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Understanding the Energy Handling Tests of IEEE C62.11-2020 Rev. July 2021

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Introduction

Part of selecting a good quality arrester is understanding the published data. A good-quality supplier will fully disclose the relevant data in a format that is comprehensible and user-friendly. This article is a guide to understanding the arrester datasheet and what is behind it. For clarification purposes, the terms lightning arrester, arrester, and surge arrester are considered synonymous.

Edition 2 Comments

The original document, Understanding the Arrester Datasheet, was published in 2016. In 2020, a new edition of C62.11 was published; it contained several new arrester parameters as well as specification changes. This 2nd edition of "Understanding the Arrester Datasheet" covers the changes as they affect the publication of arrester data.

Arrester Classifications

All arresters that are certified by IEEE Standards have a classification. When an arrester model is certified to a specific class, such as heavy-duty distribution arrester, it means that it passed all the tests that the Standard requires for that class. Most datasheets will indicate what class the arresters have been certified to. One class is not necessarily better than another, only different. Station class arresters are typically larger in size than the same MCOV in a different class. Although the station arrester may be the best suited for an application, in some instances, its size or weight might make choosing another class the best solution. **Table 1** shows the classifications as tested in the latest C62.11 Standard.

Table 1 Arrester Classifications found on Datasheets

Arrester Classifications per C62.11-2020	
Distribution Class Heavy Duty (HD) Normal Duty (ND) Light Duty (LD)	Intermediate Class
	Station Class A-N

Discharge Voltage and TOV Table

In every arrester datasheet, you will find a table on the discharge voltage of the arrester in question. The discharge voltage table documents how well the arrester clamps lightning and switching surges, which is the fundamental purpose of arresters, making this very important information for the user. In more recent editions of arrester datasheets, the TOV data is also included in the discharge voltage table (TOV is covered in a later section in this document). This table is for a distribution class arrester but can be used to understand all discharge voltage tables of all arresters.

Arrester MCOV

Per C62.11-2020, the metal-oxide varistor (MOV) type arresters now have only one AC rating, whereas, in the past, they had two AC ratings. The term "Rated Voltage" with respect to arresters is now an obsolete term and used in the Standard for historical purposes only. The arrester MCOV is shown in group 1 of **table 2** is now considered the AC rating of the arrester and is given in kV (1 kV=1000 volts). The MCOV of an arrester is determined during the course of testing the arrester to IEEE Standard C62.11 and is the most important voltage rating of the arrester. It is an AC rating and should, in all circumstances, be higher than the maximum line-to-ground voltage of the system to which it will be applied. In some circumstances, due to higher temporary overvoltage (TOV) conditions, the MCOV may need to be increased on the arrester, but it should never be decreased below the steady-state line-to-ground voltage of the system.

Table 2 Arrester Discharge Voltage and TOV Table

Group 1	Group 2		Group 3	Group 4						Group 5	
Typical Discharge Voltage and TOV Table											
Arrester MCOV	TOV		Front-of-Wave (Steep Current Impulse)	Maximum Discharge Voltage (Lightning Protective Level)						Switching Surge Protective Level (kV peak) 45/90µs	
	(kV AC rms)		(kV peak) 1/10 µs	(kV peak) 8/20 µs Current Wave							
(kV rms)	1 Sec	10 Sec	10kA	1.5 kA	3kA	5kA	10kA	20kA	40kA	125A	250A
Distribution Arresters											
2.55	4	3.75	11	8.2	8.7	9.1	9.9	10.9	12.3	7.2	7.5
5.1	8	7.5	21.9	16.3	17.4	18.2	19.8	21.9	24.7	14.5	15.0
7.65	11.9	11.2	33	24.6	26.1	27.3	29.8	33.0	37.1	21.8	22.5
8.4	13.1	12.3	35	26.0	27.7	29.0	31.6	34.9	39.4	23.1	23.9
10.2	15.9	15	43.9	32.7	34.8	36.4	39.7	43.9	49.5	29.0	30.0
12.7	19.8	18.7	53.1	39.6	42.1	44.0	48.0	53.1	59.8	35.0	36.3
15.3	23.9	22.5	66	49.1	52.3	54.7	59.6	65.9	74.2	43.5	45.1
17	26.5	25	70	52.1	55.4	58.0	63.2	69.9	78.7	46.1	47.8
19.5	30.4	28.7	80.9	60.2	64.1	67.0	73.1	80.8	91.1	53.4	55.3
22	34.3	32.3	94	70.0	74.5	77.9	84.9	93.9	106.0	62.0	64.2
24.4	38.1	35.9	102	76.1	81.0	84.7	92.4	102.0	115.0	67.5	69.9
27	42.1	39.7	116	86.5	92.1	96.3	105.0	116.0	131.0	76.7	79.4
29	45.2	42.6	123	91.5	97.3	102.0	111.0	123.0	138.0	81.0	83.9

8/20µs Maximum Discharge Voltage

Group 4 data in **table 2** shows the discharge voltage across an arrester impulsed by lightning type surges. The data shows the discharge voltages for seven different impulse current amplitudes, all of the same 8/20µs wave shape. The wave shapes are shown in **figure 1**. Since lightning comes in various amplitudes, from a few kA (1 kA=1000 amps) to occasionally >100kA, this table shows what the clamping voltage would be for 95% of the impulse current levels that occur in nature. The data found in the 10kA column is most often used to compare one arrester to another. It is often referred to as the "lightning protective level." If two arresters are being compared, the 10kA, 8/20 discharge voltage in this column can be used to compare similar ratings, and the lower level is considered better protection.

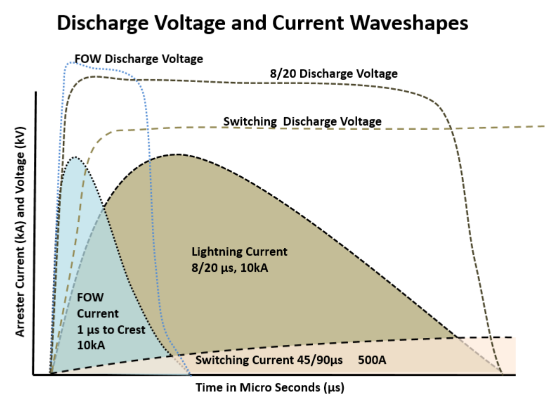

Figure 1 Typical wave shapes for discharge current and discharge voltage

Front-of-wave Protective Level

The data found in group 3 is another form of discharge voltage, also known as the equivalent front-of-wave discharge voltage. In this case, the waveshape has a faster rise time than the 8/20µs used for maximum discharge voltage and represents the second subsequent surge in a multi-stroke lightning flash. Per IEEE C62.11-2020, the front-of-wave discharge current wave shape for this protective level is 1 µs to crest, with no specification on the tail.

Switching Surge Protective Level

The data found in group 5 of **table 2** (switching surge protective level, 45/90µs discharge voltage) is the third type of discharge voltage that is measured and published for arresters. The peak current levels can vary from 125 amps to 2000 amps, depending on the class of the arrester. This discharge voltage represents the response of an arrester to a slow-rising surge generated within the power systems during breaker or switch operations.

TOV Levels

These two columns are new to the main table of arrester characteristics. Group 2 in **table 2** shows the maximum AC voltage an arrester can withstand without damage for 1 and 10 seconds. These two columns are a quick look at the TOV capability of an arrester. This characteristic is covered in detail later in this document.

Arrester MCOV Selection Table

Probably the most widely used table in arrester datasheets is the arrester MCOV selection table. The example in **table 3** is for both distribution and transmission systems. The two most important factors used to select an arrester rating are the system voltage and the neutral grounding configuration of the source transformer. These tables assume that the maximum duration and amplitude of the worst-case overvoltage during a line-to-ground fault are unknown. When two ratings are offered, the lower rating would be the minimum possible, and the higher rating is for the worst-case scenario when nothing is known about potential overvoltage events.

Table 3 Arrester MCOV Selection Table

System line-to-line voltages (kV rms)		Recommended Arrester MCOV Ratings (kV rms)		
Nominal	Assumed Maximum	Four-wire wye Multi-grounded Neutral	Three-wire or Four-wire Wye Solidly Grounded@ Source	Delta and Ungrounded Wye
12	12.6	7.65	7.65 or 8.40	10.2 or 12.7
12.47	13.1	7.65	7.65 or 8.40	12.7 or 15.3
13.2	13.9	8.4	8.40 or 10.2	12.7
13.8	14.5	8.4	8.40 or 10.2	12.7 or 15.3
20.78	21.8	12.7	12.7 or 17.0	19.5 or 22.0
22.86	24	15.3	15.3 or 17.0	19.5 or 22.0
24.9	26.2	15.3	15.3 or 17.0	19.5 or 22.0
34.5	36.2	22	22.0 or 24.4	29.0 or 31.5
46	48.3	N/A	29.0 or 31.5	39.0
69	72.5	N/A	42.0 or 48.0	57.0
115	121	N/A	70.0 or 76.0	84.0
138	145	N/A	84.0 or 98.0	106 or 115
161	169	N/A	98.0 or 115	115 or 131
230	242	N/A	140 or 152	180 or 190

System Line-to-Line Voltages

Since most three-phase systems are referred to by the phase-to-phase voltage, that is how the table is set up. In many cases, the MCOV rating is less than the line-to-line voltage because arresters are applied line to ground. The line-to-ground voltage is line-line voltage divided by 1.73 for those wishing to calculate it.

The nominal and maximum system voltages are both shown in the table; the arrester rating is calculated based on the maximum expected system voltage.

Recommended Arrester MCOV Ratings

This MCOV rating is divided into several columns to cover the various system configurations. The neutral configuration of the transformer providing the power to the circuit is the only neutral configuration that needs to be considered. Downstream transformers do not affect the potential overvoltages unless it is part of the fault source.

Four-Wire Wye Multi-Grounded Neutral

This column is primarily a distribution-type circuit where the neutral conductor is grounded in many places along the circuit as well as at the feed transformer. In this case, the maximum overvoltage on this type of system is 1.25 per unit of line-ground voltage (pu), and the duration of an overvoltage is very short (a few cycles).

Three- or Four-Wire Wye Solidly Grounded Neutral at Source

This circuit can be a distribution or transmission-type circuit. The selected arrester is the same for both types of circuits. In this case, the maximum overvoltage magnitude is about 1.4pu and could last for a very long duration.

Delta and Ungrounded Wye

This can be either a distribution or transmission circuit. In this case, the worst-case overvoltage from a faulted circuit is 1.73pu line-to-ground voltage. This means the line-to-ground voltage can increase to equal the line-to-line voltage in some instances.

Short Circuit, Fault Current Tables, or Pressure Relief Ratings

Per IEEE C62.11-2020, all arresters shall have a fault current rating. This rating indicates how much 60Hz short-circuit current from the power system can flow through the arrester without violent rupture and large fragment expulsion. Note that this is not a lightning or switching current but instead a power frequency, system-sourced current.

Table 4 Typical Pressure Relief Ratings Table

Arrester type	Short-circuit test current (amps)	Short-circuit test duration (seconds)
Model A	15000	0.2
	7500	0.2
	600	1
Model B	2000	0.2
	1000	0.2
	600	1

The short-circuit test is conducted by putting a failed arrester in series with a fault current source for the given duration in seconds, or cycles, as shown in column three of **table 4**. The listed current level must flow through or around the arrester for the given duration without expulsion of internal parts in order to pass the tests. Distribution arresters are tested at current levels up to 20,000 amps for 12 cycles, and station class arresters are tested as high as 63,000 amps and up. A lower current of 500 amps is also tested and is shown in **table 4**.
To ensure minimum collateral damage to other equipment in the event that an arrester is overloaded, the available system short-circuit current should not exceed the level as shown in column two of **table 4**.

Energy Handling Specification Tables

All arrester datasheets will contain arrester energy classification tables. In 2020, there is new nomenclature describing the energy handling capabilities. These terms were adopted from the IEC Standards where they have been in use for several years.

a. **Thermal energy withstand rating (W_{th}):** This energy rating is associated with station arresters only and is a measure of how much energy an arrester can absorb during a switching surge without failure. This test has been in the Standards since 2005, but the name W_{th} is only now being used to describe this parameter.
b. **Thermal charge transfer rating (Q_{th}):** This is a new way to quantify the lightning discharge capability of a distribution arrester. Prior to this, there was only the high current impulse classifying current that partially quantified this characteristic. This is strictly a distribution arrester rating. This rating is demonstrated in the operating duty test.
c. **Single-impulse charge transfer rating (Q_{rs}):** This new characteristic quantifies the single impulse withstand capability of an arrester that will not cause damage to the internal varistors. This test applies to all arrester classes.
d. **Impulse Classifying Current:** The impulse classification current, shown in **table 5**, is a value that some manufacturers choose to add to their datasheets to provide extra information. This is the impulse current level used during the IEEE duty cycle tests in IEEE C62.11. For distribution arresters, it can be 5 or 10kA, and for station arresters, it can be 5, 10, 15, or 20kA. Generally, the higher the current, the higher the arrester durability. High Current Impulse may still be in a datasheet, though it is a parameter in the thermal energy withstand rating.

Table 5 Arrester Energy Ratings and Minimum Levels per C62.11

Arrester Type	Classification Current	High current Impulse	Switching Impulse Discharge Current	Minimum Single Impulse Charge Transfer Rating Q_{rs}	Minimum Thermal Energy Withstand Rating Q_{th}
Distribution					
	kA	kA	kA	Coulombs (C)	Coulombs
Heavy Duty	10	100	na	≥ .4	1.1
Normal Duty	5	65	na	≥ .2	0.7
Light Duty	2.5	40	na	≥ .1	0.45
Station					
Example Ratings	kA	kA	Amps	Coulombs (C)	Minimum W_{th} kJ/kV-MCOV
Intermediate	From 10 to 20	65	From 500-2000	No Minimum Required, but is still tested and should have a value on the datasheet	3
Station Class B					4.5
Station Class C					6
Station Class D					7.5
Station Class E					9

Temporary Overvoltage

All good arrester datasheets will have a TOV curve similar to the one shown in **figure 3**. This curve is used to determine the minimum MCOV rating that can be used for systems that can experience a TOV. Note that arresters are designed to withstand AC overvoltages, not mitigate them. TOVs can be caused by single line-to-ground faults, loss of neutral, or other system phenomena. See IEEE C62.22 for more details on how to use this curve. In simplest terms, if a line representing the amplitude and duration of a TOV, as shown in **figure 3**, crosses the arrester TOV curve, then a higher-rated arrester should be used.

For example, a TOV of 1.4 times MCOV for a duration of 100 seconds would exceed the capability of this arrester, and a higher MCOV would need to be selected. If a TOV of 1.3 times MCOV for a duration of 10 seconds (green line in **figure 3**) would not exceed the arrester capability, and the MCOV selected can be used.

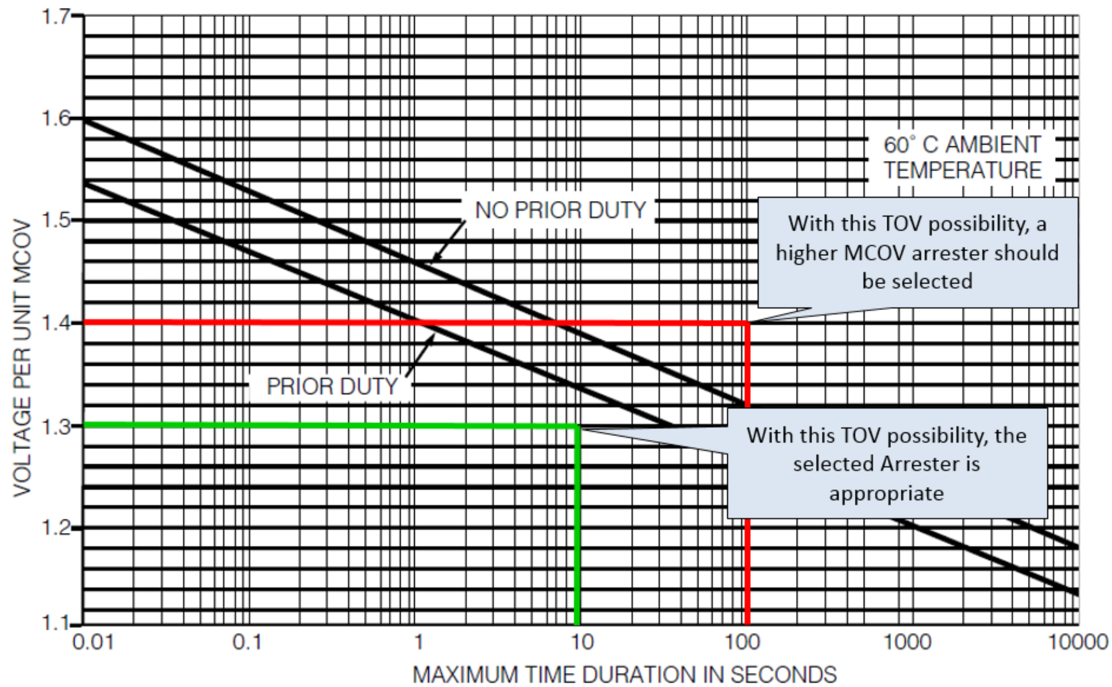

Figure 3 Typical TOV curve

The “no prior duty” curve in **figure 3** should be used if it is certain that the arrester would not absorb energy prior to the TOV. This is usually the case for single line-to-ground faults. If it is uncertain whether the arrester in question could absorb energy prior to the TOV, then the prior duty curve must be used, which is the more conservative method. Per-unit MCOV on the vertical axis is a convenient way to show the TOV for all arrester ratings. To get the actual overvoltage level that can be withstood by the arrester selected, multiply the PU level on the curve for the given duration by the MCOV of the selected arrester. As shown in **figure 3**, if the MCOV of the selected arrester is 98kV, then the TOV withstand capability for 10 seconds of the arrester 98kV arrester is 98 x 1.4 = 137kV.

TOV is sometimes specified in a table with specific voltages that can be withstood for 1 or 10 seconds (See **table 2 group 2)**. This is the same data that is supplied with the TOV curve, but instead of being per unit MCOV, the TOV withstand voltage is in actual kV rms.

Table 6 Insulation withstand voltages and creepage distances table

Arrester MCOV	1.2/50 impulse	Switching surge impulse	60 Hz dry 60 seconds	60 Hz wet 10 seconds	Creepage (Leakage) distances
kV RMS	kV peak	kV peak	kV RMS	kV RMS	Inches
7.65	149	153	102	68	20.3
8.4	149	153	102	68	20.3
15.3	193	189	126	93	28.4
22	236	216	144	117	36.5
42	344	273	182	178	56.7
48	366	288	192	190	60.8
68	602	495	330	308	97.2
70	623	507	338	320	101.3
76	644	519	346	332	105.3
84	710	561	374	368	117.5
98	732	576	384	380	128.1
115	890	776	517	467	166.5
144	1029	960	586	533	192.2
152	1212	1166	690	633	222
160	1256	1208	708	657	230.6

Insulation Withstand Tables

The insulation withstand table presented in arrester datasheets, as shown in **table 6**, is easily misunderstood. The misunderstanding occurs when these values are compared to system basic lightning impulse insulation levels (BIL). ***Arrester housing withstand values are not a BIL rating***; they are the voltage withstand of the housing when the internal components of the arrester are removed (more below). The creepage distance is often but not always reported in the same table.

Creepage Distance

The creepage distance for arresters, shown in **table 6**, should be similar to that of all insulators on the system to which it will be applied. Often for coastal or high-pollution areas, extra creep units are used. The definition of creepage distance is shown in **figure 4.**

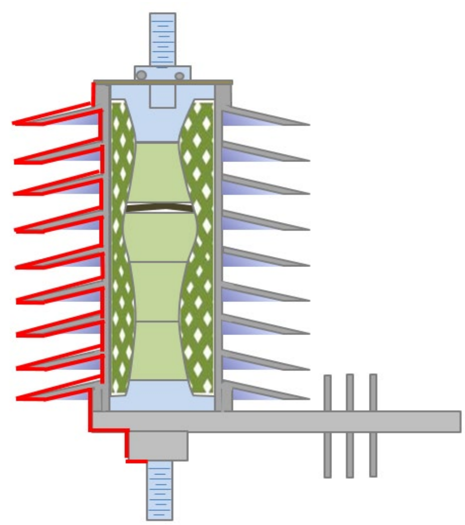

Figure 4 Demonstration of creepage distance

1.2/50μs Impulse

This is the lightning impulse withstand voltage of the arrester housing if the internal varistors are removed from the arrester, as shown in column three of **table 6**. Since the arrester will always be self-protected with the internal components, this characteristic is essentially irrelevant. This 1.2/50μs level does not and should not match the BIL of the insulators on the system. The level on the arrester datasheet will always be lower than the BIL of the system. The minimum value is mandated in IEEE C62.11-2020

Switching Surge Impulse

This characteristic of the arrester housing is also measured without the internal components of the arrester installed, shown in column four of **table 7**. With the internal components of the arrester installed, this level will never be reached because of the self-protecting nature of an arrester. This level will very likely not be as high as the switching impulse withstand characteristics of the system. The minimum value is mandated in IEEE C62.11-2020.

60Hz Wet and Dry

These two withstand characteristics have mandated minimum values per IEEE C62.11, as shown in columns four and five of **table 7**. The minimum value is based on the system voltage, maximum application altitude, and maximum TOV of the arrester. These values do not need to be the same as the insulators on the system.

Disconnector Ignition Curve

If a distribution arrester is equipped with a ground lead disconnector, the datasheet will likely contain an ignition curve, as shown in **figure 5**. Arrester users that are interested in how fast a disconnector operates can use this curve to show the point in time when the disconnector begins to operate. It is important to note that this is not a clearing curve but an ignition curve. This is because disconnectors are not clearing devices

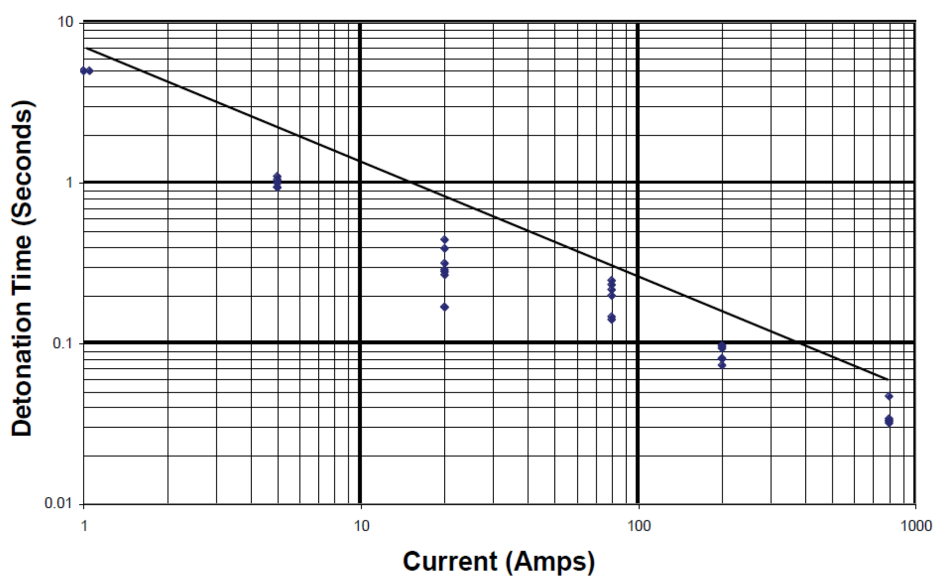

Figure 5 Typical disconnector ignition curve

Mechanical Properties of Arresters

Polymer-Housed Arresters

The maximum design cantilever strength (MDCL static), as tabulated in **table 7**, is tested and verified during the IEEE certification test process. This is the steady-state working strength of an arrester should it be used to support buss or cable. It is generally understood that for mechanical systems, such as the polymer housed arrester, the breaking force or ultimate strength (column two of **table 7**) is 60% above the working strength. **Figure 6** shows the basic setup of the test.

Table 7 Typical Mechanical Strength Ratings of Arresters

Mechanical withstand capability		
Cantilever strength (in-lbs.)	**Ultimate**	**MDCL static**
Model A	15,000	6,000
Model B	20,000	8,000
Model C	35,000	14,000
Model D	100,000	40,000

Porcelain-Housed Arresters

The cantilever strength is tested by applying a force until the unit breaks. This is the ultimate mechanical strength (UMS) of a porcelain housed arrester. It is accepted that the working strength is 40% of this level.

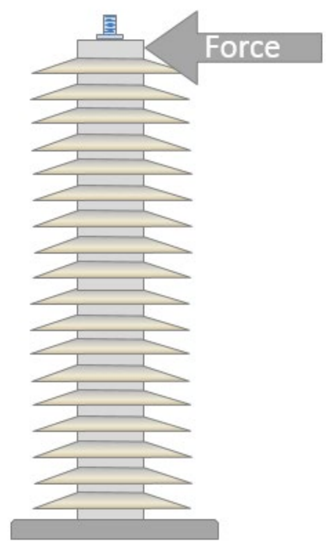

Figure 6 Typical cantilever force diagram

Conclusions

Arrester datasheets will vary from manufacturer to manufacturer, but the basic data is all the same. The definitions above cover all complex characteristics found on these datasheets. If the datasheet does not cover all the topics discussed in this document, a quality supplier will be able to provide this information.

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