Data Sheet

AC Industrial Electric Motors

Standards' organisations

The RS-ABB range of ac induction motors is produced to common European standards, these being IEC and CENELEC (Comité Européen de Normalisation Electrotechnique).

These two organisations work together on harmonisations of standards both worldwide and within Western Europe.

GENELEC in particular aims to remove trade obstacles in Western Europe that may occur due to differences in the regulations and standards.

New national standards are increasingly identical to or broadly based on these European standards issued by CENELEC.

Dimensional and power standards

The first edition of IEC Publication 72 was issued in 1959 and supplemented in 1970 by IEC (International Electrotechnical Commission) Publication 72A.

These contained the first recommendations and outline proposals that electric motors should be produced with similar rated powers and mounting dimensions, i.e. shaft height, fixing dimensions and shaft extension dimensions.

In 1974 the joint agreement was superseded by a harmonisation document HD231 from CENELEC. The resulting standardisation enabled a complete interchangeability between motors of different manufacture. The sizes, versions and rated outputs of 4-pole and 2-pole motors covered by the standard are shown in Table 1.

However, the European standardisation does not fully coincide with corresponding USA standards, which tend to be based on imperial dimensions rather than the corresponding metric-based European motor. Power ratings also differ between US and European motors.

Three-phase induction motor

Features

- Manufactured to metric frame sizes
- Totally enclosed fan cooled (TEFC) construction
- Environmentally protected to IP55
- Three-phase motors available in both foot and flange mounting
- Wide voltage range on three-phase motors of 220-240V/250-280V if delta (Δ) connected or 380-420/440-480V if star (U) connected for motors up to frame size 100
- Wide voltage range 380-420/440-480V delta (Δ) connected or 660-690V star C'Ω connected for motors with frame size 112 as above
- Suitable for use on 50/60Hz supplies
- Single-phase motors available in both permanent capacitor and capacitor start-run formats
- 2-pole and 4-pole motors available.

Table 1

Ratings according to IEC frame sizes IEC 34/1. IP55 For squirrel-cage motors

Frame Size	Rated output, KW	
	2 Pole	4 Pole
63B	0.25	0.18
71A	0.37	0.25
71B	0.55	-
71C	0.75	0.55
80A	0.75	0.55
80B	1.1	0.75
80C	1.5	1.1
90S	1.5	1.1
90L	2.2	1.5
90LB	2.7	2.2
100L	3.0	-
100LA	-	2.2
100 LB	4.0	3.0
100LC	-	4.0
112M	4.0	4.0
112MB	5.5	5.5
132S	-	5.5
132M	-	7.5
132MBA	-	9.2
132MB	-	11.0
132SA	5.5	-
132SB	735	-
132SBB	9.2	-
132SC	11.0	-
160M	15.00	11.0
160MA	11.0	-
160L	18.5	15.0
160LB	22.0	18.5

The meaning of the standardised letters in the size designation for sizes 90-132 are S = small, M = medium long and L = long version.

Insulation classes

IEC Publication IEC85 divides insulation into classes. Each class is given a designation that corresponds to the upper temperature limit of the insulating material when used under normal operating conditions.

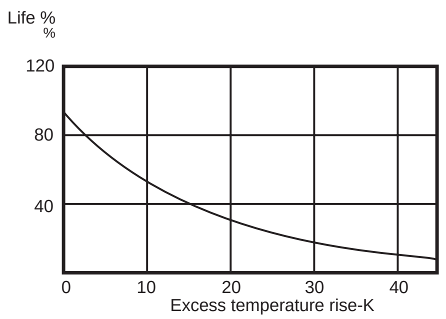
The correct insulation of the winding of a motor is therefore determined by both the temperature rise in the motor and the temperature of the ambient air. If a motor is subjected to an ambient temperature higher than 40°C, it must normally be derated or a high insulation class of material used.

International standards measure temperature in degrees Celsius (°C), whilst temperature difference is stated in the unit Kelvin (K). One degree Celsius is equivalent to 1K.

The RS-ABB range of ac induction motors is manufactured to a class F insulation rating. For class F the temperature rise must not exceed 105K, provided that the ambient temperature does not exceed +40°C.

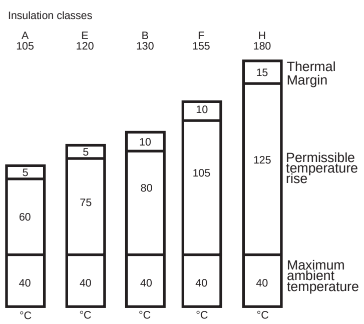
It should be noted that if the upper temperature limit of the insulation material is exceeded by 8 to 10K (Table 2), the life of the insulation will be approximately halved.

Table 2



The graph illustrates the effect of exceeding the highest permitted winding temperature on winding life.

Figure 1 Temperature limits of the different insulation classes



General characteristics

The following is a list of general characteristics of the ac induction motors supplied by RS Components. Each one should be considered before choosing the appropriate motor for the application.

Voltage

Single-speed, three-phase motors can usually be re-connected for two voltages.

The usual way is to connect the three stator phase windings in star (U) or delta (Δ). All RS-ABB motors are supplied configured in star (U) up to frame size 100 for 380-420V 50Hz, motors above this size are supplied delta primarily but may be converted for delta (Δ). This means that the three-phase input voltage range is wide. For example if the motor was connected in delta it would accept a three-phase input voltage range of 220-240V for a 50Hz supply frequency or 250-280V for 60Hz frequency.

Similarly with the motor connected in star an input voltage range of 380-420V is acceptable on 50Hz or 440-480V on a 60Hz supply system.

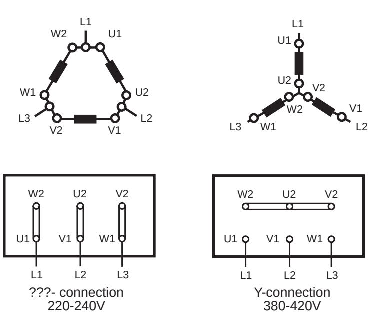
This wide voltage range and dual operating frequency enables the motors to be used throughout the world.

To convert the motors refer to Figure 2 where indication is given of the required link change.

Note: To use these motors in conjunction with single-phase 240V input, three-phase output ac motor speed controllers, these three-phase motors must be connected in delta (Δ).

Motors from frame size 112 are supplied delta connected for 380-420V 50Hz, 440-480V 60Hz. They can be connected in a star configuration for 660-690V 50Hz operation if required.

Figure 2 **Arrangement of windings and terminal blocks for Δ and Y connections**



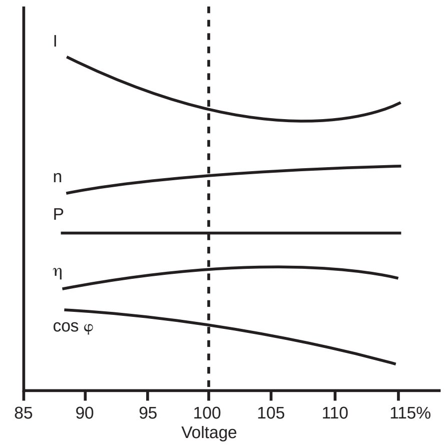
Voltage deviation

If the supply voltage at constant output power deviates from the rated voltage of the motor, the starting and maximum torques of the motor vary approximately as the square of the voltage.

The change in torque will also result in a change in the speed, efficiency and power factor (Figure 3).

Voltage deviations also affect the temperature rise in the motor windings. If the voltage is low the temperature will rise in both large and small framed motors; if the voltage is high the temperature may drop slightly in large sized motors but rise rapidly in the small output motors.

Figure 3



Graph showing current (I), speed (n), efficiency (η) and power factor (cosØ) as a function of the voltage at constant output (P).

Power

When choosing a motor size it is essential to bear in mind that it is the power demand of the driven machine that determines the output delivered by the motor and therefore the power drawn from the supply. For example if a machine needs 4kW it will take 4kW, regardless of whether the motor is 3kW or 7.5kW.

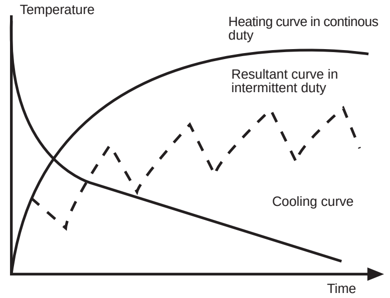
If the smaller motor is installed it will be subjected to a continuous 25% overload that it will not be able to sustain for long periods. The protective overload device fitted should, however, protect against these types of high overloads, and disconnect the motor supply within a suitable time period.

A motor must be capable of delivering the power needed by the driven machine, and it is prudent to provide a safety margin since minor overloads that are difficult to foresee can often occur.

If a motor winding is overheated the insulation of the copper conductors may be destroyed. Given a choice between two motor sizes the larger one should always be used. However it is not a good idea to choose an unnecessarily large motor since it will be disproportionately costly to purchase and have a low power factor in service. In addition, when a squirrel cage motor is started the starting current will be excessively high, since it is proportional to the size of the motor. If a motor is loaded at full load only for short periods with periods of idling between them, known as intermittent duty, its temperature rise will be lower, and it will have a capacity to deliver a higher output than during continuous operation.

Figure 4 shows a typical temperature/time graph for a motor in both continuous and intermittent duty.

Figure 4



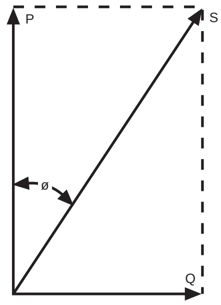
Temperature/Time graph for a motor on continous and intermittent duty.

Power factor

A motor consumes not only active power (kW), which it converts into mechanical work, but also reactive power (kVAr) which is needed for magnetisation but does not perform any useful function.

The active and reactive powers are shown in Figure 5 together with the apparent power (kVA). The ratio between the active power and the apparent power is known as the power factor. The angle between P (kW) and S (kVA) is usually designated Ø. The power factor usually being referred to as cos Ø.

Figure 5



P= Active power (kW)
Q= Reactive power (kVAr)
S= Apparent power (kVA)
ø= Power factor

The power factor is usually between 0.7 and 0.9, however this may vary depending on the motor size and rating.

If there are many motors in an installation they will consume a lot of reactive power and will therefore have a lower power factor. Power supply authorities sometimes require the power factor of the installation to be raised. This is usually done by correction capacitors to the supply: these generate reactive power and thus raise the power factor level.

Power factor correction

With phase compensation the correction capacitors are usually connected in parallel with the motor or group of motors. Capacitors must not be connected in parallel with any single phases of the winding otherwise difficulty may be experienced in starting using star/delta methods.

To calculate the value of power factor correction capa-citor required the following formula should be used:

$$C = 3.2\ 3\ 10^6 \text{ x } \frac{Q}{U}$$

where C = Capacitance, μF
U = Capacitor voltage, V
Q = Reactive power, kVAr.

The reactive power is obtained by using the formula:

$$Q = K \text{ x } \frac{P}{h}$$

where K = constant from Table 2a
P = rated power of motor, kW
h = efficiency of motor.

Table 2a

cos Ø without compensation	Constant K Compensation to cos Ø =			
	0.95	0.90	0.85	0.80
0.50	1.403	1.248	1.112	0.982
0.51	1358	1.202	1.067	0.936
0.52	1.314	1.158	1.023	0.892
0.53	1.271	1.116	0.980	0.850
0.54	1.230	1.074	0.939	0.808
0.55	1.190	1.024	0.898	0.768
0.56	1.150	0.995	0.859	0.729
0.57	1.113	0.957	0.822	0.691
0.58	1.076	0.920	0.785	0.654
0.59	1.040	0.884	0.748	0.618
0.60	1.005	0.849	0.713	0.583
0.61	0.970	0.815	0.679	0.548
0.62	0.937	0.781	0.646	0.515
0.63	0.904	0.748	0.613	0.482
0.64	0.872	0.716	0.581	0.450
0.65	0.841	0.685	0.549	0.419
0.66	0.810	0.654	0.518	0.388
0.67	0.779	0.624	0.488	0.358
0.68	0.750	0.594	0.458	0.328
0.69	0.720	0.565	0.429	0.298
0.70	0.692	0.536	0.400	0.270
0.71	0.663	0.507	0.372	0.241
0.72	0.625	0.480	0.344	0.214
0.73	0.608	0.452	0.316	0.186
0.74	0580	0425	0289	0.158
0.75	0.553	0.398	0.262	0.132
0.76	0527	0.371	0.235	0.105
0.77	0.500	0.344	0.209	0.078
0.78	0474	0.318	0.182	0.052
0.79	0.447	0.292	0.156	0.026
0.80	0.421	0.266	0.130	
0.81	0.395	0.240	0.104	
0.82	0.369	0.214	0.078	
0.83	0.343	0.188	0.052	
0.84	0.317	0.162	0.026	
0.85	0.291	0.135		
0.86	0.265	0.109		
0.87	0.238	0.082		
0.88	0.211	0.055		
0.89	0.184	0.027		
0.90	0.156			

Efficiency

IEC Publication 34-2 describes two methods for determining the efficiency of a motor, one being the direct method the other known as indirect.

With the indirect method input power and output are each measured individually. Most motor figures quoted are determined by this method, which also includes a calculation of the losses involved.

Typical motor losses include:

- Bearing and air friction losses
- Current heat losses in stator and rotor
- Iron losses
- Stray losses.

Figure 6 gives a graphic indication if the relationship between these losses.

The standards define the stray losses as 0.5% of the input power at rated duty. The standard tolerance is:

15% of (1 - h) for motors up to 15kW where h = efficiency of motor. NEMA, the standards most widely used in the USA, permit no tolerance on the losses. Stray losses are generally calculated at 0.9% of the output.

Figure 6

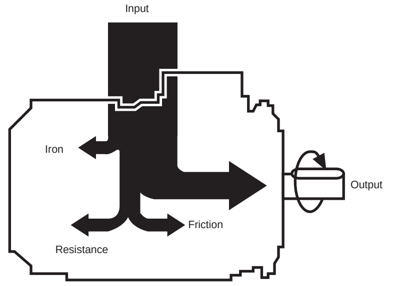


Diagram of relationship between input iron losses, resistance losses and output.

Speed

The speed of an ac motor depends on the mains frequency and the number of poles of the stator winding.

$$n = \frac{2.f.60}{P} \text{ r/min.}$$

where
n = speed
f = frequency
P = number of poles.

The rule of thumb to follow for a 50Hz mains frequency is that the speed in revolutions per minute (r/min. or rpm) is 6000 divided by the number of poles.

For example a 4-pole motor will have a synchronous speed of:

$$\frac{6000}{4} = 1{,}500 \text{ r/min.}$$

This speed can never actually be achieved on load due to slip. On no load, however, speed is practically equal to the synchronous speed.

To calculate slip the following equation can be used:

$$S = \frac{n_1 - n}{n1} \times 100\%$$

where
S = slip %
n_1 = synchronous speed, r/min.
n = asynchronous speed, r/min.

Motor slip is proportional to the power taken from the motor.

For example

A 4-pole motor of 4kW at 415V, 50Hz, 1425 r/min.
At 4kW slip equals

$$S = \frac{1500 - 1425}{1500} \times 100 = 5\%$$

corresponding to 1500 - 1425 = 75 r/min.
At 3kW

$$S = {}^{3}/4 \times \frac{1500 - 1425}{1500} \times 100 = 3.8\%$$

corresponding to $^{3}/4 \times$ (1500 - 1425 = 56 r/min.
Therefore n at 3kW will be 1500 - 56 = 1444 r/min.
The slip is inversely proportional to the square of the voltage.

For example

4-pole motor, 4kW, 415V, 50Hz, 1425 r/min.

$$\text{At 380V; } S = \frac{415}{380} \times \frac{1500 - 1425}{1500} \times 100$$

$$= 5.96\%$$

$$\text{corresponding to } \frac{415}{380} \times (1500 - 1425)$$

89 r/min.

n will therefore be 1500 - 89 = 1411 r/min.

Table 3 gives details of synchronous speed for various numbers of motor poles and operation on either 50 or 60Hz.

Table 3

Poles	Synchronous speed at 50Hz	60Hz
2	3000	3600
4	1500	1800
6	1000	1200
8	750	900
10	600	720
12	500	600
16	375	450
20	300	360
24	250	300
32	187.5	225
48	125	150

Operation at 60Hz

A motor wound for a given voltage at 50Hz can be used unmodified on a 60Hz supply: in such cases the motor data will change as shown in Table 4.

Notes:
1. That M/start/M and M max/M must be calculated on the basis of the 60Hz value of M.
2. The different torque figures at 60Hz. The starting torque and minimum torque figures in particular are reduced on 60Hz operation with the same supply voltage, this may lead to starting problems in certain applications.

Table 4

Motor wound for 50Hz and	Connection to 60Hz and	Data at 60Hz as % of 50Hz data: Output	M[1]	M_{max}/M^1	M_{start}/M^1	Speed
220V	220V	100	83	85	70	120
	255V	115	96	98	95	120
380V	380V	100	83	85	70	120
	415V	110	91	93	85	120
	440V	115	96	98	95	120
	460V	120	100	103	100	120
415V	415V	100	83	85	70	120
	460V	110	91	94	85	120
	480V	115	96	98	95	120
500V	500V	100	83	85	70	120
	550V	110	91	94	85	120
	575V	115	96	98	95	120
	600V	120	100	103	100	120

1. M — Rated torque at 60Hz
M_{max}/M — Maximum torque/rated torque
M_{start}/M — Starting torque/rated torque

Table 5

Quantity	Data at 50Hz	Conversion factor	Data at 60Hz
Voltage	380V	-	440V
Output	11kW	1.15	12.6kW
Current	23A	1.0	23A
M_{max}/M	2.4	0.98	2.4
M_{start}/M	2	0.95	1.9
Speed	1450 r/min	1.20	1740 r/min

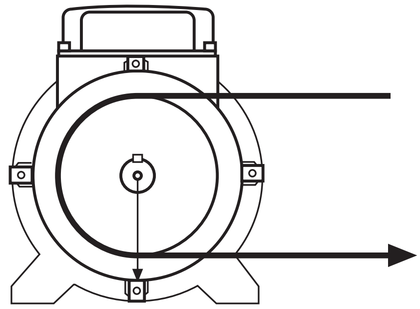
Example of a typical conversion of data from 50 to 60Hz operation.

Torque

The torque of a motor is the measure of its turning ability. If the power and speed are known it is easy to calculate the torque.

If we refer to Figure 7 we can see that at the periphery of a pulley there is a certain force in the belt. If this force is referred to as F and the radius of the pulley r, the product Fr is known as the torque M of the motor.

Figure 7



Pictoral representation of torque determination

The power is the work performed by the motor per unit of time; work is force times distance. The force F rotates n revolutions in one minute and covers the distance $n \times 2 \times \pi \times r$.

During motor acceleration the torque developed first drops slightly then rises to its maximum (Figure 8).

In normal motors the maximum torque occurs at 85 to 90% of full speed.

At synchronous speed torque is zero.

To calculate the rated torque of a motor the following formula can be used:

$$M = \frac{30{,}000 \times P}{\pi \times n} \text{Nm}$$

Where P = output, kN
n = motor speed, r/min.

For example

A motor is rated at 1.5kW and 1400r/min. the diameter of pulley is 100mm i.e. r = 0.05m. The torque and traction developed at full power will be:

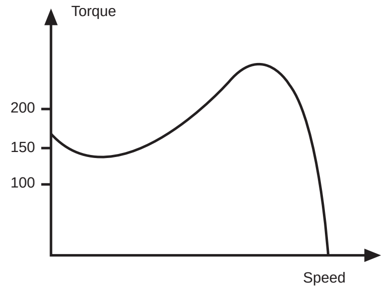
$$M = \frac{30{,}000 \times 1.5}{\pi \times 1400}$$

$$M = 10.2\text{Nm}$$

$$\text{Therefore } F = \frac{10.2}{0.05}$$

$$= 205\text{N}$$

Figure 8



Typical torque/speed curve of an ac induction motor.

Minimum torque

IEC Publication 34-1 states certain figures for general purpose three-phase squirrel cage motors. For single-speed motors with rated output <100KW the minimum torque delivered during run up at rated voltage must not be less than 50% of the rated torque and not less than 50% of the starting torque. The figure for single-phase motors is 30% of the rated torque.

Maximum torque

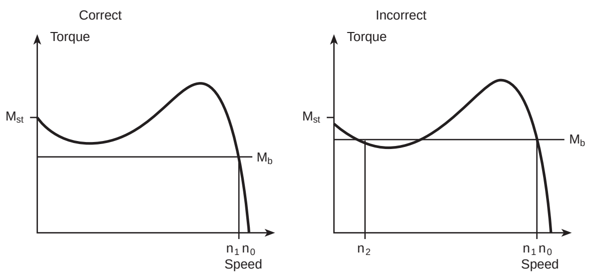
The maximum torque is a measure of the overload capability of the motor IEC Publication 34-1 lays down that general purpose motors must be capable of developing at least 160% of the rated torque for 15 seconds - without stopping or suddenly changing speed - if the rated voltage or frequency is maintained. Four-pole motors made by ABB usually have a maximum torque that is approximately 200 to 300% of the rated torque. Low speed motors usually have a slightly lower maximum torque than high speed ones.

Torque on voltage deviation

With ac induction motors, the starting current decreases slightly more than proportionately to the voltage. Thus at 90% of the rated voltage the motor draws approximately 87-89% of the starting current.

The starting torque is proportional to the square of the current. The torque delivered at 90% of rated voltage is therefore only 75-79% of the starting torque. This factor may be of particular importance when choosing a motor for use on a weak electrical supply or when starting techniques based on current reduction methods are employed (Figure 9).

Figure 9



Choice of motor size with reference to load torque

M_{st}	= starting torque	n_1 =	speed at rated power
M_b	= load torque	n_2 =	speed at excessive load torque
n_o	= synchronous speed		

Frequency of starting and reversing

When a motor is frequently started, counter-current braked or reversed, extra heat, due to the increase in losses, is produced reducing the motors ability to perform at its rated loaded output.

The following formula can be used to obtain an approximate value.

$$P2 = P1 \times \sqrt{\frac{3600 - k_1 \times X \times ts \times \frac{1st}{1}}{3600 - X \times ts}}$$

where

- P2 = permitted load
- P1 = rated output of motor
- X = number of starts, braking or reversals per hour
- ts = starting or braking time
- $\frac{1st}{1}$ = starting current/braking current
- K_1 = constant: 1 for starting, 3 for braking and 4 for reversing.

The permitted value of X is determined with regards to the temperature rise within the motor.

For example

A 4-pole motor 4kW, $\frac{1st}{1} = 5.5$

starting time ts = 0.5s. X = 10 starts per hour.

Therefore

$$\frac{P2}{P1} = \sqrt{\frac{3600 - 1 \times 10 \times 0.5 \times (5.5)^2}{3600 - 10 \times 0.5}} = .979$$

If the same formula is used to calculate the required derating on 10 reversals per hour

$$\frac{P2}{P1} = \sqrt{\frac{3600 - 4 \times 10 \times 0.5 \times (5.5)^2}{3600 - 10 \times 0.5}} = .912$$

Types of duty

Various types of duty have been defined by IEC Publication 34-1 that describe how the load, and thus the motor output varies with time. The motor must undergo a load test without exceeding the temperature limits laid down in the specification.

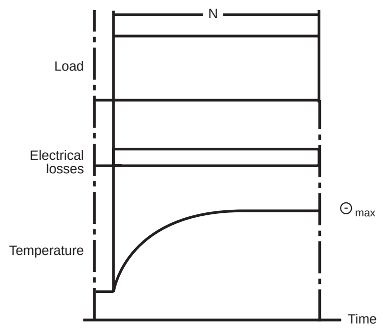
Actual operating conditions are often of a more irregular nature than those corresponding to any of the standard duty types. It is therefore essential that when choosing and rating a motor to decide on the type of duty that corresponds best to the thermal stresses that are expected to occur in practice.

The most standard types of duty classes are:

S1 continuous duty

Operation at a constant load, long enough for thermal equilibrium to be reached (Figure 10).

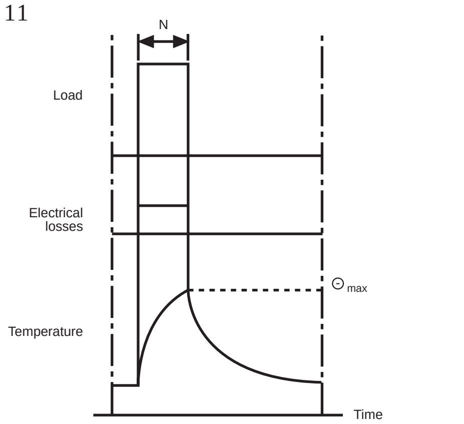
Figure 10



S2 short time duty

Operation at constant load for a given time that is shorter than the time needed to reach thermal equilibrium, followed by a rest and de-energised period. De-energisation period should be long enough to allow the motor to reach a temperature that does not deviate from the temperature of the cooling medium by 2K (Figure 11).

Figure 11

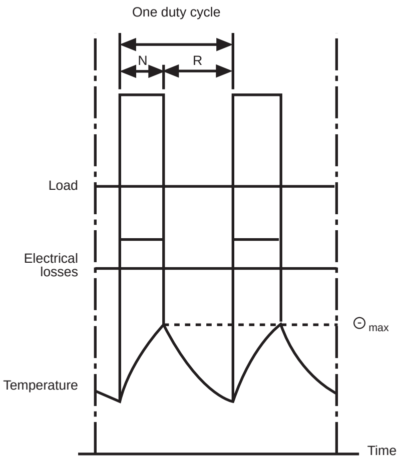


N = operation under rated condition
Θ_{max} = maximum temperature attained during the duty cycle

S3 intermittent duty

A sequence of identical duty cycles, where each cycle is in two parts, one at constant load and the other at rest and de-energised. In this type of duty the starting current has no significant effect on the temperature rise. The duty cycle is too short for thermal equilibrium to be reached (Figure 12).

Figure 12



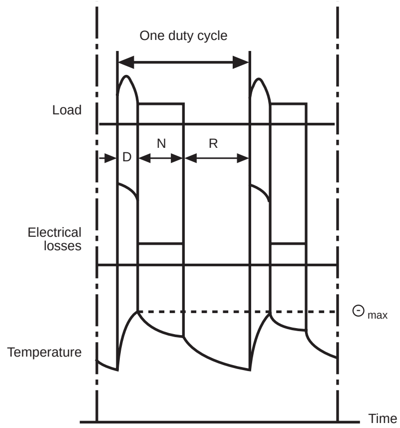
N = operation under rated condition
R = at rest and de-energised
Θ_{max} = maximum temperature attained during the duty cycle

Cycle duration factor = $\frac{N}{N+R}$ -100%

S4 intermittent duty with starting

A sequence of individual duty cycles, where each cycle consists of a start that is sufficiently long to have a significant effect on the motor temperature, a period of constant load and a period at rest and de-energised. In this type of duty the starting current is insignificant on the temperature rise. The duty cycles are too short for thermal equilibrium to be reached (Figure 13).

Figure 13



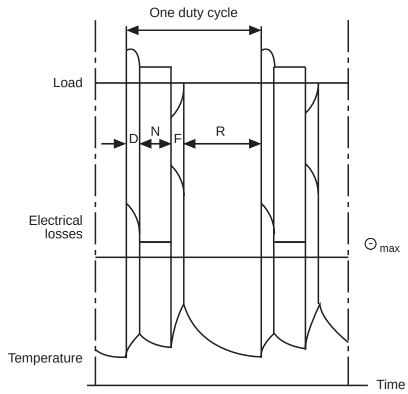
N = operation under rated condition
R = at rest and de-energised
Θ_{max} = maximum temperature attained during the duty cycle

Cycle duration factor = $\frac{D+N}{D+N+R}$ -100%

S5 intermittent duty with electrical braking

A sequence of identical duty cycles, where each cycle consists of a start, a period at constant load followed by rapid electrical braking, and a rest and de-energised period. The duty cycle is too short for thermal equilibrium to be reached (Figure 14).

Figure 14



D = starting
N = operation under rated condition
F = electrical braking
R = at rest and de-energised
Θ_{max} = maximum temperature attained during the duty cycle

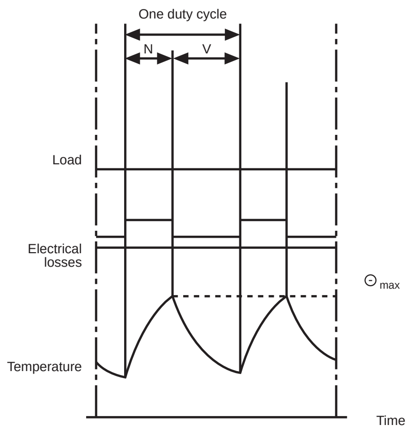
Cycle duration factor = $\frac{D+N+F}{D+N+F+R}$ -100%

S6 continuous operation

Periodic duty

A sequence of identical duty cycles, where each cycle is in two parts, one at constant load and the other at no load, no rest and no de-energised period. The duty cycles are too short for thermal equilibrium conditions to be reached (Figure 15).

Figure 15



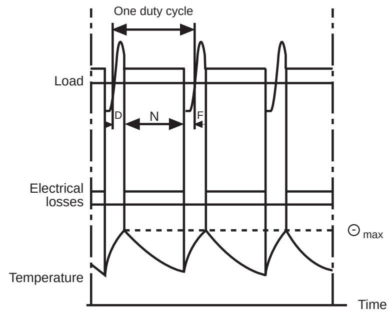
N = operation under rated condition
V = operation at no load
R = at rest and de-energised
Θ_{max} = maximum temperature attained during the duty cycle

Cycle duration factor = $\frac{N}{N+V}$ -100%

S7 continuous operation, periodic duty with electrical braking

A sequence of identical duty cycles, where each cycle consists of a start and a period at constant load, followed by electrical braking, no rest and de-energised period. The duty cycles are too short for thermal equilibrium conditions to be reached (Figure 16).

Figure 16



D = starting
N = operation under rated condition
F = electrical braking
Θ_{max} = maximum temperature attained during the duty cycle
Cyclic duration factor = 1

Uprating

Because of the lower temperature rise in a motor operated on short time or intermediate duty it is usually possible to take a higher output from the motor on these types of duty than on continuous duty S1. Table 6 gives details.

Table 6

Short-time duty, S2	Poles	Permitted output as % of rated output in S1 continuous duty for motor size: 63-100 112-250
30 min	4-8	110 120
60 min	2-8	100 110
Intermittent duty, S3	**Poles**	**Permitted output as % of rated output in S1 continuous duty for motor size: 63-100 112-250**
15%	4	140 145
25%	4	130 130
40%	4	120 110
60%	4	110 107

Changing direction

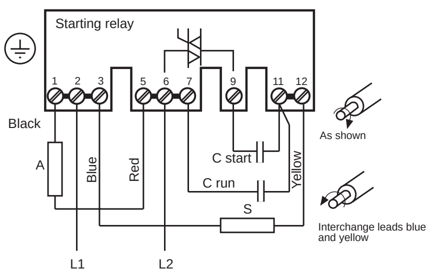
Three-phase motors

If the mains supply to the stator terminals marked U, V and W of a three-phase motor and the phase sequence of the mains is L1, L2, L3, the motor will rotate clockwise (when viewed from the drive end). To reverse direction interchange any two of the three cables connected to the starter device or the motor.

Single-phase motors
Capacitor start - capacitor run type

To reverse the direction of this type of motor the blue and yellow cables connected to terminals 3 and 12 should be interchanged (Figure 17).

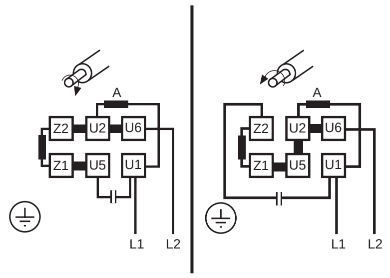
Figure 17



Permanent split capacitor type

To reverse the direction of this type of motor the connected capacitor should be moved from between terminals U1 and U5 to U1 and Z2 (refer to Figure 18).

Figure 18



Single-phase motor variations

CSR (Capacitor start and run)

Motors are fitted with both a separate start and run capacitor. These motors are also fitted with an electronic relay which prevents any risk of damage to the starting capacitor either during heavy start or overload of the motor.

CSR motors have a starting torque of approximately 160% of full load torque, making them ideal for driving compressors, piston pumps, high pressure cleaners, etc.

CSR motor (single-phase)

PSC (permanent split capacitor)

These motors are fitted with one capacitor only that is connected in circuit both during starting and running. These motors tend to have lower starting torques typically between 25 and 50% of full load torque. PSC meters are particularly suitable for use on drives having comparatively light starting loads such as fans and centrifugal pumps.

PSC motor (single-phase)

1502325812

RS Components, PO Box 99, Corby, Northants, NN17 9RS
An Electrocomponents Company
Telephone: 01536 201234