximum temperature of the cooling air	
(m)	(ft)		(°C)	(°F)
1000	3300	1.00	40	104
2000	6600	0.99	35	95
3000	9900	0.96	30	86

9.1.2 Effect on dielectric strength

The dielectric strength of a high-voltage cable termination that depends on air for its insulation varies with altitude. Table 8 shows the approximate relative dielectric strength for altitudes above 1000 m (3300 ft) at any given temperature.

Table 8—Altitude-dielectric strength correction factors

Altitude		Altitude correction factor for dielectric strength
(m)	(ft)	
1000	3300	1.00
1500	5000	0.95
2100	7000	0.89
3000	9900	0.80

9.2 Effect of solar radiation (ultraviolet light)

Solar radiation can cause molecular scission to occur on most polymer surfaces unless adequately protected by UV stabilizers. This degradation can shorten service life of polymers significantly.

Little has been reported to correlate ASTM weatherometer test results with anticipated 30-year service life. Solar radiation varies significantly between geographical areas (513 langleys/day in Phoenix, AZ and

352 langleys/day in Indianapolis, IN) so that a test life of 1000 h may be adequate for one area while 3000 h may be inadequate for another.

The following test methods are recommended to evaluate effects of solar radiation on polymeric terminations or exposed polymer components used with porcelain terminations:

Operating light and water-exposure apparatus (fluorescent UV-condensation type): [B11] (UVA-340 lamp) or (UVB-313 lamp)

Xenon arc methods: [B9] or [B10]

Surface cracking or crazing constitutes failure. Three thousand hours is recommended, but because of the above reasons, the manufacturer should be consulted.

9.3 Environmental exposure

Terminations are installed in a range of environments, from very benign to extremely severe. Airborne pollutants coupled with water can lower design electrical withstand values and cause flashover.

The following pollution severity guide is for distribution voltages and is meant to assist the user to broadly define the environment in which the termination is to be installed. Minimum termination requirements are given within the definitions of clause 3 to assist the user in consulting with the manufacturer if there is a concern on the type of environment involved.

9.3.1 Indoor terminations

a) *Dry*. Applications where the termination is protected from exposure to sunlight and precipitation, not subject to condensation or excessive (90% RH) continuous humidity, and protected from wind-driven pollutants. An example would be unit substations located inside office and industrial buildings.

   Class 1A terminations without weathersheds are often used. Class 2 and 3 terminations can be considered.

b) *Wet*. Applications where the termination is protected from exposure to sunlight and precipitation, but subject to climatic changes causing condensation on the termination surfaces and infiltration of wind-driven particles settling on these surfaces. Generally, these would be outdoor free-standing enclosures.

   Class 1 terminations are recommended. If the above conditions are frequent and/or severe, designs with weathersheds should be considered.

9.3.2 Outdoor terminations

These terminations are not protected from solar radiation, airborne pollutants, or precipitation. Environments are broadly defined as follows:

a) *Light*

   1) Areas without industries and with low-density housing
   2) Areas subjected to frequent winds and/or rainfall with low density of industries or housing
   3) Agricultural areas
   4) Mountainous areas

All of these regions should be situated at least 7–15 mi from the coast and should not be exposed to coastal winds. Distances from coast depend on the topography of the coastal area and on the extreme wind conditions.

Class 1 terminations with weathersheds are recommended.

b) *Medium*

1) Nonpolluting industrial areas subject to infrequent rainfall and/or with average-density housing
2) Areas subjected to frequent winds and/or rainfall with high-density industries and/or housing
3) Areas exposed to wind from the coast, but generally over 2 mi from the coast

Use of fertilizers by spraying, or the burning of crop residues, can lead to a higher pollution level due to dispersal by wind.

Class 1 terminations are normally used with weathersheds for these applications.

c) *Heavy*

1) High-density industrial areas and some urban areas with high-density housing, especially those with infrequent rainfall

2) Areas subjected to a moderate concentration of conductive dust, particularly industrial smoke-producing deposits

3) Areas generally close to the coast and exposed to coastal spray or to strong winds carrying sand and salt, and subjected to regular condensation

Class 1 terminations with weathersheds are often used, but the next higher voltage level or extended creepage should be considered if the general area has a known history of contamination problems.

d) *Extremely heavy*

1) Usually very limited areas having extremely heavy pollutants from industrial sites, especially those located near oceans and subjected to prevailing winds from the sea

2) Very small isolated areas where terminations are located immediately adjacent to a pollutant source, especially downwind (cement plants, paper mills, etc.)

Normally additional creepage length is required, e.g., next voltage level, and often extra maintenance such as periodic washing is needed.

9.3.3 Apparatus termination environments

Apparatus terminations must be compatible with the insulating medium, i.e., no degradation of the termination and the medium over the intended temperature operating range.

9.4 Accelerated contamination testing

While there are a number of test procedures in use, none has been adopted as an industry standard.

Investigators have found modification of a given procedure can significantly affect test time and/or failure modes, especially between material types. This has been documented in several IEEE papers.

Manufacturer(s) should be consulted concerning contamination test history of the product if there is a question for use in areas having high contamination levels.

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