SEVES

SEDIVER

High Resistivity Toughened Glass insulators for HVDC applications

USA / CANADA

2015

Introduction to Sediver HRTG insulators

At the end of the 1950's Sediver was among the first manufacturers to develop insulators for HVDC overhead transmission line applications.

Thanks to this unique and substantial field experience and ongoing research programs with utilities and international experts, the Sediver research team introduced a state of the art new DC insulator using high resistivity toughened glass (HRTG) in the mid 1980's.
This development has largely contributed to establish a high performance benchmark in the industry, including specific criteria later on introduced in IEC 61325 which still is the only international standard describing HVDC performance requirements.

Today, more than 6 million Sediver insulators have been in operation on HVDC lines with great success.
The applications cover all climatic and environmental conditions at up to 800 kV DC.

HVDC specific stresses

Insulators used on HVDC lines have to sustain very unique and specific stress conditions associated with the unidirectional e-field and current flow.

1. Ionic migration

Electrical conduction in insulating materials is the result of the movement of ions through the material.
During the life of insulators on a DC line, certain units can be exposed for extended periods to a combination of a high voltage - due to non-uniform voltage distribution - and high temperatures arising from ambient conditions and solar heating.
In DC applications, the unidirectional current can generate a significant increase of temperature locally in the dielectric.
Ionic migration is also sensitive to the purity of the dielectric material.
The effect of ionic migration on dielectric materials not specifically designed for DC application, or having an improper formulation, is a risk of formation of depletion layers resulting in a weakening of the dielectric itself.
This can lead to puncture for porcelain or shattering for toughened glass.

2. Thermal runaway

Thermal runaway can occur in insulators with a low resistivity material when the temperature of the dielectric is much higher than the ambient temperature, or when ionic currents flow in the vicinity of internal discontinuities of the dielectric. The temperature rise associated with the local heating increases the current which increases the temperature in a runaway spiral and finally leads to puncture for porcelain or shattering for toughened glass.

3. Pollution accumulation

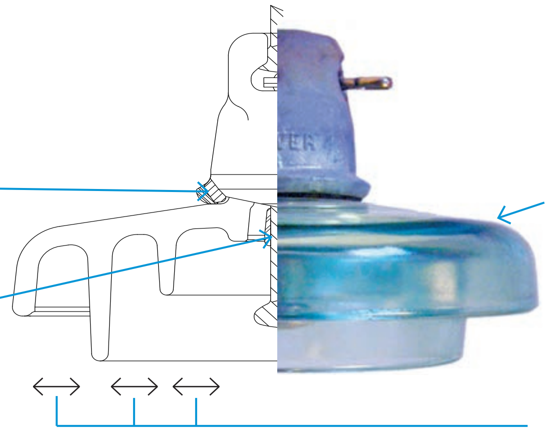
Under HVDC, the electrostatic field along the length of an insulator string, in conjunction with the wind, lead to a steady build-up of pollutants on the insulator surface. This pollution accumulation can be as high as 10 times more severe than that on comparable HVAC insulation in the same environment.
Therefore, while for high voltage alternating current (HVAC) systems, switching and lightning performance are the dominant factors influencing the overall length of insulation, for HVDC systems the length of the string is more often controlled by the level of pollution.

4. Metal part corrosion

Additionally direct current when associated with humidity conditions accelerates the corrosion of the metal parts due to electrolytic effects.

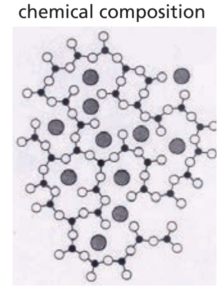
Sediver HRTG insulator design: the answer for HVDC T/L reliability

To achieve an optimum performance in DC and to cope with these 4 additional constraints, Sediver developed the High Resistivity Toughened Glass (HRTG) insulator, having a special type of glass and an adapted insulator design.



High Resistivity Toughened Glass to solve internal current effects

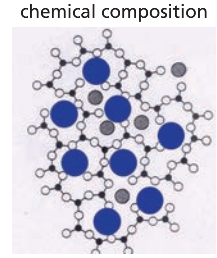
AC glass chemical composition



Glass is an amorphous material. Its atomic structure is a basic Silica/Oxygen network in which several other oxides are added, either for processing or for achieving specific properties depending upon the final application.

In AC glass chemistry, oxides such as Sodium are used.
In this case Sodium, which is not linked to the structural atomic backbone, can move under an electric field leading to ionic conductivity.

DC glass chemical composition



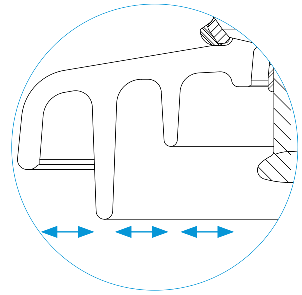
In DC, such ionic conductivity has to be inhibited.
In order to reduce ionic migration, the atomic network is modified by replacing part of the sodium ions with bigger cations or other cations having lower mobility.
The resulting glass material (HRTG) is characterized by a reduced mobility of sodium which is hindered by the addition of bigger cations.
The electrical resistivity of the glass is therefore increased by a factor of about 100, eliminating the risk of failure due to ionic migration or thermal runaway.

Additionally, Sediver has developed a special manufacturing process able to produce glass shells with a very high degree of purity, and therefore having a lower impact on ionic accumulation.

Adapted glass shell design to prevent pollution accumulation

The specific pollution conditions of DC applications require that the insulators be designed with care to reduce the risk of excessive dust accumulation resulting from unidirectional electric fields. (See IEC 60815 part 4).
Test laboratory and field experience have largely demonstrated that the bottom of the insulator is of prime importance in this regard. The best insulators will offer an adapted leakage distance distributed in a way that will prevent both dust nests as well as rib to rib arc bridging.
In this regard, Sediver has been able to adapt the shape of the glass shell to DC specifics, made possible thanks to the glass pressing and toughening processes, which:

- avoids arc bridging,
- reduces dust accumulation,
- maintains self-cleaning.



Protection of the metal end fittings against corrosion

Pin protection

Under DC stresses, the galvanized coating of the pin deteriorates over time leading to the corrosion of the pin itself which in the long term can lead to significant reduction of the mechanical strength.
In order to prevent this form of pin damage, Sediver HVDC insulators are equipped with a corrosion prevention sleeve made of high-purity zinc.

Field observations

Corroded pin without zinc sleeve

Pin with zinc sleeve

Cap protection

In HVDC, arcing activity and corrosion can also take place around the cap leading to rust deposits on the top surface of the skirt.
While no mechanical risk is expected from this phenomenon the generation of a conductive path on the insulators can substantially reduce the overall leakage distance of the entire string and therefore its electrical performance.

In order to avoid this type of corrosion, Sediver, went beyond the IEC specification in the early 80's and patented a specific zinc collar design to protect the cap.

Field observations

Rust appears on cap due to surface current

User benefits

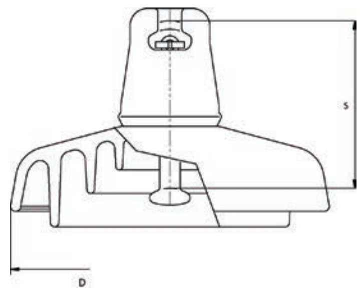
Sediver HRTG developments and User benefits

	HVDC stress consequence	Risk	Sediver HRTG solution	User benefit
Internal current	**Ionic migration Thermal runaway**	Dielectric breakdown	**High Resistivity Toughened Glass** imparting high resistance to localised thermal stresses and ion flow	No puncture = less maintenance
External current	**Pollution accumulation**	String flashover	**Adapted glass shell design** with wide spacing between ribs and increased leakage distance	High pollution efficiency = less maintenance
	Metal parts corrosion	String flashover Mechanical failure	**Protection of the metal end fittings** with pure zinc collar bonded to the cap and pure zinc sleeve bonded to the pin	Longer life expectancy

The condition of Sediver DC insulators after 30 years in service has been monitored jointly with Utilities. Today millions of Sediver HRTG insulators have proven their outstanding performance and reliability under all kinds of environmental conditions.

Sediver toughened glass suspension insulators

Ball & Socket coupling
DC Fog type



		DC Fog type profile						
Insulator type		**N120PF/ C146DR**	**N160P/ C170DR**	**N180P/ C170DR**	**N220P/ C170DR**	**F300PU/ C195DR**	**F400PQ/ C205DR**	**F550/ C240DR**
ANSI CLASS[1] / IEC designation						U300BP	U400B	U530B
CSA Mechanical Class		CSDC-1	CSDC-2		CSDC-3	CSDC-4		
ANSI/IEC Coupling		Type J	Type K	Type K	Type K	24	28	32
MECHANICAL CHARACTERISTICS								
Combined M&E strength	lbs	25.000	36.000	40.000	50.000	66.000	90.000	125.000
	kN	120	160	180	222	300	400	550
Impact strength	in-lbs	400	400	400	400	400	400	400
	N-m	45	45	45	45	45	45	45
Tension proof	lbs	12.500	18.000	20.000	25.000	33.000	45.000	62.500
	kN	60	80	90	111	150	200	275
DIMENSIONS								
Diameter (D)	in	13	13	13	13	14 1/8	14 1/8	14 1/8
	mm	330	330	330	330	360	360	360
Spacing (S)	in	5 3/4	6 3/4	6 3/4	6 3/4	7 5/8	8	9 1/2
	mm	146	170	170	170	195	205	240
Leakage distance	in	21 1/2	21 5/8	21 5/8	21 5/8	25	24 1/4	25
	mm	545	550	550	550	635	625	635
ELECTRICAL CHARACTERISTICS[2]								
DC withstand voltage								
- Dry one minute ±	kV	150	150	150	150	170	170	170
- Wet one minute ±	kV	65	65	65	65	70	70	70
Dry lightning impulse withstand	kV	140	140	140	140	150	150	150
SF6 DC puncture withstand voltage	kV	225	225	225	225	255	255	255
Critical Impulse Flashover Voltage ± [3]	kV	150	150	150	150	160	160	160
PACKING AND SHIPPING DATA								
Approx. net weight per unit	lbs	18.6	20.5	20.5	21.8	29.8	34.2	40.1
	kg	8.4	9.3	9.3	9.9	13.5	15.5	18.2
No of insulators per crate		6	6	6	6	5	4	4
Volume per crate	ft³	3.92	4.34	4.34	4.34	4.77	3.96	4.63
	m³	0.11	0.12	0.12	0.12	0.14	0.11	0.13
Gross weight per crate	lbs	126.21	139.77	139.77	146.83	165.79	152.12	177.91
	kg	57.25	63.4	63.4	66.6	75.2	69	80.7
No. of insulators per pallet		54	54	54	54	45	36	36
Volume per pallet	ft³	47.11	48.88	48.88	48.88	55.62	47.18	53.57
	m³	1.334	1.384	1.384	1.384	1.575	1.336	1.517
Gross weight per pallet	lbs	1192.7	1313.1	1313.1	1377	1530	1411	1653
	kg	541	595.6	595.6	624.6	694	640	749.8

Custom products, not shown here are also available

(1) Mechanical rating and couplings
(2) in accordance with IEC publication 61325
(3) in accordance with ANSI publication C29.2B

Sediver on HVDC T/L in the World

> Over 6 million toughened glass DC insulators are installed all around the world
> More than 48 years of experience up to 800 kV DC

Sediver extensive HVDC worldwide experience

1	**± 260 kV DC,** USA, Vancouver Islands 42km, 1967	22	**± 500 kV DC,** Congo DR, Inga-Shaba 1700 km, 2013-14
2-3	**± 500 kV DC,** USA, Pacific Inertie 1360 km, 1969	23	**± 500 kV DC,** Mozambique, Cahora Bassa 1420 km, 1977/2011/2013
4	**±500 kV DC,** Canada, Eastern Alberta, 500 km, 2013	24	**± 500 kV DC,** India, Chandrapur Padghe, 752 km, 1997
5	**± 500 kV DC,** USA, Dickinson - Coal Creek 687km, 1978	25	**± 500 kV DC,** India, Rihand Dadri 814 km, 1987
6-7-8	**± 450&500 kV DC,** Canada, Bipole I,II & III 2x870 km & 1364 km 1972 & 2014-15	26	**± 800 kV DC,** India, Biswanath Agra 1825 km, 2010/11/12
9	**± 450 kV DC,** Canada, Quebec- New England, 1100 km, 1988	27	**± 500 kV kV DC,** India, Ballia Bhiwadi 780 km, 2008/2009
10	**± 500 kV DC,** USA, New England 85 km,1984	28	**±500 kV DC,** China, Deyang - Baoji 534 km, 2009
11	**± 350 kV DC**, Labrador-Newfoundland – Muskrat Falls, 2014	29	**±800 kV DC,** China, Hami - Zhengzhou 2208 km, 2013
12-13	**±600 kV DC,** Brazil, Itaipu 1 & 2, 2 x 800 km, 1984/87	30	**±500 kV DC,** China, Ge Hu 1929 km, 2009
14-15	**±600 kV DC,** Brazil, Rio Madeira 1&2, 2 x 2500 km, 2012/13	31	**±800 kV DC,** China, Jinping - Sunan 2089 km, 2011
16	**± 250&350 kV DC,** Denmark-Norway, Skagerrak 217 km, 1&2;3 1975/1993	32	**±500 kV DC,** China, Guizhou - Guangdong 1 & 2 2007 km, 2003
17	**± 500 kV DC,** Finland-Sweden, Fenno Skan 1&2 136 km, 1988/2009	33	**±500 kV DC,** China, Tianshengqiao - Guangdong 1050 km, 2001/2004
18	**± 300 kV DC,** Denmark-Sweden,Konti-Skan 1;2 and 3, 1965/1988	34	**±800 kV DC,** China, Nuozhadu - Guangdong 1413 km, 2012
19	**± 300 kV DC,** Sweden, South-West Link – the Southern part, 2012	35	**±500 kV DC,** China, Xiloudu - Guangdong 1251 km, 2012
20	**± 200 kV DC,** Italy-France, Corsica-Sardinia-Italy 264 km, 1967/1992	36	**±500 kV DC,** China, Yunnan - Guangdong 1418 km, 2008
21	**± 400 kV DC,** Italy-Greece Interconnection, 110 km, 1999	37	**±350 kV DC,** New Zealand, North South Island 535 km, 1990

Sediver contribution within international standardization committees

Since the very beginning of international technical cooperation, Sediver has always been an active member in fields of research and standardization in international committees and working groups dealing with all aspects of high voltage insulation.

Committee	International Electrotechnical Commission	International Council on Large Electric Systems	Institute of Electrical and Electronics Engineers
	Main Committees & Working Group in which Seves is active		
Working Groups	IEC TC 36: Insulators	WG D1.27: Material Properties for New and Nonceramic Insulation	T&D Committee WG Insulator contamination
	WG 11: Revision of IEC 60815	WG B2.21: Arc protection and Diagnosis for Composite String Insulators	WG Insulator strength
	IEC SC 36B: Insulators for overhead lines	WG B2.41: AC to DC Conversion	WG Application of non ceramic insulators
	EC SC 36C: Insulators for substations	WG C4.303: Pollution and environmental influence on the electrical performance of power systems	ESMOL
	IEC TC 37: Surge arresters		

HVDC international publications and Sediver research activities on HVDC insulators

Bibliography

J.F. NOLASCO – L.F.P. FERREIRA "Aspectos especiais de projeto e ensaios de isoladores para LT's de corrente continua" CIGRE XV ERIAC 2013

CIGRE WG C4.303 "Outdoor Insulation in Polluted Conditions : Guidelines for Selection and Dimensioning - Part 2 : The DC Case" CIGRE Technical Brochure 518 - 2012

J.M. GEORGE – Z. LODI "Design and Selection criteria for HVDC Overhead Transmission Lines Insulators" CIGRE CANADA Conference on Power Systems, Toronto, October 4-6, 2009

J.M. GEORGE "Long term Performance Evaluation of Toughened Glass Insulators and the consequences for UHV and DC Applications" International Conference on UHVTransmission , Beijing, China, 21-22 may 2009

L.F. FERREIRA – J.M. GEORGE "HVDC Toughened Glass Insulators" INMR Rio de Janeiro 2007

J.M. GEORGE – E. DEL BELLO "Assessment of electrical and mechanical performance of Toughened Glass Insulators removed from existing HV Lines" CIGRE Regional Meeting August 27-28, 2007 Calgary Canada

D. DUMORA – R. PARRAUD "Reliability of Toughened Glass Insulator on HVAC and HVDC Transmission Lines : Design Improvements, Field Experience and Maintenance" CBIP International Conference Recent Trend in Maintenance Techologies of EHV, 29-30 April 2002, New Dehli, India

R. PARRAUD – D. DUMORA – R. JOULIE – C. LUMB "Improvement in the Design and the Reliability of Toughened Glass Insulators for AC and DC Transmission Lines" CEPSI 21-25 October 1996

M. O'BRIEN – C. BURLEIGH – J. GLEADOW "New Zealand ± 250 KV 600 MW HVDC Link Reliability, Operating Experience and Improvements" CIGRE Colloquium on HVDC New Dehli 9-11, September 1991

L. PARGAMIN "Contaminated Insulator Performance on HVDC Lines and Substations" IEEE T&D PANEL SESSION 1989

L. PARGAMIN – D. DE DECKER – D. DUMORA "Improvement of the Performances of HVDC Toughened Glass Insulators" HVDC Insulator Symposium Los Angeles November 19-21, 1985

ISO certifications

All our manufacturing facilities worldwide are certified
ISO 9001 & ISO 14001

Catalogs and Technical Brochures

- Sediver suspension toughened glass insulators CSA-Canada
- Sediver suspension toughened glass insulators ANSI-USA
- Sediver HRTG insulators for HVDC applications
- Sedicoat, RTV silicone coated toughened glass insulators
- Sediver toughened glass: endurance

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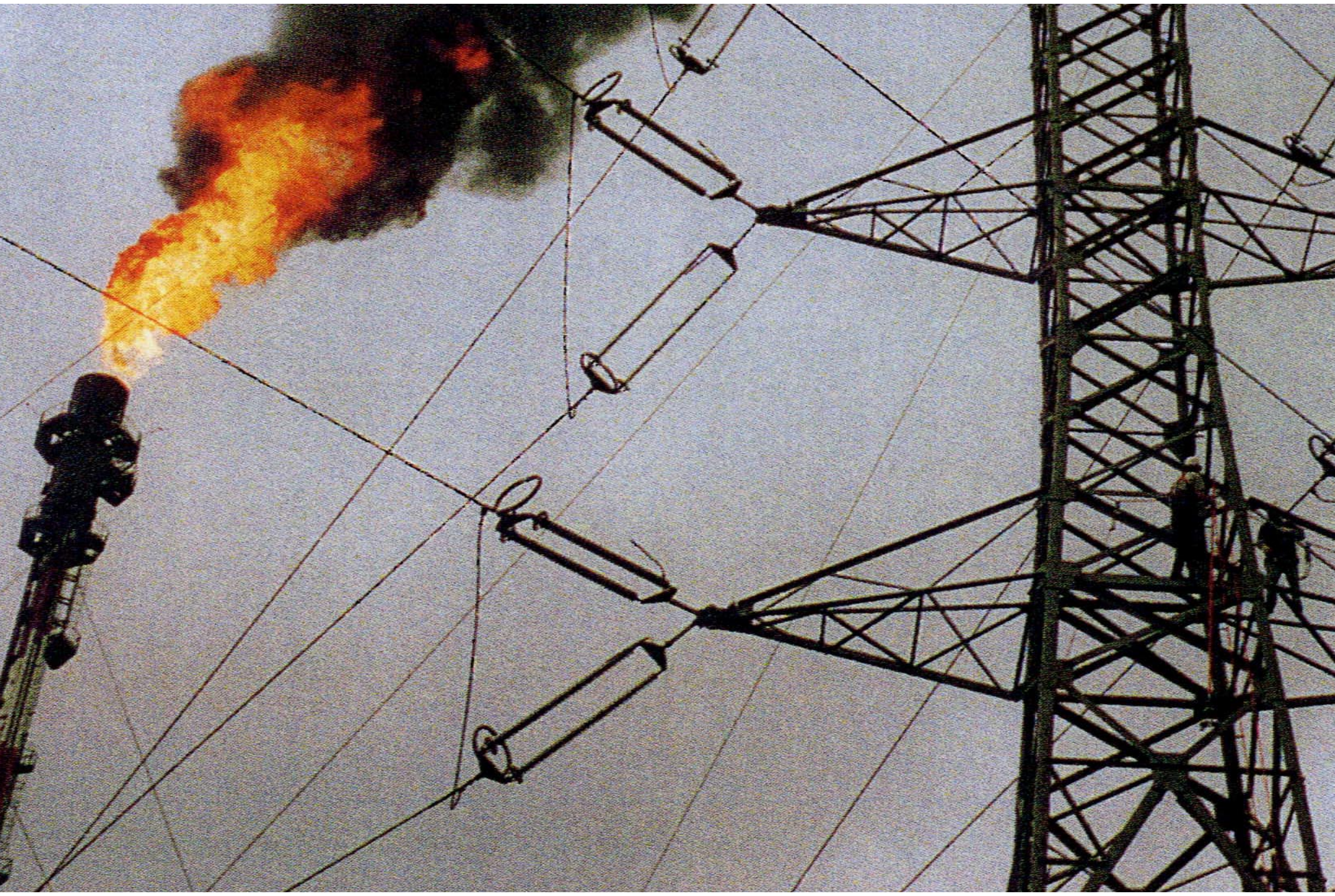
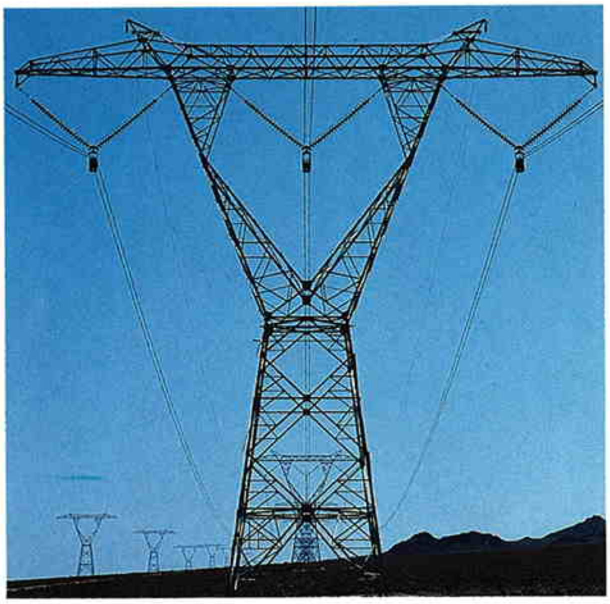


Sediver toughened glass for contaminated area applications

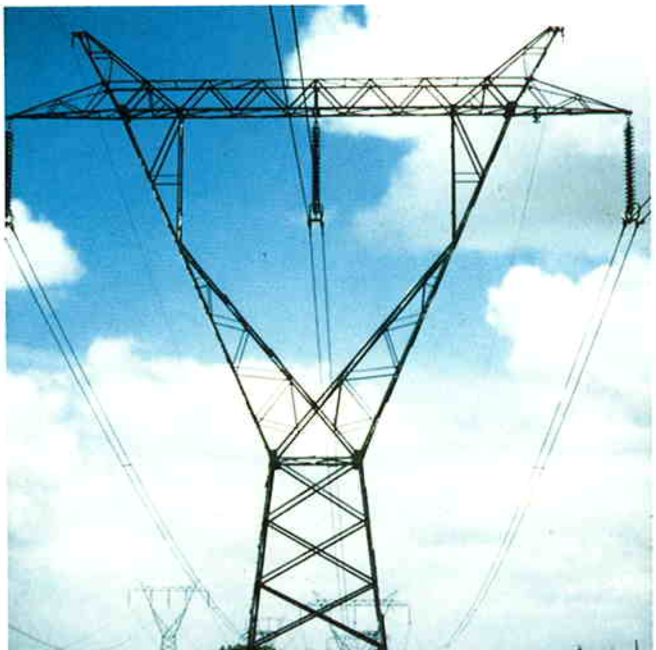
SEDIVER SUSPENSION INSULATOR INSTALLATIONS IN CONTAMINATED AREAS

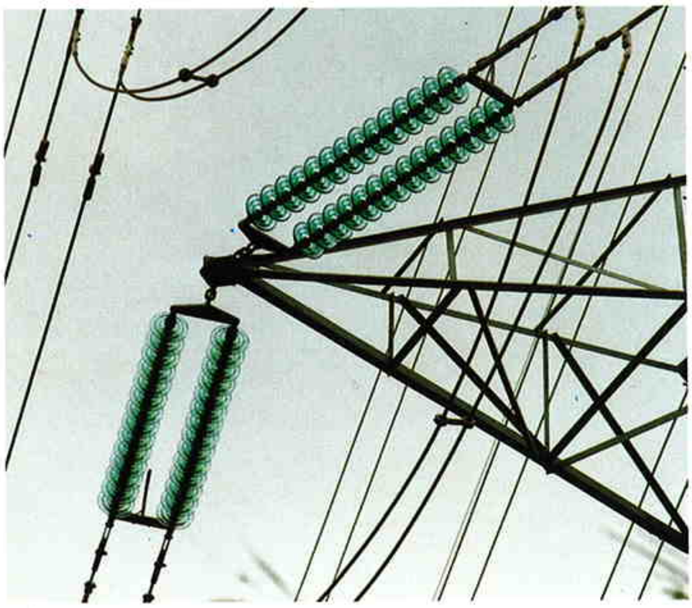
◄ FRANCE 245 kV
Industrial and coastal conditions

▼ DUBAI 132 kV
Desert conditions



◄ IRAN 400 kV
Desert conditions





▲ Malaysia 275 and 132 kV
Tropical climate and coastal conditions

▲ Venezuela 400 kV
Tropical climate and desert conditions

TOUGHENED GLASS SUSPENSION INSULATORS FOR CONTAMINATED AREA APPLICATIONS

More than ten million Toughened Glass Suspension Insulators are now in service throughout the world in polluted areas which involve almost all possible combinations of contaminant source and weather pattern. Regardless of the contaminated condition encountered, these Sediver Insulators have successfully prevented power system disturbances due to contamination flashover, in a great many cases for time periods longer than 25 years.

In this brochure, the insulator design principles which influence performance under contaminated conditions are explained, the available Sediver Toughened Glass Insulator Types are presented, and guidelines for proper selection and string length determination are provided.

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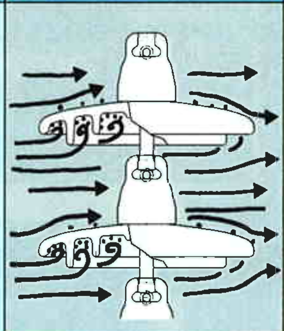
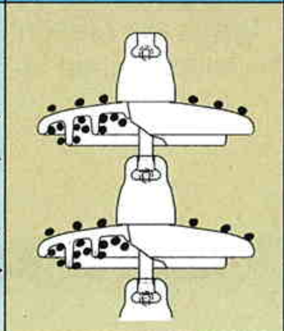
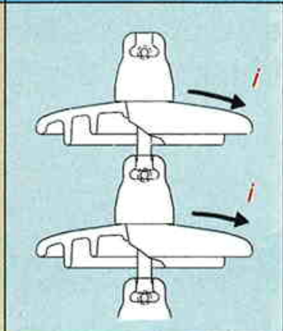
DIRECT CURRENT APPLICATIONS

While much of the information provided in this brochure is valid for insulator applications on both AC and DC lines, there are several unique characteristics of direct current which lead to much more severe electrical stresses on suspension insulators. For that reason, the DC application must be considered as a special case, and readers should request the SEDIVER bulletins and technical papers which deal with this subject.

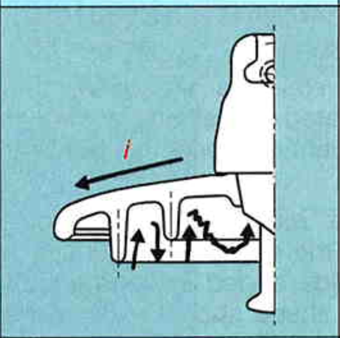
THE PROCESSES WHICH DETERMINE INSULATOR

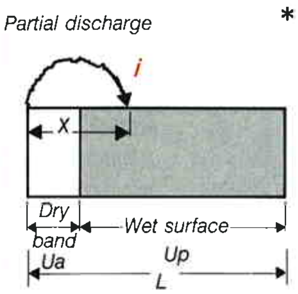
In designing transmission lines for operation in areas of atmospheric pollution, insulators of proper design must be chosen and an appropriate string length determined. When this is done, and when proper maintenance procedures are followed, system disturbances due to contamination flashover of insulators will be prevented, and a high degree of line reliability will be achieved.

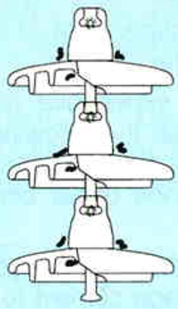
	CONTAMINATED ENVIRONMENT AT LINE LOCATION	DEPOSITION OF CONTAMINANT ON INSULATOR	EVOLUTION OF CONTAMINANT DEPOSIT	WETTING OF CONTAMINANT DEPOSIT
				
A DESCRIPTION OF THE PROCESS	Presence of a source of pollution: natural, industrial or mixed. Typical sources are: salt spray, desert sand, industrial emissions, engine exhaust fumes, fertilizer deposits, generating station emissions.	Contaminant particles are brought into vicinity of insulators by wind, and are selectively deposited on various parts of insulator surface.	Deposition process continues, sometimes interrupted by washing and then starts again. After seasonal variations, the amount of deposit usually stabilizes around an average value.	Atmospheric moisture in the form of fog, mist, dew or light rain slowly wets deposit. Contaminant deposit becomes conductive and a leakage current occurs.
B MECHANISM OF THE PROCESS	Contaminant particles are carried by wind. Distance carried can be long or short.	Laminar flow of air is disturbed by insulator. Particles are deposited in areas of turbulence between insulator ribs and behind cap.	Deposit can be washed away by heavy rain or blown away by high velocity wind. Major cleaning effect is on top surface of insulator.	During wetting cycle, conductivity and current increase with time but are then reduced due to washing effects. Insoluble material in deposit traps water due to capillarity and maintains wetness on surface of insulator. Wetted contaminant deposit becomes electrically conductive. Leakage current flows when there is a continuous path of wetted contaminant deposit between cap and pin.
C PARAMETERS WHICH AFFECT THE PROCESS	Particle size and weight. Distance from source of pollution. Wind velocity. Presence or absence of screen to wind (tower, nearby hills or buildings). Orientation of line and insulators with respect to wind.	Insulator configuration (I-String, V-String, Deadend). Insulator orientation with respect to prevailing wind, and height of insulators above ground. Screening effect of structure. Insulator shell shape --with or without ribs and ribs spacing-- prevents accumulation and facilitates washing and wind.		Nature and amount of dissolved salts in contaminant deposit. Nature and amount of insoluble materials in contaminant deposit. Time. Hydrophobicity of material.

PERFORMANCE IN CONTAMINATED AREAS

In order to identify the insulator design characteristics which most effectively prevent contamination flashover, it is necessary to have an understanding of the processes by which contaminant layers build up on insulator surfaces and the mechanisms which explain leakage current flow and surface arcing effects. This chart presents these inter-related subjects in outline form. For more detailed information, thorough reading of the Technical Papers shown in the List of References on page 16 is suggested.







FORMATION OF "DRY BANDS"	EVOLUTION OF SURFACE ARCING	RESULT OF SURFACE ARCING: STRING WITHSTAND	RESULT OF SURFACE ARCING: STRING FLASHOVER
At locations on the dielectric shell where leakage current density is high, water evaporates due to heating effect of current. A "dry band" forms on those surface areas, most frequently near the insulator pin.	Leakage current flow is limited by "dry band". Surface arcs bridge the "dry band". Arc length may increase or decrease.	Visible arcing, but arc length does not increase. Arcs extinguish when moisture disappears, or when conductive deposit is removed by washing effects.	Length of "dry band" arc increases. Arcs extend completely across insulator.
Voltage distribution on the insulator surface is modified by the presence of the "dry band". Most of the voltage is applied to the "dry band".	Voltage is sufficient to cause arcing across "dry band". Resistance of wet contaminated surface layer is in series with arc, and therefore controls current in arc. As result of further wetting, resistance of contaminated surface layer decreases. An increase in leakage current occurs, allowing arcs length to increase.	Insulator leakage distance is long enough, even when all soluble salts are dissolved, to limit leakage current to a value less than Ic, the critical current, because any further small current increase results in a very large increase in arc length.	Because of increase of conductivity of the wetted contaminant path, and insufficient leakage distance, the current increases to the critical current value Ic. In such conditions, the system becomes instable, leading to a point where the entire insulator is bridged by arcing.
Resistivity of wet contaminated surface. Leakage distance, which limits leakage current.		Adequate leakage distance of string. Properly shaped dielectric shell.	Inadequate leakage distance of string. Improperly shaped dielectric shell.

* The applied voltage U is equal to the sum of the arc voltage Ua and the voltage drop in the wet pollution layer Up.

$U_a = A\,X\,I^{-n}$

$U_p = Z\,(L - X)\,I$

Where A and n are arc constants
- X is the arc length
- I is the arc current
- Z is the uniform resistance per unit length of the creepage distance
- L is the creepage distance of the insulator.

INSULATOR DIELECTRIC SHELL PROFILE

A key conclusion that can be derived from systematic analysis of the contamination build-up and surface arcing processes on insulators is that ability to withstand contamination flashover is:

- strongly influenced by dielectric shell shape,
- but independent of ceramic dielectric shell material.

Through experience and research, it is known that the following aspects of insulator shell shape are essential to efficient performance under contaminated conditions:

1. A leakage distance long enough to limit leakage current to a value less than that which causes a critical increase in dry band arc length.

2. When ribs are incorporated into the underside of the shell to provide the leakage length required, their location, depth and thickness must permit effective removal of pollutant deposits by wind, natural washing and artificial cleaning.

3. Shell profiles involving ribs should have shape characteristics which discourage pollutant particle accumulation on underside surfaces, particularly in the area of the pin which is subjected to high electrical stress.

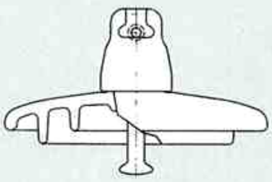
4. When several ribs are used, they should be located at positions far enough apart to prevent arc bridging between adjacent ribs.

5. When an extended overhanging extension of the upper shell surface is used to provide added leakage length, the resultant shape should avoid water bridging across adjacent insulators in a string.

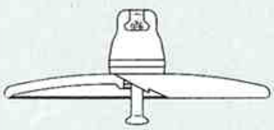
6. A shell profile completely free of ribs, but with a perimeter long enough to provide required leakage length, is useful in certain situations.

EFFECT OF DIELECTRIC SHELL PROFILE ON SEVERITY OF CONTAMINANT DEPOSIT

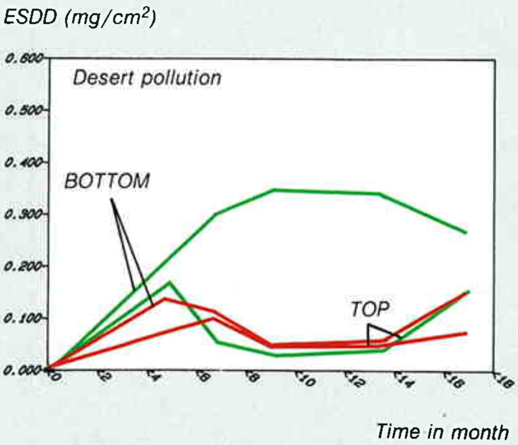
The curves shown below illustrate the effect of dielectric shell profile on the amount and severity of contaminant build-up. The data source is a project in which Sediver engineers made E.S.D.D. measurements on the dielectric shells of two types of toughened glass insulators installed on a 132kV line located in the Arabian Peninsula. As indicated, the measurements were taken at two sites with different environments.

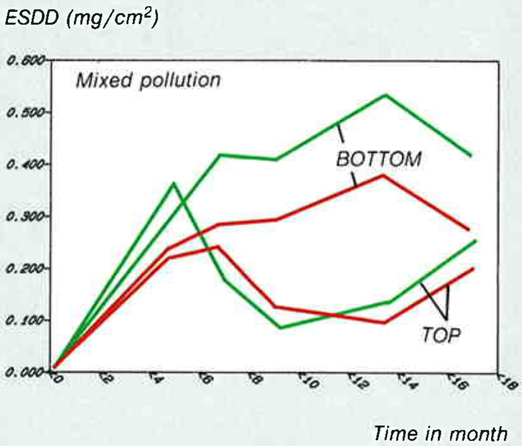


F12



F12D





The test data clearly illustrate the tendency for wind-driven solid pollutants to accumulate more rapidly on the bottom surfaces of insulators with underribs, and demonstrates the effectiveness of a completely smooth profile in reducing contaminant accumulation, particularly in a desert environment.

CHARACTERISTICS OF POLLUTANT MATERIAL

There are three general categories of atmospheric pollution which lead to the formation of the conductive deposits which, when moistened, cause leakage current flow across insulator surfaces.
In the chart which follows, detailed listings of the sources of pollution are given, and the general characteristics of the pollutant materials are described.

POLLUTION CATEGORY		SOURCE OF POLLUTANT	CHARACTERISTICS OF DEPOSIT	AREA AND EXTENT OF EFFECT
NATURAL	Inland	Soil dust	Usually not very conductive and adhesive; may therefore be removed by natural or artificial washing.	May be extended. Occurs in areas of sandy soil or in desert locations.
NATURAL	Desert	Sand	Conductivity may be high; some sands contain more than 20 % of soluble materials.	
NATURAL	Coastal	Salt water leading to microscopic salt crystals carried by the wind	Crystalline deposit not very adhesive; can be removed by natural or artificial washing.	In direct vicinity of coast, but can some times be carried inland as far as 10-20 km.
INDUSTRIAL		Steel mills, Coke Plants, Cement factories, Chemical Plants, Generating Stations, Quarries.	Usually highly conductive. Often combined with insoluble materials.	Localized to close vicinity of plant involved; therefore affects only a few structures.
MIXED		Industries indicated above, but located close to sea coast or desert.	Very adhesive and often conductive; repeated washing necessary for effective removal.	Localized to close vicinity of plant involved.

Pollutant deposits may consist entirely of conductive materials, or may be a combination of conductive and inert materials. Typically, the conductive component is an ionic salt, of which chlorides and sulphates are typical examples. These salts dissolve in the water added by wetting and form the conductive path on the insulator surface through which leakage current flows.
The inert components in pollutant deposits usually do not dissolve but may often form a mechanical matrix in which particles of the conductive component become embedded. Examples of such materials are silica and various clays. The significance of this matrix is that it acts as a coating which tends to decrease the effect of natural or artificial washing of the insulator.

NATURE OF WETTING PROCESS

The most critical situation arises when atmospheric conditions are such that the contaminant deposit becomes moistened at a slow rate. Specific weather conditions which produce slow moistening are fog, mist, sleet, or a sudden temperature change causing condensation (dew). Light and intermittent rain can also lead to humidification, but steady or heavy rainfall does not cause serious trouble because a washing effect occurs as soon as heavy precipitation begins.

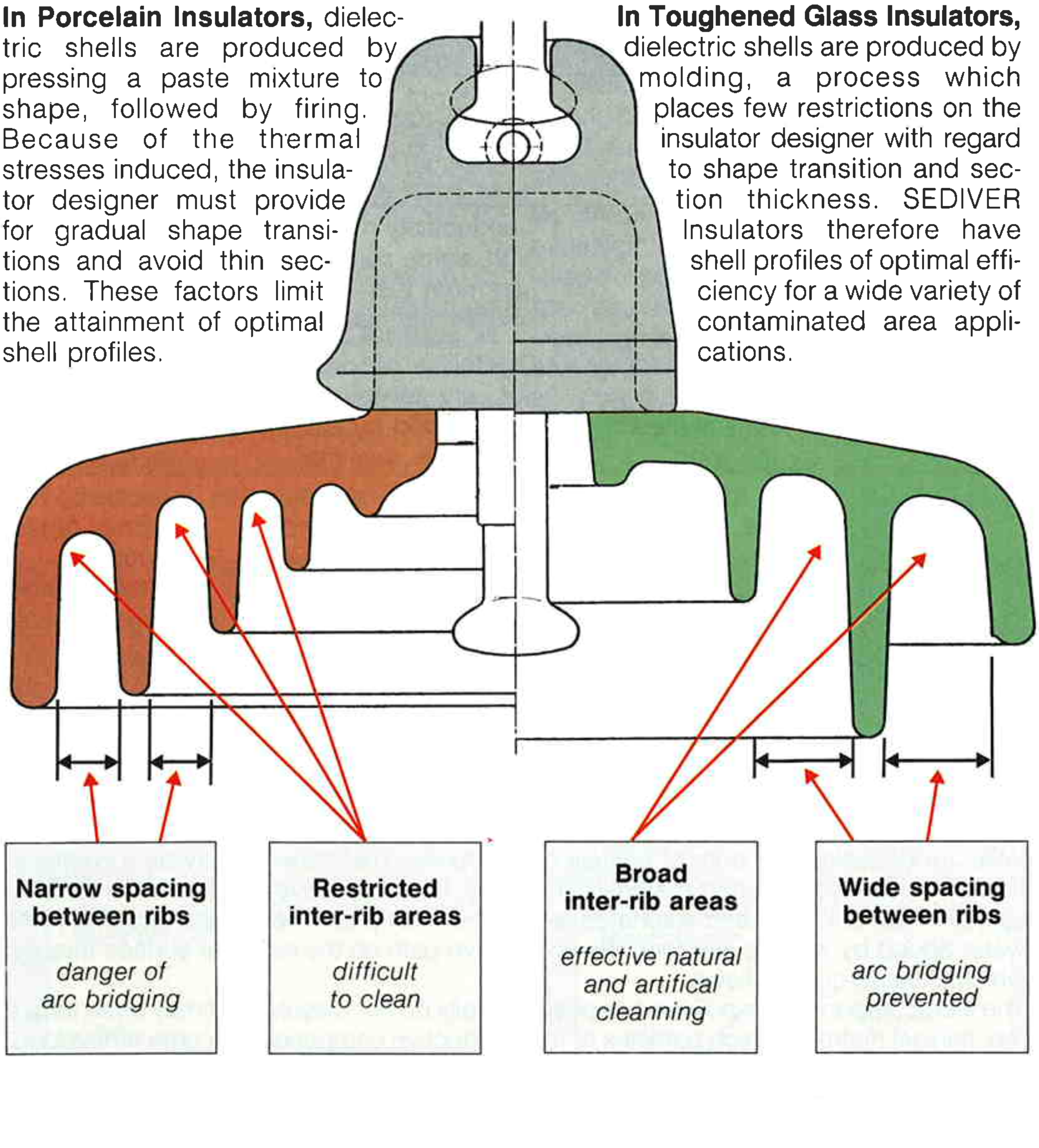
TOUGHENED GLASS: AN IDEAL DIELECTRIC

OPTIMIZED DIELECTRIC SHELL SHAPE

Since the performance of a suspension insulator in a polluted environment is closely related to the accumulation of pollutant particles on its surface, the evolution of the shell shapes which most effectively reduce these deposits is SEDIVER's primary design objective.

In Porcelain Insulators, dielectric shells are produced by pressing a paste mixture to shape, followed by firing. Because of the thermal stresses induced, the insulator designer must provide for gradual shape transitions and avoid thin sections. These factors limit the attainment of optimal shell profiles.

In Toughened Glass Insulators, dielectric shells are produced by molding, a process which places few restrictions on the insulator designer with regard to shape transition and section thickness. SEDIVER Insulators therefore have shell profiles of optimal efficiency for a wide variety of contaminated area applications.



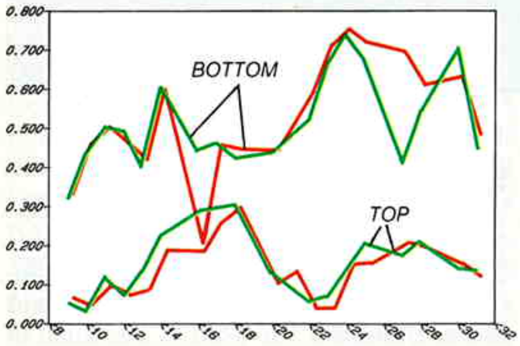
Tests conducted under field and laboratory conditions illustrate the superior contamination performance characteristics of SEDIVER Toughened Glass Insulators as compared to the porcelain types.
In the example shown on page 7, the evolution and amount of surface contamination on two dimensionally equivalent SEDIVER and porcelain insulators is shown to be similar. Howewer when contamination flashover tests were performed in a laboratory on identical samples, the SEDIVER Toughened Glass Insulator had a significantly higher flashover voltage at all levels of contamination. This result clearly illustrates the influence of the more optimal and efficient shape of the Sediver Toughened Glass Insulator.

COMPARATIVE PERFORMANCE TEST RESULTS SEDIVER TOUGHENED GLASS AND PORCELAIN INSULATORS

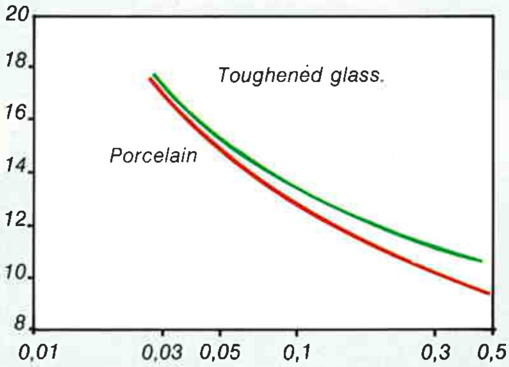
Ratings & dimensions of the tested insulators

INSULATOR TYPE	MECHANICAL STRENGTH RATING	SPACING	DIAMETER	LEAKAGE DISTANCE
TOUGHENED GLASS	178 kN	170 mm	320 mm	530 mm
PORCELAIN	178 kN	171 mm	321 mm	546 mm

Comparative accumulation of surface contamination (data from test site in middle east desert location)



Comparative contamination flashover characteristics (data from laboratory tests)



RESISTANCE TO SURFACE ATTACK

Due to the superior mechanical and physical properties of toughened glass, surface damage related to the presence of pollution is prevented. Examples of such conditions are:

Chemical: SEDIVER glass is almost completely inert. It is therefore immune to attack by acidic or caustic chemical compounds. The only exception is hydrofloric acid, a pollutant rarely found in areas served by transmission lines at large enough concentration.

Abrasion: Even under prolonged exposure to sand storms, the surface hardness of SEDIVER Toughened Glass Shells prevents mechanical damage by wind-driven sand particles.

Sustained surface arcing: This effect only occurs under conditions of exceptionally severe contamination and steady humidification which lead to extremely high leakage currents. The heat of the resultant sustained and intense arc produces surface effects which evolve slowly with time, observable first as a loss in polish and then as a roughening followed by patterns of narrow and shallow channelling.

This effect rarely occurs on toughened glass and porcelain insulators in actual field applications, but is occasionally observed during certain non-representative laboratory tests involving accelerated procedures. In the highly exceptional case of field conditions severe enough to cause roughening and channelling effects, the compressive pre-stresses in the surface region of SEDIVER Toughened Glass dielectric shells retain their effectiveness in preventing formation and growth of surface microcracks. Any possible reduction in mechanical or electrical strength is thereby prevented.

TRANSPARENCY OF GLASS

In areas with severe contamination, or low annual rainfall, periodic insulator cleaning is highly advisable. Because glass is transparent, the effectiveness of such cleaning operations is visually detectable on SEDIVER Suspension Insulators.

TOUGHENED GLASS INSULATORS:

SEDIVER Suspension Insulators are available with dielectric shells of five different shapes, and in a broad range of mechanical strength ratings. The following chart indicates the specific mechanical ratings available for each shell shape, and is followed by descriptions of their general characteristics. All types shown have dielectric shells which are designed in accordance with the insulator profile parameters stated in IEC document 815 (Guide for the Selection of Insulators for Polluted Conditions).

Insulator shell profile	MINIMUM FAILING LOAD RATING, kN									
	40	70	80	100	120	160	210	240	300	530
Standard	X	X	X	X	X	X	X	X	X	X
Fog-Type Shape A				X	X	X	X	X	X	
Shape B				X	X			X		
Open		X			X	X	X			
Spherical	X				X					

Standard Profile:
Shape and dimensions are in accordance with international standard IEC 305/1978 and with such national standards as ANSI C29.2-1983 (USA) and British Standard 137 (Part II). Because of shallow, well-spaced underside ribs and a leakage distance generally in excess of standard duty requirements, this design performs well in areas of mild contamination.

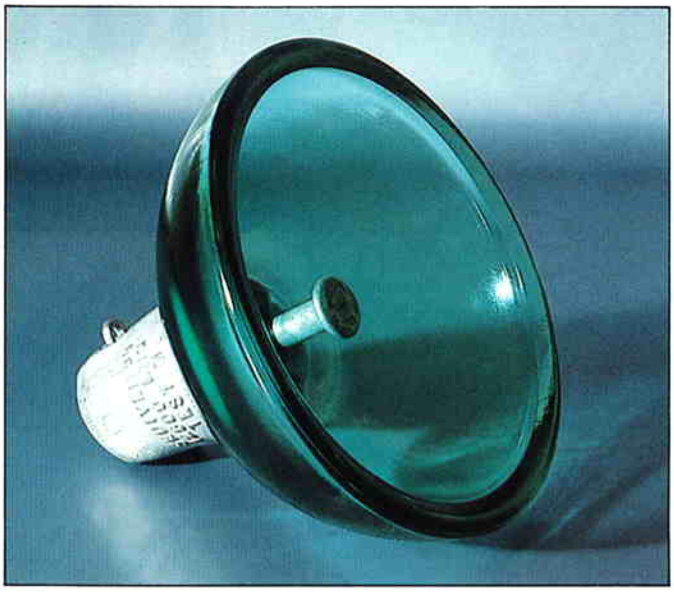
Fog-Type Profile (Shape A): A design with a larger diameter than the standard profile type, and with two or three ribs of greater depth. The profile and wide spacing of the ribs promote effective self-cleaning action by wind or rain, and permit easy manual cleaning if required. The wider spacing also prevents arcing across adjacent ribs under severe contamination, and the overall underside profile simplifies hot line maintenance.

A BROAD RANGE OF AVAILABLE TYPES

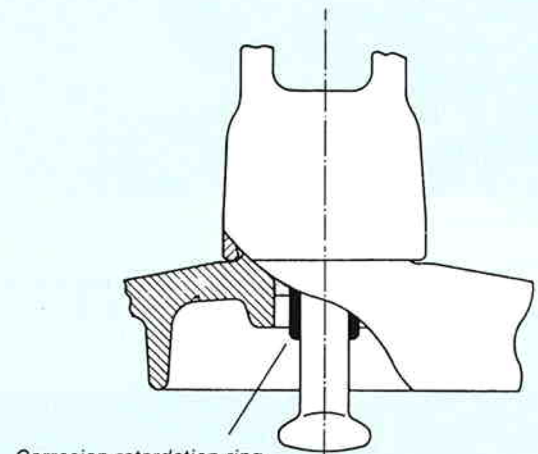
Fog-Type Profile (Shape B) :
In this design, the deep outside rib on the lower surface acts as a barrier against accumulation of pollutants at inner shell areas close to the pin. Also, the more sharply sloped upper surface reduces pollutant deposits in that area of the shell. This shell shape is effective against salt spray carried by off-shore winds in coastal areas, especially in suspension strings.

Open Profile:
Complete elimination of underside ribs in this shell type greatly reduces pollutant accumulation on the lower surface because air flow is smooth and uninterrupted. This design is particularly effective in desert areas where natural washing by rain is infrequent.

Spherical Profile:
The spherical shape permits a leakage distance equivalent to that of standard profile types, and the absence of underside ribs makes for easy, efficient manual cleaning.



CORROSION RETARDATION RING



Corrosion retardation ring.

In severely corrosive marine and industrial atmospheres, the galvanized coating on Suspension Insulator pins may deteriorate in time and be followed by corrosion of the pin itself. To prevent this form of pin damage, SEDIVER supplies a corrosion retardation ring made of 99.7% purity zinc. As shown here, this ring is cast directly on to the pin and is located at the cement line. Because of position and relative mass, the ring acts as a sacrificial anode and thereby protects the pin against galvanic action.

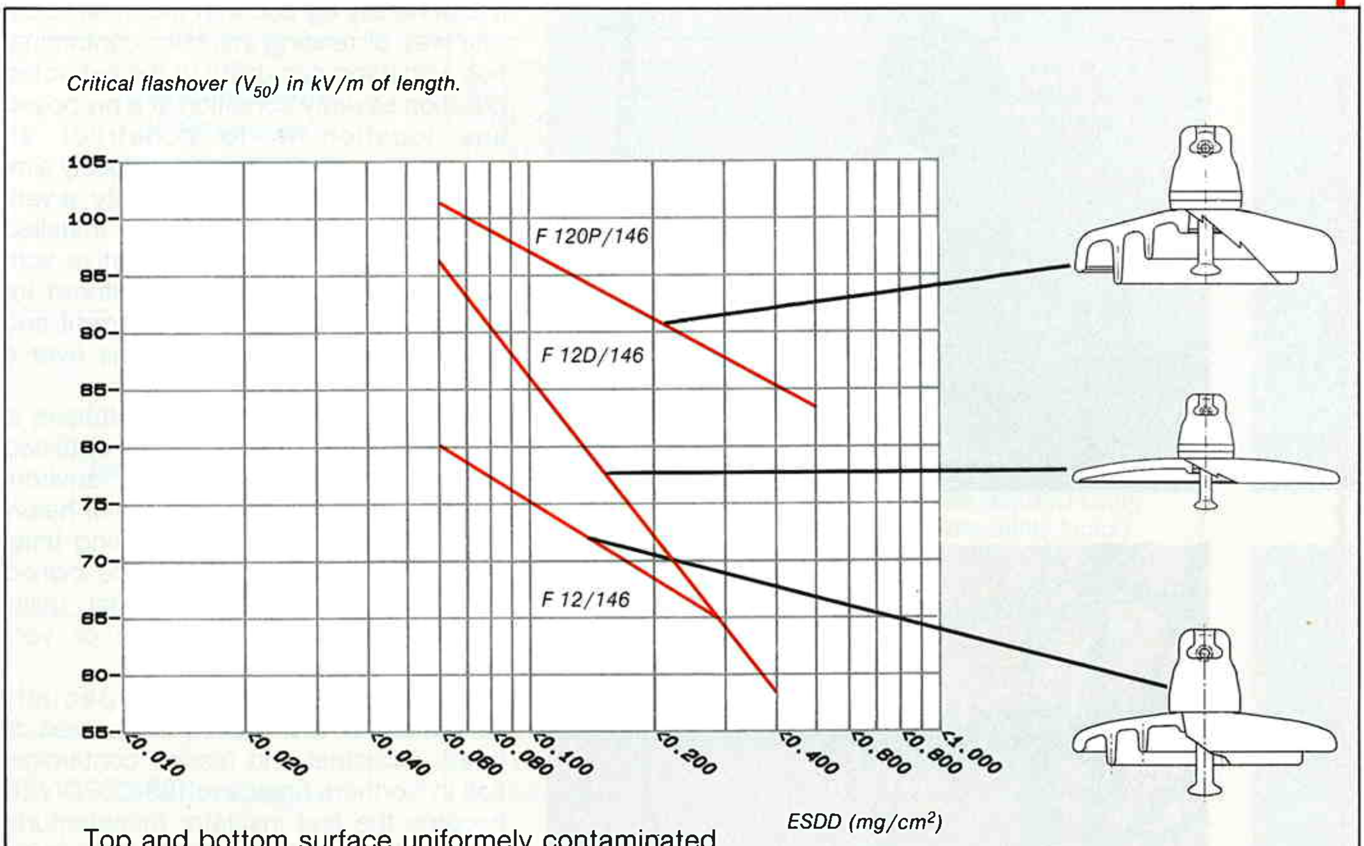
In certain very severely contaminated atmospheres, extended exposure to corrosive attack can cause pin expansion and a resultant high mechanical hoop-stress in the head area of the dielectric shell. However, as shown in this photograph of a SEDIVER toughened glass insulator removed after several years of service in a hot and coastal contaminated atmosphere in Senegal even through severe pin expansion hed occured, damage to the dielectric shell was prevented by the presence of surface prestresses imparted by the toughening process.
In similar condition even high strength porcelain will crack.

ARTIFICIAL CONTAMINATION FLASHOVER CHARACTERISTICS

Typical data on contamination withstand characteristics of several SEDIVER Toughened Glass Insulators at various ESDD levels appear below. Additional data on other types are available on request.

ESDD, or Equivalent Salt Deposit Density, is a measurement of the amount and severity of contaminants which collect on a given insulator shape over a given period of time. It represents the equivalent quantity of Sodium Chloride (Na Cl) per unit surface of the insulator which, when dissolved in a determined volume of distilled water at a measured temperature, gives an electrical conductivity equal to that of the actual deposit.

For a description of the procedure for measuring ESDD, see article, pp. 101-116, ELECTRA N° 64 - 1979: "The Measurement of Pollution Severity and Its Application to insulator dimensioning for A.C. Systems" by working Group 04 of CIGRE Study Committee N°.33.



Top and bottom surface uniformely contaminated.

SELECTION OF INSULATORS

Two basic steps are involved in selecting the optimal insulator type and the string length necessary to prevent contamination flashover in a given polluted area:

• Determination of the relative ability of available or proposed insulator types to limit contaminant deposit build-up and to promote natural cleaning under the particular conditions of atmosphere and weather which prevail at the proposed line location.

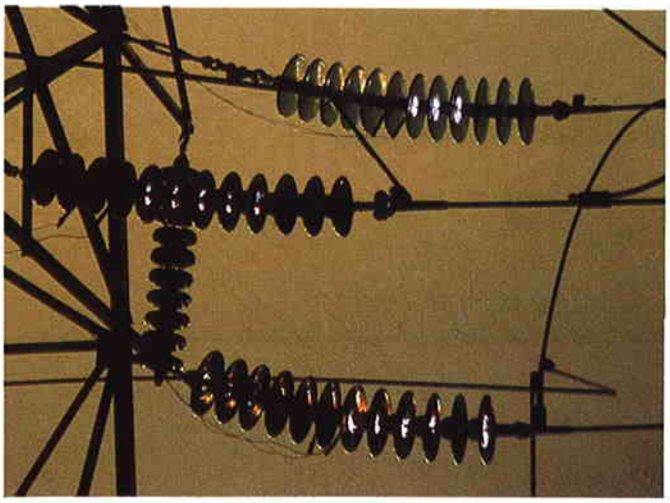
• Determination of the flashover performance characteristics of those insulators after their surfaces have been contaminated by exposure to line location conditions.

Some of the more commonly employed methods for making these important determinations are :

• In an instrumented Test Station, located in an environment very similar to the proposed line location.

• Natural Contamination of the proposed insulator types, followed by laboratory testing for insulator flashover performance or by use of manufacturer's flashover characteristic curves.

TEST STATIONS



It is generally agreed that the most accurate way of relating insulator contamination withstand capability to the expected pollution severity condition at a proposed line location is to construct an instrumented test station in a closely similar environment. At such a facility, a variety of insulator types may be installed and energized at a representative voltage, and then constantly monitored for flashover incidents, leakage current and temperature/humidity conditions over a 2-5 year period.

The prime advantage of test stations is the dependability of the results obtained and the close duplication of environmental conditions, but because of heavy expenditure and extended testing time, facilities of this type tend to be owned and operated by the national utility authorities of major countries or very large privately owned utilities.

Having constructed a specially instrumented test station in an area of heavy industrial and marine contamination in Northern France in 1984, SEDIVER became the first insulator manufacturer to operate an outdoor facility exclusively devoted to the acquisition of data on shell profile efficiency, component behavior and contamination withstand performance.

SELECTION METHODS

Two other and relatively less costly methods exist for selecting optimal insulator type and required insulator string length for reliable performance in contaminated areas. These methods, which involve a combination of field and laboratory procedures, are summarized below and comments are given on their relative advantages and disadvantages.

	INSULATOR SELECTION METHODS	
	Natural contamination of insulators and laboratory testing for insulator flashover performance	Natural contamination of insulators. Use of flashover characteristic curves
Assessment of contaminant build-up on insulator surface	Expose insulator strings of several alternate designs to natural conditions of pollution and weather on a typical structure located at proposed line location. Period of exposure: 2 - 5 years	**1.** Same exposure of insulator strings as at left. **2.** Determine Equivalent Salt Deposit Density (ESDD) of the naturally polluted insulators by computing the average of the data from top and bottom surfaces, or by using the higher of the two values.
Determination of flashover characteristic of contaminated insulator	**1.** Conduct contamination flashover test (clean fog type) in laboratory on all samples of naturally contaminated insulators. **2.** Measure and record flashover or withstand voltage on all samples.	Obtain contamination flashover characteristic curves from the manufacturers of the alternate insulator designs under consideration. (Curves are for flashover voltage vs. ESDD, and are usually based on artificially contaminated insulators.)
Insulator selection	Based on laboratory test results: **1.** Determine flashover or withstand voltage per unit of insulator section length for all types tested. **2.** Calculate required string length (allow safety factor) **3.** Select most efficient and cost-effective insulator.	Based on manufacturers' flashover characteristic curves: **1.** Determine flashover or withstand voltage (kV/m of section length) at selected ESDD level. **2.** Calculate required string length (allow safety factor). **3.** Select most efficient and cost-effective insulator.
Advantages	**1.** High degree of accuracy **2.** Close duplication of actual environmental conditions	**1.** Fair degree of accuracy **2.** Lower cost due to elimination of laboratory testing
Disadvantages	**1.** Time-consuming **2.** High cost	**1.** Time-consuming **2.** Does not consider effect of not-soluble contaminant particles

Recognizing that it is not always possible for utilities to perform complex field and laboratory investigations, SEDIVER has developed guidelines for the selection of toughened glass insulators for contaminated area applications, and for determination of the string length necessary for optimal performance at a given line voltage. These guidelines, evolved from Sediver insulator application experience and contamination research, are based on the relative ability of the listed SEDIVER insulators to meet the following requirements:

Minimized leakage current by providing a leakage length and leakage efficiency necessary for the applicable type of contamination.

Minimized pollution deposit by having a profile best adapted to the applicable type of contamination and natural cleaning condition.

STEP ONE - Identification of pollution category

This step is generally equivalent to defining relative pollution severity.
The four categories involved are listed below, and are more fully described on page 5. : Inland, coastal, industrial, mixed.

STEP TWO - Choice of insulator profile

Choose the applicable SEDIVER insulator profile on the basis of string position (suspension or tension) and pollution category as indicated in Chart A.

CHART A

	For suspension strings (vertical or "V")				For tension strings (horizontal)			
Type of pollution	Standard profile	Fog-type profile	Open profile	Spherical profile	Standard profile	Fog-type profile	Open profile	Spherical profile
Coastal								
Desert						N.R.		
Industrial						N.R.		
Mixed	N.R.	N.R.			N.R.	N.R.		

recommended — possible — = N.R. = not recommended

NOTE: If the level of pollution is critically high and cleaning or washing operations are envisaged, it is desirable to consider the use of open profile or spherical-profile insulators which can be more effectively cleaned or washed. Ribbed insulators (fog-types or standard types) are less advisable in this case.

STEP THREE - Determination of insulator string length

Determine the number of insulators per string by multiplying phase-to-phase voltage of line by the cm/kV level shown in following charts. Then divide by leakage distance (in cm) of insulator type chosen. Obtain string length by multiplying number of insulators by the spacing dimension of the insulator. Chart B should be used when very highly polluted areas are involved, while Chart C is applicable to less severe pollution situations.
If, for suspension strings, Chart B or C indicates alternate recommendations of two or three different profiles for the given pollution situations, the more desirable choice is the profile type which results in shortest string length. This permits reduction of structure height and cost of the line.

CHART B - VERY HIGHLY POLLUTED AREAS

- Areas subjected to conductive dust and to industrial smoke producing particularly thick conductive deposits.
- Areas very close to the coast and exposed to salt spray or to very strong and polluting winds from the sea.
- Desert areas, characterised by no rain for long periods, exposed to strong winds carrying sand and salt, and subjected to regular condensation.

	For suspension strings (vertical or "V")			For tension strings (horizontal)		
	Required leakage distance (cm/kV) for indicated insulator profile			Required leakage distance (cm/kV) for indicated insulator profile		
Type of pollution	Fog-type profile	Open profile	Spherical profile	Standard profile	Open profile	Spherical profile
Coastal	3	2.8	2.8	2.75	2.7	2.7
Desert	3.3	2.5	2.8	2.75	2.5	2.7
Industrial	3	2.5	3.25	3	2.5	3
Mixed	N.R.	3.5	4	N.R.	3.25	3.75

CHART C - LESS SEVERE POLLUTION SITUATIONS

- Areas with high density of industries; suburbs of large cities with high density of heating plants producing pollution.
- Areas close to the sea or exposed to relatively strong winds from the sea.

	For suspension strings (vertical or "V")			For tension strings (horizontal)		
	Required leakage distance (cm/kV) for indicated insulator profile			Required leakage distance (cm/kV) for indicated insulator profile		
Type of pollution	Fog-type profile	Open profile	Spherical profile	Standard profile	Open profile	Spherical profile
Coastal	2.75	2.5	2.5	2.5	2.4	2.5
Desert	3.25	2.25	2.5	2.5	2.25	2.5
Industrial	2.75	2.25	3.0	2.75	2.25	2.75
Mixed	N.R.	3.25	3.75	N.R.	3	3.5

EXAMPLE OF INSULATOR SELECTION

Conditions:
240 kV line close to seacoast - Strong offshore wind carries salt spray to line structures. Required mechanical ratings for insulators are 160 kN (suspension) and 210 kN (tension).

Selection:
1. Pollution category is "COASTAL". Area is "highly polluted".
2. From Chart A, fog-type profile is recommended for suspension strings, and standard profile for tension strings.
3. From Chart B, required leakage distance for suspension string is 3 cm/kV. Total string leakage distance needed is 720 cm.

From SEDIVER Catalog TG 87, page 21, the fog-type insulator rated at 160 kN is Cat. N° F 160 P/170 (leakage distance = 54.5 cm)
720 cm ÷ 54.5 cm = 13.21.
Suspension string should therefore be 14 F 160 P/170 insulators.

4. From Chart B, required leakage distance for tension string is 2.75 cm/kV.

From Catalog TG 87, page 19, the standard profile insulator rated at 210 kN is Cat. N° F 21/170 (leakage distance = 38.0 cm).
600 cm ÷ 38.0 cm = 17.36.
Tension string should therefore be 18 F 21/170 insulators.

SOME IMPORTANT APPLICATION PRECAUTIONS

1. Addition of insulators to increase string flashover

Experience has shown that the addition of clean insulators at the end of a polluted string in order to increase the insulation level often creates more problems than it solves. In fact, the resulting modification of the voltage distribution along the string can bring about flashovers. Therefore, if it is decided to lengthen the string, it is necessary to clean the existing insulators and to use insulators of the same type.

2. Precautions when greasing

Greasing of insulators, for the purpose of improving performance in contaminated areas, has some serious drawbacks. It is a time-consuming and expensive procedure which must be repeated once the grease becomes saturated with pollutant particles, and determination of the need for cleaning and re-greasing is difficult. In addition, certain types of greases are not suitable because decomposition occurs when they become saturated. This conditions causes formation of silica paths which favor concentration of leakage currents leading to damage of the dielectric shell.

List of reference documents

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SFORZINI M. - CORTINA R. - MARRONE G.
A statistical approach for insulator design in polluted areas
IEEE PES Winter Meeting 1983 Paper 83 WM 134-4

SEDIVER TOUGHENED GLASS INSULATORS... IDEAL FOR CONTAMINATED AREA APPLICATIONS

Dielectric shell profiles of optimal efficiency available for all combinations of contaminant source and weather conditions.

All shell profiles available in a broad range of mechanical strength ratings.

All component parts resist surface attack and corrosive effects.

Superior ability to endure mechanical and electrical overhead line conditions.

Mechanical strength unaffected by time and cyclic load.

ISO certifications

All our manufacturing facilities worldwide are certified ISO 9001-2000

Catalogs

- Sediver thoughened glass suspension insulators
- Sediver toughened glass multiglass station post insulators
- Sediver toughened glass for contaminated area applications
- Sediver toughened glass: endurance

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SEVES

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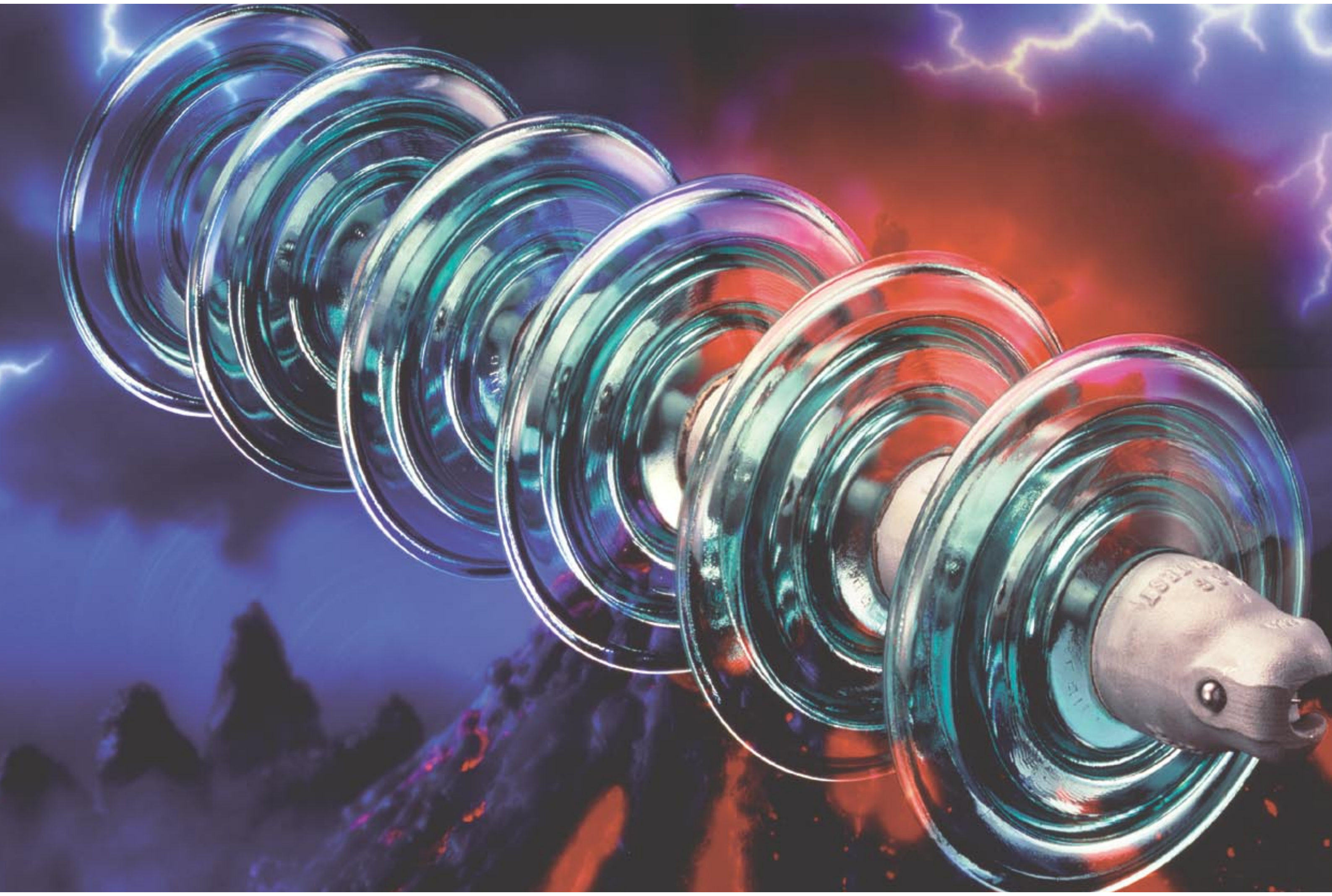
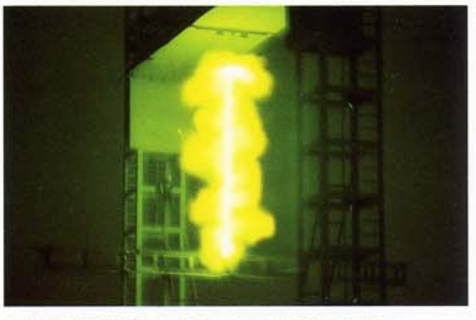


Sediver toughened glass: endurance

1



2

3

1. A SEDIVER insulator returned from over 20 years service in polluted conditions in Malaysia. It can be seen on the cleaned half that no surface degradation has occurred.

2. Power arc tests performed on SEDIVER toughened glass insulators. Power impulse of 63 kA., 0.3 seconds.

3. Hot line maintenance can be performed in complete safety as toughened glass insulators can have no hidden defects.

Today the world's longest high voltage transmission lines, operating under the most challenging conditions and requiring the highest degree of reliability, are equipped with Sediver Toughened Glass Suspension Insulators.

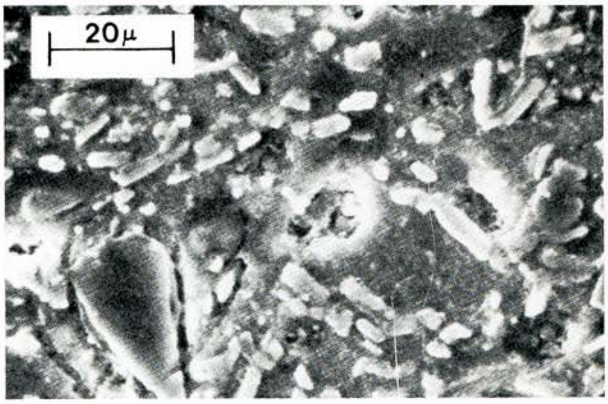
Two basic benefits explain this world-wide preference:

- Toughened Glass Insulators indefinitely withstand the effects of time and the elements and
- Toughened Glass Insulators have a superior ability to endure mechanical and electrical overload conditions.

The benefits of Sediver Toughened Glass Insulators are directly related to the structural purity and the unique properties of Sediver Glass. These characteristics are not present in wet process porcelain, the other mineral dielectric material commonly used for suspension insulators.

Because of this fact, there are important differences in the performance characteristics of Toughened Glass and porcelain insulators. In this brochure, the significance of dielectric material structure and other aspects of insulator design are explained, and the performance characteristics of the two insulator types are compared.

Dielectric Shell Material...
the Key to Suspension Insulator Performance



The two most widely used inorganic materials for suspension insulator dielectric shells are toughened glass and wet process porcelain. Although both materials are silicate-based ceramics, and are therefore similar in chemical composition, glass and porcelain are not at all alike in internal structure because of the very dissimilar production processes involved:

Fig. 1 Electron Micrograph of electrical insulator porcelain (etched 10 sec., 0 °C, 40% hf) showing silicate crystals embedded in a glassy matrix and pores.

Porcelain:

The raw materials, in the form of a paste mixture, are molded or machined to shape and then dried. After glazing, firing in a kiln causes partial cohesion, together with some glass formation. The result is *an extremely heterogeneous internal structure* composed of silicate crystals embedded in a glassy matrix. (See Fig. 1)

Toughened Glass:

All raw materials are melted in a furnace, where *complete fusion* into liquid glass takes place. During molding and toughening, no solid particles form in the solution, nor does any crystallization occur. The result is a *completely uniform internal structure.*

Effect of Internal Shell Structure
on Insulator Performance

In such brittle ceramic materials as porcelain and glass, the presence (or absence) of internal discontinuities is extremely significant. This is because of the many microcracks which may form at these locations during processing and which, under the mechanical stresses produced by service conditions, will propagate with time and ultimately lead to breakage. In short, the presence and propagation of internal microcracks is a major reason why porcelain insulators lose strength with age.

Under electrical stresses - particularly those which result from voltage impulses due to lightning and switching surges - a breakdown process originates at points of structural irregularity in insulator dielectric shells. Thermal effects then take place, and lead to eventual puncture.

When porcelain and toughened glass insulators are compared on the basis of these failure mechanisms, the conclusions are:

Porcelain:

Is a material which loses strength with age and is vulnerable to electrical failure due to the presence and growth of microcracks within its heterogeneous and porous internal structure.

Toughened Glass:

Is a material with the structural purity necessary to endure the severe combination of mechanical and electrical stresses imposed on overhead line insulators.

Effect of Surface Condition on Insulator Performance

Microcracks at the surface of ceramic dielectric shell materials have an equally important effect on the mechanical and electrical performance of suspension insulators due to the intense concentration of stress which occurs at critical surface cracks and which causes propagation leading to eventual failure. Since surface microcracks are inherent to such brittle ceramic materials as glass and porcelain, some form of compensation or control over this condition is necessary. The methods used to overcome the effects of surface microcracks are:

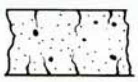
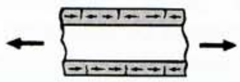
In Porcelain Insulators

The rough and porous original shell surface is improved by a compressive glaze, but since the glaze coating is thin (.15 mm; .006 in.) and the compressive pre-stress is of a low order (15MPa; 2300 psi), it is not very effective in preventing the propagation of surface microcracks.

In Toughened Glass Insulators

Permanent compressive pre-stresses are imparted into the surface region of glass dielectric shells by the controlled cooling process known as toughening. Because the compressive pre-stress is substantial (250MPa; 35,000 psi), the formation and propagation of surface microcracks is very strongly inhibited - another reason why Sediver Toughened Glass insulators endure the brutal conditions of overhead line service.

Control of Microcrack Growth in Porcelain and Toughened Glass

Load Condition	Porcelain	Toughened Glass
Unstressed	 Thin Glaze Does not Prevent Crack Formation	 Pre-Stress Acts to Keep Initial Microcracks Closed
Normal Stress	 Pre-Stress Insufficient to Prevent Crack Propagation	 Pre-Stress Prevents Spreading of Microcracks
Effect of Fatigue	 Progressive Growth of Microcracks  Complete Fracture	 Only an Extreme External Stress Can Overcome Compressive Pre-Stress

Thermal Expansion Characteristics

Insulators installed on overhead power lines are subjected to wide variations in temperature due to rapidly changing weather conditions and fluctuating electrical loads. Suspension insulator components expand and contract as a result of temperature changes, and at differing rates. Therefore, to avoid damaging internal stresses and fatigue effects due to temperature changes, suspension insulator components should have similar thermal expansion coefficients.

In fact, because of increased evidence of correlation between the differential expansion effect and the field performance of suspension insulators, the principal international standard governing suspension insulators (IEC Document 383) now includes a thermal-mechanical test requirement.

The values for thermal expansion coefficients of suspension insulator components are shown below:

Insulator Component	Thermal Expansion Coefficient (mm/mm/°C x 10^{-6}	
	Porcelain Insulator	Toughened Glass Insulator
Dielectric Shell	6.5	9.1
Cap (Malleable Cast Iron)	11.5	11.5
Pin (Steel)	11.7	11.7
Cement	10.0	10.0

On the basis of these values, the conclusions are:

In Porcelain Insulators:

The expansion coefficient of the dielectric shell is 44% less than that of the cap and pin components. Because of this basic vulnerability to the temperature change effect, porcelain insulators should always be evaluated by conducting Sample Tests in accordance with the thermal-mechanical test requirements of IEC Document 383.

In Toughened Glass Insulators:

The expansion coefficient of toughened glass is only 20% less than that of the cap and pin. The fact that Toughened Glass Insulators endure temperature change is demonstrated by their consistent ability to pass the IEC thermal-mechanical test requirement.

Relationship Between Dielectric Shell Material and Insulator Residual Strength Characteristics

Whether made of glass or porcelain, any suspension insulator dielectric shell may be badly damaged during construction and service by an exceptionally high mechanical impact or by power arc effects, but the residual mechanical strength of the insulator must nevertheless be high enough to prevent line drop, and the insulator must also retain a high level of electrical integrity. How do the two insulators compare?

Porcelain Insulators:

"Stub" behaviour is unpredictable because the failure mechanism of shells subjected to heavy impact or power arcs involves major cracking and subsequent fracture in the shell head area. Also, from the electrical view-point, the development of major internal cracks in the shell head is usually a prelude to puncture when subjected to heavy electrical load.

Toughened Glass Insulators:

The permanent compressive pre-stresses imparted by the Sediver toughening process are balanced by equal tensile pre-stresses in the internal region of the shell. Therefore, when the compressive pre-stress at the surface is overcome by an exceptional external stress, the internal pre-stress is also released. The effect is for the unsupported region of the shell to crumble and fall away, but in the head area of the shell (Fig. 2), the crumbled glass particles are restrained by the surrounding cement layers and are tightly wedged against each other. Because of this condition, the residual mechanical strength of a Toughened Glass Insulator "stub" is only very slightly less than rated mechanical strength of the insulator in undamaged form.

The electrical behaviour of the "stub" is equally reliable, again due to the tightly packed and entrapped particles of glass. Therefore, if the voltage on a string unit in "stub" form were to increase sharply for some reason, the arc will be external to the stub because of the very short distance in air between the lower edge of the metal cap and the nearest point on the metal pin. (Fig. 3).

Fig. 2 Internal Condition of Toughened Glass Insulator "Stub"

Fig. 3 External Flashover of Toughened Glass Insulator "Stub"

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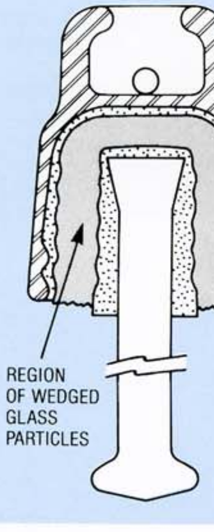

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Cement Used for Assembly... Another Factor Affecting Insulator Performance

In suspension insulators of the cap and pin type, the ceramic and metal parts are arranged as illustrated in Fig. 4, and are retained in place by the cement used to fill the voids between these parts. The cement employed must not react chemically with the metal components of the insulator, and must not be subject to volume changes due to chemical transformation with time.

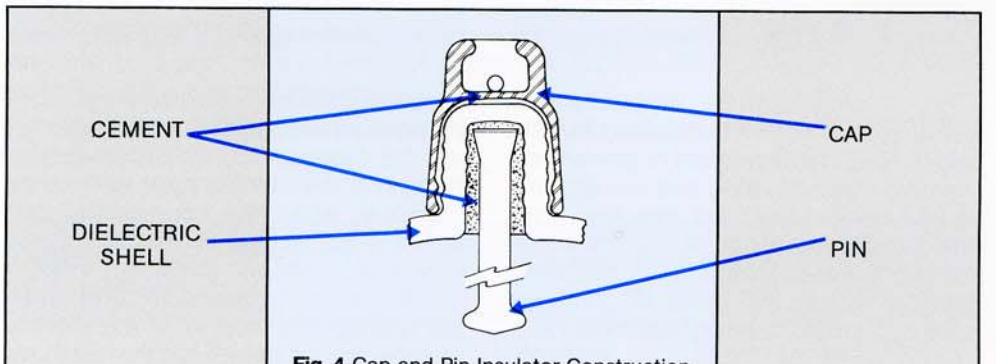


Fig. 4 Cap and Pin Insulator Construction

Porcelain Insulators:

Portland cement is commonly used. In this type of cement, lime is liberated in free form during curing and with age and will react with the metal pin to produce by-products whose volume is greater than the cement itself. Also, depending on composition and processing methods, expansion processes involving the magnesium oxide and gypsum content will take place. The forces exerted as the result of these volume growth effects cause porcelain shell cracking and subsequent insulator failure.

Toughened Glass Insulators:

The cement used in assembling Sediver Toughened Glass insulators is an aluminous type in which the predominant chemical compound is mono-calcium aluminate. In the curing process, only the alumina portion of this compound is liberated in excess. Since alumina is an inert material, it does not react chemically with the metal components of toughened glass suspension insulators. Also, in aluminous cement, no compounds subject to expansion effects are present. Toughened Glass Insulators are therefore free from the "cement growth" problem.

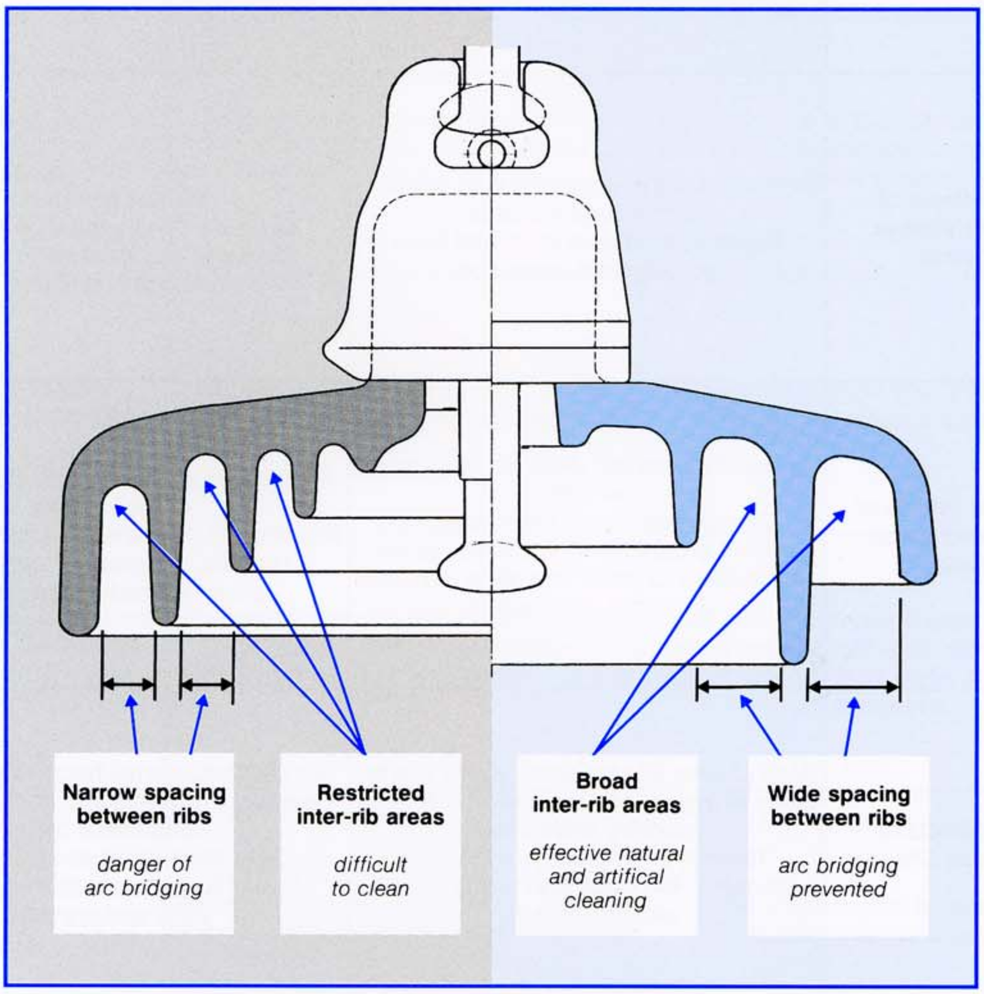
Optimized Dielectric Shell Shape

In Porcelain Insulators

Dielectric shells are produced by pressing a paste mixture to shape, followed by firing. Because of the thermal stresses induced, the insulator designer must provide for gradual shape transitions and avoid thin sections. These factors limit the attainment of optimal shell profiles.

In Toughened Glass Insulators

Dielectric shells are produced by molding, a process which places few restrictions on the insulator designer with regard to shape transition and section thickness. SEDIVER Insulators therefore have shell profiles of optimal efficiency for a wide variety of contaminated area applications.



Performance Comparison of Toughened Glass and Porcelain Insulators

Insulator Performance Requirement	Performance Comparison	
	Porcelain Suspension Insulators	**SEDIVER Toughened Glass Suspension Insulators**
Isolate Conductor From Ground and Provide Mechanical Load Support for Conductor	Usually meet mechanical and electrical rating requirements of National and International Standards. BUT Can often fail to meet other requirements stated below.	Always meet mechanical electrical rating requirements of National and International Standards. AND All other requirements stated below.
Resist Effects of Overload Voltage Impulses	Vulnerable to puncture due to steep front voltage impulses Because of internal structural flaws (porosity and inclusions)	Withstand steep front voltage impulses without puncture Because of homogenous internal structure and inherently superior dielectric strength.
Withstand Effects of Cyclic Mechanical Loads	Mechanical strength declines by as much as 30% Compressive glaze inadequate to prevent propagation of surface cracks; also subject to crack formation at points of internal discontinuity.	Mechanical strength unaffected by time or cyclic loads Presence of permanent compressive pre-stresses imparted by toughening prevents crack propagation.
Resist Effects of Temperature Change	Much higher internal hoop stress due to unequal expansion and contraction; shell cracking more likely Thermal expansion coefficient of porcelain is 44% less than metal cap and pin components	Very limited internal hoop stress due to unequal expansion and contraction of component parts Because thermal expansion coefficient of glass is very close to that of metal parts and cement
Resist Destruction Due to Power Arc Effects	Dielectric shell can be blown apart by power arc effects Because of existence of cracks or puncture channels caused by previous voltage impulse or temperature change effects	Withstands extreme thermal effects of high current power arcs; no line drop due to dielectric shell destruction Because internal structure is virtually free of flaws, destructive disturbances of shell are prevented

Performance Comparison of Toughened Glass and Porcelain Insulators

Requirement	Comparison	
	Porcelain Suspension Insulators	SEDIVER Toughened Glass Suspension Insulators
Easily Transportable to Construction Site	Crate of Six 100kN (22,000 lbs.) Insulators Weighs 37kg (82 lbs.)	Crate of Six 100kN (22,000 lbs.) Insulators Weighs 26kg (57 lbs.)
Resist Damage During Transport, Storage and Assembly	Vulnerable to damage; mechanical strength is 70% less than Toughened Glass	High Mechanical Strength of Toughened Glass prevents damage during shipping, storage and assembly
Quick & Simple Detection of Damage	Identification of damaged units requires special equipment and considerable time	Visual inspection from a distance immediately identifies a damaged unit
In Damaged Condition, Sufficient Mechanical Strength to Prevent Line Drop	Mechanical strength greatly reduced due to effect of major internal cracks in dielectric shell; Distinct possibility of line drop	Retains a high percentage of rated mechanical strength even after complete loss of external shell material. Line drop is prevented.
In Damaged Condition, No Destructive Internal Arcing	Internal flashover due to cracks in dielectric shell; possibility of pin ejection and complete destruction due to thermal effects of power arc current	Arcing which occurs is external; no disruptive internal discharge
Adaptability to Hot Line Maintenance Procedures	For safety reasons, all insulators in string must be tested for possible puncture before starting hot line maintenance operations on strings Extra weight makes hot line maintenance more difficult Dielectric shell obscures cotter key	Not necessary to check individual insulators for puncture prior to hot line maintenance operations on strings Light weight simplifies hot line maintenance Transparency of glass makes cotter key location easier

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SEVES

SEDIVER

Sediver toughened glass suspension insulators

ANSI - USA

2015

Sediver, Experts and Pioneers in insulation technology

This catalog presents a selection of the Sediver toughened glass insulator range of products answering the needs of USA customers in term of standards (ANSI), current practices and environmental conditions. ANSI standard C29.2B sets the basic and minimum requirements for wet-process porcelain and toughened glass transmission suspension insulators.
Sediver toughened glass insulators meet and exceed the performance requirements of ANSI standards.

Our expertise

500 million toughened glass insulators installed in more than 150 countries up to 1,000 kV AC & 800 kV DC.

- > 6 million toughened glass DC insulators
- > 5 million composite insulators up to 735 kV
- > 1 million Sedicoat insulators, silicone coated toughened glass insulators for both AC and DC applications
- > 50 years of service experience in the USA, with more than 15 million units installed

Research & Development, a permanent and continuous investment

Always on the lookout for continuous technological improvements, Sediver heavily invests in Research and Development. Our research and testing facilities as well as our high voltage CEB laboratory both located in France boast state-of-the-art equipment that allows extensive research programs as well as testing of complete strings for systems up to 800 kV.

Worldwide presence – reinforced proximity

France	Commercial & Marketing Headquarters Technical Assistance Research & Testing laboratories Logistics Platform
Canada	Sales office Technical Assistance Logistics platforms
USA	Sales office Technical Assistance Logistics platforms
Italy	Sales office Manufacturing plant Testing facilities
Brazil	Sales office Technical Assistance Testing facilities Logistics platform
China	Sales office Technical Assistance Manufacturing plants Testing facilities

- ■ Commercial & Marketing Headquarters
- ● Center of expertise and R&D laboratories
- ● Manufacturing plants and Logistics platforms
- ● Sales offices

Unique manufacturing processes

Sediver manufacturing processes are unique.
These processes have been developed and improved thanks to the experience Sediver has gained over 60 years following-up and assessing the performance of millions of insulators in service as well as through the integration of the latest technological innovations.

Sediver, our experts at your service

In-depth technical expertise
Our team of multidisciplinary and highly skilled engineers is dedicated to the research and development of optimum solutions in the field of high-voltage insulation and protection.

Innovative products
Our engineers and scientists are always searching for new materials, products, designs and technologies that will contribute to improve the performance and the reliability of your systems while reducing the environmental impact and carbon footprint.

Sediver technical assistance
Our technical assistance teams help you throughout all the stages of the insulation related matters from the selection of the optimum insulation solution to the monitoring of performance in service.
We offer specifically:

- Testing and evaluation programs
- Joint research programs related to solving insulation issues
- Training programs dedicated to design, handling, construction and maintenance teams
- End-of-life and failure diagnostics
- Optimization of line insulation for polluted environments

State of the art research and testing facilities

The equipment and facilities of our six research and testing centers ensure the development of insulators with excellent long term behavior and performance.

- Investigation and research in material science:
Vital to ensure a high level of performance and reliability of our insulators

- Mechanical endurance testing:
Essential to designing insulators with excellent long term behavior under extreme service conditions

- Evaluation of the insulators' electrical performance:
Fundamental to assess the performance of any type of insulator string configuration

- Evaluation of the pollution performance of insulators and complete strings:
Critical for the choice of the right insulator adapted to each specific environmental condition

Overview of main testing equipment per country

	Brazil	China	France	Italy
Dielectric tests on insulator units	✔	✔	✔	✔
Dielectric tests on complete strings			✔	
AC Salt-fog Pollution tests			150 kV	40 kV
AC Solid layer Pollution tests			250 kV	
DC Pollution tests (salt fog/solid layer)			120 kV	
DC Sample tests according to IEC 61325	✔	✔	✔	✔
DC Type tests according to IEC 61325			✔	
Mechanical tests on insulator units	✔	✔	✔	✔
Thermal-mechanical tests	✔	✔	✔	✔
Long duration vibration tests on complete strings			✔	
Standard sample tests according to national and international standards	✔	✔	✔	✔

Sediver laboratories are all ISO 9001 or ISO 17025 certified

Toughened glass design features and advantages...

What is Toughened Glass?

The toughening process consists in inducing pre-stresses to the glass shell by a rapid and precisely controlled cooling of the still hot molded glass. The pre-stresses result in compressive forces on the outer surface layer balanced by tensile forces inside the body of the glass shell.
The presence of permanent outer surface compressive stresses prevents crack formation or propagation in the glass shell for an unlimited period of time (no aging).
The combination of compressive and tensile stresses in the glass shell body gives toughened glass insulators the unique property of always breaking in a predictable pattern when overstressed mechanically or electrically.
Crumbling of the glass shell always results in small corn-size chunks with no razor–edged shards.

Sediver Toughened Glass offers features not available with porcelain or composite insulators, the most highly appreciated by users worldwide being:

- **Endurance and no aging**
  Sediver Toughened Glass have the unique ability to resist the effects of time and the elements with no degradation of mechanical or electrical performance for the following reasons:
  • Toughened glass shell is immune to the effects of micro-crack propagation with time and load / temperature cycling, which is typical of porcelain.
  • The hot cured alumina cement used in Sediver Toughened Glass insulators is very strong, stable, and immune to any cement growth phenomena.
  • A highly automated manufacturing process, perfected along the years by Sediver, guarantees an extremely homogenous and consistently high level of quality in the materials and the final product assembly. The stability over time of the quality of Sediver Toughened Glass is demonstrated not only by in-service experience records but also by numerous laboratory test results which confirm that the fluctuation of normal electrical, mechanical and thermal stresses over many decades does not degrade the electrical or mechanical characteristics of Sediver Toughened Glass insulators.

- **Live-line maintenance:**
  Sediver Toughened Glass insulators are, above any other technology, highly suitable for safe live-line maintenance operations.

Live-line maintenance and worker safety

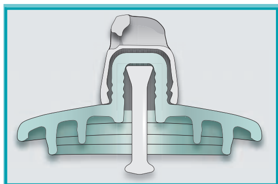
While more and more utilities are faced with the technical and economical challenge of keeping their lines energized "whatever happens", live-line work is often a necessity. Live-line maintenance requires specialized crews and equipment and rigorous procedures which generates higher cost than traditional de-energized maintenance operations. However the financial impact of live-line maintenance is negligible compared to shutting down a line.

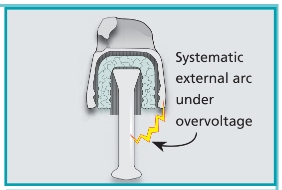
Before working on a live line, maintenance crews have to assess the condition of insulator strings to avoid risks of flashover or mechanical failure while they are working on them. Doing this assessment in safe manner is very expensive with porcelain, and even more so with polymer insulators without highly sophisticated and specialized thermal imaging, corona inspection or e-field measurement equipment. Thanks to the unique properties of toughened glass, which cannot have hidden puncture nor become conductive due to tracking, maintenance crews can do live-line work in full confidence since there are no hidden risks due to internally damaged insulators. A simple glance at the string gives a complete and reliable assessment of the electrical condition of each insulator. Even with a missing shell, Sediver remaining stub is non-conducting and maintains a guaranteed mechanical strength (at least 80% of the rating) to safely support the line.

Toughened glass design features and advantages

❑ High residual strength and no risk of line drop:

Sediver Toughened Glass insulators can only exist in two well defined conditions: intact or shattered. There is no intermediate cracked or punctured state. Therefore it is easy to quickly and infallibly inspect strings of toughened glass, with no need for instruments other than the naked eye.





Shell intact	Shell shattered
Guaranteed absence of internal cracks or electrical punctures.	- **Residual mechanical strength** 80% of the mechanical rating, guaranteed over prolonged periods of time even with in-service dynamic loads and temperature cycling. - **Residual electrical strength** Avoiding internal puncture and forcing overvoltage induced discharges externally.

Therefore

- No need of instruments for condition inspection of glass insulator strings.
- Enhanced worker's safety in live line operations.
- Very low cost of inspection for the entire service life of the line.
- No risk of separation or line drops.
- No urgency in replacing a unit with broken shell.
- Long-term savings in maintenance operations.

❑ Safety in handling and construction

Because of the impossibility of hidden internal damage, it is not possible to install mistakenly a faulty string of Sediver Toughened Glass insulators.

❑ Puncture resistance

Thanks to the homogeneous and amorphous internal structure of the toughened glass shell, Sediver insulators resist the most extreme surges such as switching surges, steep front lightning strikes and power arcs. There can be no hidden puncture in a Sediver Toughened Glass insulator.

❑ Environmental considerations

• Complete recycling: toughened glass insulators are made of fully recyclable components, so they do not represent an environmental liability.

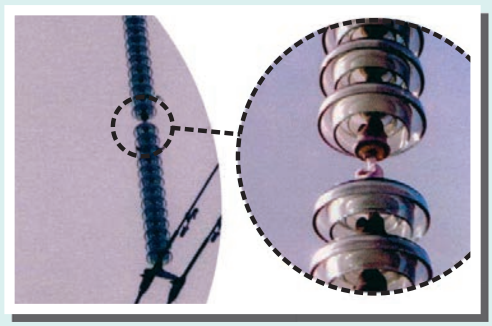
• Visual impact: toughened glass insulators, thanks to their transparency, easily blend with the sky or any background and consequently have minimal visual impact once installed on any line.

Infallible and easy visual inspection and low maintenance costs: Reliability at a glance

Power supply reliability is of great concern to all utilities. With time, as HV systems age, utilities need to carry out more frequent diagnostics of their lines and insulation in order to prevent unforeseen failures.

Inspection of porcelain and particularly composite insulators is recognized as being very difficult. For both of them, a visit to each support structure by a ground or helicopter crew is necessary in order to "buzz" or examine the insulators with specialized equipment.

On the other hand, with toughened glass, if the external shell is visible, the insulator is good. A damaged glass shell will instantly reveal its condition by shattering into small fragments. Sediver remaining "stub" is electromechanically sound.



Condition assessment of Sediver Toughened Glass insulator strings can therefore be accomplished by a simple "at-a-glance" inspection from a distance by ground patrol or from a helicopter, without the need to climb towers. Complete 100 % inspection of each insulator can be done by helicopter at a rate of up to 100 line-miles per hour, for any voltage level.

Therefore, the inspection and condition assessment of long and remote glass insulated HV lines can be done very quickly and at a fraction of the cost required for lines equipped with porcelain or composite insulators. To achieve such a complete and reliable inspection, porcelain and composite insulators need to be individually tested, an operation which is prohibitively expensive and not practical for long lines.

Due to their long life and ease of inspection, Sediver Toughened Glass insulators offer the lowest life cycle cost of all insulating solutions.

Sediver's unique manufacturing processes

The Sediver design and manufacturing processes have been developed over the past 60 years, taking advantage of know-how gained from millions of insulators supplied and leading to the emergence of new technologies, with always the same goal in mind: **the highest performance and reliability.**

Sediver's unique processes

Glass composition and melting

Sediver glass is obtained through a unique melting process based on the use of a specific furnace technology and proprietary Sediver manufacturing process control and parameters.
The technology developed by Sediver :

- Ensures an outstanding homogeneity in the chemical composition of the glass
- Provides high purity glass without heterogeneity

Molding

Our unique know-how enables us to create complex glass shapes and products up to 16.5" (420 mm) in diameter and weighing more than 22 lbs. (10 kg).

Toughening

The toughening process developed by Sediver generates a permanent compressive pre-stress on the surface of the glass shells which confers to the glass :

- high mechanical strength
- high resistance to thermal shocks and mechanical impacts
- immunity to the effects of aging

Thanks to the toughening, the behavior of the dielectric shell becomes binary:
1) either the glass is intact: no possible internal cracks nor puncture
2) or the glass is shattered: the glass is no longer visible outside the metal cap (stub)

Assembly of the glass shell with metal fittings

The assembly of Sediver glass insulators is done by a specific hot curing process, using a chemically inert cement (high strength aluminous cement).
Thanks to this process our insulators offer:

- outstanding mechanical stability over time
- very high residual mechanical strength

Systematic control and inspection of the insulators during manufacturing

Guaranteed quality thanks to continuous inspection and control of the production lines

- All glass shells undergo specific and repeated thermal shocks and successive quality controls so as to eliminate pieces that could present defects
- All insulators are subjected to stringent quality inspection by automated systems

The entire process is constantly monitored by highly qualified inspectors.

User benefits

Appropriate solutions

Thanks to the different shapes of the glass shells and to mechanical strengths ranging up to 170 klbs., Sediver offers solutions adapted to all applications and the most varied environmental conditions.

Easy installation, inspection and detection

As Sediver glass insulators are very resistant to mechanical shocks, the stringing and line construction is much easier. The number of accidentally damaged insulators is significantly lower than with porcelain and polymer insulators.
As the detection of any damages during installation is evident and immediate, the risk of installing a damaged unit is non-existent.

Reduced inspection and maintenance costs

- Unlike other materials, such as porcelain or composites, a quick and easy visual inspection is enough to identify the state of the toughened glass insulators and this without any possible mistake. The inspection costs are thus reduced to a minimum throughout the life cycle of the line.
- Sediver toughened glass insulators are unpuncturable and resistant to overvoltage stresses thanks to a defect-free dielectric body and the homogeneity of the glass shell.
- The shattering rate of glass shells in service is negligible thanks to the high purity of Sediver glass.
- The residual mechanical strength of Sediver glass insulators remains almost unchanged compared to an intact insulator thanks to unique hot cured aluminous cement assembly process. Therefore, there is no urgency to replace an insulator with a broken glass shell.

Asset longevity

The life time of Sediver glass insulators equals or exceeds the life time of the conductors, hardware and structure. Since they do not age, there is no need to replace the insulators during the life of the line.

Product consistency and traceability

As Sediver technology and quality are homogenous throughout all its production sites, Sediver can therefore guarantee full consistency of its product performance worldwide.
Each insulator is marked with the manufacturing plant's identification code and the production batch.

The marking and QA system implemented by Sediver allow total traceability of our insulators.

Sediver toughened glass: beyond standard performance

When developing and manufacturing toughened glass insulators, Sediver does not limit itself to minimum standard requirements but offers a superior level of performance to its products providing higher safety margins and benefits for end-users.

Comparison of ANSI requirements and Sediver criteria

Type of test	Test designation	ANSI C29.2B-2013 requirements	Sediver criteria	User benefits
Design tests	**Thermal-mechanical load-cycle test** • Four 24-hour cycles of temperature variation • After the thermal cycles, the insulators are subjected to mechanical test up to breakage	Test on 10 units Temperature range: -22°F/ +104°F Applied tensile load: 60% of the rating Evaluation: $\overline{X}$ ≥ rating + 3 S	Test on 20 units Temperature range:-60° F/ +120°F 10 units followed by a steep front wave impulse test: no puncture Applied tensile load: 70% of the rating Evaluation: $\overline{X}$ ≥ rating + 4 S*	**High reliability along service life** • No aging • High mechanical strength even in case of extreme service conditions or natural disasters
	Residual strength test Mechanical tensile load test on 25 insulator units which have had the shells completely broken off	No thermal cycles Evaluation : $\overline{X}$ ≥ 0.6 x rating + 1.645 S	Test on insulators after thermal cycles Evaluation: $\overline{X}$ ≥ 0.8 x rating + 1.645 S	**Reduced maintenance costs** High residual strength means that replacement is not urgent and can be safely scheduled. This results in reduced maintenance costs
	Impact test	45 to 90 in-lbs	400 in-lbs	**Reduced damages** High impact strength reduces damages during handling and installation
Quality conformance tests (on each lot)	**Combined Mechanical and Electrical test** A mechanical tensile load is applied to insulator units up to failure	Evaluation: $\overline{X}$ ≥ rating + 3 S Individual values ≥ rating	Evaluation: $\overline{X}$ ≥ rating + 4 S* Individual values ≥ rating	**Reinforced reliability** A narrow standard deviation is the result of high quality components and manufacturing; this means enhanced safety and dependability
	Power-frequency puncture test	A low frequency voltage is applied to the insulator units immersed in oil	• A steep front wave impulse simulating real lightning stress is applied to the insulator units with a peak voltage of 2.8 p.u. (see IEC 61211) • No puncture allowed	**No risk of puncture** • Even in case of lightning
Routine test	**Visual inspection**	None	• Inspection whether there are no visual defects that would be prejudicial to satisfactory performance in service • Marking verification	**Complete traceability** • Complete identification of each insulator • Quality Control full traceability to the finished product
	Tension proof test	50 % Rating	• 50 % Rating • Marking proving that each insulator passed the routine test	**Guarantee** that each insulator passed the mechanical test
	Dimensional verification	None	Spacing verification of each unit	**Dimensional conformity** • Guarantee of the string spacing • Easy installation
	Thermal shocks	One cold-to-hot shock One hot-to-cold shock	Such as required by ANSI with additional thermal treatments specific to Sediver on each glass shell	**Reduced operating cost** • Extremely low shattering rate in service thanks to a very high quality glass

S : Standard deviation of the test results $\overline{X}$: average value of test results

*Upon request

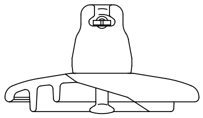
Sediver toughened glass suspension insulators

Dielectric shell profiles

Throughout decades, Sediver engineers have developed and designed different types of insulators adapted to all climates and environments, such as described in technical standard IEC 60815-1.

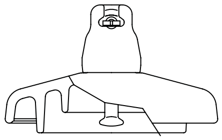
Standard profile:

The standard profile is characterized by a leakage distance* higher than the values indicated in the ANSI C29.2B and by well-spaced under-ribs that allow an effective self-cleaning action by wind or rain. It features a "leakage distance/spacing" ratio of around 2.2 and is particularly effective in suspension and tension applications in very light to medium polluted areas where typically the pollution level (ESDD) is lower than 0.1 mg/cm^2. (Examples: zones E1 to E4).



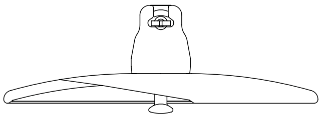
Fog type profile:

The fog type profile is characterized by long and widely-spaced under-ribs so as to avoid arc bridging between adjacent ribs. It features a « leakage distance/spacing » ratio of around 3.2 and is particularly effective in coastal areas (Salt fog) as well as in polluted areas where a higher specific leakage distance is required. (Examples: areas E5 to E7).



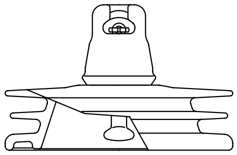
Open profile:

The open type profile features a « leakage distance/spacing » ratio of around 2.4, with no under-ribs so as to avoid the accumulation of solid pollution deposits (dust, sand) on its lower surface. It is particularly adapted to suspension and tension applications in dry desertic areas where wind is predominant and rain infrequent. (Example: areas E1 to E4).
It is also effective for dead-end strings in cases of extreme industrial pollution and can solve ice-bridging problems when it is alternated with others profiles in the string.



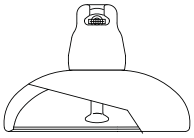
External shed profile:

This profile offers a leakage distance equivalent to the anti-pollution profile and is adapted to the most extreme cases of solid pollution.
The elimination of the under-ribs reduces pollution build-up, promotes self-cleaning and facilitates manual cleaning when necessary.



Spherical profile:

The spherical shape offers a leakage distance equivalent to that of standard profile type. With a spherical profile manual cleaning is easy and effective.

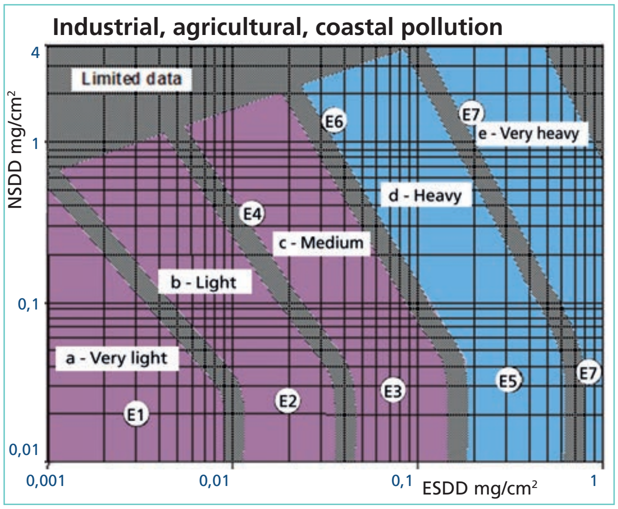


* or creepage distance

Selection criteria for pollution management

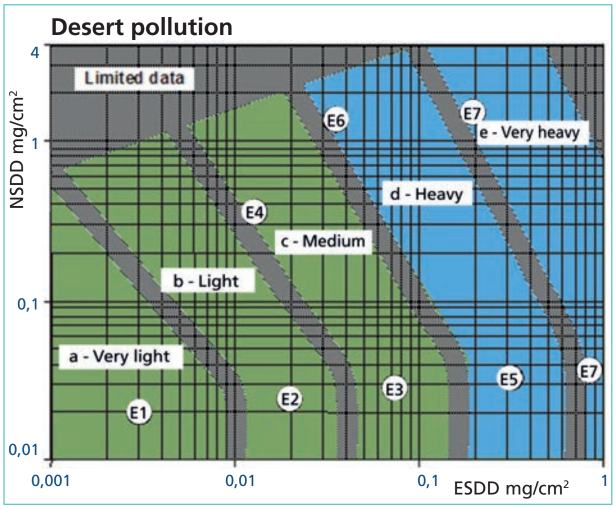
Choice of the insulator profile

Technical standard IEC 60815-1 defines 5 levels of pollution according to the pollution severity: very light, light, medium, heavy and very heavy.
The levels of pollution are defined according to the Equivalent Salt Deposit Density (ESDD) and the Non-Soluble Deposit Density (NSDD) on the surface of the insulator.



Standard type   Fog type

In the case of industrial, agricultural and coastal pollution, Sediver recommends the use of the standard profile in very light, light and medium polluted areas and the fog type profile in heavy and very heavy polluted areas.

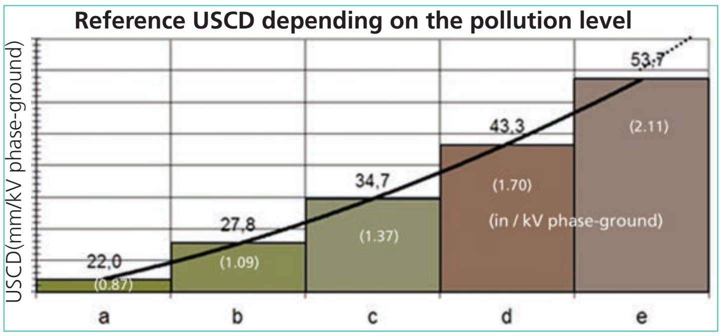


Open type   Fog type

In the case of desert pollution Sediver recommends the use of the open profile in very light, light and medium polluted areas and the fog type profile in heavy and very heavy polluted areas.

Choice of insulation level

The number of insulators per string depends on the maximum voltage of the transmission line and the pollution severity of the region.
It should be calculated in accordance with the specific creepage distance (USCD*) as defined by the IEC 60815-2 standard.



Pollution level

(*) USCD = Leakage distance of the string of insulators divided by the RMS value of the highest power frequency voltage seen by the string (phase - ground).

String dimensioning example:
For a 500 kV line,
(max. phase-ground voltage: 525 / √ 3=303 kV)
located on the coast in a heavy pollution level
Selected insulator: N 180P / 160
(fog type profile with 21 $^{1/2}$ in leakage distance)

Total leakage distance needed:
- 1.7 x303 = **515.1 inch.**

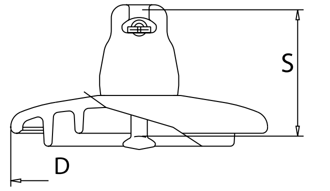
Number of insulators in the string:
- 515.1 / 21.5 = 24 **insulators.**

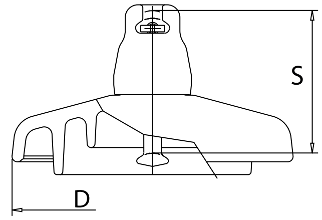
SEDICOAT : RTV coated glass

In cases of extreme pollution when regular washing of the insulator strings may become necessary,
Sediver offers **Sedicoat®**:
Sediver silicone coated toughened glass insulator
(see page13)

Sediver toughened glass suspension insulators

Ball & Socket coupling





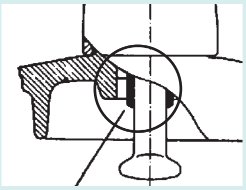
		Standard Profile			Fog Profile		
CATALOG No		**N100/146**	**N14/146**	**N180/146**	**N100P/146DC**	**N14P/146DC**	**N180P/160DC**
ANSI class		52-3-H	52-5-H	52-8-H			
Ball and socket coupling		Type B	Type J	Type K	Type B	Type J	Type K
MECHANICAL CHARACTERISTICS							
Combined M&E strength	lbs	22,000	30,000	40,000	22,000	30,000	40,000
	kN	*100*	*136*	*180*	*100*	*136*	*180*
Impact strength	in-lbs	400	400	400	400	400	400
	N-m	*45*	*45*	*45*	*45*	*45*	*45*
Tension proof	lbs	11,000	15,000	20,000	11,000	15,000	20,000
	kN	*50*	*68*	*90*	*50*	*68*	*90*
DIMENSIONS							
Diameter (D)	in	10	10	11	11	11	13
	mm	*255*	*255*	*280*	*280*	*280*	*330*
Spacing (S)	in	5 3/4	5 3/4	5 3/4	5 3/4	5 3/4	6 1/3
	mm	*146*	*146*	*146*	*146*	*146*	*160*
Leakage distance	in	12 5/8	12 5/8	15	17 1/2	17 1/2	21 1/2
	mm	*320*	*320*	*380*	*445*	*445*	*545*
ELECTRICAL CHARACTERISTICS							
Low frequency dry flashover	kV	80	80	80	90	90	100
Low frequency wet flashover	kV	50	50	50	55	55	60
Critical impulse flashover +	kV	125	125	125	140	140	145
Critical impulse flashover -	kV	130	130	130	140	140	145
Low frequency puncture voltage	kV	130	130	130	130	130	130
R.I.V low frequency test voltage	kV	10	10	10	10	10	10
Max. RIV at 1 MHz	µV	50	50	50	50	50	50
PACKING AND SHIPPING DATA							
Approx. net weight per unit	lbs	8.8	10	14.1	12.8	13.2	19.4
No of insulators per crate		6	6	6	6	6	6
Volume per crate	ft³	1.977	1.977	2.472	2.47	2.47	2.82
Gross weight per crate	lbs	59.5	66.7	92.7	84.9	87.3	126.4
No. of insulators per pallet		72| 96	72| 96	54	54	54	54
Volume per pallet	ft³	35.3| 49.4	35.3| 49.4	42.3	42.3	42.3	46
Gross weight per pallet	lbs	790| 1050	880| 1165	934	862	886	1245
Former designation		**N8**	**N14**	**N18**	**N8HL**	**N14HL**	

ANSI designations 52-3-L, 52-5-L, 52-8-L and custom products are also available

Corrosion prevention solutions

Corrosion prevention sleeve

In severely corrosive marine and industrial atmospheres, the galvanized coating on suspension insulator pins may deteriorate over time and be followed by corrosion of the pin itself. To prevent this form of pin damage, Sediver can supply insulators equipped with a corrosion prevention sleeve made of high-purity zinc. The insulators are then designated by "DC" (N100P/146 with zinc sleeve becomes N100P/146DC).



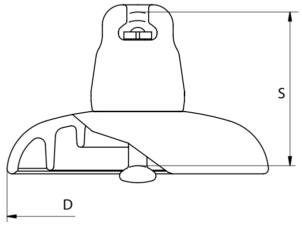
Corrosion prevention sleeve

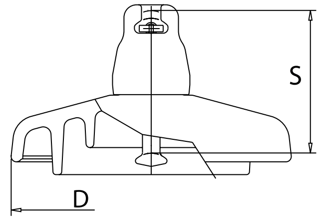
Heavy galvanization

All Sediver ferrous metal fittings are hot-dip galvanized. ANSI C29.2B and ASTM A153 require a zinc coating mass of 2.00/1.80 oz/ft² (610/550 g/m²) corresponding to a thickness of 3.4/3.1 mil (86/79 µm). In severe conditions, where this standard protection is known to be insufficient, Sediver offers enhanced protection of the cap and the pin by increasing the thickness of zinc to 4.3/3.9 mil (110/100 µm), or up to 4.9/4.5 mil (125/114 µm), upon request.

Sediver toughened glass suspension insulators

Ball & Socket coupling



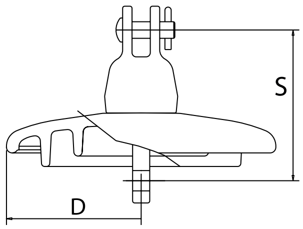


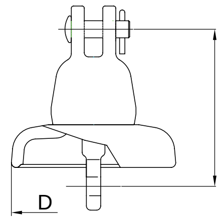
		Standard Profile				Fog Profile	
CATALOG No		**N21/156**	**F300/195**	**F400/205**	**F530/240**	**N21P/171DC**	**F300P/195DC**
ANSI class		52-11					
Ball and socket coupling		Type K	IEC 24	IEC 28	IEC 32	Type K	IEC 24
MECHANICAL CHARACTERISTICS							
Combined M&E strength	lbs	50,000	66,000	90,000	120,000	50,000	66,000
	kN	*222*	*300*	*400*	*530*	*222*	*300*
Impact strength	in-lbs	400	400	400	400	400	400
	N-m	*45*	*45*	*45*	*45*	*45*	*45*
Tension proof	lbs	25,000	33,000	45,000	60,000	25,000	33,000
	kN	*111*	*150*	*200*	*265*	*111*	*150*
DIMENSIONS							
Diameter (D)	in	11	12 5/8	14 1/8	14 1/8	13	14 1/8
	mm	*280*	*320*	*360*	*360*	*330*	*360*
Spacing (S)	in	6 1/8	7 11/16	8 1/16	9 7/16	6 3/4	7 11/16
	mm	*156*	*195*	*205*	*240*	*171*	*195*
Leakage distance	In	15	19	21 5/8	24 7/16	21 1/2	25
	mm	*380*	*480*	*550*	*620*	*545*	*635*
ELECTRICAL CHARACTERISTICS							
Low frequency dry flashover	kV	80	95	100	100	100	105
Low frequency wet flashover	kV	50	55	60	60	60	65
Critical impulse flashover +	kV	140	145	150	150	145	150
Critical impulse flashover -	kV	140	145	150	150	145	150
Low frequency puncture voltage	kV	130	130	130	130	130	130
R.I.V low frequency test voltage	kV	10	10	10	10	10	10
Max. RIV at 1 MHz	μV	50	50	50	50	50	50
PACKING AND SHIPPING DATA							
Approx. net weight per unit	lbs	15.4	24	30.8	39.5	21.4	30.2
N° of insulators per crate		6	5	2	2	6	5
Volume per crate	ft³	2.472	3.531	2.503	2.118	3.04	4.944
Gross weight per crate	lbs	100.5	130	72	83.6	140.4	167
No. of insulators per pallet		54	45	36	36	54	45
Volume per pallet	ft³	42.3	45.9	46.4	55.6	48	39.6
Gross weight per pallet	lbs	1005	1268	1394	1605	1360	1607
Former designation		**N21**				**N222P**	

Custom products are also available

Sediver toughened glass suspension insulators

Clevis coupling CT





		Standard Profile		Ground wire insulator
CATALOG N°		CT100/146	CT14/146	CT14-6/146
ANSI class		52-4-H	52-6-H	
MECHANICAL CHARACTERISTICS				
Combined M&E strength	lbs	22,000	30,000	30,000
	kN	*100*	*136*	*136*
Impact strength	in-lbs	400	400	400
	N-m	*45*	*45*	*45*
Tension proof	lbs	11,000	15,000	15,000
	kN	*50*	*68*	*68*
DIMENSIONS				
Diameter (D)	In	10	10	6
	mm	*255*	*255*	*155*
Spacing (S)	In	5 3/4	5 3/4	5 3/4
	mm	*146*	*146*	*146*
Leakage distance	In	12 5/8	12 5/8	5 1/3
	mm	*320*	*320*	*135*
ELECTRICAL CHARACTERISTICS				
Low frequency dry flashover	kV	80	80	40
Low frequency wet flashover	kV	50	50	20
Critical impulse flashover pos.	kV	125	125	70
Critical impulse flashover neg.	kV	130	130	70
Low frequency puncture voltage	kV	130	130	90
R.I.V low frequency test voltage	kV	10	10	7.5
Max. RIV at 1 MHz	μV	50	50	50
PACKING AND SHIPPING DATA				
Approx. net weight per unit	lbs	8.8	10	4.4
N° of insulators per crate		6	6	6
Volume per crate	ft³	1.977	1.977	0.70
Gross weight per crate	lbs	59.5	66.7	32.2
No. of insulators per pallet		72|96	72|96	150
Volume per pallet	ft³	35.3|49.4	35.3|49.4	28.8
Gross weight per pallet	lbs	790|1050	880|1165	833
Former designation		CT8	CT14	

Sediver model **CT14-6/146** is an ideal solution for supporting and insulating ground (shield) wires.

It can be installed in either suspension or dead-end configurations.

Custom products and clevis insulators for distribution applications are also available

Packing

The methods employed by Sediver to pack and palletize our toughened glass insulators are the result of the experience we gained from shipping hundreds of millions of insulators to warehouses and construction sites in 150 countries worldwide.

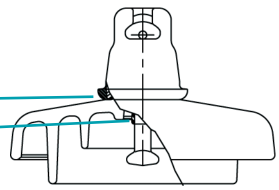
Factory-assembled short strings of Sediver Insulators are packed in wooden crates, which are reinforced and held closed by external wire bindings (no nails are used).

Crate in open position with its internal brace to permit stacking.

Crates are evenly stacked on a sturdy four-way wooden pallet. This assembly is held tightly in place with either steel or plastic bands, and is protected with a polyethylene film.

HVDC applications:
Sediver High Resistivity Toughened Glass insulators

Specific electric stresses resulting from a unidirectional flow of direct electric current require the use of specially designed insulators able to resist corrosion, pollution accumulation and other phenomena directly related to DC field conditions.

HVDC specific stresses	Sediver solution		User benefits
Electrostatic attraction of the dust on insulator surface	Adapted glass shell design with wide spacing between ribs and increased leakage distance		High pollution efficiency : reduced maintenance costs
Unidirectional leakage current leading to metal part corrosion	Protection of the metal fittings Pure zinc collar bonded to the cap Pure zinc sleeve bonded to the pin		Longer life expectancy and no rust deposit on the dielectric
Ionic migration Ionic accumulation	Special glass chemistry imparting high resistance to localized thermal stress and ion flow		No puncture : reduced maintenance costs

For extreme pollution: **Sedicoat® solution**

In case of extreme or exceptional pollution, it may become necessary to wash the glass and porcelain insulators so as to reduce the risk of flashover due to the critical deposit of pollution. Composite insulators can be used in these conditions. Nonetheless, the benefits linked to the hydrophobicity and profile of polymer insulators are outweighed by the difficulties of inspection and diagnosis of aging as well as the added complexity of carrying out live line work.

Sedicoat: no washing is needed anymore

Sedicoat insulators are Sediver toughened glass insulators coated with silicone. The silicone coating procures hydrophobic properties to the surface of the glass shell and thus significantly enhances its electrical performance under extreme pollution. Sedicoat insulators offer a solution that eliminates the need for regular washing in extreme pollution conditions.

The application of the coating is done at the factory according to a specific industrial process qualified by Sediver.

Main advantages:

- Reduce the maintenance cost as there is no need for washing
- Keep the inherent properties of the toughened glass in terms of:
  - easiness and reliability of visual inspection
  - safe live-line working
  - long term electrical and mechanical reliability
  - no aging
- No need to modify tower design
- Can be applied on all glass profiles

A solution confirmed by +1 million insulators in service & 20 years of satisfactory service

Sedicoat is the solution that maintains the unique properties of Sediver toughened glass insulators while eliminating the need for washing under extreme pollution conditions.

Sediver toughened glass suspension insulators

ANSI string electrical ratings

Standard profile

Standard profile suspension insulator string flashover voltages based on the test procedure of the American Standard ANSI C 29.2B.

Catalog N°	Diameter / Spacing Ø 10 / 5 3/4 - Ø 11 / 5 3/4				Diameter / Spacing Ø 11 / 6 1/8			
	N100/146 - N14/146 - N 180/146				N21/156			
Number of units	Low frequency flashover voltage (kV)		Critical impulse flashover voltage (kV)		Low frequency flashover voltage (kV)		Critical impulse flashover voltage (kV)	
	DRY	WET	+	-	DRY	WET	+	-
2	145	90	220	225	145	90	230	230
3	205	130	315	320	210	130	325	330
4	270	170	410	420	275	170	425	440
5	325	215	500	510	330	215	515	540
6	380	255	595	605	385	255	610	630
7	435	295	670	695	435	295	700	720
8	485	335	760	780	490	335	790	810
9	540	375	845	860	540	375	880	900
10	590	415	930	945	595	415	970	990
11	640	455	1015	1025	645	455	1060	1075
12	690	490	1105	1115	695	490	1150	1160
13	735	525	1185	1195	745	525	1240	1245
14	785	565	1265	1275	790	565	1330	1330
15	830	600	1345	1360	840	600	1415	1420
16	875	635	1425	1440	890	635	1500	1510
17	920	670	1505	1530	935	670	1585	1605
18	965	705	1585	1615	980	705	1670	1700
19	1010	740	1665	1700	1025	740	1755	1795
20	1050	775	1745	1785	1070	775	1840	1890
21	1100	810	1825	1870	1115	810	1925	1985
22	1135	845	1905	1955	1160	845	2010	2080
23	1180	880	1985	2040	1205	880	2095	2175
24	1220	915	2065	2125	1250	915	2180	2270
25	1260	950	2145	2210	1290	950	2260	2365
26	1300	985	2220	2295	1330	958	2390	2465
27	1340	1015	2300	2380	1370	1015	2470	2555
28	1380	1045	2375	2465	1410	1045	2570	2650
29	1425	1080	2455	2550	1455	1080	2650	2740
30	1460	1110	2530	2635	1490	1110	2740	2830

These electrical ratings are applicable to Sediver suspension insulator strings not equipped with arcing devices or grading rings.
According to the American Standard the average value of three tested strings shall equal or exceed:
95% of the guaranteed values as given in the data sheet, for low frequency dry flashover,
90% of the guaranteed values as given in the data sheet, for low frequency wet flashover,
92% of the guaranteed values as given in the data sheet, for critical impulse flashover.

Sediver toughened glass suspension insulators

ANSI string electrical ratings

Fog type profile

Fog type profile suspension insulator string flashover voltages based on the test procedure of the American Standard ANSI C 29.2B.

Catalog N°	Diameter / Spacing Ø 11 / 5 3/4 N100P/146DC - N14P/146DC				Diameter / Spacing Ø 13 / 6 3/4 N21P/171DC			
Number of units	Low frequency flashover voltage (kV)		Critical impulse flashover voltage (kV)		Low frequency flashover voltage (kV)		Critical impulse flashover voltage (kV)	
	DRY	WET	+	-	DRY	WET	+	-
2	155	95	270	260	160	110	315	300
3	215	130	380	355	230	145	440	410
4	270	165	475	435	290	155	550	505
5	325	200	570	520	350	225	660	605
6	380	240	665	605	405	265	775	705
7	435	275	750	690	460	310	870	800
8	485	315	835	775	515	355	970	900
9	540	350	920	860	570	390	1070	1000
10	590	375	1005	950	625	430	1170	1105
11	640	410	1090	1040	680	460	1270	1210
12	690	440	1175	1130	735	495	1370	1315
13	735	470	1260	1220	790	530	1465	1420
14	785	500	1345	1310	840	565	1565	1525
15	830	525	1430	1400	885	595	1665	1630
16	875	555	1515	1490	935	630	1765	1735
17	920	580	1600	1595	980	660	1860	1845
18	965	615	1685	1670	1030	690	1960	1945
19	1010	640	1770	1755	1075	725	2060	2040
20	1055	670	1850	1840	1120	755	2155	2140
21	1100	695	1930	1925	1165	785	2245	2240
22	1145	725	2010	2010	1210	820	2340	2340
23	1190	750	2090	2095	1255	850	2430	2440
24	1235	780	2170	2180	1300	885	2525	2540
25	1280	810	2250	2265	1345	910	2620	2635
26	1325	835	2330	2350	1385	945	2710	2735
27	1370	860	2410	2435	1430	975	2805	2835
28	1410	890	2490	2520	1470	1005	2900	2935
29	1455	915	2560	2600	1515	1035	2980	3025
30	1495	940	2630	2680	1555	1065	3060	3120

These electrical ratings are applicable to Sediver suspension insulator strings not equipped with arcing devices or grading rings.
According to the American Standard the average value of three tested strings shall equal or exceed:
95% of the guaranteed values as given in the data sheet, for low frequency dry flashover,
90% of the guaranteed values as given in the data sheet, for low frequency wet flashover,
92% of the guaranteed values as given in the data sheet, for critical impulse flashover.

Contribution to international committees

Since the very beginning of international technical cooperation, Sediver has always been an active member in fields of research and standardization in international committees and working groups dealing with all aspects of high voltage insulation; for example Sediver experts are Project Leaders in IEC working groups 36WG11, 36BMT10, CIGRE D1-B2 and contribute to the activities of NEMA-ANSI, IEEE and CSA standard Committees.

List of some IEEE and international publications on glass:

- GEORGE JM., PRAT S., VIRLOGEUX F. *"Coating Glass Insulators for Service in Severe Environments"* INMR Quarter 4 2014
- GEORGE JM., LODI Z. *"Mechanical and electrical behaviour of a damaged toughened glass insulator"* EDM - Fort Collins USA 2014
- GEORGE JM., PRAT S., TARTIER S., LODI Z. *"Electrical characteristics and properties of a stub"* ISH 2013 SEOUL, KOREA
- GEORGE JM., DEL BELLO E. *"Assessment of electrical and mechanical performance of toughened glass insulators removed from existing HV lines"* CIGRE REGIONAL MEETING – CALGARY AUGUST 2007
- PAIVA O ; SUASSUNA R ; DUMORA D ; PARRAUD R ; FERREIRA L ; NAMORA M *"Recommendations to solve corrosion problem on HV insulator strings in tropical environment"* CIGRE SYMPOSIUM CAIRNS 2001 Paper 300-05
- DUMORA , R. PARRAUD *"Corrosion mechanism of insulators in tropical environment"* CIGRE SYMPOSIUM CAIRNS 2001 Paper 300-04
- PARRAUD R ; PECLY H *"Long term performance of toughened glass insulators on AC and DC transmission lines : improvement, field experience and recommendations"* CIGRE INTERNATIONAL WORKSHOP ON INSULATORS – RIO JUNE 1998
- CROUCH A ; SWIFT D ; PARRAUD R ; DE DECKER D *"Aging mechanisms of AC energised insulators"* CIGRE 1990 Paper 22-203
- PARRAUD R ; LUMB C ; SARDIN JP *"Reflexions on the evaluation of the long term reliability of ceramic insulators"* IEEE WG INSUL.STRENGTH RATING 1987
- PARGAMIN L ; PARRAUD R *" A key for the choice of insulators for DC transmission lines"* IEEE HVDC TRANSMISSION MADRAS 1986
- PARRAUD R ; LUMB C *"Lightning stresses on overhead lines"* IEEE BANGKOK 1985
- MAILFERT R ; PARGAMIN L ; RIVIERE D *"Electrical reliability of DC line insulators"* IEEE ELECTRICAL INSULATION 1981 N° 3
- COUQUELET F ; RIVIERE D ; WILLEM M *"Experimental assessment of suspension insulator reliability"* IEEE CONFERENCE PAPER 1972 Paper 173-8

ISO certifications

All our manufacturing facilities worldwide are certified ISO 9001 & ISO 14001

Catalogs and Technical Brochures

- Sediver HRTG insulators for HVDC applications
- Sedicoat, RTV silicone coated toughened glass insulators
- Sediver toughened glass: endurance

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SEVES

SEDIVER

Sediver toughened glass suspension insulators

ANSI - USA

2015

Sediver, Experts and Pioneers in insulation technology

This catalog presents a selection of the Sediver toughened glass insulator range of products answering the needs of USA customers in term of standards (ANSI), current practices and environmental conditions. ANSI standard C29.2B sets the basic and minimum requirements for wet-process porcelain and toughened glass transmission suspension insulators.
Sediver toughened glass insulators meet and exceed the performance requirements of ANSI standards.

Our expertise

500 million toughened glass insulators installed in more than 150 countries up to 1,000 kV AC & 800 kV DC.

> 6 million toughened glass DC insulators
> 5 million composite insulators up to 735 kV
> 1 million Sedicoat insulators, silicone coated toughened glass insulators for both AC and DC applications
> 50 years of service experience in the USA, with more than 15 million units installed

Research & Development, a permanent and continuous investment

Always on the lookout for continuous technological improvements, Sediver heavily invests in Research and Development. Our research and testing facilities as well as our high voltage CEB laboratory both located in France boast state-of-the-art equipment that allows extensive research programs as well as testing of complete strings for systems up to 800 kV.

Worldwide presence – reinforced proximity

France	Commercial & Marketing Headquarters Technical Assistance Research & Testing laboratories Logistics Platform
Canada	Sales office Technical Assistance Logistics platforms
USA	Sales office Technical Assistance Logistics platforms
Italy	Sales office Manufacturing plant Testing facilities
Brazil	Sales office Technical Assistance Testing facilities Logistics platform
China	Sales office Technical Assistance Manufacturing plants Testing facilities

- Commercial & Marketing Headquarters
- Center of expertise and R&D laboratories
- Manufacturing plants and Logistics platforms
- Sales offices

Unique manufacturing processes

Sediver manufacturing processes are unique.
These processes have been developed and improved thanks to the experience Sediver has gained over 60 years following-up and assessing the performance of millions of insulators in service as well as through the integration of the latest technological innovations.

Sediver, our experts at your service

In-depth technical expertise

Our team of multidisciplinary and highly skilled engineers is dedicated to the research and development of optimum solutions in the field of high-voltage insulation and protection.

Innovative products

Our engineers and scientists are always searching for new materials, products, designs and technologies that will contribute to improve the performance and the reliability of your systems while reducing the environmental impact and carbon footprint.

Sediver technical assistance

Our technical assistance teams help you throughout all the stages of the insulation related matters from the selection of the optimum insulation solution to the monitoring of performance in service.
We offer specifically:

- Testing and evaluation programs
- Joint research programs related to solving insulation issues
- Training programs dedicated to design, handling, construction and maintenance teams
- End-of-life and failure diagnostics
- Optimization of line insulation for polluted environments

State of the art research and testing facilities

The equipment and facilities of our six research and testing centers ensure the development of insulators with excellent long term behavior and performance.

> Investigation and research in material science:
Vital to ensure a high level of performance and reliability of our insulators

> Mechanical endurance testing:
Essential to designing insulators with excellent long term behavior under extreme service conditions

> Evaluation of the insulators' electrical performance:
Fundamental to assess the performance of any type of insulator string configuration

> Evaluation of the pollution performance of insulators and complete strings:
Critical for the choice of the right insulator adapted to each specific environmental condition

Overview of main testing equipment per country

	Brazil	China	France	Italy
Dielectric tests on insulator units	✔	✔	✔	✔
Dielectric tests on complete strings			✔	
AC Salt-fog Pollution tests			150 kV	40 kV
AC Solid layer Pollution tests			250 kV	
DC Pollution tests (salt fog/solid layer)			120 kV	
DC Sample tests according to IEC 61325	✔	✔	✔	✔
DC Type tests according to IEC 61325			✔	
Mechanical tests on insulator units	✔	✔	✔	✔
Thermal-mechanical tests	✔	✔	✔	✔
Long duration vibration tests on complete strings			✔	
Standard sample tests according to national and international standards	✔	✔	✔	✔

Sediver laboratories are all ISO 9001 or ISO 17025 certified

Toughened glass design features and advantages...

What is Toughened Glass?

The toughening process consists in inducing pre-stresses to the glass shell by a rapid and precisely controlled cooling of the still hot molded glass. The pre-stresses result in compressive forces on the outer surface layer balanced by tensile forces inside the body of the glass shell.
The presence of permanent outer surface compressive stresses prevents crack formation or propagation in the glass shell for an unlimited period of time (no aging).
The combination of compressive and tensile stresses in the glass shell body gives toughened glass insulators the unique property of always breaking in a predictable pattern when overstressed mechanically or electrically.
Crumbling of the glass shell always results in small corn-size chunks with no razor–edged shards.

Sediver Toughened Glass offers features not available with porcelain or composite insulators, the most highly appreciated by users worldwide being:

- **Endurance and no aging**
  Sediver Toughened Glass have the unique ability to resist the effects of time and the elements with no degradation of mechanical or electrical performance for the following reasons:
  • Toughened glass shell is immune to the effects of micro-crack propagation with time and load / temperature cycling, which is typical of porcelain.
  • The hot cured alumina cement used in Sediver Toughened Glass insulators is very strong, stable, and immune to any cement growth phenomena.
  • A highly automated manufacturing process, perfected along the years by Sediver, guarantees an extremely homogenous and consistently high level of quality in the materials and the final product assembly. The stability over time of the quality of Sediver Toughened Glass is demonstrated not only by in-service experience records but also by numerous laboratory test results which confirm that the fluctuation of normal electrical, mechanical and thermal stresses over many decades does not degrade the electrical or mechanical characteristics of Sediver Toughened Glass insulators.

- **Live-line maintenance:**
  Sediver Toughened Glass insulators are, above any other technology, highly suitable for safe live-line maintenance operations.

Live-line maintenance and worker safety

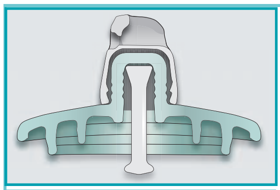
While more and more utilities are faced with the technical and economical challenge of keeping their lines energized "whatever happens", live-line work is often a necessity. Live-line maintenance requires specialized crews and equipment and rigorous procedures which generates higher cost than traditional de-energized maintenance operations. However the financial impact of live-line maintenance is negligible compared to shutting down a line.

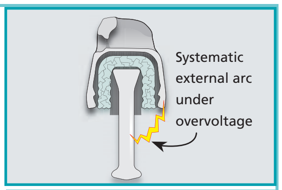
Before working on a live line, maintenance crews have to assess the condition of insulator strings to avoid risks of flashover or mechanical failure while they are working on them. Doing this assessment in safe manner is very expensive with porcelain, and even more so with polymer insulators without highly sophisticated and specialized thermal imaging, corona inspection or e-field measurement equipment. Thanks to the unique properties of toughened glass, which cannot have hidden puncture nor become conductive due to tracking, maintenance crews can do live-line work in full confidence since there are no hidden risks due to internally damaged insulators. A simple glance at the string gives a complete and reliable assessment of the electrical condition of each insulator. Even with a missing shell, Sediver remaining stub is non-conducting and maintains a guaranteed mechanical strength (at least 80% of the rating) to safely support the line.

Toughened glass design features and advantages

❑ High residual strength and no risk of line drop:

Sediver Toughened Glass insulators can only exist in two well defined conditions: intact or shattered. There is no intermediate cracked or punctured state. Therefore it is easy to quickly and infallibly inspect strings of toughened glass, with no need for instruments other than the naked eye.





Shell intact	Shell shattered
Guaranteed absence of internal cracks or electrical punctures.	**- Residual mechanical strength** 80% of the mechanical rating, guaranteed over prolonged periods of time even with in-service dynamic loads and temperature cycling. - **Residual electrical strength** Avoiding internal puncture and forcing overvoltage induced discharges externally.
Therefore	
• No need of instruments for condition inspection of glass insulator strings. • Enhanced worker's safety in live line operations. • Very low cost of inspection for the entire service life of the line.	• No risk of separation or line drops. • No urgency in replacing a unit with broken shell. • Long-term savings in maintenance operations.

❑ Safety in handling and construction

Because of the impossibility of hidden internal damage, it is not possible to install mistakenly a faulty string of Sediver Toughened Glass insulators.

❑ Puncture resistance

Thanks to the homogeneous and amorphous internal structure of the toughened glass shell, Sediver insulators resist the most extreme surges such as switching surges, steep front lightning strikes and power arcs. There can be no hidden puncture in a Sediver Toughened Glass insulator.

❑ Environmental considerations

• Complete recycling: toughened glass insulators are made of fully recyclable components, so they do not represent an environmental liability.

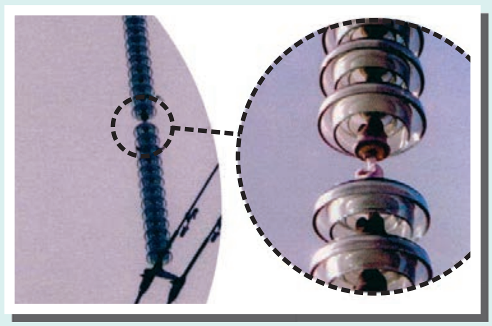
• Visual impact: toughened glass insulators, thanks to their transparency, easily blend with the sky or any background and consequently have minimal visual impact once installed on any line.

Infallible and easy visual inspection and low maintenance costs: Reliability at a glance

Power supply reliability is of great concern to all utilities. With time, as HV systems age, utilities need to carry out more frequent diagnostics of their lines and insulation in order to prevent unforeseen failures.

Inspection of porcelain and particularly composite insulators is recognized as being very difficult. For both of them, a visit to each support structure by a ground or helicopter crew is necessary in order to "buzz" or examine the insulators with specialized equipment.

On the other hand, with toughened glass, if the external shell is visible, the insulator is good. A damaged glass shell will instantly reveal its condition by shattering into small fragments. Sediver remaining "stub" is electromechanically sound.



Condition assessment of Sediver Toughened Glass insulator strings can therefore be accomplished by a simple "at-a-glance" inspection from a distance by ground patrol or from a helicopter, without the need to climb towers. Complete 100 % inspection of each insulator can be done by helicopter at a rate of up to 100 line-miles per hour, for any voltage level.

Therefore, the inspection and condition assessment of long and remote glass insulated HV lines can be done very quickly and at a fraction of the cost required for lines equipped with porcelain or composite insulators. To achieve such a complete and reliable inspection, porcelain and composite insulators need to be individually tested, an operation which is prohibitively expensive and not practical for long lines.

Due to their long life and ease of inspection, Sediver Toughened Glass insulators offer the lowest life cycle cost of all insulating solutions.

Sediver's unique manufacturing processes

The Sediver design and manufacturing processes have been developed over the past 60 years, taking advantage of know-how gained from millions of insulators supplied and leading to the emergence of new technologies, with always the same goal in mind: **the highest performance and reliability.**

Sediver's unique processes

Glass composition and melting

Sediver glass is obtained through a unique melting process based on the use of a specific furnace technology and proprietary Sediver manufacturing process control and parameters.
The technology developed by Sediver :

- Ensures an outstanding homogeneity in the chemical composition of the glass
- Provides high purity glass without heterogeneity

Molding

Our unique know-how enables us to create complex glass shapes and products up to 16.5" (420 mm) in diameter and weighing more than 22 lbs. (10 kg).

Toughening

The toughening process developed by Sediver generates a permanent compressive pre-stress on the surface of the glass shells which confers to the glass :

- high mechanical strength
- high resistance to thermal shocks and mechanical impacts
- immunity to the effects of aging

Thanks to the toughening, the behavior of the dielectric shell becomes binary:
1) either the glass is intact: no possible internal cracks nor puncture
2) or the glass is shattered: the glass is no longer visible outside the metal cap (stub)

Assembly of the glass shell with metal fittings

The assembly of Sediver glass insulators is done by a specific hot curing process, using a chemically inert cement (high strength aluminous cement).
Thanks to this process our insulators offer:

- outstanding mechanical stability over time
- very high residual mechanical strength

Systematic control and inspection of the insulators during manufacturing

Guaranteed quality thanks to continuous inspection and control of the production lines

- All glass shells undergo specific and repeated thermal shocks and successive quality controls so as to eliminate pieces that could present defects
- All insulators are subjected to stringent quality inspection by automated systems

The entire process is constantly monitored by highly qualified inspectors.

User benefits

Appropriate solutions

Thanks to the different shapes of the glass shells and to mechanical strengths ranging up to 170 klbs., Sediver offers solutions adapted to all applications and the most varied environmental conditions.

Easy installation, inspection and detection

As Sediver glass insulators are very resistant to mechanical shocks, the stringing and line construction is much easier. The number of accidentally damaged insulators is significantly lower than with porcelain and polymer insulators.
As the detection of any damages during installation is evident and immediate, the risk of installing a damaged unit is non-existent.

Reduced inspection and maintenance costs

- Unlike other materials, such as porcelain or composites, a quick and easy visual inspection is enough to identify the state of the toughened glass insulators and this without any possible mistake. The inspection costs are thus reduced to a minimum throughout the life cycle of the line.
- Sediver toughened glass insulators are unpuncturable and resistant to overvoltage stresses thanks to a defect-free dielectric body and the homogeneity of the glass shell.
- The shattering rate of glass shells in service is negligible thanks to the high purity of Sediver glass.
- The residual mechanical strength of Sediver glass insulators remains almost unchanged compared to an intact insulator thanks to unique hot cured aluminous cement assembly process. Therefore, there is no urgency to replace an insulator with a broken glass shell.

Asset longevity

The life time of Sediver glass insulators equals or exceeds the life time of the conductors, hardware and structure. Since they do not age, there is no need to replace the insulators during the life of the line.

Product consistency and traceability

As Sediver technology and quality are homogenous throughout all its production sites, Sediver can therefore guarantee full consistency of its product performance worldwide.
Each insulator is marked with the manufacturing plant's identification code and the production batch.

The marking and QA system implemented by Sediver allow total traceability of our insulators.

Sediver toughened glass: beyond standard performance

When developing and manufacturing toughened glass insulators, Sediver does not limit itself to minimum standard requirements but offers a superior level of performance to its products providing higher safety margins and benefits for end-users.

Comparison of ANSI requirements and Sediver criteria				
Type of test	**Test designation**	**ANSI C29.2B-2013 requirements**	**Sediver criteria**	**User benefits**
Design tests	**Thermal-mechanical load-cycle test** • Four 24-hour cycles of temperature variation • After the thermal cycles, the insulators are subjected to mechanical test up to breakage	Test on 10 units Temperature range: -22°F/ +104°F Applied tensile load: 60% of the rating Evaluation: $\overline{X}$ ≥ rating + 3 S	Test on 20 units Temperature range:-60° F/ +120°F 10 units followed by a steep front wave impulse test: no puncture Applied tensile load: 70% of the rating Evaluation: $\overline{X}$ ≥ rating + 4 S*	**High reliability along service life** • No aging • High mechanical strength even in case of extreme service conditions or natural disasters
	Residual strength test Mechanical tensile load test on 25 insulator units which have had the shells completely broken off	No thermal cycles Evaluation : $\overline{X}$ ≥ 0.6 x rating + 1.645 S	Test on insulators after thermal cycles Evaluation: $\overline{X}$ ≥ 0.8 x rating + 1.645 S	**Reduced maintenance costs** High residual strength means that replacement is not urgent and can be safely scheduled. This results in reduced maintenance costs
	Impact test	45 to 90 in-lbs	400 in-lbs	**Reduced damages** High impact strength reduces damages during handling and installation
Quality conformance tests (on each lot)	**Combined Mechanical and Electrical test** A mechanical tensile load is applied to insulator units up to failure	Evaluation: $\overline{X}$ ≥ rating + 3 S Individual values ≥ rating	Evaluation: $\overline{X}$ ≥ rating + 4 S* Individual values ≥ rating	**Reinforced reliability** A narrow standard deviation is the result of high quality components and manufacturing; this means enhanced safety and dependability
	Power-frequency puncture test	A low frequency voltage is applied to the insulator units immersed in oil	• A steep front wave impulse simulating real lightning stress is applied to the insulator units with a peak voltage of 2.8 p.u. (see IEC 61211) • No puncture allowed	**No risk of puncture** • Even in case of lightning
Routine test	**Visual inspection**	None	• Inspection whether there are no visual defects that would be prejudicial to satisfactory performance in service • Marking verification	**Complete traceability** • Complete identification of each insulator • Quality Control full traceability to the finished product
	Tension proof test	50 % Rating	• 50 % Rating • Marking proving that each insulator passed the routine test	**Guarantee** that each insulator passed the mechanical test
	Dimensional verification	None	Spacing verification of each unit	**Dimensional conformity** • Guarantee of the string spacing • Easy installation
	Thermal shocks	One cold-to-hot shock One hot-to-cold shock	Such as required by ANSI with additional thermal treatments specific to Sediver on each glass shell	**Reduced operating cost** • Extremely low shattering rate in service thanks to a very high quality glass
S : Standard deviation of the test results			$\overline{X}$: average value of test results	

*Upon request

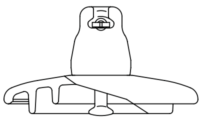
Sediver toughened glass suspension insulators

Dielectric shell profiles

Throughout decades, Sediver engineers have developed and designed different types of insulators adapted to all climates and environments, such as described in technical standard IEC 60815-1.

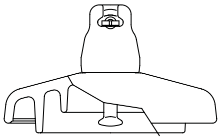
Standard profile:

The standard profile is characterized by a leakage distance* higher than the values indicated in the ANSI C29.2B and by well-spaced under-ribs that allow an effective self-cleaning action by wind or rain. It features a "leakage distance/spacing" ratio of around 2.2 and is particularly effective in suspension and tension applications in very light to medium polluted areas where typically the pollution level (ESDD) is lower than 0.1 mg/cm^2. (Examples: zones E1 to E4).



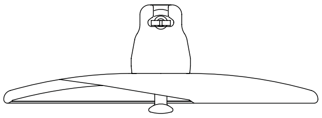
Fog type profile:

The fog type profile is characterized by long and widely-spaced under-ribs so as to avoid arc bridging between adjacent ribs. It features a « leakage distance/ spacing » ratio of around 3.2 and is particularly effective in coastal areas (Salt fog) as well as in polluted areas where a higher specific leakage distance is required. (Examples: areas E5 to E7).



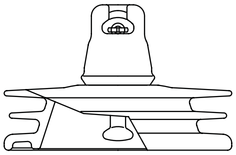
Open profile:

The open type profile features a « leakage distance/spacing » ratio of around 2.4, with no under-ribs so as to avoid the accumulation of solid pollution deposits (dust, sand) on its lower surface. It is particularly adapted to suspension and tension applications in dry desertic areas where wind is predominant and rain infrequent. (Example: areas E1 to E4).
It is also effective for dead-end strings in cases of extreme industrial pollution and can solve ice-bridging problems when it is alternated with others profiles in the string.



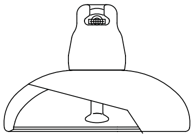
External shed profile:

This profile offers a leakage distance equivalent to the anti-pollution profile and is adapted to the most extreme cases of solid pollution.
The elimination of the under-ribs reduces pollution build-up, promotes self-cleaning and facilitates manual cleaning when necessary.



Spherical profile:

The spherical shape offers a leakage distance equivalent to that of standard profile type. With a spherical profile manual cleaning is easy and effective.



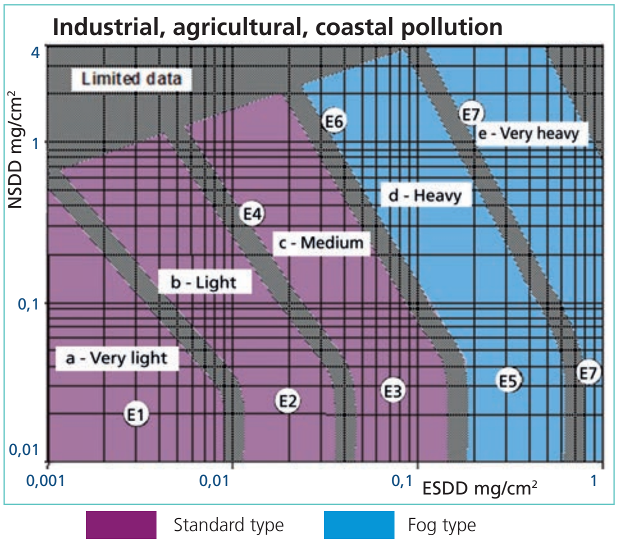
* or creepage distance

Selection criteria for pollution management

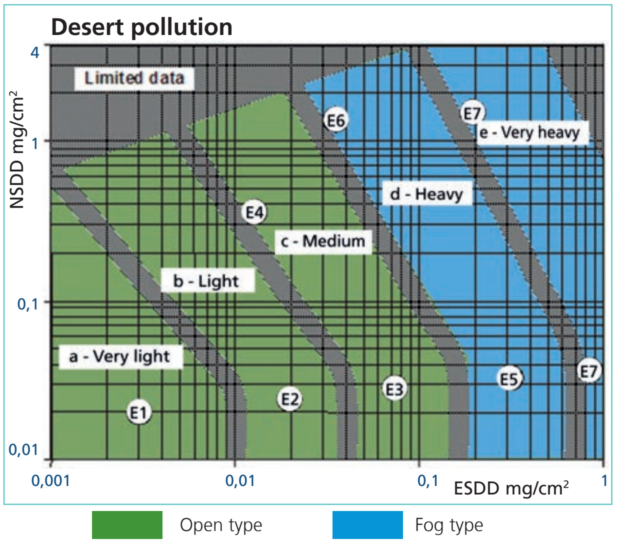
Choice of the insulator profile

Technical standard IEC 60815-1 defines 5 levels of pollution according to the pollution severity: very light, light, medium, heavy and very heavy.

The levels of pollution are defined according to the Equivalent Salt Deposit Density (ESDD) and the Non-Soluble Deposit Density (NSDD) on the surface of the insulator.



In the case of industrial, agricultural and coastal pollution, Sediver recommends the use of the standard profile in very light, light and medium polluted areas and the fog type profile in heavy and very heavy polluted areas.

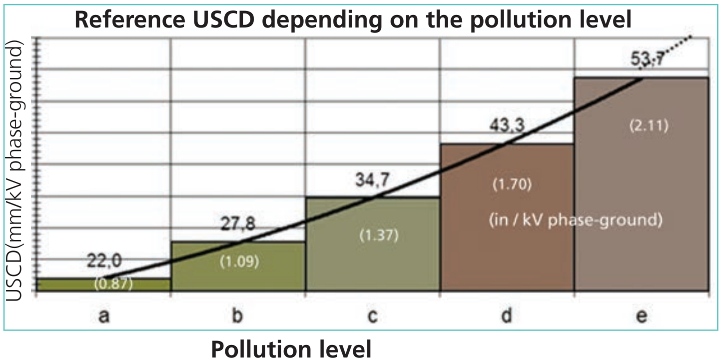


In the case of desert pollution Sediver recommends the use of the open profile in very light, light and medium polluted areas and the fog type profile in heavy and very heavy polluted areas.

Choice of insulation level

The number of insulators per string depends on the maximum voltage of the transmission line and the pollution severity of the region.

It should be calculated in accordance with the specific creepage distance (USCD*) as defined by the IEC 60815-2 standard.



Pollution level

(*) USCD = Leakage distance of the string of insulators divided by the RMS value of the highest power frequency voltage seen by the string (phase - ground).

String dimensioning example:

For a 500 kV line,

(max. phase-ground voltage: 525 / √ 3=303 kV)

located on the coast in a heavy pollution level

Selected insulator: N 180P / 160

(fog type profile with 21 1/2 in leakage distance)

Total leakage distance needed:

- 1.7 x303 = **515.1 inch.**

Number of insulators in the string:

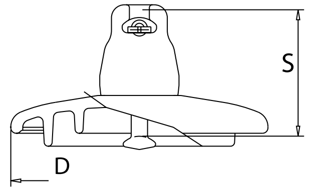
- 515.1 / 21.5 = 24 **insulators.**

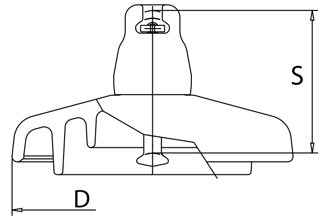
SEDICOAT : RTV coated glass

In cases of extreme pollution when regular washing of the insulator strings may become necessary, Sediver offers **Sedicoat®**: Sediver silicone coated toughened glass insulator (see page13)

Sediver toughened glass suspension insulators

Ball & Socket coupling





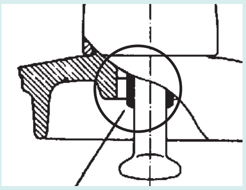
		Standard Profile			Fog Profile		
CATALOG No		**N100/146**	**N14/146**	**N180/146**	**N100P/146DC**	**N14P/146DC**	**N180P/160DC**
ANSI class		52-3-H	52-5-H	52-8-H			
Ball and socket coupling		Type B	Type J	Type K	Type B	Type J	Type K
MECHANICAL CHARACTERISTICS							
Combined M&E strength	lbs	22,000	30,000	40,000	22,000	30,000	40,000
	kN	*100*	*136*	*180*	*100*	*136*	*180*
Impact strength	in-lbs	400	400	400	400	400	400
	N-m	*45*	*45*	*45*	*45*	*45*	*45*
Tension proof	lbs	11,000	15,000	20,000	11,000	15,000	20,000
	kN	*50*	*68*	*90*	*50*	*68*	*90*
DIMENSIONS							
Diameter (D)	in	10	10	11	11	11	13
	mm	*255*	*255*	*280*	*280*	*280*	*330*
Spacing (S)	in	5 3/4	5 3/4	5 3/4	5 3/4	5 3/4	6 1/3
	mm	*146*	*146*	*146*	*146*	*146*	*160*
Leakage distance	in	12 5/8	12 5/8	15	17 1/2	17 1/2	21 1/2
	mm	*320*	*320*	*380*	*445*	*445*	*545*
ELECTRICAL CHARACTERISTICS							
Low frequency dry flashover	kV	80	80	80	90	90	100
Low frequency wet flashover	kV	50	50	50	55	55	60
Critical impulse flashover +	kV	125	125	125	140	140	145
Critical impulse flashover -	kV	130	130	130	140	140	145
Low frequency puncture voltage	kV	130	130	130	130	130	130
R.I.V low frequency test voltage	kV	10	10	10	10	10	10
Max. RIV at 1 MHz	μV	50	50	50	50	50	50
PACKING AND SHIPPING DATA							
Approx. net weight per unit	lbs	8.8	10	14.1	12.8	13.2	19.4
No of insulators per crate		6	6	6	6	6	6
Volume per crate	ft^3	1.977	1.977	2.472	2.47	2.47	2.82
Gross weight per crate	lbs	59.5	66.7	92.7	84.9	87.3	126.4
No. of insulators per pallet		72| 96	72| 96	54	54	54	54
Volume per pallet	ft^3	35.3| 49.4	35.3| 49.4	42.3	42.3	42.3	46
Gross weight per pallet	lbs	790| 1050	880| 1165	934	862	886	1245
Former designation		**N8**	**N14**	**N18**	**N8HL**	**N14HL**	

ANSI designations 52-3-L, 52-5-L, 52-8-L and custom products are also available

Corrosion prevention solutions

Corrosion prevention sleeve

In severely corrosive marine and industrial atmospheres, the galvanized coating on suspension insulator pins may deteriorate over time and be followed by corrosion of the pin itself. To prevent this form of pin damage, Sediver can supply insulators equipped with a corrosion prevention sleeve made of high-purity zinc. The insulators are then designated by "DC" (N100P/146 with zinc sleeve becomes N100P/146DC).



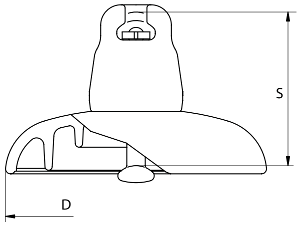
Corrosion prevention sleeve

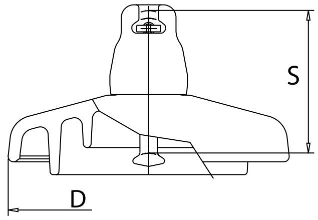
Heavy galvanization

All Sediver ferrous metal fittings are hot-dip galvanized. ANSI C29.2B and ASTM A153 require a zinc coating mass of 2.00/1.80 oz/ft^2 (610/550 g/m^2) corresponding to a thickness of 3.4/3.1 mil (86/79 μm). In severe conditions, where this standard protection is known to be insufficient, Sediver offers enhanced protection of the cap and the pin by increasing the thickness of zinc to 4.3/3.9 mil (110/100 μm), or up to 4.9/4.5 mil (125/114 μm), upon request.

Sediver toughened glass suspension insulators

Ball & Socket coupling



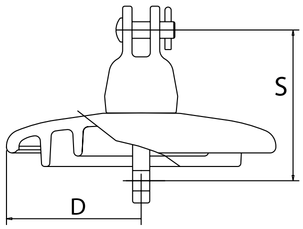


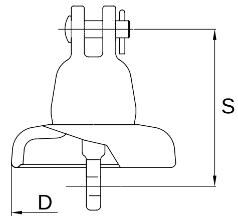
		Standard Profile				Fog Profile	
CATALOG No		**N21/156**	**F300/195**	**F400/205**	**F530/240**	**N21P/171DC**	**F300P/195DC**
ANSI class		52-11					
Ball and socket coupling		Type K	IEC 24	IEC 28	IEC 32	Type K	IEC 24
MECHANICAL CHARACTERISTICS							
Combined M&E strength	lbs	50,000	66,000	90,000	120,000	50,000	66,000
	kN	*222*	*300*	*400*	*530*	*222*	*300*
Impact strength	in-lbs	400	400	400	400	400	400
	N-m	*45*	*45*	*45*	*45*	*45*	*45*
Tension proof	lbs	25,000	33,000	45,000	60,000	25,000	33,000
	kN	*111*	*150*	*200*	*265*	*111*	*150*
DIMENSIONS							
Diameter (D)	in	11	12 5/8	14 1/8	14 1/8	13	14 1/8
	mm	*280*	*320*	*360*	*360*	*330*	*360*
Spacing (S)	in	6 1/8	7 11/16	8 1/16	9 7/16	6 3/4	7 11/16
	mm	*156*	*195*	*205*	*240*	*171*	*195*
Leakage distance	In	15	19	21 5/8	24 7/16	21 1/2	25
	mm	*380*	*480*	*550*	*620*	*545*	*635*
ELECTRICAL CHARACTERISTICS							
Low frequency dry flashover	kV	80	95	100	100	100	105
Low frequency wet flashover	kV	50	55	60	60	60	65
Critical impulse flashover +	kV	140	145	150	150	145	150
Critical impulse flashover -	kV	140	145	150	150	145	150
Low frequency puncture voltage	kV	130	130	130	130	130	130
R.I.V low frequency test voltage	kV	10	10	10	10	10	10
Max. RIV at 1 MHz	μV	50	50	50	50	50	50
PACKING AND SHIPPING DATA							
Approx. net weight per unit	lbs	15.4	24	30.8	39.5	21.4	30.2
N° of insulators per crate		6	5	2	2	6	5
Volume per crate	ft³	2.472	3.531	2.503	2.118	3.04	4.944
Gross weight per crate	lbs	100.5	130	72	83.6	140.4	167
No. of insulators per pallet		54	45	36	36	54	45
Volume per pallet	ft³	42.3	45.9	46.4	55.6	48	39.6
Gross weight per pallet	lbs	1005	1268	1394	1605	1360	1607
Former designation		**N21**				**N222P**	

Custom products are also available

Sediver toughened glass suspension insulators

Clevis coupling CT





		Standard Profile		Ground wire insulator
CATALOG N°		CT100/146	CT14/146	CT14-6/146
ANSI class		52-4-H	52-6-H	
MECHANICAL CHARACTERISTICS				
Combined M&E strength	lbs	22,000	30,000	30,000
	kN	*100*	*136*	*136*
Impact strength	in-lbs	400	400	400
	N-m	*45*	*45*	*45*
Tension proof	lbs	11,000	15,000	15,000
	kN	*50*	*68*	*68*
DIMENSIONS				
Diameter (D)	In	10	10	6
	mm	*255*	*255*	*155*
Spacing (S)	In	5 3/4	5 3/4	5 3/4
	mm	*146*	*146*	*146*
Leakage distance	In	12 5/8	12 5/8	5 1/3
	mm	*320*	*320*	*135*
ELECTRICAL CHARACTERISTICS				
Low frequency dry flashover	kV	80	80	40
Low frequency wet flashover	kV	50	50	20
Critical impulse flashover pos.	kV	125	125	70
Critical impulse flashover neg.	kV	130	130	70
Low frequency puncture voltage	kV	130	130	90
R.I.V low frequency test voltage	kV	10	10	7.5
Max. RIV at 1 MHz	µV	50	50	50
PACKING AND SHIPPING DATA				
Approx. net weight per unit	lbs	8.8	10	4.4
N° of insulators per crate		6	6	6
Volume per crate	ft³	1.977	1.977	0.70
Gross weight per crate	lbs	59.5	66.7	32.2
No. of insulators per pallet		72|96	72|96	150
Volume per pallet	ft³	35.3|49.4	35.3|49.4	28.8
Gross weight per pallet	lbs	790|1050	880|1165	833
Former designation		CT8	CT14	

Sediver model **CT14-6/146** is an ideal solution for supporting and insulating ground (shield) wires.

It can be installed in either suspension or dead-end configurations.

Custom products and clevis insulators for distribution applications are also available

Packing

The methods employed by Sediver to pack and palletize our toughened glass insulators are the result of the experience we gained from shipping hundreds of millions of insulators to warehouses and construction sites in 150 countries worldwide.

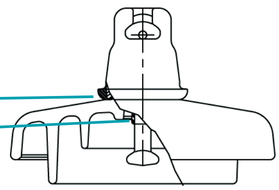
Factory-assembled short strings of Sediver Insulators are packed in wooden crates, which are reinforced and held closed by external wire bindings (no nails are used).

Crate in open position with its internal brace to permit stacking.

Crates are evenly stacked on a sturdy four-way wooden pallet. This assembly is held tightly in place with either steel or plastic bands, and is protected with a polyethylene film.

HVDC applications:
Sediver High Resistivity Toughened Glass insulators

Specific electric stresses resulting from a unidirectional flow of direct electric current require the use of specially designed insulators able to resist corrosion, pollution accumulation and other phenomena directly related to DC field conditions.

HVDC specific stresses	Sediver solution		User benefits
Electrostatic attraction of the dust on insulator surface	Adapted glass shell design with wide spacing between ribs and increased leakage distance		High pollution efficiency : reduced maintenance costs
Unidirectional leakage current leading to metal part corrosion	Protection of the metal fittings Pure zinc collar bonded to the cap Pure zinc sleeve bonded to the pin		Longer life expectancy and no rust deposit on the dielectric
Ionic migration Ionic accumulation	Special glass chemistry imparting high resistance to localized thermal stress and ion flow		No puncture : reduced maintenance costs

For extreme pollution: **Sedicoat® solution**

In case of extreme or exceptional pollution, it may become necessary to wash the glass and porcelain insulators so as to reduce the risk of flashover due to the critical deposit of pollution. Composite insulators can be used in these conditions. Nonetheless, the benefits linked to the hydrophobicity and profile of polymer insulators are outweighed by the difficulties of inspection and diagnosis of aging as well as the added complexity of carrying out live line work.

Sedicoat: no washing is needed anymore

Sedicoat insulators are Sediver toughened glass insulators coated with silicone. The silicone coating procures hydrophobic properties to the surface of the glass shell and thus significantly enhances its electrical performance under extreme pollution. Sedicoat insulators offer a solution that eliminates the need for regular washing in extreme pollution conditions.

The application of the coating is done at the factory according to a specific industrial process qualified by Sediver.

Main advantages:

- Reduce the maintenance cost as there is no need for washing
- Keep the inherent properties of the toughened glass in terms of:
  - easiness and reliability of visual inspection
  - safe live-line working
  - long term electrical and mechanical reliability
  - no aging
- No need to modify tower design
- Can be applied on all glass profiles

A solution confirmed by +1 million insulators in service & 20 years of satisfactory service

Sedicoat is the solution that maintains the unique properties of Sediver toughened glass insulators while eliminating the need for washing under extreme pollution conditions.

Sediver toughened glass suspension insulators

ANSI string electrical ratings

Standard profile

Standard profile suspension insulator string flashover voltages based on the test procedure of the American Standard ANSI C 29.2B.

Catalog N°	Diameter / Spacing Ø 10 / 5 3/4 - Ø 11 / 5 3/4 N100/146 - N14/146 - N 180/146				Diameter / Spacing Ø 11 / 6 1/8 N21/156			
Number of units	Low frequency flashover voltage (kV)		Critical impulse flashover voltage (kV)		Low frequency flashover voltage (kV)		Critical impulse flashover voltage (kV)	
	DRY	WET	+	-	DRY	WET	+	-
2	145	90	220	225	145	90	230	230
3	205	130	315	320	210	130	325	330
4	270	170	410	420	275	170	425	440
5	325	215	500	510	330	215	515	540
6	380	255	595	605	385	255	610	630
7	435	295	670	695	435	295	700	720
8	485	335	760	780	490	335	790	810
9	540	375	845	860	540	375	880	900
10	590	415	930	945	595	415	970	990
11	640	455	1015	1025	645	455	1060	1075
12	690	490	1105	1115	695	490	1150	1160
13	735	525	1185	1195	745	525	1240	1245
14	785	565	1265	1275	790	565	1330	1330
15	830	600	1345	1360	840	600	1415	1420
16	875	635	1425	1440	890	635	1500	1510
17	920	670	1505	1530	935	670	1585	1605
18	965	705	1585	1615	980	705	1670	1700
19	1010	740	1665	1700	1025	740	1755	1795
20	1050	775	1745	1785	1070	775	1840	1890
21	1100	810	1825	1870	1115	810	1925	1985
22	1135	845	1905	1955	1160	845	2010	2080
23	1180	880	1985	2040	1205	880	2095	2175
24	1220	915	2065	2125	1250	915	2180	2270
25	1260	950	2145	2210	1290	950	2260	2365
26	1300	985	2220	2295	1330	958	2390	2465
27	1340	1015	2300	2380	1370	1015	2470	2555
28	1380	1045	2375	2465	1410	1045	2570	2650
29	1425	1080	2455	2550	1455	1080	2650	2740
30	1460	1110	2530	2635	1490	1110	2740	2830

These electrical ratings are applicable to Sediver suspension insulator strings not equipped with arcing devices or grading rings.
According to the American Standard the average value of three tested strings shall equal or exceed:
95% of the guaranteed values as given in the data sheet, for low frequency dry flashover,
90% of the guaranteed values as given in the data sheet, for low frequency wet flashover,
92% of the guaranteed values as given in the data sheet, for critical impulse flashover.

Sediver toughened glass suspension insulators

ANSI string electrical ratings

Fog type profile

Fog type profile suspension insulator string flashover voltages based on the test procedure of the American Standard ANSI C 29.2B.

Catalog N°	Diameter / Spacing Ø 11 / 5 3/4 N100P/146DC - N14P/146DC				Diameter / Spacing Ø 13 / 6 3/4 N21P/171DC			
Number of units	Low frequency flashover voltage (kV)		Critical impulse flashover voltage (kV)		Low frequency flashover voltage (kV)		Critical impulse flashover voltage (kV)	
	DRY	WET	+	-	DRY	WET	+	-
2	155	95	270	260	160	110	315	300
3	215	130	380	355	230	145	440	410
4	270	165	475	435	290	155	550	505
5	325	200	570	520	350	225	660	605
6	380	240	665	605	405	265	775	705
7	435	275	750	690	460	310	870	800
8	485	315	835	775	515	355	970	900
9	540	350	920	860	570	390	1070	1000
10	590	375	1005	950	625	430	1170	1105
11	640	410	1090	1040	680	460	1270	1210
12	690	440	1175	1130	735	495	1370	1315
13	735	470	1260	1220	790	530	1465	1420
14	785	500	1345	1310	840	565	1565	1525
15	830	525	1430	1400	885	595	1665	1630
16	875	555	1515	1490	935	630	1765	1735
17	920	580	1600	1595	980	660	1860	1845
18	965	615	1685	1670	1030	690	1960	1945
19	1010	640	1770	1755	1075	725	2060	2040
20	1055	670	1850	1840	1120	755	2155	2140
21	1100	695	1930	1925	1165	785	2245	2240
22	1145	725	2010	2010	1210	820	2340	2340
23	1190	750	2090	2095	1255	850	2430	2440
24	1235	780	2170	2180	1300	885	2525	2540
25	1280	810	2250	2265	1345	910	2620	2635
26	1325	835	2330	2350	1385	945	2710	2735
27	1370	860	2410	2435	1430	975	2805	2835
28	1410	890	2490	2520	1470	1005	2900	2935
29	1455	915	2560	2600	1515	1035	2980	3025
30	1495	940	2630	2680	1555	1065	3060	3120

These electrical ratings are applicable to Sediver suspension insulator strings not equipped with arcing devices or grading rings.
According to the American Standard the average value of three tested strings shall equal or exceed:
95% of the guaranteed values as given in the data sheet, for low frequency dry flashover,
90% of the guaranteed values as given in the data sheet, for low frequency wet flashover,
92% of the guaranteed values as given in the data sheet, for critical impulse flashover.

Contribution to international committees

Since the very beginning of international technical cooperation, Sediver has always been an active member in fields of research and standardization in international committees and working groups dealing with all aspects of high voltage insulation; for example Sediver experts are Project Leaders in IEC working groups 36WG11, 36BMT10, CIGRE D1-B2 and contribute to the activities of NEMA-ANSI, IEEE and CSA standard Committees.

List of some IEEE and international publications on glass:

- GEORGE JM., PRAT S., VIRLOGEUX F. *"Coating Glass Insulators for Service in Severe Environments"* INMR Quarter 4 2014
- GEORGE JM., LODI Z. *"Mechanical and electrical behaviour of a damaged toughened glass insulator"* EDM - Fort Collins USA 2014
- GEORGE JM., PRAT S., TARTIER S., LODI Z. *"Electrical characteristics and properties of a stub"* ISH 2013 SEOUL, KOREA
- GEORGE JM., DEL BELLO E. *"Assessment of electrical and mechanical performance of toughened glass insulators removed from existing HV lines"* CIGRE REGIONAL MEETING – CALGARY AUGUST 2007
- PAIVA O ; SUASSUNA R ; DUMORA D ; PARRAUD R ; FERREIRA L ; NAMORA M *"Recommendations to solve corrosion problem on HV insulator strings in tropical environment"* CIGRE SYMPOSIUM CAIRNS 2001 Paper 300-05
- DUMORA , R. PARRAUD *"Corrosion mechanism of insulators in tropical environment"* CIGRE SYMPOSIUM CAIRNS 2001 Paper 300-04
- PARRAUD R ; PECLY H *"Long term performance of toughened glass insulators on AC and DC transmission lines : improvement, field experience and recommendations"* CIGRE INTERNATIONAL WORKSHOP ON INSULATORS – RIO JUNE 1998
- CROUCH A ; SWIFT D ; PARRAUD R ; DE DECKER D *"Aging mechanisms of AC energised insulators"* CIGRE 1990 Paper 22-203
- PARRAUD R ; LUMB C ; SARDIN JP *"Reflexions on the evaluation of the long term reliability of ceramic insulators"* IEEE WG INSUL.STRENGTH RATING 1987
- PARGAMIN L ; PARRAUD R *" A key for the choice of insulators for DC transmission lines"* IEEE HVDC TRANSMISSION MADRAS 1986
- PARRAUD R ; LUMB C *"Lightning stresses on overhead lines"* IEEE BANGKOK 1985
- MAILFERT R ; PARGAMIN L ; RIVIERE D *"Electrical reliability of DC line insulators"* IEEE ELECTRICAL INSULATION 1981 N° 3
- COUQUELET F ; RIVIERE D ; WILLEM M *"Experimental assessment of suspension insulator reliability"* IEEE CONFERENCE PAPER 1972 Paper 173-8

ISO certifications

All our manufacturing facilities worldwide are certified ISO 9001 & ISO 14001

Catalogs and Technical Brochures

- Sediver HRTG insulators for HVDC applications
- Sedicoat, RTV silicone coated toughened glass insulators
- Sediver toughened glass: endurance

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