NEMA WC 73

WIRE SELECTION GUIDELINES FOR WIRES RATED AT 200–450°C

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NEMA Standards Publication WC 73-2000

Wire Selection Guidelines for Wires Rated at 200–450°C

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Foreword

This standard has been developed by the WC 73 Task Force under the Electronics/Communications and Control Cable Subcommittee (members as listed below) of the High Performance Wire and Cable Section of NEMA in close coordination between manufacturers, users, third party certifying agencies and others having specialized experience. The High Performance Wire and Cable Section of NEMA periodically reviews this standard for any revisions necessary to keep it up to date. Proposed revisions or comments should be submitted to:

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Members of NEMA High Performance Wire and Cable Section that participated in the development of this standard were:

Alcatel Electronics – Elm City, NC
American Insulated Wire – Pawtucket, RI
Barcel/CDT – Irvine, CA
Cable USA – Naples, FL
Judd Wire – Turners Falls, MA
Quirk Wire – West Brookfield, MA
Radix Wire – Cleveland, OH
Rockbestos/Surprenant Cable – Clinton, MA
Tyco Electronics/Raychem Wire and Cable – Redwood City, CA

This standard was developed with the participation of members from The Committee on Mold Safety of the Society of the Plastics Industry, Washington, D.C.

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Section 1
SCOPE

This standard contains guidelines for calculating amperages and selecting wires for temperatures from 200°C to 450°C and for voltage ratings up to and including 1000 volts rms.

Ampacity charts, temperature correction factors, and derating factors are provided along with extensive examples of calculations.

This information is provided to assist users in their selection of wire or cable for a particular application. This guideline contains the best engineering estimates for calculation, but it cannot guarantee a successful performance. It is recommended that a trial installation be prepared and appropriate evaluations be conducted to assure acceptable performance of the completed systems.

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Section 2
REFERENCED STANDARDS

American Society for Testing and Materials (ASTM)
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959

ASTM B 3-95	*Soft or Annealed Copper Wire*
ASTM B 33-94	*Tinned Soft or Annealed Copper Wire for Electrical Purposes*
ASTM B 160-99	*Standard Specification for Nickel Rod and Bar*
ASTM B 298-99	*Standard Specification for Silver-Coated Soft or Annealed Copper Wire*
ASTM B 355-85	*Standard Specification for Nickel-Coated Soft or Annealed Copper Wire*

National Fire Protection Association (NFPA)
Batterymarch Park
Quincy, MA 02269

ANSI/NFPA-70-1999	*National Electrical Code (NEC)*
NFPA 79-1997	*Electrical Standard for Industrial Machinery*

Underwriters Laboratories Inc. (UL)
333 Pfingsten Road
Northbrook, IL 60062

UL 1581	*Standard for Electrical Wires, Cables, and Flexible Cords*

Canadian Standards Association (CSA)
178 Rexdale Boulevard
Etobicoke, ON M9W 1R3
Canada

CSA C22.2 #210.2-M90	*Appliance and Wiring Materials Products*
CSA C22.2 #0.3-96	*Test Methods for Electrical Wires and Cables*

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Section 3
BACKGROUND

This guideline was developed to assist the Mold Makers Division of the Society of Plastics Industry in their goal to provide an engineering baseline for the selection of wires used in the hot runner systems for injection molding equipment.

To this end, consideration of amperages, derating factors for number of conductors, operating temperatures, and overall safe operating conditions must be considered and understood.

Most calculations for amperages start with tables developed for wires rated at maximum temperatures of 90° – 200°C. However, wires used in hot runner systems are required to operate at temperatures of 200°C up to 450°C. Few references cover this higher temperature range. In view of this, it is strongly recommended that the guidelines in this document be verified by trial to assure a safe installation.

This guideline provides amperage tables and derating tables from the NEC which can be used by knowledgeable engineers to calculate current carrying values for high temperature (200°C – 450°C) wires and cables. The examples in this standard illustrate how these tables may be used in practice. Also included are various wire types and ratings which may be used for these types of applications.

The goal of this guideline is to assure that a standardized system is used in selecting high temperature wires for hot runner applications.

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Section 4
DESCRIPTION OF CONDUCTORS

4.1 CONDUCTOR COMPOSITION

Bare Copper (BC)
Tin Coated Copper (TCC)
Silver Coated Copper (SCC)
Nickel Coated Copper Class 2 – Class 10 (2%-10%) (NCC)
Nickel Coated Copper Class 27 "A" nickel

4.2 TEMPERATURE RANGE

Material	Temperature Range	Reference
Bare Copper, Tin-Coated Copper[1], and Silver-Coated Copper	200°C	ASTM B3, ASTM B33, ASTM B298, UL 1581, CSA C22.2 #210.2-M90, CSA C22.2 #0.3-96
Nickel-Coated Copper[2]	250°C	ASTM B355, UL 1581, CSA C22.2 #210.2-M90, CSA C22.2 #0.3-96
Class 27 Nickel-Coated Copper	450°C	ASTM B355, UL 1581, CSA C22.2 #210.2-M90, CSA C22.2 #0.3-96
"A" Nickel	450°C	ASTM B160, UL 1581, CSA C22.2 #210.2-M90, CSA C22.2 #0.3-96

4.3 GAUGE SIZE

This guideline covers sizes #24 through #8 AWG

[1] With strand size equal to or larger than 0.015 in.
[2] Nickel Coated Copper Class 2 – Class 10 (2%-10%) (NCC)

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Table 4-1
TYPICAL WIRE TYPES

Wire Temperature Rating	Conductor Composition*	Insulation Material(s)	Generic Designation
200°C	BC, TCC, NCC Class 2-10 SCC	FEP	FEP
		ETFE	ETFE
		PTFE	PTFE
		Unbraided Silicone Rubber	BSR
		Silicone Rubber/Glass Braid	SF Types
		Polyimide/FEP Tape	KF/KFF
250°C	NCC Class 2 - 10	PFA	PFA
		MFA	MFA
		PTFE	PTFE
		Unbraided Silicone rubber	BSR
		Silicone Rubber/Glass Braid	SF Types
		PTFE/Glass/Glass Braid	TGGT
		PTFE/Ceramic/Glass Braid	TCGT
		PTFE/Aramid/Glass Braid	TKGT
		Polyimide/PTFE Tape	----
		Polyimide/Glass Braid	KGT
450°C	NCC Class 27, "A" Nickel	Mica/Glass Braid	MGT
		Mica/Glass Braid /SS Shield	MGT-Shield

* Per paragraph 4.1

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Section 5
AMPACITIES AND CORRECTION FACTORS

5.1 INTRODUCTION

Establishing ampacity ratings is an inexact procedure. These tables should only be used as a starting point when establishing ratings for any given situation. Values may be lesser or greater than those given in the tables because of the influence of installation method, environment, number of conductors, conductor composition and size, ambient temperatures, insulation types, etc. It is recommended that design engineers desiring accurate ampacity data closely study the 1999 National Electrical Code, Articles 310-15 through 310-84. Additional information can be derived from AIEE, Paper Number 57-660: "The Calculation of the Temperature Rise and Load Capability of Cable Systems" by J. H. Neher and M. H. McGrath. This paper was presented to the AIEE general meeting in Montreal, Quebec, Canada on June 24-28, 1957, and was published in the "AIEE Transactions," Part 3 (power apparatus and systems), Volume 76, October, 1957, pp. 752-772. The information contained therein is still applicable.

The following tables are to be used in series to determine a wire's ampacity in a given application. Reference Section 6 for examples of applications of these tables. The tables include values for 150°C which are for reference only.

5.2 BASE AMPACITIES

TABLE 5-1
AMPACITIES OF THREE SINGLE INSULATED CONDUCTORS RATED 0 THROUGH 1000 VOLTS, 200° TO 450°C (392° TO 842° F) IN RACEWAY OR CABLE , BASED ON AMBIENT TEMPERATURES OF 40°C (104°F)[3]

AWG	150° C[4] BC, TCC	200°C BC, TCC, SCC, or NCC 2%-10%	250°C NCC 2%-10%	250°C "A" Nickel	450°C NCC-Class 27	450°C "A" Nickel
24	6.6	7.2	8	4	9	4.3
22	9	9.6	10.8	5	12	5.6
20	13	14.0	15	7	18	8
18	17	18	20	9.4	23	11
16	22	24	26	12	30	14
14	34	36	39	18	45	21
12	43	45	54	25	56	26
10	55	60	73	34	75	35
8	76	83	93	43	104	49

[3] 14-8 AWG 150°C, 200°C and 250°C NCC data is from NEC Table 310-18
[4] This column is for reference purposes only.

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Table 5-2
AMPACITIES OF THREE SINGLE INSULATED CONDUCTORS RATED 0 THROUGH 1000 VOLTS, 200°C TO 450°C (392°F TO 842°F) IN RACEWAY OR CABLE BASED ON AMBIENT TEMPERATURES OF 40°C (104°F) [5]

(For Reference Only)

AWG	150°C BC, TCC	200°C BC, TCC, SCC, or NCC 2%-10%	250°C NCC 2%-10%	250°C "A" Nickel	450°C NCC-Class 27	450°C "A" Nickel
6[6]	96	110	117	55	138	65
4	120	125	148	69	162	76
3	143	152	166	78	182	85
2	160	171	191	90	210	99
1	186	197	215	101	236	110
1/0	215	229	244	114	268	126
2/0	251	260	273	128	300	141
3/0	288	297	308	144	338	159
4/0	332	346	361	169	397	186
250	365	385	398	187	--	--
300	414	436	452	212	--	--
350	461	486	503	236	--	--
400	495	522	540	254	--	--
500	563	593	613	288	--	--

[5] 6-4/0 150°C, 200°C, and 250°C NCC data is from NEC Table 310-18.
[6] This table is for reference purposes only.

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5.3 TEMPERATURE CORRECTION FACTORS

Table 5-3
CORRECTION FACTORS FOR AMBIENT TEMPERATURES OTHER THAN 40°C (104°F)

(Multiply the Ampacities Shown in Tables 5-1 and 5-2 by the Appropriate Factor Shown Below)

(Wire Temperature Rating)

Ambient Temp. C	150°C[7]	200°C	250°C	450° C	Ambient Temp. F
41-50	0.95	0.97	0.98	0.99	106-122
51-60	0.90	0.94	0.95	0.99	124-140
61-70	0.85	0.90	0.93	0.96	142-158
71-80	0.80	0.87	0.90	0.95	160-176
81-90	0.74	0.83	0.87	0.93	177-194
91-100	0.67	0.79	0.85	0.92	195-212
101-120	0.52	0.71	0.79	0.89	213-248
121-140	0.30	0.61	0.72	0.86	249-284
141-160	…	0.50	0.65	0.84	285-320
161-180	…	0.35	0.58	0.81	321-356
181-200	…	...	0.49	0.78	357-392
201-225	…	...	0.35	0.74	393-437
226-250	…	...	...	0.69	439-482
251-275	…	...	...	0.65	483-527
276-300	…	...	...	0.60	528-572
301-325	…	...	...	0.55	573-617
326-350	…	...	...	0.49	618-662
351-375	…	...	...	0.42	663-707
376-400	…	...	...	0.34	708-752
401-450	…	...	...	…	753-842

5.4 CORRECTION FACTORS FOR MORE THAN THREE CONDUCTORS

Multiply the resulting ampacity calculated from Tables 5-1, 5-2, and 5-3 by the appropriate factors shown in Table 5-4. Since the values in Table 5-4 are expressed as percents, these values are to be converted to the decimal equivalent for calculation purposes.

[7] 150°C data is from NEC Table 310-18 and is for reference only.

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Table 5-4
ADJUSTMENT FACTORS FOR MORE THAN THREE CURRENT-CARRYING CONDUCTORS IN A RACEWAY OR CABLE

(NEC Table 310-15 (b)(2)(a))

Number of Current-Carrying Conductors	Percent of Values in Tables 5-1 through 5-3 as Adjusted for Ambient Temperature if Necessary
4-6	80
7-9	70
10-20	50
21-30	45
31-40	40
41 and above	35

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Section 6
AMPACITY CALCULATION EXAMPLES FROM THE HOT RUNNER INDUSTRY

6.1 BACKGROUND

Examples are shown of calculations for high temperature wire used in high temperature applications. The examples are from the injection molding hot runner industry where many systems are unique designs and component testing does not relate to a system's reliability. For this reason, the guidelines developed here show various examples for how to calculate the ampacity in high heat applications.

The ampacity calculation and deratings in this guideline can be used in other industry applications where high temperature wires and temperatures create similar operating conditions.

Within the hot runner industry, for the purposes of ampacity calculations, there are three types of systems based on ambient heat at the wire due to the wire routing:

1. Wire grooves or raceways in "cooled" plates. The wires from the heaters are routed away from the heaters to the outside or cooler faces of the manifold and manifold backing plate(s). The temperature that the wires see is related to the operating temperature of the cooling passages within the plates and the temperature of the manifold. Mold plates are typically cooled by chilled water, heated water, or heated oil. Even when heated the plates are cool relative to the temperature of the heated manifold and nozzles. Tests have shown that particularly for chilled water systems the wire grooves or wire raceways are above the chilled water temperature but significantly below the manifold temperature.

2. Wire grooves or raceways are within or immediately alongside the heated manifold. The wires are expected to be at the operating temperature of the manifold.

3. Wire channels are exposed within the manifold pocket of the manifold plate. The wire temperature is essentially the same as running the wires along the manifold in (2) above.

For the hot runner industry, the process temperature of the manifold and nozzles is monitored by a controller system with a shutdown mode if temperatures exceed a specified upper limit

Cautionary Note: Not all controllers provide this feature. Some controllers do not even provide an obvious alarm that the system is over temperature.

The following examples show both systems that work and systems that don't work, giving real life industry examples. Where a heater's ampacity limits are exceeded, the heater itself is not bad or poorly constructed. The application of the heater is inappropriate to the environment variables. The choice then is to change the heater to a lower wattage or increase the size or temperature rating of the heater wire as appropriate to meet the operating and ampacity requirements.

The examples start with simple application calculations and expand into more complex application calculations.

The major difficulty is estimating the ambient temperature during the design phase of a hot runner system. Once constructed, it is easy to measure the ambient temperature of a wire groove or raceway, but, without this data, the only option is to apply conservative estimates and verify the application.

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6.2 GENERAL CALCULATION EXAMPLE

The following example shows the effect of additional wires in a wire groove.

What is the ampacity of numerous manifold heater wires in a hot runner system? Many molds use chilled water to cool the mold plates. This is a calculation to show the effect of additional wires in the mold plate raceway or wire groove.

FACTS:

- Manifold Heater Wire is 12 AWG NCC Class 2-10. The heater lead wire is routed away from hot manifold.
- Temperature Rating of Wire Insulation: 250°C (482°F); therefore, maximum ampacity: is 54
- Temperature of Mold Plates: 51°C - 60°C (124°F - 140°F) assuming the use of chilled water on the plates and the effect of thermal radiation into the plates. Therefore, Temperature Correction Factor is 0.95.

Table 6-1
ACTUAL LOAD BASED ON NUMBER OF CONDUCTORS[3]

Number of Conductors in Channel (Regardless of Wire Gauge)	Adjustment factor (Function of Number of Conductors Within Channel)	Actual Load (AMP) of 12 AWG (Manifold Heater Wire)
0 - 3	1.00	51.30
4 - 6	0.80	41.04
7 - 9	0.70	35.91
10 - 20	0.50	25.65
21 - 30	0.45	23.09
31 - 40	0.40	20.52
41 – and over	0.35	17.96

[3] Information from Table 310-15 (b)(2)(a) of the 1999 NEC and Table 5-4 herein.

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Figure 1 presents the findings of Table 1 in line graph format.

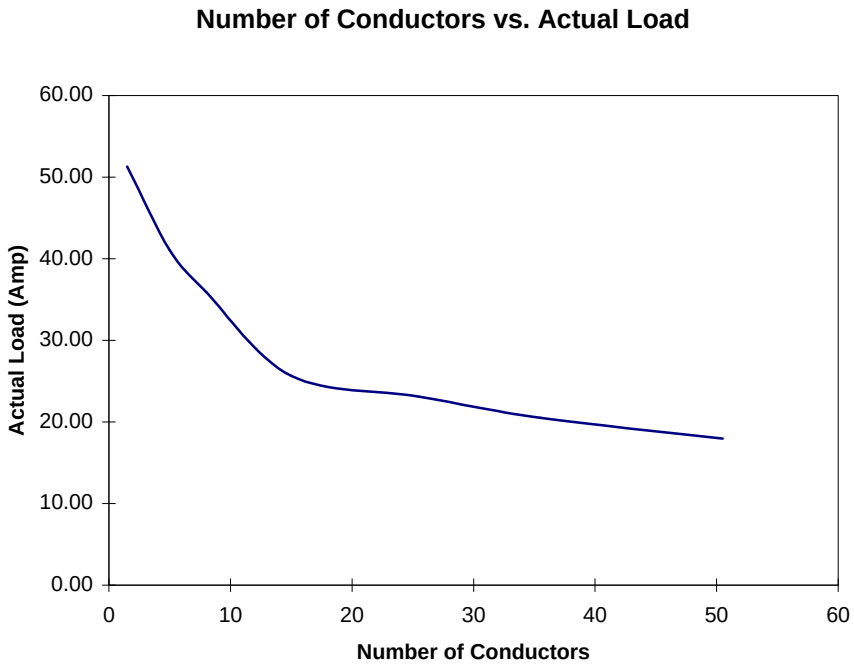

Figure 6-1
ACTUAL LOAD BASED ON NUMBER OF CONDUCTORS
FOR 12 AWG NCC CLASS 2-10 RATED 250ºC

Example Calculation #1

What is the ampacity of four manifold heater lead wires in a hot runner system?

FACTS:

- The processing or manifold temperature is 300°C (580°F).
- The manifold heater lead wire is routed away from the hot manifold into the mold plates.
- The mold is processing an engineering resin.
- The mold is heated with a water/glycol mixture to 66°C (150°F).
- All manifold heater lead wires are routed through a single raceway or wire groove in the mold plates.
- The manifold heater wire is 12 AWG NCC Class 2-10 with a temperature rating of 250°C.

CALCULATIONS:

1. From the tables, the maximum single conductor ampacity at 40°C is:
   54 amps for 12 AWG 250ºC NCC Class 2-10.

2. The ambient temperature exceeds 40°C (104°F); ampacity correction applied is:
   54A is 0.93 at 66°C; therefore, 54A x 0.93 = 50.22A.

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3. Since there are more than three conductors (four manifold heaters x two wires per heater = eight), a further adjustment factor is required. The adjustment factor for eight wires is 0.70; therefore:

   50.22 x 0.70 = 35.15A.

4. The maximum current carrying capacity for each wire is:

   35.15 A.

5. If a heater exceeds 35.15A, a further division of the heaters in the manifold is required, or a larger AWG conductor must be substituted, and the calculation performed again.

Example Calculation #2

What is the ampacity of 96 nozzle heaters in a hot runner system?

FACTS:

- The processing or manifold temperature is 290°C (550°F).
- The nozzle heater lead wires are routed away from the nozzle into the mold plates.
- The nozzle heater is rated for 250 watts at 240 volt.
- The mold is processing a polyester resin.
- The mold is cooled with chilled water. Assume the plates reach a temperature of 60°C (140°F) due to the radiation and conduction of heat into the plates from the manifold.
- The nozzle heater wires are grouped and routed through connecting raceways until there are two raceways (wire grooves in the plates) before entering the connectors on the mold. This creates a maximum bundle of 96 wires in the raceway.
- The nozzle heater wire is 18 AWG NCC Class 2-10 with a temperature rating of 200°C.

CALCULATIONS:

1. From the tables, the maximum single conductor ampacity at 40°C is:

   18 amps for 18 AWG 200ºC NCC Class 2-10.

2. The ambient temperature exceeds 40°C (104°F); ampacity correction applied is:

   18 A is 0.94 at 60°C; therefore, 18 A x 0.94 = 16.92 A.

3. Since there are more than three conductors (48 manifold heaters x two wires per heater = 96), a further adjustment factor is required. The adjustment factor for 96 wires is 0.35; therefore:

   16.92 x 0.35 = 5.92 A.

4. The maximum current carrying capacity for each wire is:

   5.92 Amps.

Example Calculation #3

What is the ampacity of 96 nozzle heaters in a hot runner system plus eight manifold heaters per hot runner system?

FACTS:

- The processing or manifold temperature is 290°C (550°F).
- The nozzle heater lead wire is routed away from the nozzles and manifold into the mold plates.
- The nozzle heater is rated for 250 watts at 240 volt.
- The manifold heater lead wire is routed away from the manifold into the mold plates. The largest manifold heater is rated for 6000 watts at 240 volt.
- The mold is processing a polyester resin.
- The mold is chilled with water. Assume the plates reach a temperature of 60°C (140°F) or less due to the radiation and conduction of heat into the plates from the manifold.

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- The nozzle heater and manifold wires are grouped and routed through two raceways or wire grooves in the plates, before entering the connectors on the mold. This creates a bundle of 96 nozzle heater wires and eight manifold heater wires in each raceway, a total of 104 wires.
- The nozzle heater wire is 18 AWG NCC Class 2-10 with a temperature rating of 200°C.
- The manifold heater wire is 12 AWG NCC Class 2-10 with a temperature rating of 250°C.

CALCULATIONS:

1. The examples in Calculations #1 and #2 include the same parameters with the two combined into one system. The calculation required here is to redo the derating for the number of wires in the raceway.
2. Since there are more than three conductors (48 nozzle heaters x two wires per heater = 96 plus four manifold heaters x two wires per heater = eight. 96+8 equals a total of 104 wires), a further adjustment factor is required. The adjustment factor for 104 wires is 0.35; therefore:

   16.92 x 0.35 = 5.92 A for 200ºC NCC Class 2-10, and
   50.22 x 0.35 = 17.57 A for 250º NCC Class 2-10.
3. The maximum current carrying capacity for each wire is:

   5.92 Amps for 200ºC NCC Class 2-10, and
   17.57 Amps for 250º NCC Class 2-10.

Example Calculation #4

What is the ampacity of 12 nozzle heaters in a hot runner system plus eight manifold heaters at 900 Watts plus eight manifold heaters at 2750 Watts?

FACTS:

- This example consists of a self-contained manifold system where the manifold nozzles and electrical for the hot runner are assembled together as a sub-assembly and then installed in the manifold plate. The wires for the manifold and nozzles are routed along the heated manifold to an electrical tower.
- The processing or manifold temperature is 340°C (644°F).
- The manifold heater lead wire is routed along the face of the manifold to an electrical tower or conduit attached to the heated manifold.
- The nozzle heater wires are grouped and routed along raceways or conduits on the face of the manifold before entering the electrical tower or conduit attached to the heated manifold.
- The nozzle heater is rated for 250 Watts at 240 volt.
- The first eight manifold heaters are rated for 900 Watts at 240 volt.
- The other eight manifold heaters are rated for 2750 Watts at 240 volt.
- The mold is processing an engineering resin and is heated with water/glycol mixture to 120°C (250°F).
- The manifold heater plus nozzle heater wires create a bundle of 56 wires in the tower.
- The manifold heater wire is 12 AWG NCC (Class 27) with a temperature rating of 450°C.
- The nozzle heater wire is 18 AWG NCC (Class 27) with a temperature rating of 450°C.

CALCULATIONS:

1. From tables, the maximum single conductor ampacity at 40°C is:

   23 amps for nozzle heater wire, and
   56 amps for manifold heater wire.
   The temperature of the mold has no effect on the calculation due to the wires being next to the higher temperature manifold. The processing temperature must be used.

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2. Temperature ampacity correction applied to both nozzle and manifold heater wires:

   Nozzle heater wire is 23 A at 0.49 for 340°C; therefore, 23 A x 0.49 = 11.27 A, and
   Manifold heater wire is 56 A at 0.49 for 340°C; therefore, 56 A x 0.49 = 27.44 A.

3. Since there are more than 41 wires (12 nozzle heaters x two wires per heater = 24 plus eight manifold heaters x two wires per heater = 16 plus eight manifold heaters x two wires per heater = 16. 24+16+16 equals a total of 56 wires), a further adjustment factor is required. The adjustment factor for 56 wires is 0.35; therefore:

   Nozzle wire ampacity is 11.27 x 0.35 = 3.94 A, and
   Manifold wire ampacity is 27.44 x 0.35 – 9.6 A

4. The maximum current carrying capacity for each wire is:

   Nozzle heater: 3.94 amp rating > 1.04 amp actual (12 nozzle heaters)
   Manifold heater: 9.6 amp rating < 11.46 amp actual (eight manifold heaters)

5. There is a problem in this example with the manifold heater wires for the 2750 Watt heaters; they require a larger AWG wire or the heaters must be reduced in wattage.

Example Calculation #5

What is the ampacity of eight nozzle heaters in a hot runner system plus three manifold heaters and a sprue bushing heater?

FACTS:

- This example contains an internally heated system where a heater distributor tube is inserted into drilled melt channels in a mold plate. The plastic flows through a series of annular channels from the machine nozzle to the nozzles (probes) at the product.
- The mold is processing linear low density polyethylene (LLDPE) resin.
- The process or manifold temperature of the resin is 230°C (450°F).
- The mold is cooled with chilled water. Assume the mold plates reach a temperature of 50°C (120°F) due to the radiation and conduction of heat into the plates from the manifold (distributor tubes in the cooled mold plate).
- The nozzle (probe) heater lead wire is routed away from the nozzles and manifold into the cooler mold plates.
- The eight nozzle heaters are rated for 250 watts at 240 volt or 1.04 amps each, they use 24 AWG (250°C) PTFE coated “A” nickel wire.
- There is one heated sprue bushing rated for 190 watts at 240 volt or 0.79 amps; it uses 18 AWG (450°C) “A” nickel wire.
- There is one distributor heater rated for 940 watts at 240 volts or 3.92 amps, it uses 18 AWG (450°C) “A” nickel wire.
- There are two distributor heaters rated for 1340 watts at 240 volts or 5.58 amps each; they use 18 AWG (450°C) “A” nickel wire.
- The manifold heater lead wire is routed away from the manifold into the cooler mold plates.
- The largest bundle of wires is under the terminal mounting box where all wires for nozzles (probes), sprue bushing, and distributor tubes (equivalent of the manifold) meet.
- The estimated temperature in the mold plates at the wire bundle is 50°C.

CALCULATIONS:

1. From the tables, the maximum single conductor ampacity at 40°C is:
   4 amps for 24 AWG 250°C “A” nickel, and for
   11 amps for 18 AWG 450°C “A” nickel.

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2. Ambient temperature exceeds 40°C (104°F); ampacity correction applied is:

   250°C wire is 0.98 at 50°C; therefore, 4 A x 0.98 = 3.92 A, and for
   450ºC wire is 0.99 at 50ºC; therefore, 11 A x 0.99 = 10.89 A.

3. Since there are more than three conductors (three manifold heaters x two wires per heater = six and eight nozzle heaters x two wires per heater = 16 plus two wires for the sprue bushing heater equals a total of 24 wires), a further adjustment factor for the wire bundle is required. The adjustment factor for 24 wires is 0.45; therefore:

   3.92 A x 0.45 = 1.76 A for 250°C "A" nickel wire, and for
   10.89 A x 0.45 = 4.90 A for 450ºC "A" nickel wire.

4. Maximum current carrying capacity for each wire is:

   24 AWG: 1.76 amp rating > 1.04 amp actual (eight nozzle heaters)
   18 AWG: 4.90 amp rating > 0.79 amp actual (sprue bushing)
   18 AWG: 4.90 amp rating > 3.92 amp actual (one distributor 940 watts)
   18 AWG: 4.90 amp rating < 5.58 amp actual (two distributors 1340 watts)

5 Since the two 1340 watt 18 AWG heaters exceeded the amperage ratings above, a further division of the heaters in the manifold is required, or a larger AWG conductor must be used in the heater construction, and the calculation must be performed again.

Example Calculation #6

FACTS:

- The mold is processing a polyphenylene oxide (PPO) resin.
- The processing or manifold temperature of the polyphenylene oxide (PPO) is 300ºC (572ºF).
- The mold is cooled with chilled water.
- Assume the mold plates reach a temperature of 55°C (131°F) due to the radiation and conduction of heat into the plates from the manifold.
- The manifold and nozzles are externally heated. The manifold and nozzle heaters are:
  four manifold heaters rated 2180 watts at 240 volt or 9.08 amps, 18 AWG "A" nickel (450°C) wire;
  two manifold heaters rated 2000 watts at 240 volt or 8.33 amps each, 18 AWG "A" nickel (450°C) wire;
  one nozzle at 950 watts rated 240 volt or 3.96 amps, 18 AWG "A" nickel (450°C) wire; and one nozzle heater rated 1000 watts at 240 volt or 4.17 amps, 18 AWG "A" nickel (450°C) wire.
- The largest wire bundle is the four manifold heaters and one nozzle heater.

CALCULATIONS:

1. From the tables, maximum single conductor ampacity at 40°C is:

   11 amps for 18 AWG 450°C "A" nickel.

2. The temperature exceeds 40°C (104°F); therefore, ampacity correction applied is:

   450ºC wire is 0.99 at 51-60ºC, and 11 A x 0.99 = 10.89 A.

3. Since there are more than three conductors (four manifold heaters x two wires per heater = eight and one nozzle heaters x two wires per heater = two equals a total of 10 wires), a further adjustment factor for the wire bundle is required. The adjustment factor for 10 wires is 0.50; therefore:

   10.89 x 0.50 = 5.44 A for 450ºC "A" nickel wire.

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4. The maximum current carrying capacity for each wire is:

   18 AWG: 5.44 amp rating < 9.08 amp actual, (four manifold heaters 2180 watts),
   18 AWG: 5.44 amp rating < 8.33 amp actual, (two manifold heaters 2000 watts),
   18 AWG: 5.44 amp rating > 3.96 amp actual, (one nozzle 950 watts),
   18 AWG: 5.44 amp rating > 4.17 amp actual, (one nozzle 1000 watts).

5. Since all the manifold heaters exceed the amperage ratings above, a further division of the heaters in the manifold is required, or a larger AWG conductor must be used in the manifold heater construction, and the calculation performed again.

Example Calculation #7

FACTS:

- The mold is processing 50% glass filled polyphenylene sulfide (50%GF PPS) resin.
- The processing or manifold temperature for polyphenylene sulfide (50% GF) is 370ºF (700ºF).
- The mold is cooled with heated oil.
- Assume the mold plates reach a temperature of 125°C (257°F) due to the radiation and conduction of heat into the plates from the manifold and the heated oil.
- The manifold and nozzles are externally heated.
- The manifold and nozzle heaters are:
  four manifold heaters rated 3000 watts at 240 volt or 12.5 amps, 14 AWG NCC (Class 27) (450°C) wire;
  eight nozzle heaters rated 730 watts at 240 volt or 3.04 amps, 22 AWG “A” nickel (450°C) wire.
- The largest wire bundle is four manifolds and eight nozzle heaters.

CALCULATIONS:

1. From the tables, maximum single conductor ampacity at 40°C is:

   45 amps for 14 AWG 450°C NCC (Class 27), and
   5.6 amps for 22 AWG 450°C “A” nickel.

2. Temperature exceeds 40°C (104°F); therefore, ampacity correction applied for 450ºC wire is 0.86 at 121-140ºC; therefore:

   45 A x 0.86 = 38.7 A, and 5.6 A x 0.86 = 4.82 A.

3. Since there are more than three conductors, (four manifold heaters x two wires per heater = eight and eight nozzle heaters x two wires per heater = 16 equals a total of 24 wires) a further adjustment factor for the wire bundle is required. The adjustment factor for 24 wires is 0.45; therefore:

   38.7 A x 0.45 = 17.42 A for 450ºC NCC (Class 27) wire.
   4.82 A x 0.45 = 2.17 A for 450ºC “A” nickel wire.

4. Maximum current carrying capacity for each wire is:

   14 AWG: 17.42 amp rating > 12.5 A actual (four manifold heaters 3000 watts), and
   22 AWG: 2.17 amp rating < 3.04 amp actual, (eight nozzle heaters 730 watts).

5. Since the nozzle heaters exceed the amperage ratings above, a larger AWG conductor must be used in the nozzle heater construction, and the calculation performed again.

Example Calculation #8

FACTS:

- The mold is processing polypropylene (PP) resin.
- The mold is cooled with chilled water.

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- Assume the plates reach a temperature of 50°C (120°F) due to the radiation and conduction of heat into the plates from the manifold.
- The processing or manifold temperature for the polypropylene is 230ºC (450ºF).
- Externally heated system with front loaded heaters.
- The manifold and nozzle heaters are:

  eight manifold heaters rated 1400 watts at 240 volt or 5.83 amps, 14 AWG NCC (Class 27) (450°C) wire,
  four manifold heaters rated 1750 watts at 240 volt or 7.29 amps, 14 AWG NCC (Class 27) (450°C) wire, and
  64 nozzle heaters rated 300 watts at 240 volt or 1.25 amps, 22 AWG "A" nickel (250°C) wire.
- The largest bundle is one manifold @ 5.83 A, one manifold @ 7.29 A and eight nozzles: 20 wires

CALCULATIONS:

1. From the tables, maximum single conductor ampacity at 40°C is:

   45 amps for 14 AWG 450°C NCC (Class 27), and
   5 amps for 22 AWG 250ºC "A" nickel.

2. Temperature exceeds 40°C (104°F); therefore, ampacity correction applied is:

   450ºC wire is 0.99 at 41-50ºC, is 45 A x 0.99 = 44.55 A, and
   250ºC wire is 0.98 at 41-50ºC , is 5 A x 0.98 = 4.9 A.

3. Since there are more than three conductors, (two 7manifold heaters x two wires per heater = four and eight nozzle heaters x two wires per heater = two equals a total of 20 wires) a further adjustment factor for the wire bundle is required. The adjustment factor for 20 wires is 0.50; therefore:

   44.55 A x 0.50 = 22.27 A for 450ºC "NCC (Class 27) wire, and
   4.9 A x 0.50 = 2.45 A for 250ºC "A" nickel wire.

4. The maximum current carrying capacity for each wire is:

   14 AWG: 22.27 amp rating > 5.83 amp actual, (eight manifold heaters 1400 watts),
   14 AWG: 22.27 amp rating > 7.29 amp actual, (two manifold heaters 1750 watts), and
   22 AWG: 2.45 amp rating > 1.25 amp actual, (64 nozzle 300 watts).

5. All heater wires are below the maximum amperage ratings.

Example Calculation #9

FACTS:

- The mold is processing high-density polyethylene with 10% Mineral filler (HDPE + 10% Mineral) resin.
- The mold is cooled with chilled water.
- Assume the plates reach a temperature of 50°C (120°F) due to the radiation and conduction of heat into the plates from the manifold.
- The processing or manifold temperature for HDPE 10% Mineral – 260ºC (500ºF).
- Externally heated system.
- The manifold and nozzle heaters are:

  two manifold heaters rated 2500 watts at 240 volt or 10.42 amps, 14 AWG NCC (Class 27) (450°C) wire
  four nozzles rated 770 watts at 240 volt or 3.21 amps, 22 AWG "A" nickel (450°C) wire
  one extension nozzle rated 200 watts at 240 volt or 0.83 amps, 22 AWG "A" nickel (450°C) wire.
- The largest bundle is one manifold, one nozzle and the one extension nozzle.

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CALCULATIONS:

1. From the tables, maximum single conductor ampacity at 40°C is:

   45 amps for 14 AWG 450°C NCC (Class 27), and
   5.6 amps for 22 AWG 250ºC "A" nickel.

2. The temperature exceeds 40°C (104°F); therefore, ampacity correction applied is:

   450ºC wire is 0.99 at 41–50ºC, is 45 A x 0.99 = 44.55 A, and
   250ºC wire is 0.98 at 41–50ºC, is 5.6 A x 0.98 = 5.49 A.

3. Since there are more than three conductors, (one manifold heater x two wires per heater = two, one nozzle heater x two wires per heater = two, and one extension nozzle heaters x two wires per heater = two; equals a total of six wires) a further adjustment factor for the wire bundle is required. The adjustment factor for six wires is 0.80; therefore:

   44.55 A x 0.80 = 35.64 A for 450ºC "NCC (Class 27) wire, and
   5.49 A x 0.80 = 4.39 A for 250ºC "A" nickel wire.

4. The maximum current carrying capacity for each wire is:

   14 AWG: 35.64 amp rating > 10.42 amp actual, (two manifold heaters 2500 watts),
   22 AWG: 4.39 amp rating > 3.21 amp actual, (four manifold heaters 770 watts), and
   22 AWG: 4.39 amp rating > 0.83 amp actual, (one extension nozzle 200 watts).

5. All heater wires are below the maximum amperage ratings.

Example Calculation #10

FACTS:

- The mold is processing Polycarbonate (PC) resin.
- The processing or manifold temperature is 293ºC (560ºF).
- The mold is cooled with heated water at a mold temperature of 63ºC (145ºF).
- The mold plates reach a temperature of 190°C (374°F) due to the radiation and conduction of heat into the plates from the manifold as measured in the wire channel.
- Externally heated system
- The manifold and nozzle heaters are:

Table 6-2
WIRING INFORMATION

Zone	Wire Type	Temperature Rating	Heater Wattage	Voltage	Amperage
1-4	"A" Nickel 24 AWG	250°C	200	240	0.83 A
5,6	NCC Class 27 16 AWG	450°C	2880	240	12.0 A
7	"A" Nickel 22 AWG	450°C	300	240	1.25 A

- Largest bundle is seven electrical zones (14 wires) through two adjoining channels (eight conductors through one, six through the other).

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CALCULATIONS:

Zones 1-4

1. From the tables, maximum single conductor ampacity at 40°C is:
   4 amps for 24 AWG 250°C A" nickel.

2. The temperature exceeds 40°C (104°F); therefore, ampacity correction applied is:
   250ºC wire is 0.49 at 181-200ºC, is 4 A x 0.49 = 1.96 A.

3. Since there are eight conductors, a further adjustment factor for the wire bundle is required. The adjustment factor for eight wires is 0.70; therefore:
   1.96A x 0.70 = 1.37 A for 250ºC "A" nickel wire.

4. The maximum current carrying capacity for each wire is:
   24 AWG: 1.37 amp rating > 0.88 amp actual.

5. The heater wires are below the maximum amperage ratings.

Zone 5 & 6

1. From the tables, maximum single conductor ampacity at 40°C is:
   30 amps for 16 AWG 450°C NCC (Class 27) wire

2. The temperature exceeds 40°C (104°F); therefore, ampacity correction applied is:
   450ºC wire is 0.78 at 181–200ºC, is 30 A x 0.78 = 23.4 A.

3. Since there are eight conductors, a further adjustment factor for the wire bundle is required. The adjustment factor for eight wires is 0.70; therefore:
   23.4 A x 0.70 = 16.38 A for 450ºC NCC (Class 27) wire.

4. The maximum current carrying capacity for each wire is:
   16 AWG: 16.38 amp rating > 12 amp actual.

5. The heater wires are below the maximum amperage ratings.

Zone 7

From the tables, maximum single conductor ampacity at 40ºC is:
   5.6 amps for 22 AWG 450º "A" nickel wire

The temperature exceeds 40°C (104°F); therefore, ampacity correction applied is:
   450ºC wire is 0.78 at 181–200ºC; is 5.6 A x 0.78 = 4.37 A.

Since there are eight conductors, a further adjustment factor for the wire bundle is required. The adjustment factor for eight wires is 0.70; therefore:
   4.37 A x 0.70 = 3.05 A for 450ºC "A" nickel wire.

The maximum current carrying capacity for each wire is:
   22 AWG: 3.05 amp rating > 1.25 amp actual.

The heater wires are below the maximum amperage ratings.

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Example Calculation #11

Manifold wires in groove in manifold pocket. What is the ampacity of 8 nozzle heaters in a hot runner system plus three manifold heaters and a sprue bushing heater?

FACTS:

- This example is an externally heated system where the raceways are in a manifold plate pocket exposing the heat of the manifold directly to the wires through radiation.
- The mold is processing linear low density polyethylene (LLDPE) resin.
- The processing or manifold temperature of the resin is 230°C (450°F).
- The mold is cooled with chilled water. Assume the mold plates reach a temperature of 50°C (120°F) due to the radiation and conduction of heat into the plates from the manifold.
- The nozzle heater lead wire is routed away from nozzles and manifold into the hot manifold pocket rather than the cooler outside faces of the manifold plates.
- The eight nozzle heaters are rated for 250 watts at 240 volt or 1.04 amps each, they use 20 AWG (450°C) “A” nickel wire
- There is one heated sprue bushing rated for 190 watts at 240 volt or 0.79 amps; it uses 16 AWG (450°C) “A” nickel wire.
- There is one manifold heater rated for 940 watts at 240 volts or 3.92 amps, it uses 14 AWG (450°C) “A” nickel wire.
- There are two manifold heaters rated for 1340 watts at 240 volts or 5.58 amps each, they use 14 AWG (450°C) “A” nickel wire.
- The manifold heater lead wire is routed away from manifold into the cooler mold plates.
- The largest bundle of wires is under the terminal mounting box where all wires for nozzles, sprue bushing and manifold meet.
- The estimated temperature in the mold plates at the wire bundle is 50°C.

CALCULATIONS:

1. From the tables, maximum single conductor ampacity at 40°C is:

   8 amps for 20 AWG 450°C “A” nickel, and for
   14 amps for 16 AWG 450°C “A” nickel,
   21 amps for 14 AWG 450°C “A” nickel.

2. The ambient temperature exceeds 40°C (104°F), ampacity correction applied is:

   450°C wire is 0.69 at 230°C, (this temperature must be used due to the radiation heating of the wire); therefore:
   8 A x 0.69 = 5.52 A for 18 AWG “A” nickel,
   14 A x 0.69 = 9.66 for 16 AWG “A” nickel, and
   21 A x 0.69 = 14.49 A for 14 AWG.

3. Since there are more than three conductors, (three manifold heaters x two wires per heater = six and eight nozzle heaters x two wires per heater = 16 plus two wires for the sprue bushing heater equals a total of 24 wires) a further adjustment factor for the wire bundle is required. The adjustment factor for 18 wires is 0.45; therefore:

   5.52 A x 0.45 = 2.48 A for 450°C 18 AWG “A” nickel,
   9.66 A x 0.45 = 4.35 A for 450ºC 16 AWG “A” nickel, and for
   14.49 A x 0.45 = 6.52 A for 450ºC 14 AWG “A” nickel wire.

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4. The maximum current carrying capacity for each wire is:

   18 AWG: 2.48 amp rating > 1.04 amp actual, (eight nozzle heaters),
   16 AWG: 4.35 amp rating > 0.95 amp actual, (sprue bushing),
   14 AWG: 6.52 amp rating > 3.92 amp actual, (one distributor 940 watts),
   14 AWG: 7.24 amp rating > 5.58 amp actual, (two distributors 1340 watts).

5. The heater wires are below the maximum amperage ratings.

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Section 7
SUMMARY AND CONCLUSIONS

It is hoped that this guideline will be helpful to SPI and to other users of high performance high temperature wires. Suggestions for revisions should be sent to the Engineering Department of NEMA.

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