Introduction:

This paper analyzes the protection of wire from fault currents. It gives the specifier the necessary information regarding the short-circuit current rating of wire. Proper protection of wire will improve reliability and reduce the possibility of injury. Wire can be destroyed if the overcurrent devices do not limit the short-circuit current to within the short-circuit current rating of the wire. Merely matching the ampere rating of the wire with the ampere rating of a protective device will not assure component protection of the wire under short-circuit conditions.

In the past several years, there have been numerous reports in newspapers, magazines and insurance company files about destroyed electrical systems. Recognizing this as a serious problem to safety of life and property, much more emphasis has been placed on COMPLIANCE with THE 2002 NATIONAL ELECTRICAL CODE (NEC)®.

The NEC covers COMPONENT PROTECTION in several sections. The first section to note is Section 110.10.

Component Protection and the NEC:

Per NEC 110.10. Circuit Impedance and Other Characteristics:

"The overcurrent protective devices, the total impedance, the component short-circuit current ratings, and other characteristics of the circuit to be protected shall be selected and coordinated as permit the circuit-protective devices used to clear a fault to do so without extensive damage to the electrical components of the circuit. This fault shall be assumed to be either between two or more of the circuit conductors, or between any circuit conductor and the grounding conductor or enclosing metal raceway. Listed products applied in accordance with their listing shall be considered to meet the requirements of this section."

This requires that overcurrent protective devices, such as fuses and circuit breakers be selected in such a manner that the short-circuit current ratings of the system components will not be exceeded should a short-circuit occur.

The “short-circuit current rating” is the maximum short-circuit current that a component can safely short-circuit current. Failure to provide adequate protection may result in component destruction under short-circuit conditions.

The first step to verifying conductor short-circuit protection is to calculate the short-circuit current fault levels throughout the electrical system. The next step is to check the short-circuit current rating of wire and cable, based upon the calculated short-circuit fault current available and the overcurrent protective device selected.

Note: The let-through of the protective device must be equal to or less than the short-circuit current rating of the component being protected.

CAUTION: Choosing overcurrent protective devices strictly on the basis of voltage, current, and interrupting rating alone will not assure component protection from short-circuit currents. High interrupting capacity electromechanical overcurrent protective devices, especially those that are not current-limiting, may not be capable of protecting wire, cable or other components within high short-circuit ranges. The interrupting rating of a protective device pertains only to that device and has absolutely no bearing on its ability to protect connected down-stream components. Quite often, an improperly protected component is completely destroyed under short-circuit conditions while the protective device is opening the faulted circuit without damage to itself.

CONDUCTOR SIZE:

Short-Circuit Currents for Insulated Cables

The recent increase in KVA capacity of power distribution systems has resulted in possible short-circuit currents of extremely high magnitude. Fault induced, high conductor temperatures may seriously damage conductor insulation.

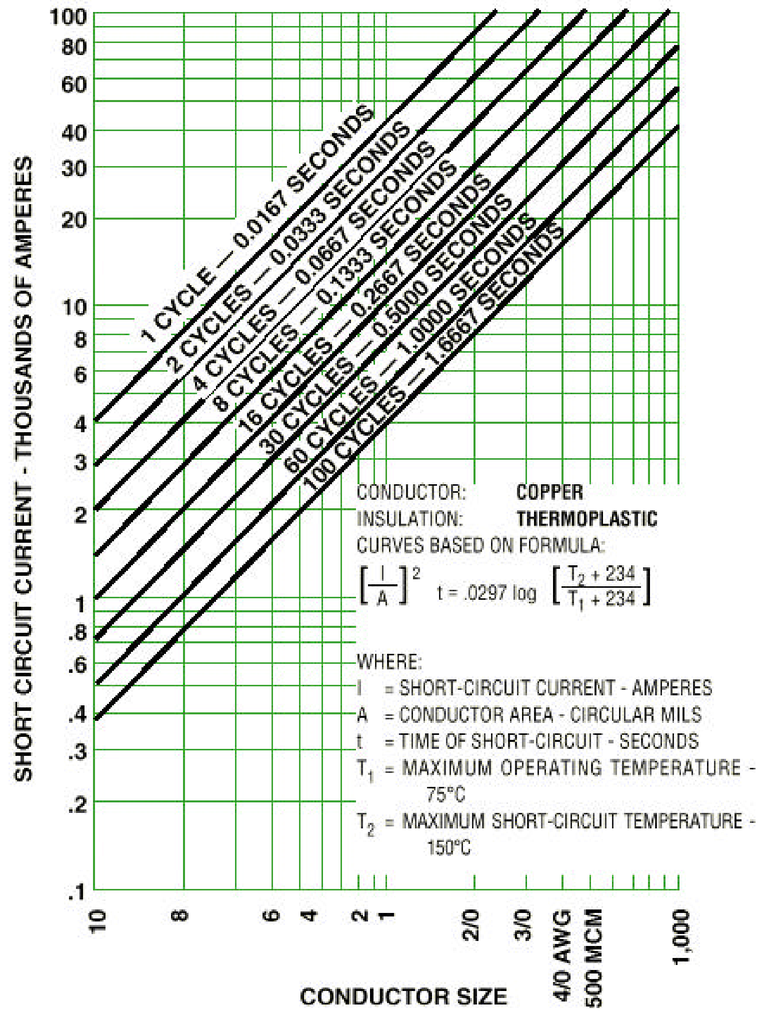
As a guide in preventing such serious damage, maximum allowable short-circuit temperatures, which begin to damage the insulation, have been established for various insulation such as, Thermoplastic at 150°C.

The Insulated Cable Engineers Association (ICEA) protection chart, to the right, shows the currents, which, after flowing for the times indicated, will produce these maximum temperatures for each conductor size. The system short-circuit capacity, the conductor cross-sectional area and the overcurrent protective device opening time should be such that these maximum allowable short-circuit currents are not exceeded.

Using the formula shown on the ICEA protection chart will allow the engineer to calculate short-circuit current ratings of cable not shown on these pages. It may be advantageous to calculate short-circuit current ratings below one cycle, when the opening time of the current-limiting device is known.

Short-Circuit Current Withstand Chart for Copper Cables with Thermoplastic Insulation

Allowable Short-Circuit Currents for Insulated Copper Conductors*



Protecting Equipment Grounding Conductors:

Safety issues arise when the analysis of equipment grounding conductors is discussed. Table 250.122 of the NEC offers minimum sizing for equipment grounding conductors.

The problem of protecting equipment grounding conductors was recognized more than 30 years ago when Eustace Soares, wrote his famous grounding book "Grounding Electrical Distribution Systems for Safety". In his book he states that the "validity" rating corresponds to the amount of energy required to cause the copper to become loose under a lug after the conductor has had a chance to cool back down. This validity rating is based upon raising the copper temperature from 75°C to 250°C.

In addition to this and the ICEA charts, a third method promoted by Onderdonk allows the calculation of the energy necessary to cause the conductor to melt (if the copper conductor reaches a temperature 1,083°C). Table 1 offers a summary of these values associated with various size copper conductors.

It becomes obvious that the word “Minimum” in the heading of table 250.122 means just that - the values in the table are a minimum - they may have to be increased due to the available short-circuit current and the current-limiting, or non-current-limiting ability of the overcurrent protective device.

Good engineering practice requires the calculation of the available short-circuit currents (3-phase and phase-to-ground values) wherever equipment grounding conductors are used. Overcurrent protective device (fuse or circuit breaker) manufacturers’ literature must be consulted. Let-through energies for these devices should be compared with the short-circuit current rating of the equipment grounding conductors. Wherever let-through energies exceed the “minimum” equipment grounding conductor short-circuit current ratings, the equipment grounding conductor size must be increased until the short-circuit current ratings are not exceeded.

Table 1: Comparison of 75°C Conductor 5 Second Current and I^2t Ratings (Based on RMS Ampere

		5 Second Rating (Amps)			I^2t Rating (Amperes Squared Seconds)		
Cond Size	**Cond Area Circ. Mils**	**ICEA Insulation 150 Deg. C**	**Soares Annealing 250 Deg. C**	**Onderdonk Melting 1083 Deg. C**	**ICEA Insulation 150 Deg. C**	**Soares Annealing 250 Deg. C**	**Onderdonk Melting 1083 Deg. C**
14 AWG	4110	97.31	139.84	251.35	47346	97774	315881
12 AWG	6530	154.61	222.18	399.34	119517	246812	797382
10 AWG	10380	245.76	353.17	634.79	301994	623640	2014813
8 AWG	16510	390.90	561.74	1009.68	764007	1577732	5097229
6 AWG	26240	621.27	892.79	1604.72	1929882	3985352	12875605
4 AWG	41740	988.25	1420.16	2552.63	4883238	10084258	32579535
3 AWG	52620	1245.85	1790.34	3218.00	7760768	16026576	51777572
2 AWG	66360	1571.17	2257.83	4058.27	12342860	25488942	82347942
1 AWG	83690	1981.48	2847.46	5118.10	19631350	40540229	130974616
1/0 AWG	105600	2500.23	3592.93	6458.01	31255818	64545637	208529659
2/0 AWG	133100	3151.33	4528.59	8139.79	49654561	102540438	331280679
3/0 AWG	167800	3972.91	5709.22	10261.88	78919977	162975743	526530956
4/0 AWG	211600	5009.94	7199.46	12940.49	125497294	259161440	837281168
250 kcmil	250000	5919.11	8505.98	15288.86	175179408	361758775	1168745667
300 kcmil	300000	7102.93	10207.18	18346.63	252258347	520932636	1682993761
350 kcmil	350000	8286.76	11908.38	21404.40	343351639	709047199	2290741508
400 kcmil	400000	9470.58	13609.57	24462.17	448459284	926102464	2991988908
500 kcmil	500000	11838.22	17011.97	30577.71	700717631	1447035100	4674982669
600 kcmil	600000	14205.87	20414.36	36693.26	1009033389	2083730545	6731975044
700 kcmil	700000	16573.51	23816.75	42808.80	1373406557	2836188797	9162966032
750 kcmil	750000	17757.33	25517.95	45866.57	1576614670	3255828976	10518711006
800 kcmil	800000	18941.16	27219.15	48924.34	1793837136	3704409857	11967955634
900 kcmil	900000	21308.80	30621.54	55039.88	2270325125	4688393726	15146943849
1000 kcmil	1000000	23676.45	34023.93	61155.43	2802870525	5788140402	18699930677

Table 1 illustrates the conductor rating for 5 seconds as well as the maximum I^2t rating based upon equipment grounding conductor size and the conductor damage level selected (ICEA, Soares or Onderdonk). However, depending upon the device selected and the resulting opening time, the amount of current the equipment grounding (or phase) conductor can handle will need to be adjusted. This is illustrated in the following tables and is valid for both phase and equipment grounding conductors.

Table 2 shows the maximum short-circuit current rating of the conductor based upon the opening time of the device. This table is based upon the ICEA Insulation damage level to raise the conductor from 75 degrees C to 150 degrees C. The opening time of the device can depend upon the device selected or the short time setting of the device. For example a low voltage power circuit breaker can have a short time delay of up to 30 cycles. Molded case circuit breakers can have similar short time delay settings up to the instantaneous setting or the instantaneous override.

Table 2: Maximum Short-Circuit Current Rating In Amperes (Per ICEA 75°C Insulation Damage)

Cond Size	Cond Area Circ. Mils	Maximum Short-Circuit Current Rating In RMS Amperes								
		1/2* Cycles 0.0083 Seconds	1 Cycle 0.0167 Seconds	2 Cycle 0.0333 Seconds	3 Cycle 0.0500 Seconds	6 Cycle 0.1 Seconds	12 Cycle 0.2 Seconds	18 Cycle 0.3 Seconds	24 Cycle 0.4 Seconds	30 Cycle 0.5 Seconds
14 AWG	4110	2384	1685	1192	973	688	487	397	344	308
12 AWG	6530	3787	2678	1894	1546	1093	773	631	547	489
10 AWG	10380	6020	4257	3010	2458	1738	1229	1003	869	777
8 AWG	16510	9575	6771	4788	3909	2764	1954	1596	1382	1236
6 AWG	26240	15218	10761	7609	6213	4393	3106	2536	2197	1965
4 AWG	41740	24207	17117	12104	9883	6988	4941	4035	3494	3125
3 AWG	52620	30517	21579	15259	12459	8810	6229	5086	4405	3940
2 AWG	66360	38486	27213	19243	15712	11110	7856	6414	5555	4968
1 AWG	83690	48536	34320	24268	19815	14011	9907	8089	7006	6266
1/0 AWG	105600	61243	43305	30621	25002	17679	12501	10207	8840	7906
2/0 AWG	133100	77192	54583	38596	31513	22283	15757	12865	11142	9965
3/0 AWG	167800	97316	68813	48658	39729	28093	19865	16219	14046	12563
4/0 AWG	211600	122718	86775	61359	50099	35426	25050	20453	17713	15843
250 kcmil	250000	144988	102522	72494	59191	41854	29596	24165	20927	18718
300 kcmil	300000	173986	123026	86993	71029	50225	35515	28998	25113	22461
350 kcmil	350000	202983	143531	101492	82868	58596	41434	33831	29298	26205
400 kcmil	400000	231981	164035	115990	94706	66967	47353	38663	33484	29949
500 kcmil	500000	289976	205044	144988	118382	83709	59191	48329	41854	37436
600 kcmil	600000	347971	246053	173986	142059	100451	71029	57995	50225	44923
700 kcmil	700000	405966	287062	202983	165735	117192	82868	67661	58596	52410
750 kcmil	750000	434964	307566	217482	177573	125563	88787	72494	62782	56154
800 kcmil	800000	463962	328070	231981	189412	133934	94706	77327	66967	59897
900 kcmil	900000	521957	369079	260978	213088	150676	106544	86993	75338	67384
1000 kcmil	1000000	579952	410088	289976	236764	167418	118382	96659	83709	74871

*** When comparing these values for 1/2 cycle with the available RMS symmetrical fault current, multiply the available RMS symmetrical by 1.3 to account for asymmetry during the first half cycle.**

Table 3 illustrates the maximum short-circuit current rating of copper conductor based upon the Soares damage level. This is the damage level associated with raising the conductor temperature from 75 degrees C to 250 degrees C. This would be the temperature that the conductor becomes loose under the lug (also known as the annealing point of copper).

Table 3:

Maximum Short-Circuit Current Rating In Amperes (per Soares Annealing 250 Deg C)

Cond Size	Cond Area Circ. Mils	Maximum Short-Circuit Current Rating In RMS Symmetrical Amperes								
		1/2* Cycles 0.0083 Seconds	1 Cycle 0.0167 Seconds	2 Cycle 0.0333 Seconds	3 Cycle 0.0500 Seconds	6 Cycle 0.1 Seconds	12 Cycle 0.2 Seconds	18 Cycle 0.3 Seconds	24 Cycle 0.4 Seconds	30 Cycle 0.5 Seconds
14 AWG	4110	3425	2422	1713	1398	989	699	571	494	442
12 AWG	6530	5442	3848	2721	2222	1571	1111	907	786	703
10 AWG	10380	8651	6117	4325	3532	2497	1766	1442	1249	1117
8 AWG	16510	13760	9730	6880	5617	3972	2809	2293	1986	1776
6 AWG	26240	21869	15464	10934	8928	6313	4464	3645	3156	2823
4 AWG	41740	34787	24598	17393	14202	10042	7101	5798	5021	4491
3 AWG	52620	43854	31010	21927	17903	12660	8952	7309	6330	5662
2 AWG	66360	55305	39107	27653	22578	15965	11289	9218	7983	7140
1 AWG	83690	69748	49320	34874	28475	20135	14237	11625	10067	9004
1/0 AWG	105600	88008	62231	44004	35929	25406	17965	14668	12703	11362
2/0 AWG	133100	110927	78437	55464	45286	32022	22643	18488	16011	14321
3/0 AWG	167800	139847	98887	69923	57092	40370	28546	23308	20185	18054
4/0 AWG	211600	176350	124698	88175	71995	50908	35997	29392	25454	22767
250 kcmil	250000	208353	147328	104177	85060	60146	42530	34726	30073	26898
300 kcmil	300000	250024	176794	125012	102072	72176	51036	41671	36088	32278
350 kcmil	350000	291694	206259	145847	119084	84205	59542	48616	42102	37658
400 kcmil	400000	333365	235725	166683	136096	96234	68048	55561	48117	43037
500 kcmil	500000	416706	294656	208353	170120	120293	85060	69451	60146	53797
600 kcmil	600000	500048	353587	250024	204144	144351	102072	83341	72176	64556
700 kcmil	700000	583389	412518	291694	238168	168410	119084	97231	84205	75315
750 kcmil	750000	625060	441984	312530	255180	180439	127590	104177	90220	80695
800 kcmil	800000	666730	471449	333365	272191	192468	136096	111122	96234	86075
900 kcmil	900000	750071	530381	375036	306215	216527	153108	125012	108263	96834
1000 kcmil	1000000	833413	589312	416706	340239	240586	170120	138902	120293	107593

*** When comparing these values for 1/2 cycle with the available RMS symmetrical fault current, multiply the available RMS symmetrical by 1.3 to account for asymmetry during the first half cycle**

Table 4 illustrates the maximum short-circuit current rating of copper conductor based upon the Onderdonk damage level. This is the damage level associated with raising the conductor temperature from 75 degrees C to 1083 degrees C. This would be the temperature at which the copper conductor melts. This value should obviously never be reached if good design practice is exercised.

Table 4:

Maximum Short-Circuit Current Rating In Amperes (per Onderdonk Melting 1083 Deg C)

Cond Size	Cond Area Circ. Mils	Maximum Short-Circuit Current Rating In RMS Symmetrical Amperes								
		1/2* Cycles 0.0083 Seconds	1 Cycle 0.0167 Seconds	2 Cycle 0.0333 Seconds	3 Cycle 0.0500 Seconds	6 Cycle 0.1 Seconds	12 Cycle 0.2 Seconds	18 Cycle 0.3 Seconds	24 Cycle 0.4 Seconds	30 Cycle 0.5 Seconds
14 AWG	4110	6157	4353	3078	2513	1777	1257	1026	889	795
12 AWG	6530	9782	6917	4891	3993	2824	1997	1630	1412	1263
10 AWG	10380	15549	10995	7775	6348	4489	3174	2592	2244	2007
8 AWG	16510	24732	17488	12366	10097	7139	5048	4122	3570	3193
6 AWG	26240	39307	27795	19654	16047	11347	8024	6551	5674	5075
4 AWG	41740	62526	44213	31263	25526	18050	12763	10421	9025	8072
3 AWG	52620	78825	55737	39412	32180	22755	16090	13137	11377	10176
2 AWG	66360	99407	70291	49704	40583	28696	20291	16568	14348	12833
1 AWG	83690	125367	88648	62684	51181	36190	25590	20895	18095	16185
1/0 AWG	105600	158188	111856	79094	64580	45665	32290	26365	22833	20422
2/0 AWG	133100	199383	140985	99692	81398	57557	40699	33231	28778	25740
3/0 AWG	167800	251364	177741	125682	102619	72562	51309	41894	36281	32451
4/0 AWG	211600	316976	224136	158488	129405	91503	64702	52829	45752	40921
250 kcmil	250000	374499	264811	187249	152889	108109	76444	62416	54054	48348
300 kcmil	300000	449399	317773	224699	183466	129730	91733	74900	64865	58017
350 kcmil	350000	524299	370735	262149	214044	151352	107022	87383	75676	67687
400 kcmil	400000	599198	423697	299599	244622	172974	122311	99866	86487	77356
500 kcmil	500000	748998	529622	374499	305777	216217	152889	124833	108109	96695
600 kcmil	600000	898798	635546	449399	366933	259460	183466	149800	129730	116034
700 kcmil	700000	1048597	741470	524299	428088	302704	214044	174766	151352	135373
750 kcmil	750000	1123497	794432	561748	458666	324326	229333	187249	162163	145043
800 kcmil	800000	1198397	847394	599198	489243	345947	244622	199733	172974	154712
900 kcmil	900000	1348196	953319	674098	550399	389191	275199	224699	194595	174051
1000 kcmil	1000000	1497996	1059243	748998	611554	432434	305777	249666	216217	193390

*** When comparing these values for 1/2 cycle with the available RMS symmetrical fault current, multiply the available RMS symmetrical by 1.3 to account for asymmetry during the first half cycle**

Current Limiting Devices:

As indicated in the footnote for the above tables, a device, which opens in one-half cycle or less, may or may not be classified as "current-limiting". The device can be labeled current limiting only if it meets the requirements of UL/CSA (489/22.2 No. 5 for molded case circuit breakers or UL/CSA/ANCE 248 for fuses).

The requirement for molded case circuit breakers is that the device must limit the asymmetrical fault current to a value below the equivalent symmetrical fault current. If the circuit breaker is not current-limiting, but clears within approximately one-half cycle, the available symmetrical fault current must be multiplied by a factor of 1.3 to account for asymmetry. Even if the molded case circuit breaker is current-limiting, the degree of current limitation is typically less than a rejection type fusible device.

The requirements for current-limiting fuses are based on the fuse type (class) and upon the maximum I^2t let-through as shown in Table 5. If the device meets the performance criteria, it meets the standard for that class of fuse and can be listed/certified per UL/CSA/ANCE.

The values shown in the table to the right can be used to compare the fuse maximum I^2t let-through for the fuse to the I^2t short-circuit rating of the conductor. As long as the I^2t let-through of the fuse is less than the I^2t short-circuit rating of the conductor, the conductor is protected under short-circuit conditions.

An example examining both the phase and grounding conductor is given on the following page.

Table 5: Clearing I^2t (Ampere^2 Seconds) per UL 248 – Table A

Fuse Class	I^2t Max Let-through Value		
	50 kA	100 kA	200 kA
Class J (600V)			
30	7,000	7,000	7,000
60	30,000	30,000	30,000
100	60,000	80,000	80,000
200	200,000	300,000	300,000
400	1,000,000	1,100,000	1,100,000
600	2,500,000	2,500,000	2,500,000
Class RK1 (250V and 600V)			
30	10,000	10,000	11,000
60	40,000	40,000	50,000
100	100,000	100,000	100,000
200	400,000	400,000	400,000
400	1,200,000	1,200,000	1,600,000
600	3,000,000	3,000,000	4,000,000
Class RK5 (250V and 600V)			
30	50,000	50,000	50,000
60	200,000	200,000	200,000
100	500,000	500,000	500,000
200	1,600,000	1,600,000	2,000,000
400	5,200,000	5,000,000	6,000,000
600	10,000,000	10,000,000	12,000,000
Class T			
30 300V	3,500	3,500	3,500
600V	7,000	7,000	7,000
60 300V	15,000	15,000	15,000
600V	30,000	30,000	30,000
100 300V	40,000	40,000	40,000
600V	60,000	80,000	80,000
200 300V	150,000	150,000	150,000
600V	200,000	300,000	300,000
400 300V	550,000	550,000	550,000
600V	1,000,000	1,100,000	1,100,000
600 300V	1,000,000	1,000,000	1,000,000
600V	2,500,000	2,500,000	2,500,000
800 300V	1,500,000	1,500,000	1,500,000
600V	4,000,000	4,000,000	4,000,000
1200 300V	3,500,000	3,500,000	4,000,000
600V	7,500,000	7,500,000	7,500,000
Class L (600V)			
800	10,000,000	10,000,000	10,000,000
1200	12,000,000	12,000,000	15,000,000
1600	22,000,000	22,000,000	30,000,000
2000	35,000,000	35,000,000	40,000,000
2500		75,000,000	75,000,000
3000		100,000,000	100,000,000
4000		150,000,000	150,000,000
5000		350,000,000	350,000,000
6000		350,000,000	500,000,000

Short-Circuit Protection of Wire and Cable:

Fusible Systems

The circuit shown originates at a distribution panel where 40,000 amperes RMS symmetrical are available. The 10 AWG THW copper conductor is protected by a Bussmann LOW-PEAK® fuse sized per NEC 240.4 (30A maximum for 10 AWG conductor).

Short-Circuit Protection of Wire and Cable

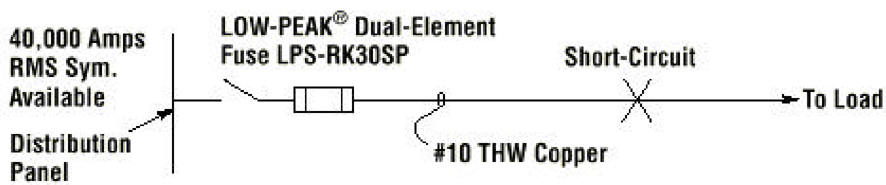


Table 1, shows the I^2t short-circuit rating of 10 AWG THW copper to be 301,994 per the ICEA Insulation damage level. Since the Bussmann LOW-PEAK® is a Class RK1 current limiting fuse, the maximum I^2t let-through per UL/CSA/ANCE 248 can be found per the table on the previous page. The maximum I^2t let-through for a Class RK1 fuse at a fault not greater than 50,000A is 10,000 A^2sec. Since the I^2t let-through of the fuse, 10,000, is considerably less than the I^2t short-circuit rating of the 10 AWG conductor, 301,994, the conductor is protected against short-circuits. In addition, since the minimum equipment grounding conductor per NEC 250.122 is also 10 AWG, the equipment grounding conductor is protected as well.

If the phase conductor was 3 AWG, the maximum fuse size per NEC 240.4 would be 100A. Looking at Table 1, the I^2t short-circuit rating of 3 AWG is shown to be 7,760,768 (per ICEA). If a Bussmann LOW-PEAK® Class RK1 current limiting fuse was selected, the maximum I^2t let-through per UL/CSA/ANCE 248, at a fault not greater than 50,000A is 100,000 A^2sec. Since the I^2t let-through of the fuse, 100,000, is less than the I^2t short-circuit rating of the 3 AWG phase conductor, 7,760,768, the conductor is protected against short-circuits. In order to meet NEC 110.10, we must also analyze the equipment grounding conductor as well. The minimum equipment grounding conductor per NEC 250.122 is 8 AWG. The I^2t short-circuit rating of 8 AWG is shown to be 764,007 (per ICEA). Since the phase-ground fault current can equal (or more if near the transformer) the bolted three-phase fault current, we can use the previous I^2t let-through of the 100A RK1 fuse. Since the I^2t let-through of the fuse, 100,000, is less than the I^2t short-circuit rating of the 8 AWG equipment grounding conductor, 764,007, the equipment grounding conductor is protected against short-circuits as well.

If the phase conductor was 500 kcmil, the maximum fuse size per NEC 240.4 would be 400A. Looking at Table 1, the I^2t short-circuit rating of 500 kcmil is shown to be 700,717,631 (per ICEA). If a Bussmann LOW-PEAK® Class RK1 current limiting fuse was selected, the maximum I^2t let-through per UL/CSA/ANCE 248, at a fault not greater than 50,000A is 1,200,000. Since the I^2t let-through of the fuse, 1,200,000, is considerably less than the I^2t short-circuit rating of the 500 kcmil conductor, 700,717,631, the conductor is protected against short-circuits. In order to meet NEC 110.10, we must also analyze the equipment grounding conductor as well. The minimum equipment grounding conductor per NEC 250.122 is 3 AWG. The I^2t short-circuit rating of 3 AWG is shown to be 7,760,768 (per ICEA). Since the phase-ground fault current can equal (or more if near the transformer) the bolted three-phase fault current, we can use the previous I^2t let-through of the 400A RK1 fuse. Since the I^2t let-through of the fuse, 1,200,000, is less than the I^2t short-circuit rating of the 3 AWG equipment grounding conductor, 7,760,768, the equipment grounding conductor is protected against short-circuits as well.

Table 6, on the next page, compares the maximum I^2t let-through for the fuse with the I^2t short-circuit rating of the conductor. If the I^2t short-circuit rating of the conductor is greater than the I^2t let-through of the fuse; the conductor will be protected. The table shows the minimum size conductor able to be protected under short-circuit conditions by the fusible device.

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Table 6:

Conductor Short-Circuit Protection (ICEA Values) Minimum Conductor Size, Based on UL 248			
Fuse Class	Available Short-Circuit Current (RMS Symmetrical Amperes)		
	50 kA	100 kA	200 kA
Class J (600V)			
30	14 AWG	14 AWG	14 AWG
60	14 AWG	14 AWG	14 AWG
100	12 AWG	12 AWG	12 AWG
200	10 AWG	10 AWG	10 AWG
400	6 AWG	6 AWG	6 AWG
600	4 AWG	4 AWG	4 AWG
Class RK1 (250V and 600V)			
30	14 AWG	14 AWG	14 AWG
60	14 AWG	12 AWG	12 AWG
100	12 AWG	12 AWG	12 AWG
200	8 AWG	8 AWG	8 AWG
400	6 AWG	6 AWG	6 AWG
600	4 AWG	4 AWG	4 AWG
Class RK5 (250V and 600V)			
30	12 AWG	12 AWG	12 AWG
60	10 AWG	10 AWG	10 AWG
100	8 AWG	8 AWG	8 AWG
200	6 AWG	6 AWG	4 AWG
400	3 AWG	3 AWG	3 AWG
600	2 AWG	2 AWG	2 AWG
Class T			
30 300V	14 AWG	14 AWG	14 AWG
600V	14 AWG	14 AWG	14 AWG
60 300V	14 AWG	14 AWG	14 AWG
600V	14 AWG	14 AWG	14 AWG
100 300V	14 AWG	14 AWG	14 AWG
600V	12 AWG	12 AWG	12 AWG
200 300V	10 AWG	10 AWG	10 AWG
600V	10 AWG	10 AWG	10 AWG
400 300V	8 AWG	8 AWG	8 AWG
600V	6 AWG	6 AWG	6 AWG
600 300V	6 AWG	6 AWG	6 AWG
600V	4 AWG	4 AWG	4 AWG
800 300V	6 AWG	6 AWG	6 AWG
600V	4 AWG	4 AWG	4 AWG
1200 300V	4 AWG	4 AWG	4 AWG
600V	3 AWG	3 AWG	3 AWG
Class L			
800	2 AWG	2 AWG	2 AWG
1200	1 AWG	1 AWG	1 AWG
1600	1/0 AWG	1/0 AWG	1/0 AWG
2000	2/0 AWG	2/0 AWG	2/0 AWG
2500	3/0 AWG	3/0 AWG	3/0 AWG
3000	4/0 AWG	4/0 AWG	4/0 AWG
4000	250 kcmil	250 kcmil	250 kcmil
5000	400 kcmil	400 kcmil	400 kcmil
6000	500 kcmil	500 kcmil	500 kcmil

Conductor Short-Circuit Protection (Soares Values) Minimum Conductor Size, Based on UL 248			
Fuse Class	Available Short-Circuit Current (RMS Symmetrical Amperes)		
	50 kA	100 kA	200 kA
Class J (600V)			
30	14 AWG	14 AWG	14 AWG
60	14 AWG	14 AWG	14 AWG
100	14 AWG	14 AWG	14 AWG
200	12 AWG	10 AWG	10 AWG
400	8 AWG	8 AWG	8 AWG
600	6 AWG	6 AWG	6 AWG
Class RK1 (250V and 600V)			
30	14 AWG	14 AWG	14 AWG
60	14 AWG	14 AWG	14 AWG
100	12 AWG	12 AWG	12 AWG
200	10 AWG	10 AWG	10 AWG
400	8 AWG	8 AWG	6 AWG
600	6 AWG	6 AWG	4 AWG
Class RK5 (250V and 600V)			
30	14 AWG	14 AWG	14 AWG
60	12 AWG	12 AWG	12 AWG
100	10 AWG	10 AWG	10 AWG
200	6 AWG	6 AWG	6 AWG
400	4 AWG	4 AWG	4 AWG
600	4 AWG	4 AWG	3 AWG
Class T			
30 300V	14 AWG	14 AWG	14 AWG
600V	14 AWG	14 AWG	14 AWG
60 300V	14 AWG	14 AWG	14 AWG
600V	14 AWG	14 AWG	14 AWG
100 300V	14 AWG	14 AWG	14 AWG
600V	14 AWG	14 AWG	14 AWG
200 300V	12 AWG	12 AWG	12 AWG
600V	12 AWG	10 AWG	10 AWG
400 300V	10 AWG	10 AWG	10 AWG
600V	8 AWG	8 AWG	8 AWG
600 300V	8 AWG	8 AWG	8 AWG
600V	6 AWG	6 AWG	6 AWG
800 300V	8 AWG	8 AWG	8 AWG
600V	4 AWG	4 AWG	4 AWG
1200 300V	6 AWG	6 AWG	4 AWG
600V	4 AWG	4 AWG	4 AWG
Class L			
800	4 AWG	4 AWG	4 AWG
1200	3 AWG	3 AWG	3 AWG
1600	2 AWG	2 AWG	1 AWG
2000	1 AWG	1 AWG	1 AWG
2500	2/0 AWG	2/0 AWG	2/0 AWG
3000	2/0 AWG	2/0 AWG	2/0 AWG
4000	3/0 AWG	3/0 AWG	3/0 AWG
5000	250 kcmil	250 kcmil	250 kcmil
6000	250 kcmil	250 kcmil	300 kcmil

<u>Short-Circuit Protection of Wire and Cable:</u>
Circuit Breaker Systems

In the previous example a 30A, Class RK1 fuse was protecting a 10 AWG conductor. If the 30A fusible device were replaced with a 30A, molded case circuit breaker with a clearing of 1/2 cycle would the 10 AWG conductor be protected?

Since the I^2t let-through of the circuit breaker is not known, Tables 2 through 4 must be used. If the 30A circuit breaker is current limiting, at a 40,000A fault, with a clearing time of 1/2 cycle, per UL 489, the let-through current could be as high as 40,000A RMS symmetrical and still be marked current limiting. If the device was not current limiting, the let-through current could be as high as 40,000 X 1.3, or 52,000A. The short-circuit current rating of 10 AWG conductor is 6,020A for 1/2 cycle (per ICEA). Since the let-through current of either the current limiting or non-current limiting circuit breaker could be much greater than the short-circuit current rating of the conductor, protection can not be assured for either the phase or equipment grounding conductor. Even if higher damage levels (Soares, Table 3 or Onderdonk, Table 4) where analyzed the let-through current could also exceed the higher short-circuit current damage levels.

If the same fault level was applied to 3 AWG conductor protected by a 100A circuit breaker, the phase conductor would not be protected to the ICEA level even if the circuit breaker device cleared within a half cycle. The short-circuit current rating of 3 AWG conductor is 30,517A for 1/2 cycle (per ICEA). Likewise the equipment grounding conductor sized as a 8 AWG, per NEC 250.122, may not be protected. Even if the device is current limiting and clears within a half cycle, 40,000A could be let-through. Since, at best, the 8 AWG conductor can withstand a short-circuit current of only 9,575A for 1/2 cycle, the equipment grounding conductor could be damaged on a phase-ground fault if the phase-ground fault was equal to the bolted three-phase fault level.

If the same fault level was applied to 500 kcmil conductor protected by a 400A circuit breaker, the phase conductor would be protected to ICEA level if the circuit breaker device cleared within 3 cycles. The short-circuit current rating of 500 kcmil conductor is 118,382A for 3 cycles (per ICEA). However, the equipment grounding conductor sized as a 3 AWG, per NEC 250.122 may not be protected. Even if the device is current limiting and clears within a half cycle, 40,000A could be let-through. Since, at best, the 3 AWG conductor can withstand a short-circuit current of only 30,517A for 1/2 cycle, the equipment grounding conductor could be damaged on a phase-ground fault if the phase-ground fault was equal to the bolted three-phase fault level.

In the above three examples, all with 40,000A available fault current, the circuit breaker could not assure short-circuit protection (by this analysis, per ICEA) of the phase or equipment grounding conductor in a 30A or 100A circuit. In the 400A circuit, the circuit breaker could provide short-circuit protection (by this analysis, per ICEA) for the phase conductors, but could not assure short-circuit protection (by this analysis, per ICEA) for the equipment grounding conductor. However, referring back to the previous example with the fusible systems, utilizing RK1 fuses, BOTH the phase conductor and equipment grounding conductor were protected in all cases. Typically, with current limiting fuses, the fuse will protect both the phase and equipment grounding conductor to the ICEA levels.

When using molded case circuit breakers, insulated case circuit breakers or low voltage power circuit breakers, conductors must be carefully analyzed for protection. This is especially true for motor circuits (overload relays provide the overload protection, with branch-circuit protection being sized at several times the ampacity of the conductor) and for equipment grounding (since the NEC allows for reduced sizing of the equipment grounding conductor).