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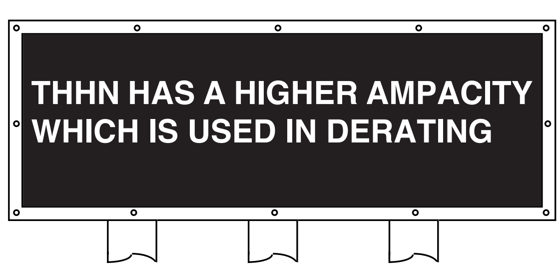
Example: A branch circuit has a noncontinuous load of 29 amps. The circuit is installed in a conduit that has a total of four current carrying conductors. The equipment in the circuit has a rating of 60°C.

A #10 TW ampacity is 30 x 80% =24 amps the maximum current permitted. A #10 TW would violate the Code in this example as the load is 29 amps.

A #10 THW ampacity is 35 x 80% = 28 amps is the maximum current permitted. A #10 THW would also be a violation as the load is 29 amps.

A #10 THHN has a normal ampacity of 40 x 80% = 32 amps is the maximum current permitted on the conductor. Next go to the 60°C column and select a conductor that will carry the 29 amp load. A #10 THHN can be used in this condition. The THHN conductor can safely carry 32 amps without damage to the *conductor insulation*. But, the 60°C column shows a #10 conductor cannot be loaded to more than 30 amps without possible damage to the *termination*.

Otherwise you would have to use a #8 TW (40a x 80% = 32a) or a #8 THW (50a x 80% = 40a). By selecting THHN insulation you can use a smaller #10 conductor.



90°C THHN VOLTAGE DROP

The 90°C THHN and XHHW conductors have higher ampacities which benefits the designer when applying the derating factors from the heat conditions. The 90°C conductors have a smaller square inch area which permits more conductors in a conduit.

The designer must also calculate the voltage drop in the 90°C conductor compared to a 60°C or 75°C.

In reality the installer would select a #8 THHN as the conductor for the branch circuit shown below. Table 310.16 lists the ampacity of a #8 THHN at 55 amps and the load is only 50. Let's apply correct designing and calculate the minimum size conductor the Code would permit. All the equipment in the circuit is 60°C rated.

From Table 310.16 the conductor choices would appear to be a #6 TW @ 55 ampacity, a #8 THW @ 50 ampacity or a #8 THHN @ 55 ampacity. In reality the most common wire sold over the counter is the THHN insulation.

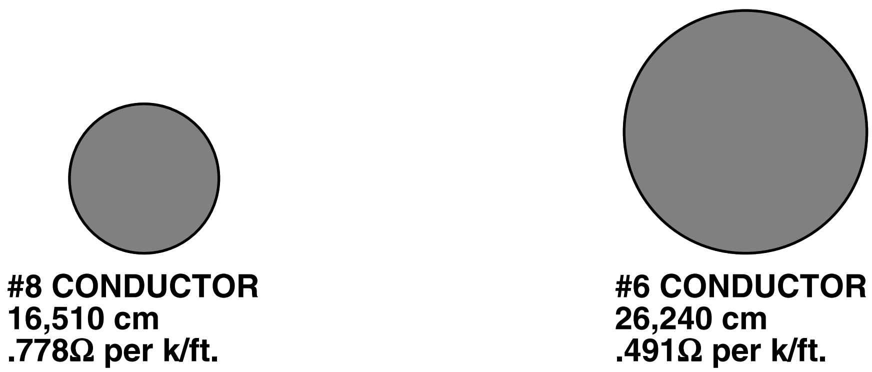
Now let's apply what we have learned so far. Since the equipment is 60°C rated which ever conductor insulation is selected would have to be used at a 60°C *ampacity*. A #8 THHN could *not* be used as a #8 @ 60°C as it can only be loaded to a maximum of 40 amps on 60°C rated equipment and the load is 50 amps.

Let's calculate the voltage drop for the branch circuit that is 100 feet in distance.

$$\text{Wire size} = \text{CM} = \frac{2 \times 12.9 \times 100' \times 50\text{a}}{7.2 \text{ vd}} = 17,917 \text{ cm required}$$

Table 8 would require a *minimum* #6 conductor with a circular mil area of 26,240. A #8 conductor has a circular mil area of 16,510, not large enough for this branch circuit.

Always remember, by selecting a #8 THHN rather than a #6 TW because of the higher ampacity a #8 has a smaller circular mil area which has a higher *resistance* and a *greater voltage drop*.



A #6 THHN will satisfy the voltage drop requirement and the 60°C ampacity which is 55.

Also the advantage of using a #6 THHN would be a big plus for derating of heat conditions.

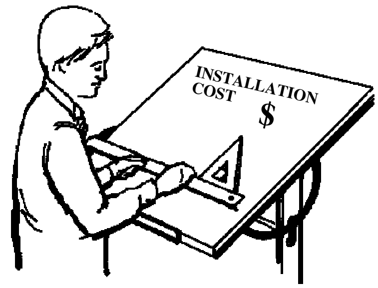
The same circuit installed in an ambient of 140°F requires a correction factor from **Table 310.15(B)(1)** to be applied.

A #6 THHN has an ampacity of 75 x .71 correction factor for 140°F = 53.25 is the maximum current that can be applied to a #6 THHN in a 140°F ambient.

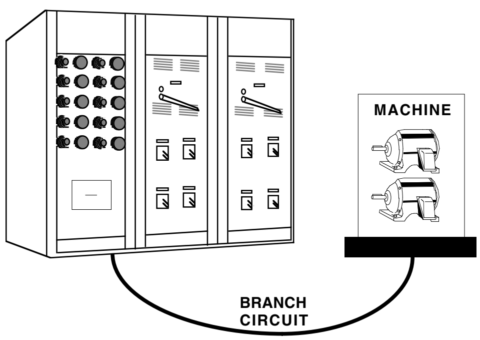
Now check Table 310.16 for the ampacity of a 60°C conductor. It will carry 55 amps.

A #6 TW could *not* be used for this circuit even though it satisfies the voltage drop requirements. A #6 TW has an ampacity of 55, but there is no correction factor for 140°F which means you could not use a 60°C insulation. A #6 THW has an ampacity of 65 x .58 correction factor = 37.7 is the maximum current that can be applied to a #6 THW in a 140°F ambient. Since the load is 50 amps, a #6 THW conductor is a violation. The Code would require a minimum #6 THHN for this branch circuit.

COST COMPARISON



Often the designer must determine the most economical circuit makeup which will meet the minimum standards required by the Code.

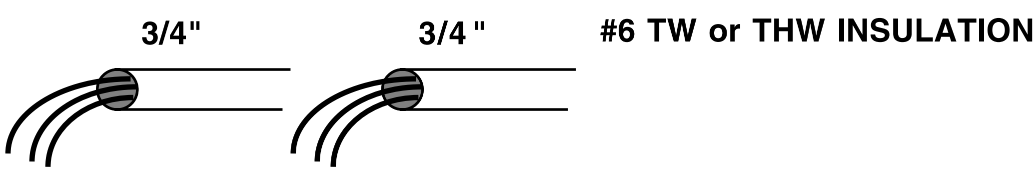


Example: A machine has two 15 hp, 230v, 3ø squirrel-cage induction motors. Each motor is fed by a *separate* branch circuit originating at a combination motor controller in a motor control center. Rigid steel conduit is to be used, assume ambient not over 86°F, and voltage drop is limited to 3%. 60°C equipment.

To calculate the load current, Table 430.250 shows the full load current for each motor is 42 amps. Section 430.22 requires each circuit to have an ampacity of not less than 125% x 42a = 53a.

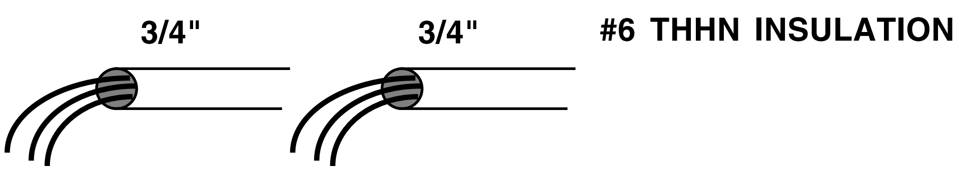
There are various circuit arrangements that could be used to supply the two motors in the machine.

I. Two separate conduit runs to the machine. From the motor control center, the branch circuits to the two motors on the machine could be carried in separate conduits. This would require three #6 TW wires which have a 55 ampacity. Table C8 would require a 3/4" conduit for each branch circuit.



Or, two runs of 3/4" conduit using #6 THW which have a 65 ampacity.

By using two runs of #6 THHN with a 70 ampacity, Table C8 also allows a 3/4" conduit for each circuit. •The THHN must be used at the 60°C ampacity per Code section 110.14(C).



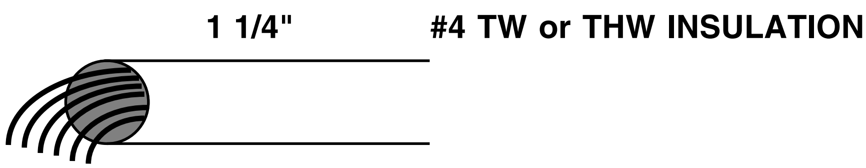
II. Single conduit run to the machine. Both branch circuits to the two motors on the machine could be carried in a single conduit. The *variable* for more than three current carrying conductors would affect the wire size in this case.

Using TW insulation, the normal ampacity of 55a x 80% Table 310.15(C)(1) = 44 ampacity. The #6 TW would not meet the 53 amp required ampacity for the motor with six wires in a single conduit.

The next larger size is a #4 TW with a normal ampacity of 70a x 80% Table 310.15(C)(1) = 56 ampacity. A #4 TW would satisfy the requirements of the Code.

Table C8 shows that six #4 TW wires require a minimum conduit size of 1 1/4".

Using a THW instead of TW insulation would also result in using a #4 with a 1 1/4" conduit.

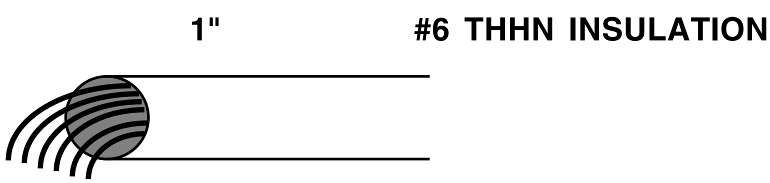


Using THHN insulation, each #6 THHN conductor has a normal ampacity of 70a x 80% Table 310.15(C)(1) = 56 ampacity, which more than meets the 53 amp required ampacity.

110.14(C) states the 90°C THHN conductors cannot be loaded to more than the 60°C TW ampacity, which is 55 amps. The full load current is 42 amps.

With a 53 amp required ampacity the #6 THHN wires are being used within the 55 ampacity rating of a #6 TW and are therefore, suitable for connection to the terminals of the motor starter and other circuit components, which are recognized by UL for use with conductors rated not over 60°C.

Table C8 shows that six #6 THHN wires require a minimum conduit size of 1".



Now calculate the #6 THHN for the 3% limit on voltage drop.

$VD = I \times R \times 1.732$ Table 8 resistance is .491Ω per k/ft. x 50 feet distance = .491 x .050' = .02455Ω

42 amps x .02455Ω x 1.732 = 1.03 vd   The Code permits 230v x 3% = 6.9 vd

Conclusions

After the material and labor costs have been compared, these comparisons show that the installation on THHN wires is less costly than installation of TW or THW, whether two conduits are run to the machine or whether both branch circuits are run in a single conduit. The installation of six THHN wires in a single 1" conduit is actually less costly than three THHN wires in each of the two 3/4" conduits.

BRANCH CIRCUIT SIZING WELDER

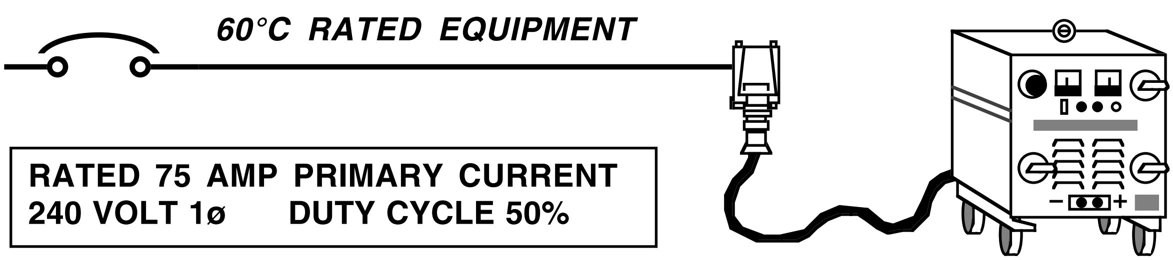
There are three types of welders and each has a duty cycle.

(1) AC Transformer and DC Rectifier Arc
(2) Motor - Generator Arc
(3) Resistance Welders

A duty cycle is the percentage of time the welder is actually drawing a current when it is welding.

Shown below and on the next page are three different types of welders, each with a different nameplate.

SINGLE AC TRANSFORMER DC RECTIFIER TYPE

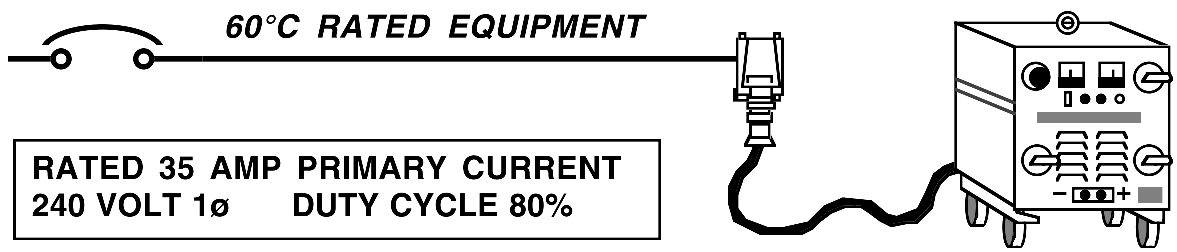


Wire size: Table 630.11(A) lists a multiplier of .71 for a 50% duty cycle. The rated primary current 75a x .71 = 53.25 required ampacity. Table 310.16 shows a #6 THHN has an ampacity of 75 amps, but connected to 60°C equipment a #6 THHN can be loaded to 55 amps. The required ampacity is 53.25 amps so a #6 THHN would meet the Code requirements.

Circuit breaker size: 630.12(A) states each welder shall have overcurrent protection rated or set at not more than 200% of the rated primary current of the welder.

75a x 200% = 150 amp circuit breaker

SINGLE MOTOR-GENERATOR ARC TYPE

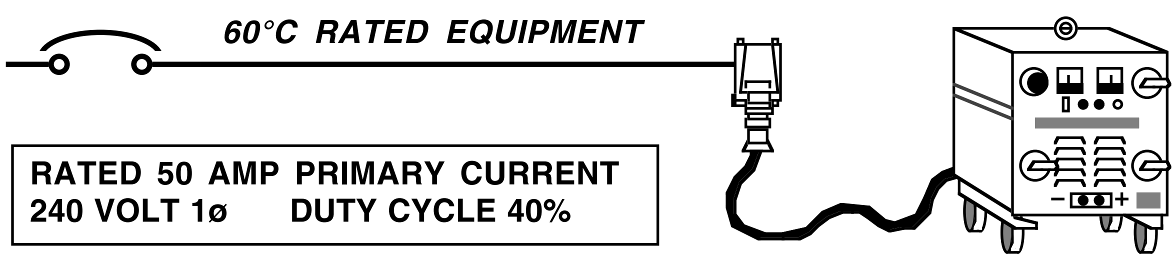


Wire size: Table 630.11(A) lists a multiplier of .91 for a 80% duty cycle. The rated primary current 35a x .91 = 31.85 required ampacity. Table 310.16 shows a #8 THHN has an ampacity of 55 amps, but connected to 60°C equipment a #8 THHN can be loaded to 40 amps. The required ampacity is 31.85 amps so a #8 THHN would meet the Code requirements.

Circuit breaker size: 630.12(A) states each welder shall have overcurrent protection rated or set at not more than 200% of the rated primary current of the welder.

35a x 200% = 70 amp circuit breaker

SINGLE RESISTANCE WELDER TYPE



Wire size:Table 630.31(A2) lists a multiplier of .63 for a 40% duty cycle. The rated primary current 50a x .63 = 31.5 required ampacity. Table 310.16 shows a #8 THHN has an ampacity of 55 amps, but connected to 60°C equipment a #8 THHN can be loaded to 40 amps. The required ampacity is 31.5 amps so a #8 THHN would meet the Code requirements.

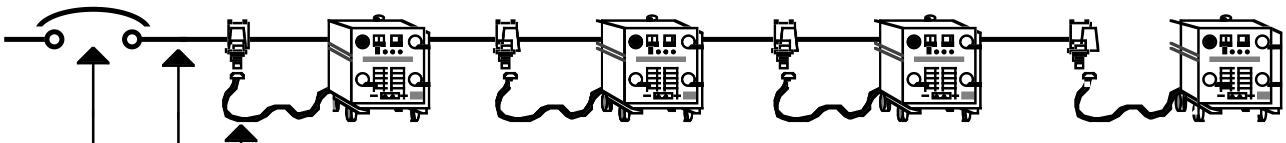
Circuit breaker size: 630.32(A) states each welder shall have overcurrent protection rated or set at not more than 300% of the rated primary current of the welder.

50a x 300% = 150 amp circuit breaker

Designing the branch circuit to a group of welders.

ALL WELDERS ARE MOTOR-GENERATOR ARC TYPE

75°C RATED EQUIPMENT



ALL THE WELDERS HAVE THE SAME NAMEPLATE

RATED 75 AMP PRIMARY CURRENT
240 VOLT 1ø   DUTY CYCLE 50%

T. 630.11(A).   75a x .75 = 56.25 required ampacity = #6 THHN

630.11(B) I.N.   Welder #1 = 75a x .75 x 100% = 56.25a
Welder #2 = 75a x .75 x 100% = 56.25a
Welder #3 = 75a x .75 x 85% = 47.81a
Welder #4 = 75a x .75 x 70% = 39.38a
199.69a
199.69 required ampacity = #3/0 THHN

630.12(B). #3/0 THHN conductor rating @ 75°C = 200 amps
200 amps x 200% = 400 amp circuit breaker