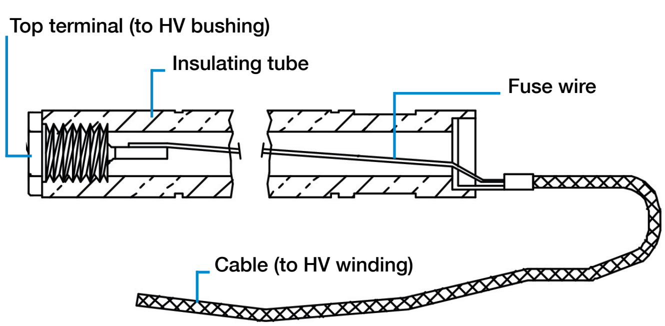
Technical and installation guide

Protective links

Introduction

The protective link is an oil immersed, expulsion type fuse designed for use in the high voltage circuit of a distribution transformer. Westinghouse originally developed the protective link as part of the CSP system of distribution transformer protection. When used in the CSP scheme, the function of the protective link is to disconnect a defective transformer from the feeder circuit and to limit the severity of the damage to the transformer in case of an internal fault. The protective link is a simple device. It consists of a fuse wire element (copper or copper alloy) contained within an insulating tube. The wire is welded to a top electrode at one end and crimped to a bottom electrode or welded directly to the cable lead at the other end.

Protective links are available in a variety of fuse sizes and voltage classes. In most applications today, the protective link is used in series with a partial range or back-up current limiting fuse. The current limiting fuse is typically mounted inside of the transformer when the transformer is the pad mounted or submersible type and mounted externally when the transformer is the overhead type. The series combination of protective link and back-up type current limiting fuse adds an additional layer of fuse coordination that must be performed for proper functioning of both devices.



Fault interruption

The fuse element contained in the insulating tube melts in response to the heating caused by the flow of fault current through the fuse wire. After the wire melts, an arc is established inside of the fuse tube. The heat of the arc burns back the fuse wire element and the arc length increases.

The arc length determines the resistance that the opening protective link inserts into the circuit. Since the arc is relatively short, the arc resistance is low and the arc voltage across the opening element is small compared to the 60-hertz system voltage. The protective link (and most expulsion type fuses) cannot develop enough arc voltage to drive the fault current to zero. The arc can only be extinguished when the fault current passes through a natural current zero. As the fault current passes through zero, the arc is momentarily extinguished and its ionized gas cloud is then pushed out of the fuse tube (hence the term “expulsion fuse”). If the voltage withstand of this un-ionized gap is strong enough to withstand the transient recovery voltage that develops as the current passes through zero, the arc will be extinguished and the fault will be cleared.

Ratings

Protective links are available in three voltage classes - 15 kV, 23 kV and 34.5 kV. Interruption rating is defined by the voltage across the protective link during and after fault interruption. The interruption rating greatly depends on the transformer tank's ability to with-stand the energy released during fault interruption. The ratings were determined for cylindrical distribution transformer tanks of the vented cover design. Ratings in rectangular pad mounted transformer tanks will be equal to, or greater than the stated values due to the rectangular tank's greater ability to withstand the energy released during fault interruption. See Table 1 for ratings details.

Table 1

Application voltage[1]	Interrupting rating (rms symmetrical amperes)
2400 V	5000
4800 V	4800
7200 V	3500
12000 V	3000
14400 V	2500
23000 V	1200
34500 V	1200

[1] Application voltage is single phase line to ground and/or three phase line to line

Time current charecteristic (TCC) curves

Two curves describe the time versus current characteristic of the protective link. Curve number 1ZUA567001-AAA represents the minimum melt curve (note that this supersedes curve number 735701). Curve number 1ZUA567001-AAB is the total clearing curve (note that this supersedes curve number 697700). These curves were created in accordance with the requirements of IEEE standard C37.47.

Minimum fuse curve selection

In general, select the smallest fuse that will meet the transformer's protection requirements. In the case of the CSP scheme, the smallest protective link is determined by the CSP breaker coordination. In all cases, the protective link has to be large enough to prevent nuisance fuse operations due to transients caused by transformer inrush currents or cold load pick-up. Fuse curve checkpoints are well established to guide in proper selection. Four TCC curve points should be checked. The protective link minimum melt curve must lie to the right of these points.

Point 1: 25 x rated transformer current at 0.01 s (transformer inrush)
Point 2: 12 x rated transformer current at 0.1 s (transformer inrush)
Point 3: 6 x rated transformer current at 1.0 s (cold load pick-up)
Point 4: 3 x rated transformer current at 10 s (cold load pick-up)

Fuse Curve Selection for CSP Transformers

When designing a CSP protection scheme, select the secondary CSP circuit breaker first in accordance with the protection required for the transformer. After selecting the secondary circuit breaker, select the protective link so that proper coordination between the primary side protective link and the secondary side circuit breaker is achieved. The simplest way to determine if proper coordination has been achieved is to compare the time versus current characteristics curves (TCC curves) of both devices (adjusting for the turns ratio of the transformer). Coordination is acceptable when, for all values of secondary fault current, the circuit breaker will clear the fault before the protective link melts.

Coordination with current limiting fuses

The nature of most expulsion fuses is their inability to drive the fault current to zero before a natural current zero occurs. These fuses will always allow at least one full loop of fault current before circuit interruption. Because of their interruption characteristics, expulsion fuses have very limited fault interruption capability. Today, most protective links are used in series with a back-up or partial range current limiting fuse so that the series combination of both devices provides interruption capability across the full range of available fault currents. When applying the protective link in series with the partial range current limiting fuse, additional coordination issues must be addressed. It is the nature of the partial range current limiting fuse that it cannot interrupt low fault currents and has, in fact, a minimum interruption rating. The function of the expulsion fuse in this series application is to interrupt the low fault currents and clear the fault before the fuse elements within the current limiting fuse melt, in a sense protecting the partial range current limiting fuse.

The coordination between the protective link and the current limiting fuse is a critical element in these series combination protection schemes. The current limiting fuse manufacturer must be consulted to obtain the requirements for proper coordination between the two fuses.

Protective link TCC curves

In order to facilitate the coordination of the ABB protective link with partial range current limiting fuses, ABB has retested and created a new set of protective link time current characteristic (TCC) curves. These curves are:

- Curve 1ZUA567001-AAA which is the minimum melt TCC curve according to IEEE standard C37.41-2000, Design Tests for High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches Fuse Disconnecting Switches, and Accessories
- Curve 1ZUA567001-AAB which is the maximum clearing TCC curve according to the same standard.

Note that the previously issued curves 697700 and 735701 can continue to be used for coordination with CSP circuit breakers, if desired. ABB recommends that the newly issued curves be used when coordinating with up stream current limiting fuses.

Traditional TCC Curve Overlay Coordination

Coordination exists if the total clearing TCC curve of the protective link crosses (with appropriate margin) the minimum melting TCC of the partial range current limiting fuse at a current equal to or greater than the current limiting fuse rated minimum interrupting current. To protect the expulsion fuse from attempting to interrupt at a current higher than its rated maximum interrupting current, the crossing of the two curves should also occur at a current below the protective link maximum interruption current rating.

Matched Melt Coordination

In certain series combination protection schemes not only must the protective link be coordinated with the current limiting fuse using traditional TCC curve overlay methods, but additional coordination techniques must also be applied to make sure that the protective link melts open under any fault condition that causes the current limiting fuse to melt and operate. This special case occurs most typically in wind farm transformer applications where the system voltage is 34 kV, delta and the voltage rating of the partial range current limiting fuse is 23 kV. In this particular situation, not only must the standard curve overlay coordination technique be used but an additional coordination technique called matched melt coordination must also be used to ensure that the protective link always opens under any fault condition.

! Warning
Always consult with the current limiting fuse manufacturer to determine the exact coordination requirements for their device.

Matched melt coordination requires that the protective link maximum melt I^2t be less than or equal to two times the current limiting fuse minimum melt I^2t.

$$\left[I^2_{\mathrm{Mm}}t\right]_{\mathrm{PL}} \leq 2\left[I^2_{\mathrm{mm}}t\right]_{\mathrm{CLF}}$$

Where

I^2_{Mm} = maximum melt I^2t for the protective link

I^2_{mm} = minimum melt I^2t for the current limiting fuse

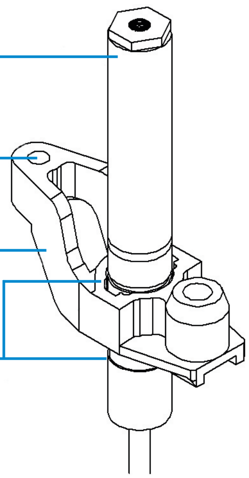
See table 2 for maximum melt I^2t values for the protective links.

Table 2 - Maximum melt I^2t

Protective link curve number	Maximum melt I^2t (A^2s)
2	125
3	300
3A	600
4	900
5	1.50×10^3
5A	3.00×10^3
6	5.25×10^3
7	10.5×10^3
7A	18.5×10^3
8	30.5×10^3
9	101×10^3
10	213×10^3
11	590×10^3

Circuit connection

The protective link is connected between the primary winding and high voltage bushing. A jack bolt (style number 240A394H01 ordered separately) fits into the 0.25 x 28 thread in the top terminal of the protective link and may be used to make up the top connection to the link. In lieu of this bolt, any standard 0.25 diameter x 28 threads per inch x 0.38 thread length bolt will work. The lower connection to the protective link is made through the flexible cable lead. The flexible cable lead is specified on the dimension sheets as: "number of wire strands" – "individual wire strand thickness" (example 259-0.005 = 259 strands of 0.005 diameter wire). Standard mounting configuration is in a near-vertical to vertical position in round tank transformers and horizontal to vertical in pad mounted units. All energized parts of the protective link must be under oil and spaced away from all other energized or grounded parts with sufficient distance to withstand all operating and test voltages. The transformer tank design must be capable of absorbing the arc energy of the protective link through tank venting or other means. The interrupting rating of this device is a function of the tank design and the live part insulation.



Mounting Accessories

Three different methods may be used to mount protective links.

The first option is to use the narrow groove flat clip (style number 75D0426H01). It is placed in the small groove around the protective link. The ends are then closed together and the mounting bolt run through the eye ends of the mounting clip into the insulating structure.

The second option is to use retaining rings and a terminal block. The retaining rings (style number 9820A65H05) fit into two small grooves on the fiber tube body and secure the fuse in the terminal block (style number 584B903H01). This mounting arrangement is shown in the figure above.

Finally, the protective link may also be mounted using an insulating block. This mounting scheme is shown on dimension sheet 44-889, page 13.

Ordering details

Protective links are ordered by style number and selected by voltage rating and curve number.

Table 3 - Protective link ordering data

Curve number	<= 15 kV	<= 23 kV	<= 34.5 kV
2	592B581G01	779C667G01	345B995G21
3	592B581G02	779C667G02	345B995G29
3A	592B581G11	779C667G03	345B995G22
4	592B581G06	779C667G08	345B995G33
5	592B581G03	779C667G04	345B995G23
5A	592B581G12	779C667G09	345B995G24
6	592B581G04	779C667G05	345B995G28
7	592B581G05	779C667G06	345B995G25
7A	592B581G13	779C667G33	345B995G34
8	592B581G07	779C667G07	345B995G26
9	592B581G08	779C667G34	345B995G27
10	592B581G09	779C667G35	345B995G31
11	592B581G14	779C667G36	345B995G32
12	592B581G31	Not available	Not available
13	592B581G32	Not available	Not available

Table 4 - Data points for minimum melt curve in Amperes [2]

Curve number	#2	#3	#3A	#4	#5	#5A	#6	#7	#7A	#8	#9	#10	#11
Time(s):													
0.01	76	126	185	225	315	441	576	828	1080	1440	2745	3960	6120
0.10	34	52	70	84	126	153	198	279	392	486	873	1197	1935
0.40	22	32	41	49	73	85	108	150	203	257	360	621	945
1.0	18	25	30	36	53	60	75	104	135	173	194	423	630
4.0	14	19	23	26	37	41	50	70	85	106	131	261	378
10	13	17	20	23	31	35	42	59	68	81	106	207	302
40	12	15	18	21	26	30	35	50	56	68	99	176	252
100	12	15	18	20	25	29	34	47	52	63	94	167	239
1000	11	14	17	20	24	29	34	47	52	61	92	162	239

[2] Data points are presented as a convenience. The published curve 1ZUA567001-AAA, Rev 2 should be used for coordination.

Table 5 - Data points for total clearing curve in Amperes [3]

Curve number	#2	#3	#3A	#4	#5	#5A	#6	#7	#7A	#8	#9	#10	#11
Time(s):													
0.014	112	190	280	350	475	680	880	1300	1700	2200	4400		
0.02	92	154	226	275	385	539	704	1012	1320	1760	3355	5000	
0.1	42	64	86	102	154	187	242	341	479	594	1067	1463	2365
0.4	27	40	50	59	89	103	132	184	248	314	440	759	1155
1	21	31	36	44	65	74	91	127	165	211	237	517	770
4	17	23	28	32	45	51	62	86	103	130	160	319	462
10	15	21	24	28	37	43	51	73	84	99	130	253	369
40	14	19	22	25	32	37	43	61	68	84	121	215	308
100	14	18	21	25	31	35	42	57	64	77	114	204	292
1000	14	18	21	24	30	35	42	57	64	75	112	198	292

[3] Data points are presented as a convenience. The published curve 1ZUA567001-AAB, Rev 2 should be used for coordination.

Notes

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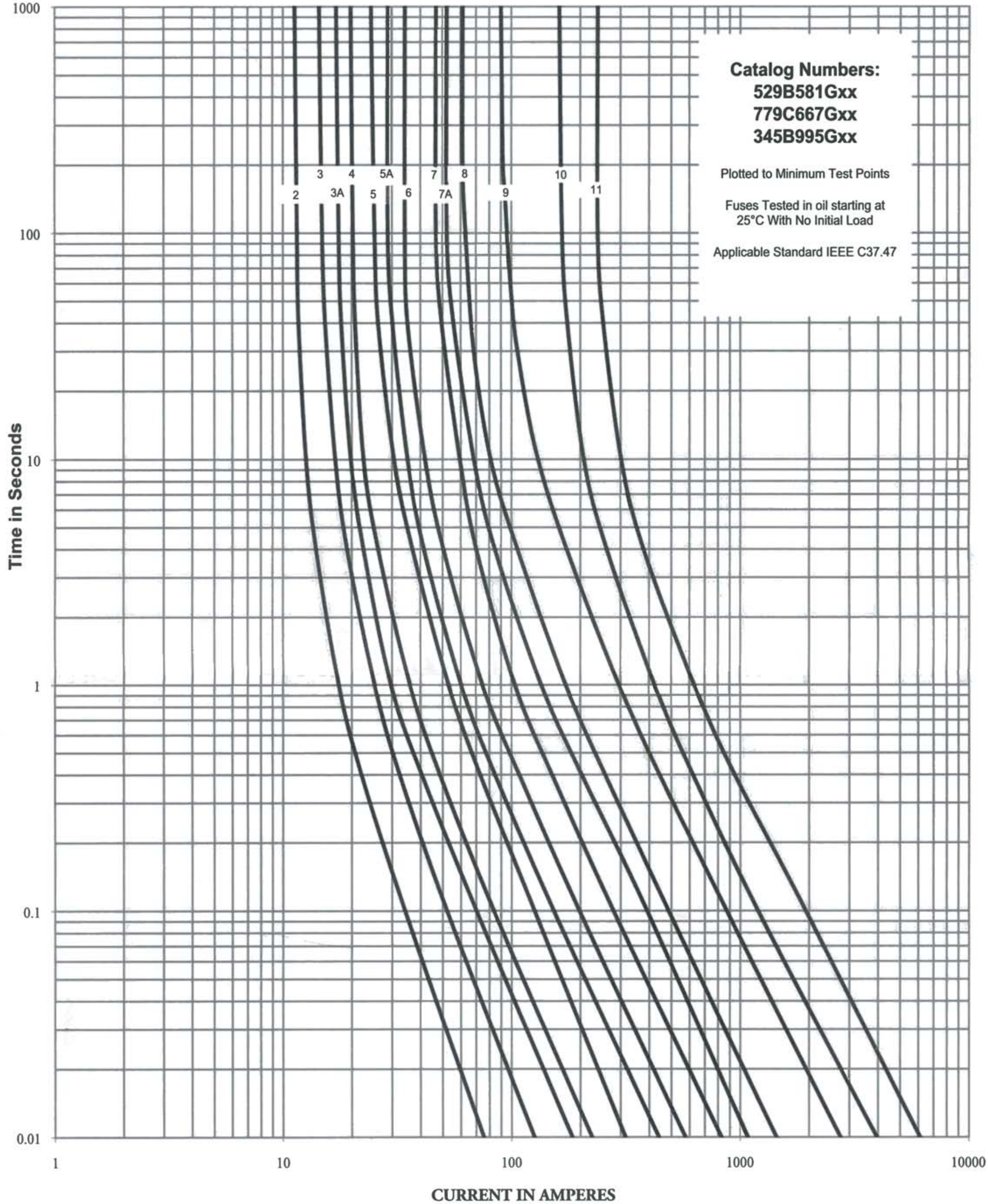

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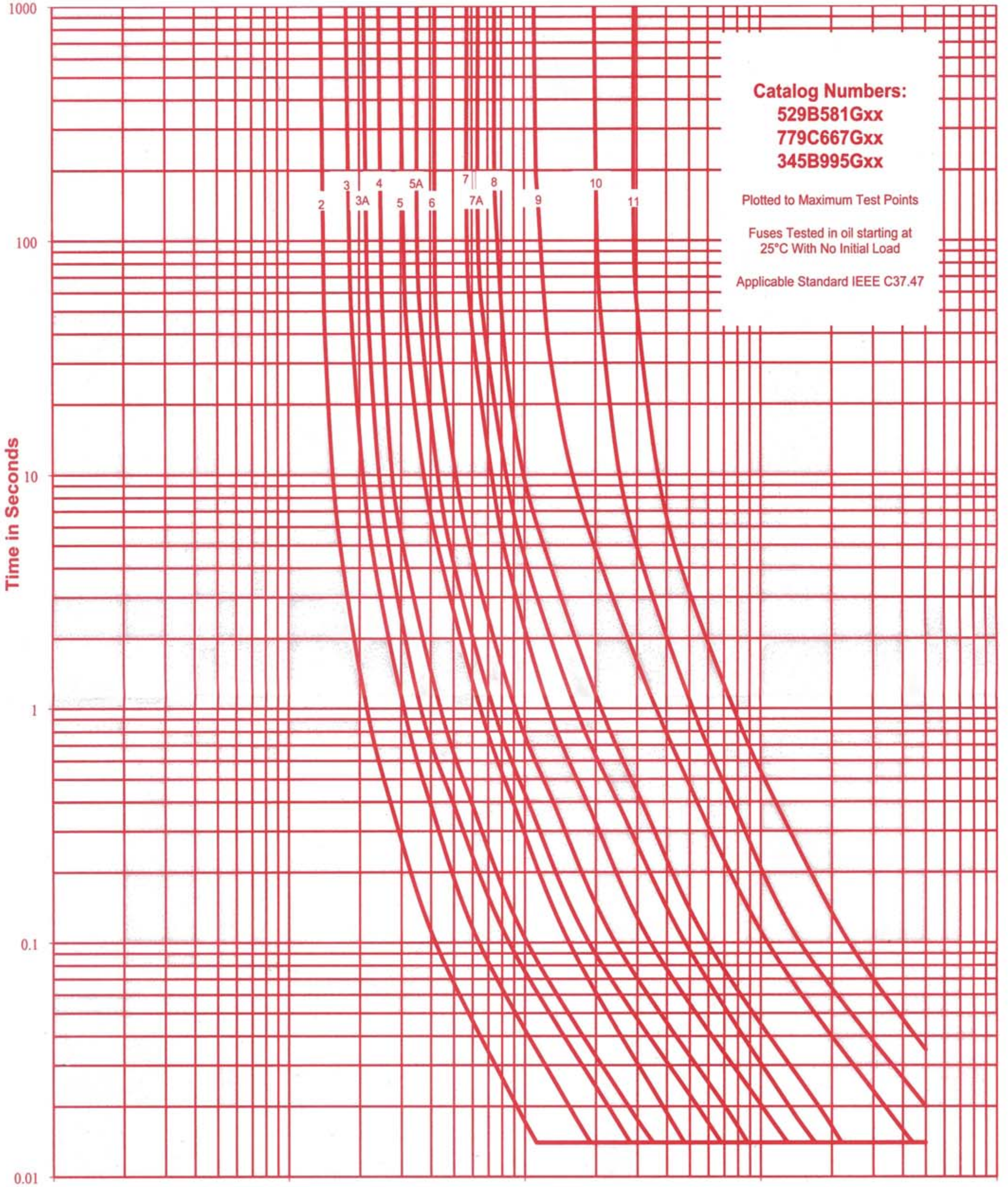
MINIMUM MELT TIME - CURRENT CHARACTERISTICS

PROTECTIVE LINKS IN TRANSFER OIL

(FOR CLEARING CHARACTERISTICS SEE CURVE NUMBER IZUA567001-AAB

CURVE NO. IZUA567001-AAA

Revision: 2
Date: June 2009



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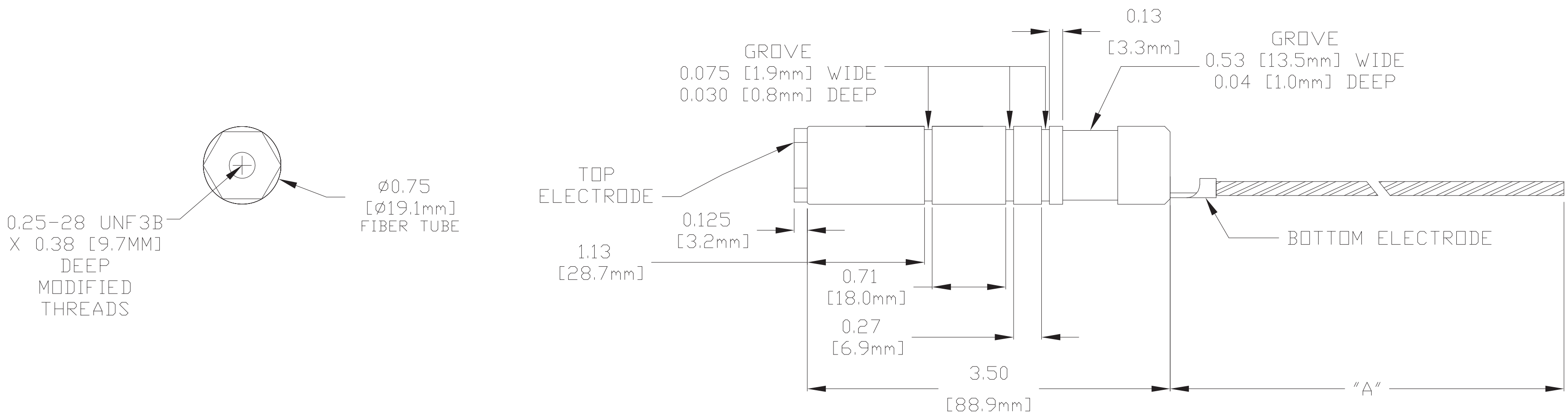
TOTAL CLEARING TIME - CURRENT CHARACTERISTICS

PROTECTIVE LINKS IN TRANSFER OIL

(FOR MINIMUM MELT CHARACTERISTICS SEE CURVE NUMBER IZUA567001-AAA

CURVE NO. IZUA567001-AAB

Revision: 2
Date: June 2009



STYLE NUMBER	CURVE	BOTTOM ELECTRODE	CABLE LEAD	FUSE DIA.	LEAD LENGTH "A"
592B581G01	2	YES	259-.005	0.013	8.25
592B581G02	3	YES	259-.005	0.016	8.25
592B581G11	3A	YES	259-.005	0.018	8.25
592B581G06	4	YES	259-.005	0.020	8.25
592B581G16	4	YES	259-.005	0.020	10.25
592B581G03	5	YES	259-.005	0.025	8.25
592B581G12	5A	YES	259-.005	0.028	8.25
592B581G04	6	YES	259-.005	0.032	8.25
592B581G05	7	YES	259-.005	0.040	8.25
592B581G13	7A	YES	259-.005	0.045	8.25
592B581G07	8	YES	259-.005	0.051	8.25
592B581G08	9	NO	259-.005	0.072	7.50
592B581G09	10	NO	427-.005	0.051	7.50
592B581G14	11	NO	427-.005	0.064	7.50
592B581G31	12	NO	19-.0295	0.081	7.50
592B581G32	13	NO	49-.0234	0.102	7.50

MINIMUM MELT TIME CURVE NO. 1ZUA567001-AAA
TOTAL CLEARING TIME CURVE NO. 1ZUA567001-AAB

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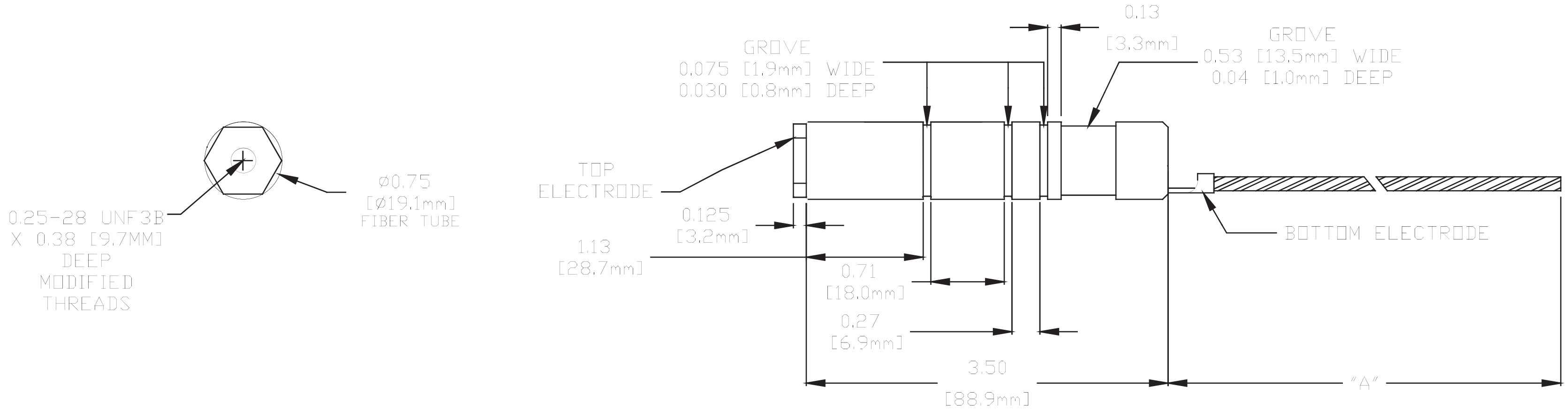
TITLE 15.0 kV PROTECTIVE LINK OUTLINE

DIMENSION SHEET:	PAGE:	REVISION:
44-889	10	05

DIMENSIONS ARE IN INCHES.



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5750D27G01	3	YES	259-.005	0.0159	5.25
5750D27G02	3A	YES	259-.005	0.0179	5.25
5750D27G03	4	YES	259-.005	0.0201	5.25
5750D27G04	5	YES	259-.005	0.0254	5.25
5750D27G05	5A	YES	259-.005	0.0285	5.25
5750D27G06	6	YES	259-.005	0.0320	5.25
5750D27G07	7	YES	259-.005	0.0400	5.25
5750D27G08	7A	YES	259-.005	0.0450	5.00
5750D27G11	9	NO	259-.005	0.0720	6.00
5750D27G12	10	NO	427-.005	0.0510	6.00
5750D27G14	11	NO	427-.005	0.0640	5.00
5750D27G15	12	NO	19-.0295	0.0810	4.75
5750D27G16	13	NO	49-.0231	0.1020	5.00
5750D27G19	8	YES	259-.005	0.0510	5.25

MINIMUM MELT TIME CURVE NO. 1ZUA567001-AAA
TOTAL CLEARING TIME CURVE NO. 1ZUA567001-AAB

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TITLE 15.0 kV PROTECTIVE LINK OUTLINE

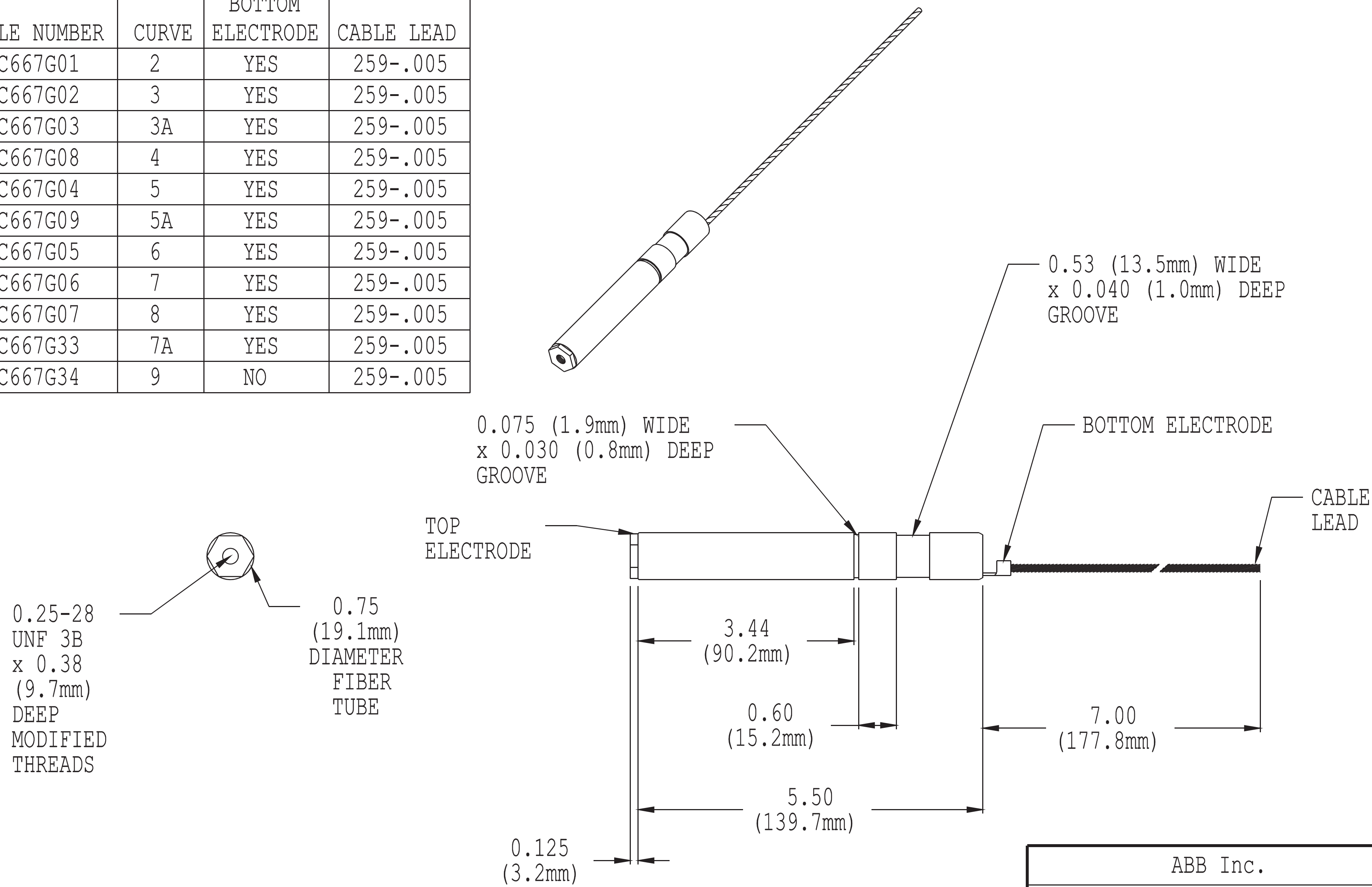
DIMENSION SHEET: 44-889

PAGE: 15

REVISION: 01

DIMENSIONS ARE IN INCHES.

STYLE NUMBER	CURVE	BOTTOM ELECTRODE	CABLE LEAD
779C667G01	2	YES	259-.005
779C667G02	3	YES	259-.005
779C667G03	3A	YES	259-.005
779C667G08	4	YES	259-.005
779C667G04	5	YES	259-.005
779C667G09	5A	YES	259-.005
779C667G05	6	YES	259-.005
779C667G06	7	YES	259-.005
779C667G07	8	YES	259-.005
779C667G33	7A	YES	259-.005
779C667G34	9	NO	259-.005



AVERAGE CLEARING TIME CURVE No. 735701
MINIMUM MELTING TIME CURVE No. 697700

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TITLE 23.0 kV PROTECTIVE LINK OUTLINE		
DIMENSION SHEET: 44-889	PAGE: 11	REVISION: 04
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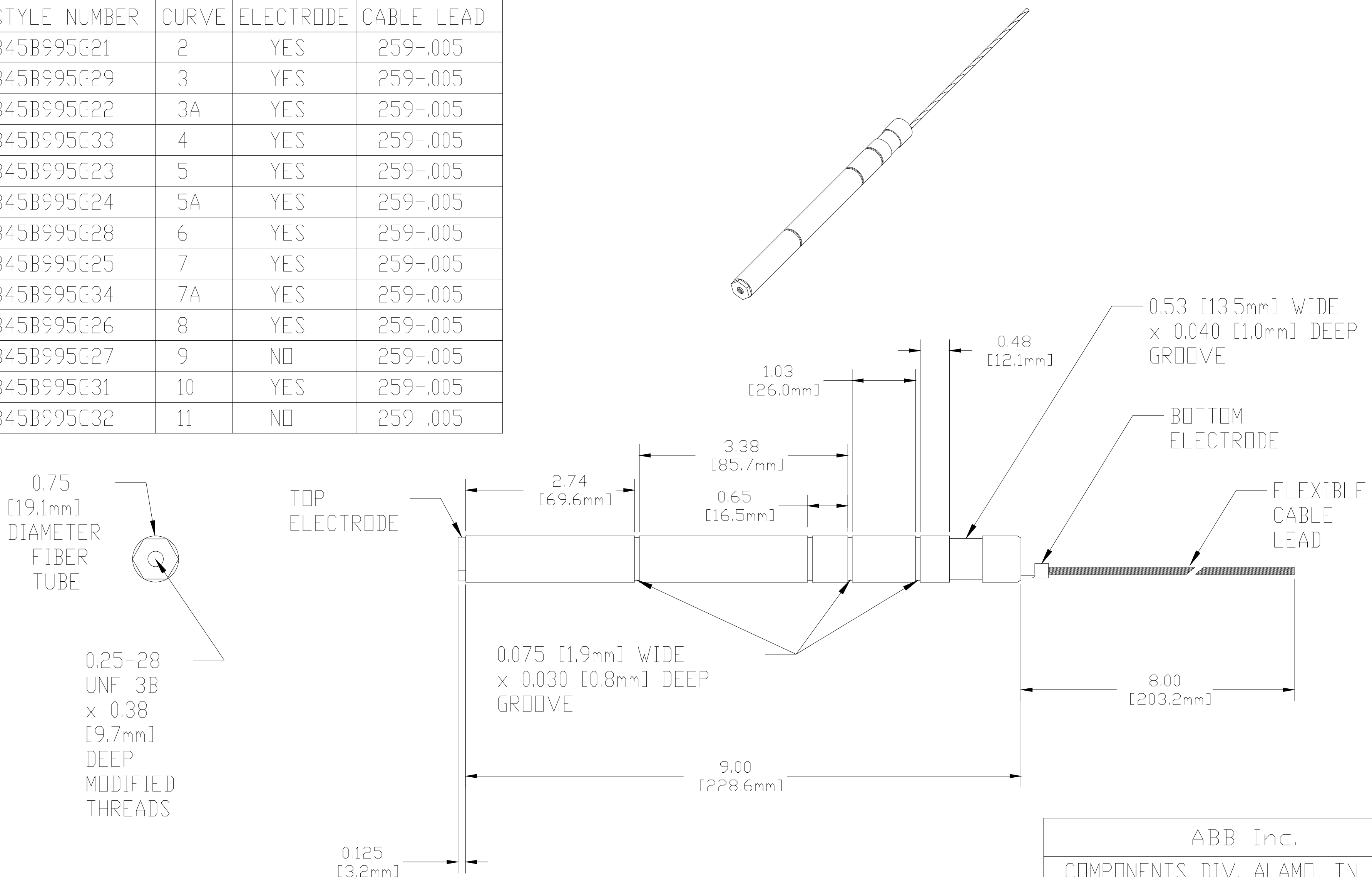
STYLE NUMBER	CURVE	BOTTOM ELECTRODE	CABLE LEAD
345B995G21	2	YES	259-.005
345B995G29	3	YES	259-.005
345B995G22	3A	YES	259-.005
345B995G33	4	YES	259-.005
345B995G23	5	YES	259-.005
345B995G24	5A	YES	259-.005
345B995G28	6	YES	259-.005
345B995G25	7	YES	259-.005
345B995G34	7A	YES	259-.005
345B995G26	8	YES	259-.005
345B995G27	9	NO	259-.005
345B995G31	10	YES	259-.005
345B995G32	11	NO	259-.005



AVERAGE TIME CLEARING CURVE No. 735701
MINIMUM TIME MELTING CURVE No. 1ZUA567001-AAA
TOTAL TIME CLEARING CURVE No. 1ZUA567001-AAB

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TITLE 34.5 kV PROTECTIVE LINK OUTLINE		
DIMENSION SHEET: 44-889	PAGE: 12	REVISION: 07
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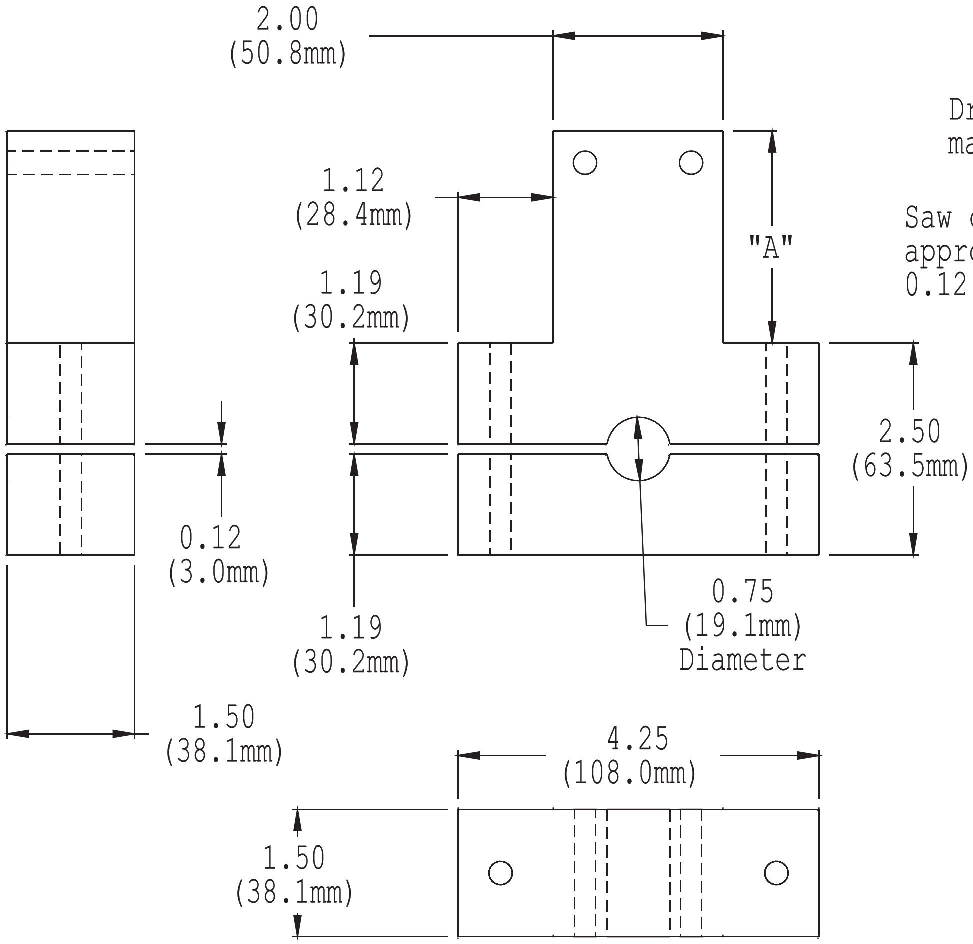
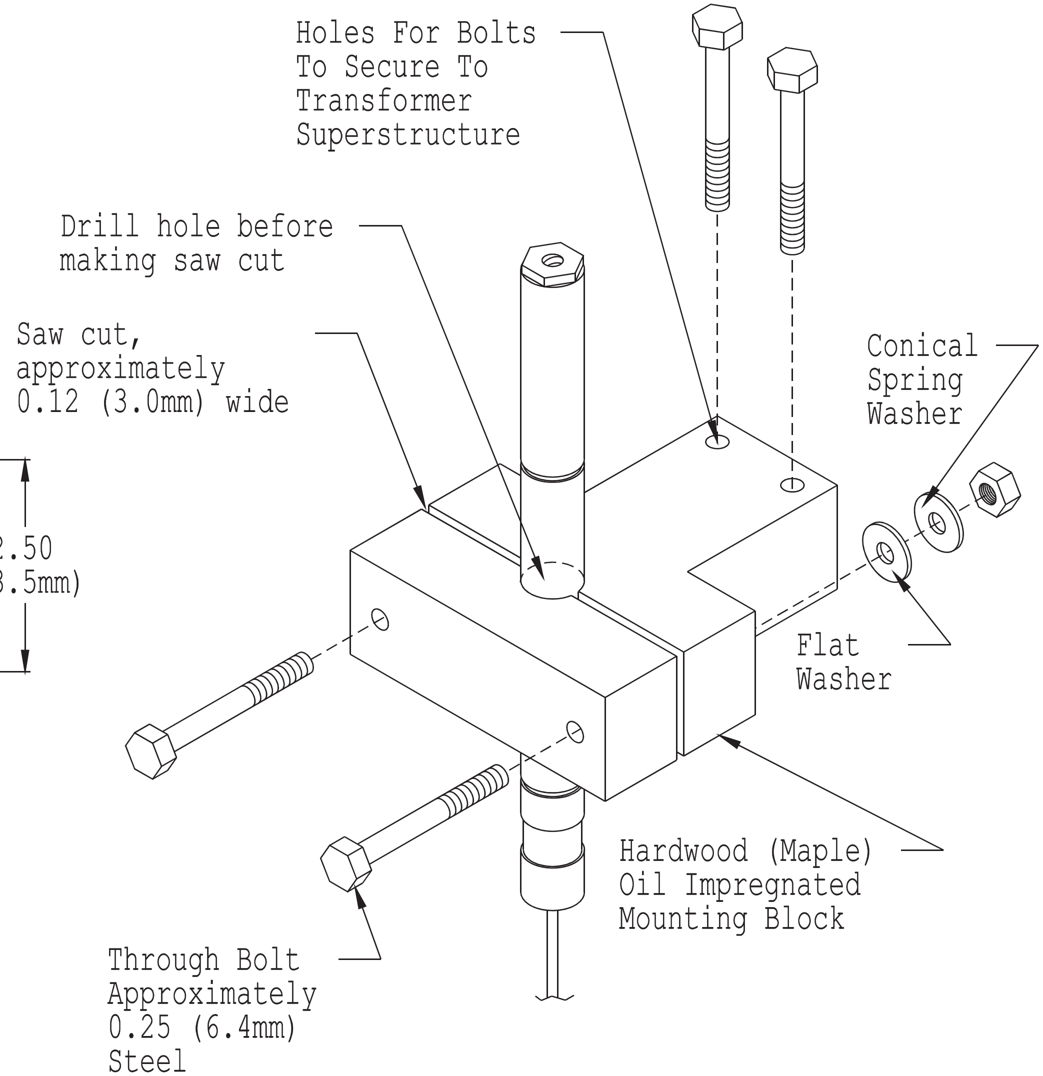
Suggested Mounting for 34.5 kV Protective Link
(Block is not supplied by ABB)





1: Dimension A=2.5 (63.5mm) when mounting to insulating board
   Dimension A=5.0 (127.0mm) when mounting to steel frame
2: Insert protective link into mounting hole
3: Tighten through bolts to secure protective link.
3: Mount to transformer superstructure using mounting
   holes and suitable hardware.

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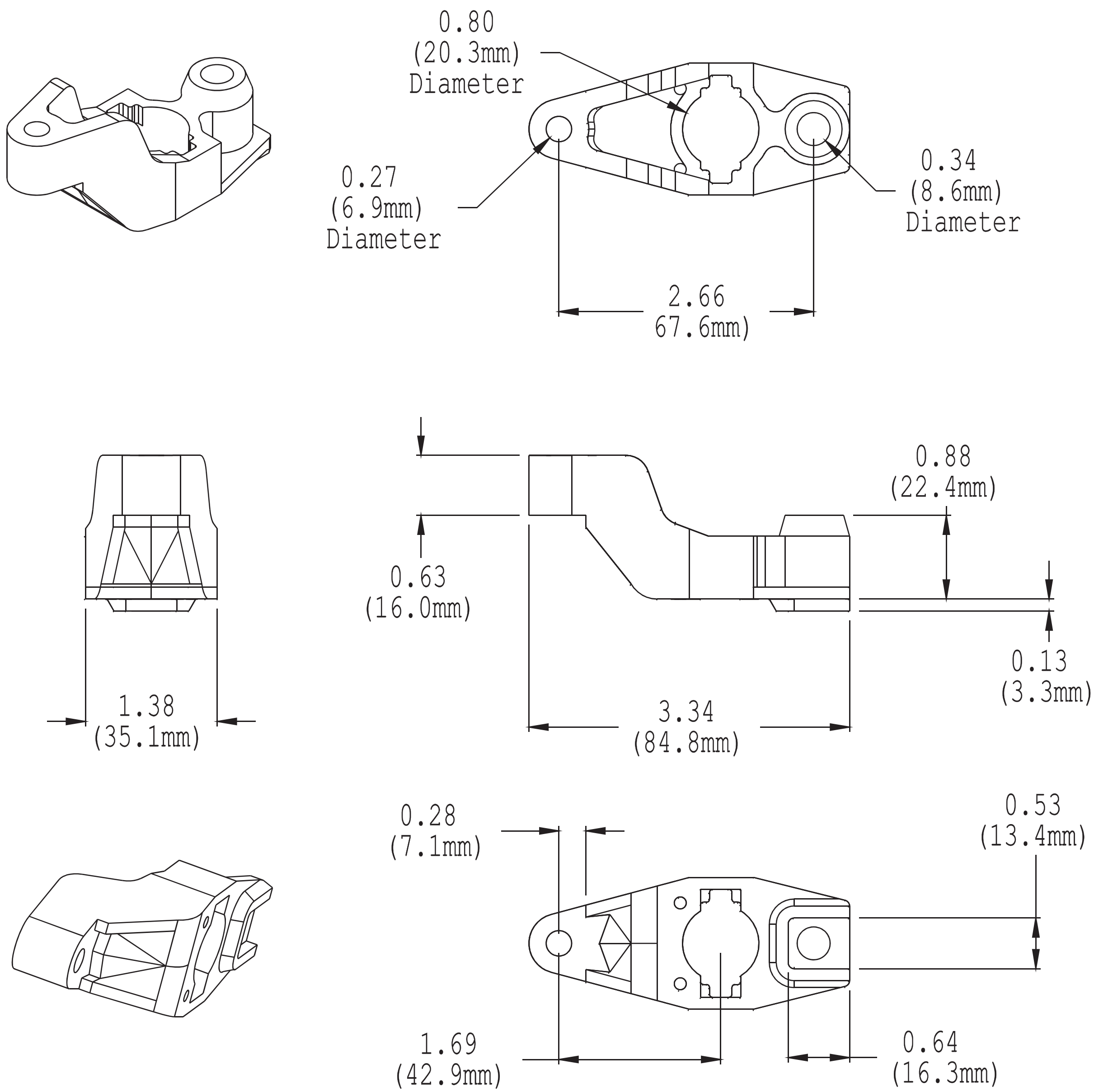
TITLE

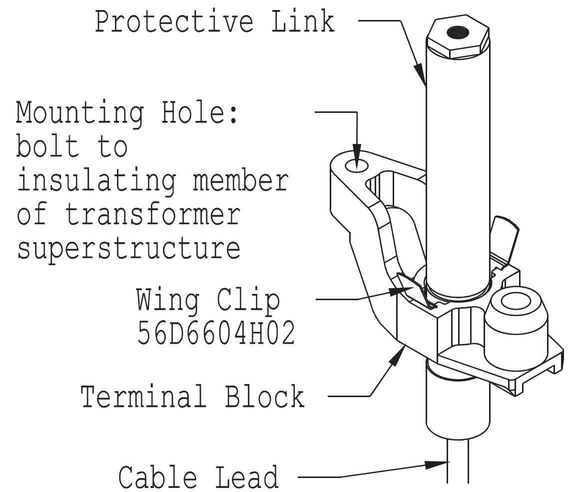
MOUNTING BLOCK

DIMENSION SHEET:	PAGE:	REVISION:
44-889	13	02

DIMENSIONS ARE IN INCHES.

STYLE NUMBER	DESCRIPTION
584B903H01	TERMINAL BLOCK - PROTECTIVE LINK MOUNTING





For Use With Wing Clip
(Style Number 56D6604G01)

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TITLE MOUNTING BLOCK		
DIMENSION SHEET: 44-889	PAGE: 14	REVISION: 03
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