AC Replacement for DC Mill-Duty Motors

THIS ARTICLE IS AVAILABLE ONLINE AT WWW.AIST.ORG FOR 30 DAYS FOLLOWING PUBLICATION.

For many years, DC mill auxiliary motors for steel mill applications such as screwdowns, shears, tables and sideguides were specified as “mill duty.” They are of an extremely rugged design based on AIST dimensional and rating standards, and are therefore interchangeable between motor manufacturers. Many thousands of mill-duty motors remain in operation today, although many have been replaced with less-rugged DC or AC motors. This paper reviews the features of direct-replacement AC mill auxiliary motors.

For many years, DC mill auxiliary motors for steel mill applications were specified as Type MD. Many of these motors have been replaced with less-rugged DC or AC motors. This paper reviews the features of direct-replacement AC mill auxiliary motors.

Some Observations on AIST Standard No. 1

The AIST Standard No. 1 was last revised in September 1968 and defines mechanical dimensions and torques for frames 802–818 and 620–624. Experience and old motor handbooks indicate additional mechanical features and electrical ratings were available while the mounting dimensions were maintained. The following are some observations about the standard.

Enclosures — The standard covers Totally Enclosed Non-Ventilated (TENV) and Totally Enclosed Forced Ventilated (TEFV) designs. Motor manufacturers added their own designations, such as “separately ventilated” and “blower ventilated” to distinguish the type of forced ventilation. In the AC world, there are many additional designations. The equivalent international standard for Totally Enclosed is IP44, protection against 1-mm solid objects and splashing water. Other standards include IP54, protection against dust and splashing water, and IP55, protection against dust and water jets. An increased enclosure protection level generally involves increased cost.

Dimensions — Figure 1 of the standard is very specific about dimensions. The key mounting and shaft height dimensions are reproduced in Table 1.

Leads — Leads were to be brought out on the left side facing the commutator end, also known as the non-drive end. Terminal (conduit) boxes are an option. In the case of AC motors, there is no commutator, so the non-drive end designation is more useful.

Frames — The standard specifies a horizontal frame split so that the armature can be lifted straight up and out. This requirement is practical in a DC machine, which has few connections crossing the split. The armature includes the commutator, the most technically complicated part of the motor, the part most prone to failure and the part that requires periodic machining. In an AC machine, many leads would cross the split, decreasing reliability while increasing the time to disassemble. There is also no commutator requiring periodic maintenance. In most cases, a split-frame AC machine is not considered practical.

Shafts — The shafts shall be replaceable and keyed according to the standard. Runout table motors generally had a straight shaft, while motors for other applications were often tapered in addition to having the key. Couplings are more




Authors

Ronald Tessendorf (top left), TM GE Automation Systems LLC (TMGE), Salem, Va. (ronald.tessendorf@temic-ge.com); **Sumiyasu Kodama** (top right), Toshiba Mitsubishi Electric Industrial Systems Corp. (TMEIC), Metals Industry Systems Engineering Dept., Tokyo, Japan (kodama.sumiyasu@tmeic.co.jp); **Ryoji Nagatini** (bottom left), Toshiba Mitsubishi Electric Industrial Systems Corp. (TMEIC), Togitsu Medium-Size Rotating Machinery Dept., Nagasaki, Japan (nagatini.ryoji@tmeic.co.jp); **Shinji Negi** (bottom right), Mitsubishi Electric Engineering Co. Ltd., Steel Plant Engineering Section, Tokyo, Japan (negi.shinji@tmeic.co.jp); and **Tatsuya Marumoto,** Mitsubishi Electric Engineering Co. Ltd., Engineering Department-3 Medium Rotating Machinery, Nagasaki, Japan (marumoto.tatsuya@tmeic.co.jp)

Table 1

Key Mounting and Shaft Height Dimensions From AIST Standard No. 1

Frame No.	D	E	F	XC
802	7.625	6.250	8.250	32.875
803	8.500	7.000	9.000	37.000
804	9.000	7.500	9.500	39.000
806	10.000	8.250	10.500	42.250
808	11.250	9.375	12.375	47.500
810	12.250	10.250	13.000	50.250
812	13.375	11.250	14.250	55.000
814	14.750	12.500	16.000	60.750
816	16.000	13.500	17.500	67.500
818	17.750	15.000	19.500	70.625
620	20.875	18.000	22.000	78.000
622	23.000	20.000	25.750	86.250
624	24.000	21.000	28.000	96.250

Definition of dimensions (inches)	
D	Bottom of foot to shaft center
E	Width: center of foot bolt to center of motor frame
F	Length: center of foot bolt to center of motor frame
XC	Length from shaft end to shaft end

Table 2

Horsepower and rpm Ratings of Frame 800 and 600 Motors in AIST Standard No. 1

Totally Enclosed 1 Hour or Force Ventilated Continuous

Frame no.	HP	RPM Series	Compound	Shunt	Adjustable speed
802A	5	900	1,025	1,025	1,025 / 2,050
802B	7.5	800	900	900	900 / 1,800
802C	10	800	900	900	900 / 1800
803	15	725	800	800	800 / 2,000
804	20	650	725	725	725 / 1,800
806	30	575	650	650	650 / 1,950
808	50	525	575	575	575 / 1,725
810	70	500	550	550	550 / 1,650
812	100	475	515	515	515 / 1,300
814	150	450	500	500	500 / 1,250
816	200	450	480	480	480 / 1,200
818	250	410	435	435	435 / 1,100

Totally Enclosed 1 Hour or Self-Ventilated Continuous at 75°C rise

Frame no.	HP	RPM Series	Compound	Shunt	Adjustable speed
620	275	370	390	390	390 / 975
622	375	340	360	360	360 / 1,080
624	500	320	340	340	340 / 1,020

convenient to field-replace when the shaft is tapered. However, since the AC motor does not have a split frame, the entire motor would be replaced and repairs done in a motor shop.

Ratings — The rating table introduces some additional terms. Totally Enclosed 1 Hour is the short-time TENV rating, while Force Ventilated Continuous is the TEFV continuous ratings. The larger 620, 622 and 624 frames use the term "self-ventilated," which is taken to mean TEFV from referencing motor manufacturer publications.

It is important that the user understand the application rating of the DC motor being considered for replacement with a new motor.

Note the following points:

- All ratings are at 230 VDC.
- Field excitation for series, compound and shunt windings are included, with the shunt wound ratings being the most applicable to AC induction motors.
- The standard does not address the 820, 822 or 824 frames.

Table 2 gives the standard horsepower ratings by frame size, while Table 3 provides the torque ratings by frame size.

AIST Standard No. 1 specifies both starting and running torques, with the starting torques higher than the equivalent running torques. This takes into consideration that the field and armature currents, and therefore motor torque, can be higher than rated during the short time required for starting. However, the rms current values must be at or below the rated value during normal operation.

It is useful to remember that motor currents were routinely measured but torque was not. In order to determine the motor torque field current, armature current and motor design curves were required to calculate the estimated torque. This occasionally led to heated discussions speculating on the motor's ability to produce torque versus the actual and specified load requirements.

Motor frame size generally determined the current and torque capabilities, while the insulation level and available applied voltage determined the horsepower and speed capabilities. This will be discussed in more detail later when comparing the AC mill-duty motor speed and torque capabilities against the standard and DC mill-duty motors supplied by motor manufacturers.

Voltage Source — The standard calls for 230 VDC ratings, but suitable for operation at 500 VDC and reduced torque. This ambiguous language was added in 1968 when DC rectifiers were beginning to be applied and the effects of harmonic currents, called "ripple" in the standard, on motor commutation and heating were not fully understood. Motor manufacturers produced designs with a variety of voltage and torque ratings. Since these were DC motors, raising the applied voltage from 230 to 500 roughly doubles the base speed and horsepower ratings, while the nameplate may have the standard 230 VDC ratings. The point here is that the user needs to understand how the motor is applied before simply changing it out with an AC motor with the same nameplate horsepower and speed.

Temperature Rise — The standard specifies a 75°C rise by thermometer method or 110°C by resistance method, but not the insulation class. In his 1969 article, Sherman observes that when the "skeleton" motor frame became obsolete around 1939, so did measurement by thermometer. Around 1968, motor manufacturers were already providing mill-duty motors with Class H insulation systems good for a total temperature of 180°C. This translates to a margin of error, commonly known as a hot spot allowance, of 30°C over a 40°C ambient (40 + 110 + 30 = 180). The equivalent is a 20°C hot spot allowance over a 50°C ambient, a more common allowance at the time. The exception was runout table service motors, which were Class F.

Class F insulation allows for a 155°C total temperature, or a 5°C hot spot allowance according to the previous calculation. The required allowance for heating errors using modern motor modeling techniques can be assumed to be much less than it was 40 years ago when the standard was issued. Also, the application of runout table motors was based on torque, and the rms loading was generally less than the 100% rating, providing additional margin. In any case, the 110°C rise over a 50°C ambient is not allowed with Class F insulation, since the total of the two is 160°C. An increased ambient temperature level generally involves increased cost.

It should be noted that Kelvin (K) and Centigrade (C) are used interchangeably for purposes of specifying temperature rise. The standard uses Centigrade.

Speed Regulation — Adjustable speed motors were to slow down (droop) no more than 15% at rated load. This referred to the technology of the day, where voltage or CEMF regulators were used to regulate speed without speed feedback devices. The equivalent AC motor would have volts-per-hertz control, which should hold speed within a few percent, i.e., have better speed regulation than the DC motor they replace.

Variations in Speed Due to Heating — DC motor flux levels are controlled by field current and motor characteristics. The standard allows for 15–20% speed variation from ambient to

Table 3

Torque Ratings of Frame 800 and 600 Motors in AIST Standard No. 1

	Maximum starting torque (lb-ft)			Maximum running torque on 230 volts (lb-ft)		
Frame no.	Series	Compound	Shunt	Series	Compound	Shunt
802A	145	115	92	116	90	75
802B	245	198	158	196	154	130
802C	330	263	175	262	205	160
803	545	445	295	440	345	265
804	810	650	435	650	505	390
806	1,370	1,100	725	1,100	855	650
808	2,500	2,050	1,370	2,000	1,600	1,220
810	3,700	3,000	2,000	2,950	2,330	1,800
812	5,500	4,600	3,060	4,430	3,600	2,750
814	8,550	7,100	4,725	6,850	5,550	4,250
816	11,700	9,800	6,550	9,300	7,650	5,900
818	16,000	13,600	9,050	12,800	10,600	8,150
	Maximum running torque on 230 volts (lb-ft)			Maximum running torque on 230 volts (lb-ft)		
Frame no.	Series	Compound	Shunt	Series	Compound	Shunt
620	19,500	16,650	13,320	15,600	12,950	11,100
622	29,000	24,600	19,660	23,200	19,110	16,380
624	41,100	34,740	27,790	32,800	27,020	23,160

Table 4

Maximum Inertia

Frame no.	AIST maximum armature inertia WK^2 (lb-ft^2)	GD^2 (kg-m^2)
802	6	1.0
803	12	2.0
804	30	5.1
806	50	8.4
808	90	15.2
810	145	24.4
812	220	37.1
814	400	67.4
816	600	101.1
818	1,100	185.4

rated operating temperature. This corresponds roughly to the change in the resistance of copper over that temperature range. Existing applications may use field control by voltage and will experience this type of speed variation, while field control by current applications will not have this speed variation. The equivalent AC motor should have little speed variation due to heating.

Variation From Rated Speed — Under normal operating temperature and rated conditions, a speed variation of 7.5% is allowed. The equivalent AC motor should not see this effect.

WK^2 Factor — The standard does not specify inertia for frames 620–624. Table 4 shows inertias given as WK^2 from the standard and also converted to GD^2.

AC 800 Series Mill-Duty Motors

Over the years, various motor manufacturers have offered AC mill-duty motors. These generally met various aspects of AIST Standard No. 1, including the dimensional standard, but were not always designed for the overload duty. The General Electric version, known as the KD, duplicated their DC-type MD design, including the rolled steel frame, and was designed for a specific AC drive type.

The AIST standard was generally recognized around the world for steel mill auxiliary drives. Toshiba Mitsubishi Electric Industrial Systems Corp. (TMEIC) recently introduced an AC mill-duty motor intended to replace existing DC mill-duty motors both dimensionally and functionally. The motors are 3-phase induction type designed for operation on pulse width modulated (PWM) inverters. AIST Standard No. 1 uses English units. The new AC mill-duty motor was designed using the metric system and converted to English units. The following is a review of the features of the frame 806–818 designs currently available.

Enclosures — Three types of enclosures are available. These are Totally Enclosed Non-Ventilated (TENV), Drip Proof Separately Ventilated (DPSV) and Totally Enclosed

Table 5

Enclosure and Protection Designations

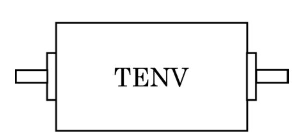
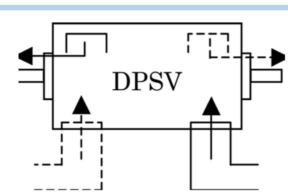
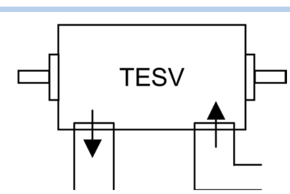
Type	Cooling	Protection	Sketch
Totally Enclosed Non-Ventilated (TENV)	IC410	IP44	
Drip Proof Separately Ventilated (DPSV)	IC06	IP24S	
Totally Enclosed Separately Ventilated (TESV)	IC37	IP44	

Table 6

Key Mounting Metric and English Dimensions

	Bottom of foot to shaft center (D/C)		Length: center of foot bolt to center of motor frame (E)		Length: center of foot bolt to center of motor frame (F)		Length from shaft end to shaft end (XC/L)	
Frame no.	mm	Inches	mm	Inches	mm	Inches	mm	Inches
806	254	10.00	210	8.25	265	10.50	1,074	42.25
808	285	11.25	238	9.38	315	12.38	1,208	47.50
810	311	12.25	260	10.25	330	13.00	1,276	50.25
812	339	13.38	285	11.25	362	14.25	1,396	55.00
814	374	14.75	318	12.50	405	16.00	1,542	60.75
816	406	16.00	342	13.50	445	17.50	1,714	67.50
818	450	17.75	380	15.00	495	19.50	1,792	70.63

Separately Ventilated (TESV) types. The Separately Ventilated (SV) description specifies a separate source of cooling air as contrasted with the more general Forced Ventilation (FV) designation. Some DC mill-duty motors were force ventilated with ambient air using motor-mounted fans, which meant they were totally enclosed but subject to mill air. The enclosure and protection types are shown in Table 5.

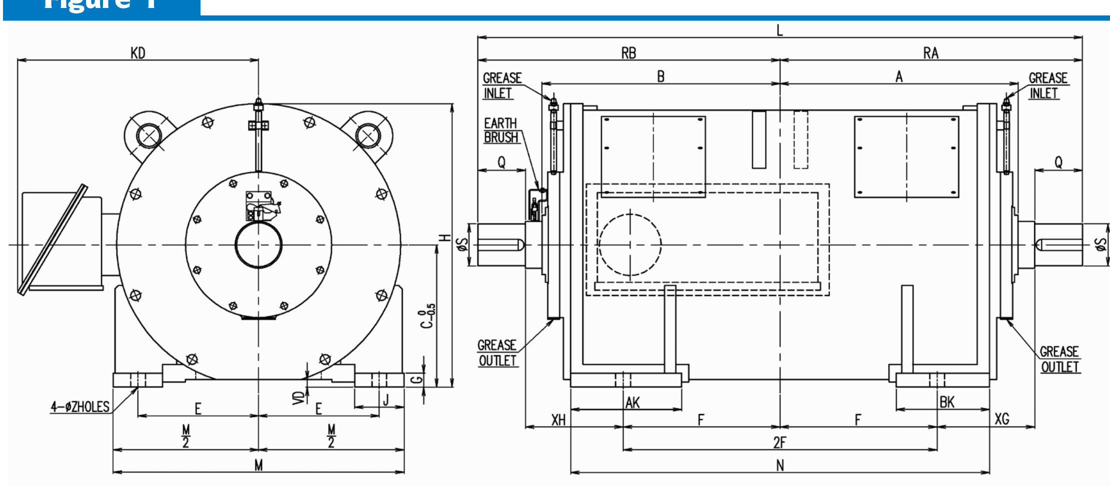
Dimensions — Key motor mounting dimensions are given in Table 6. The metric (mm) units are from the motor outline drawings, and the English (inches) units are from the standard. Conversion from the metric system using 25.4 mm/inch gives a maximum deviation of 0.07 inch.

Due to differences in nomenclature standards, a word description and the AIST/JIC is used in Table 6; for example, "Bottom of foot to shaft center (D/C)," where D is from AIST and C is shown in Figure 1.

The general AC mill-duty motor outline drawing is shown in Figure 1. The end view on the left is from the non-drive end or opposite side of the motor facing the driven equipment. The terminal box is shown on the left side for this example. Details by frame size are shown in the Leads section immediately following.

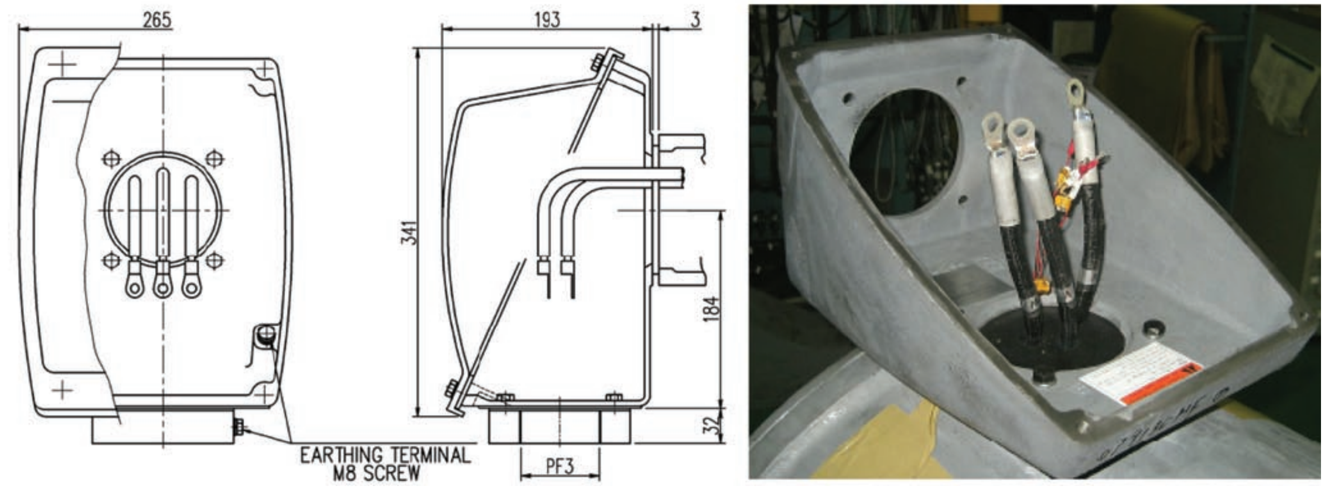
Leads — Terminal boxes for termination of the 3-phase leads are a standard feature, as pictured in Figure 2. DC mill-duty motors required two armature leads and two field leads, more if the fields were designed to be reconnected in series or parallel. Replacement of the DC motors will require replacement of the DC leads and with a new 3-phase cable terminated in the terminal box. The dimensions shown in Figure 2 are in mm.

Figure 1



AC mill-duty motor outline drawing with double shaft extension.

Figure 2



Frame 806–812 top-mounted terminal box.

The standard terminal box location for the smaller frames is on the top of the motor, allowing for ease of cable routing and termination. Left-side or right-side mounting of the terminal box is optional for the smaller frame sizes and standard for the larger frame sizes.

Table 7

Terminal Box Locations by Frame Size

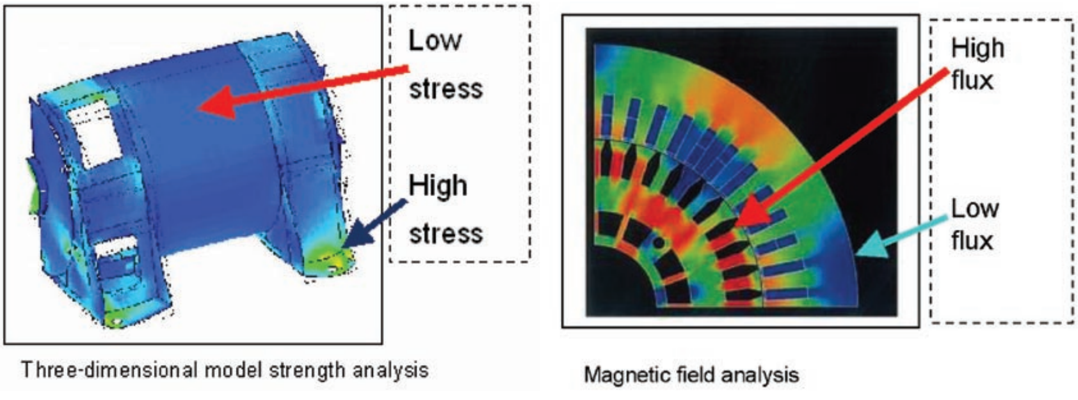
Frame no.	Location of terminal box when facing the non-drive end: Top	Left side	Right side
806	Standard	Option	Option
808	Standard	Option	Option
810	Standard	Option	Option
812	Standard	Option	Option
814	Not available	Standard	Option
816	Not available	Standard	Option
818	Not available	Standard	Option

Frames — DC mill-duty motors had rolled steel split frames. The AC mill-duty motor frames are rolled steel but not split, for the reasons noted earlier. They also feature a robust cast aluminum and copper bar squirrel cage rotor and form wound stator construction. The rotor construction process allows pull-out torques about 300%. Modern design programs allow verification of mechanical strength and electrical flux distribution.

Figure 4 shows the stator winding configuration of an AC motor. The picture shows why the split frame is not considered practical for the AC mill-duty motor.

Shafts — Some DC mill-duty motor shafts were tapered for quick field replacement of the coupling on the replacement rotor shaft. Rotor replacement was possible without removing the entire motor because the frame was split. Tapered shafts were not generally

Figure 3



AC motor design tools.

used for table motor applications, although the frame may have been split. Permanent magnet table motors did not have the split frame feature. The AC mill-duty motor shafts are keyed without taper or threaded locking nut. Special provisions for adapting the coupling must be made in cases where the original motor has these features. Since the AC motor frame is not split, the motor is replaced as a unit and the tapered shaft feature becomes less important.

Ratings — AIST Standard No. 1 provides ratings for series, compound and shunt DC motor excitation with 230 volts applied from a DC generator. While many DC mill-duty motors were applied at 230 VDC, many were also applied at 460 VDC, 500 VDC and various other ratings. At this point, it is important to remember that the motor nameplate does not necessarily correspond to the motor application. The user must know the application rating, including the rms and overload values, before attempting to apply the same frame size AC motor.

The standard and general practice used the unit of pounds, with force assumed, in defining torque and inertia. Note that Table 8 uses the more explicit term "pounds of force" (lbf).

In the case of DC motors, the horsepower (HP) and speed (RPM) are generally assumed to be directly proportional to the DC voltage applied to the armature, with the torque remaining unchanged. Therefore, doubling the applied voltage doubles the HP and RPM for the same rated torque. Although this may not be strictly correct due to motor characteristics, it is close enough for application purposes. Only the variable speed shunt applications will be considered in comparing the DC and AC mill-duty motors.

Figure 4

AC mill-duty stator before inserting in frame.

Table 8

Useful Conversion Factors

kW	=	HP x 0.746	
Torque	=	HP x 5,252 / RPM	lbf-ft
lbf-ft	=	1.3558	Nm
WK^2	=	Inertia	lbf-ft^2
GD^2	=	0.1686 x WK^2	$kgfm^2$

In DC applications, torque was not usually measured, but calculated from currents and design curves, as discussed earlier. Frames 802–818 generally did not have compensating windings necessary to make the torque and armature current values proportional over the operating range. That is, 200% current was less than 200% torque. This should be

Table 9

Ratings for 230 VDC and 500 VDC Applications

	Ratings for 230 VDC				Ratings for 500 VDC	
Frame no.	HP	Base RPM	Top RPM	Torque (lbf-ft)	HP	Base RPM
806	30	650	1,950	242	65	1,413
808	50	575	1,725	457	109	1,250
810	70	550	1,650	668	152	1,196
812	100	515	1,300	1,020	217	1,120
814	150	500	1,250	1,576	326	1,087
816	200	480	1,200	2,188	435	1,043
818	250	435	1,100	3,018	543	946

Table 10

AC Mill-Duty Ratings Compared to DC Mill-Duty at 500 VDC

	Totally Enclosed 1 Hour (TENV) or Force Ventilated Continuous (TEFV, DPSV or TESV)							
	500 VDC ratings			At design VAC ratings				
Frame no.	HP	Base RPM	Torque (lbf-ft)	kW	HP	Base RPM	Top RPM	Torque (lbf-ft)
806	65	1,413	242	44	59	1,300	1,950	238
808	109	1,250	457	74	99	1,150	1,725	453
810	152	1,196	668	104	139	1,100	1,650	666
812	217	1,120	1,020	150	201	1,030	1,545	1,025
814	326	1,087	1,576	220	295	1,000	1,500	1,549
816	435	1,043	2,188	300	402	960	1,440	2,200
818	543	946	3,018	370	496	870	1,305	2,994

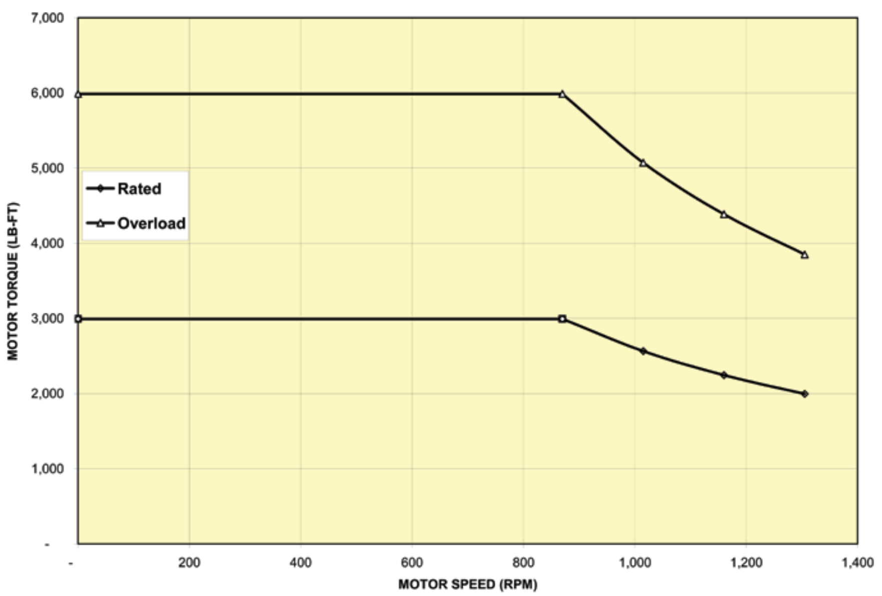
taken into consideration when specifying the equivalent AC motor.

The 500 VDC rating in Table 9 was chosen not only because it was in common usage by North American suppliers, but also to emphasize the need to understand the user's application rating. If your application is at the commonly used 460 VDC, the AC motor ratings would match within ±1 HP when converted from the design kW rating. The replacement of any existing drive system involves understanding the actual application ratings, which can be quite different than the motor nameplate.

Variable speed operation includes constant torque from zero to rated base speed, the point at which motor HP and kW are determined. Operation above base speed is at constant HP and kW; that is, torque decreases proportionally to the speed increase. NEMA MG-1 decreases the overload requirement as the top/base speed range increases, capping the decrease at 140% of the base speed overload at a 3-to-1 speed range.

The frame 818 speed-torque curve is shown in Figure 5 for a 200% overload application at base speed and the NEMA MG-1 193% overload at top speed. DC motors being replaced probably adhered to this standard. Since no equivalent standard exists for AC motors, new applications sometimes specify the same overload throughout the speed range. Induction motors inherently lose torque capability proportional to speed squared, and therefore may have no overload capability at top speed unless one is specified.

Figure 5



Frame 818 speed-torque (lb-ft) characteristic from base to top speed.

Voltage Source — The AC mill-duty motor is designed for operation from a PWM inverter and operation over the speed ranges listed above.

Temperature Rise — The AC mill-duty motor incorporates Class F insulation and is rated based on Class F rise assuming a 40°C maximum ambient.

Speed Regulation — The speed torque characteristic for the frame 818 motor shows a slip, or speed loss due to load, that is nearly linear over a wide range of loads. This means that, when used as a table motor with volts-per-hertz control, applied loads will slow the motor from its no-load speed perhaps 1 or 2%, certainly much less than the 15% allowed by the standard from no-load to rated load. Provided there is not excessive cable line drop, overloads of 250% should be possible up to base speed with basic volts-per-hertz control.

Operation above base speed requires speed feedback control using the standard motor. Requirements for higher overloads are possible but may require a larger standard frame or modified design.

WK² Factor — The AC mill-duty motor inertias are less than the maximum values allowed by AIST Standard No. 1, but higher than those of the equivalent DC motor. One of the commonly advertised features of AC versus DC is that the AC motor inertia is lower. In this particular case, the rugged, solid rotor construction results in a higher inertia than the equivalent DC motor manufactured by TMEIC.

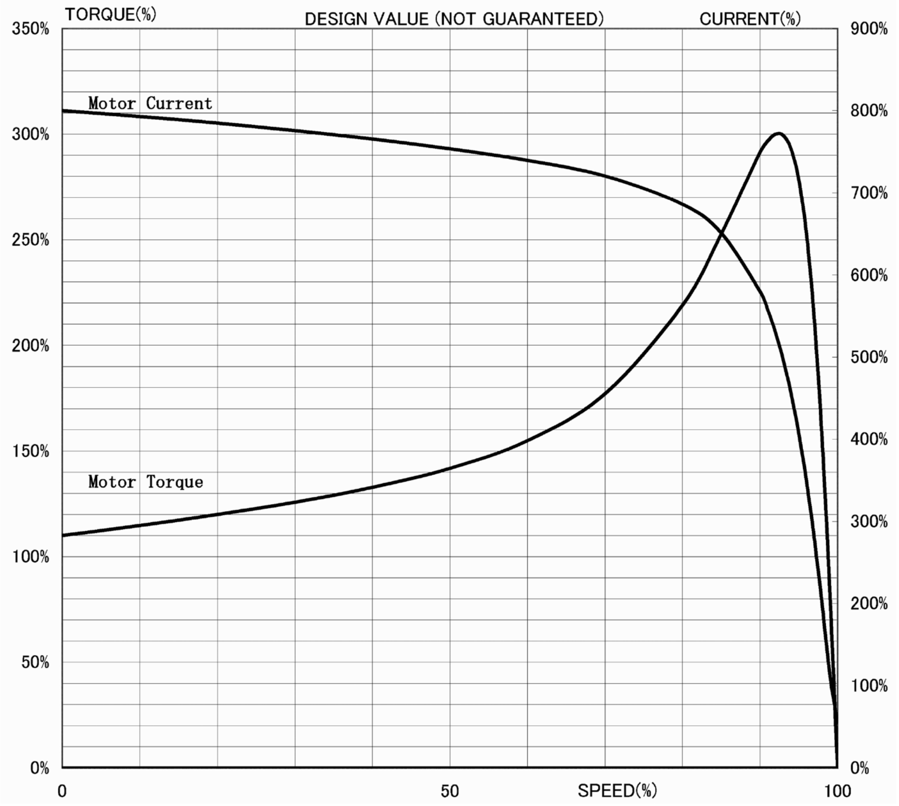
Note that the DC motor inertias from other motor manufacturers will be different and may be given with and without fans. It should also be noted that the response of modern PWM inverters, with speed feedback device or without, is usually faster than the DC drive they replace. The net result is that the overall performance of the new equipment should be at least as good as the replaced drive and motor.

The GD² values given in Table 11 are based on Toshiba and Mitsubishi Electric motors.

Additional Features of AC 800 Series Mill-Duty Motors

There are some additional features of the new AC mill-duty motor line that should be considered:

Figure 6



AC 818 mill-duty motor characteristic curve.

Efficiency — One big advantage of AC motors over DC is their improved efficiency. When replacement of a DC generator with an inverter is considered, the savings are more than doubled from those shown. Motor efficiency is a function of design and operating conditions and will vary. The numbers given in Table 12 are for reference only, comparing AC and DC mill-duty motors for the same conditions.

Table 11

AC Mill-Duty Inertia Compared to AIST and DC

	AISE maximum armature inertia		TMEIC DC mill-duty motor		TMEIC AC mill-duty motor	
Frame no.	WK² (lb-ft²)	GD² (kg-m²)	WK² (lb-ft²)	GD² (kg-m²)	WK² (lb-ft²)	GD² (kg-m²)
806	50	8.4	25–26	4.2–4.3	47	7.9
808	90	15.2	51	8.5–8.6	71	12.0
810	145	24.4	75–83	12.6–14.0	119	20.0
812	220	37.1	136–149	23–25	220	37.0
814	400	67.4	231–244	39–41	267	45.0
816	600	101.1	344–423	58–71	629	106.0
818	1,100	185.4	522–637	88–107	949	160.0

Table 12

Comparison of AC and DC Motor Efficiencies Under Same Conditions

Frame no.	TMEIC DC mill-duty motor ratings: kW	RPM	Efficiency	TMEIC AC mill-duty motor ratings: Efficiency	Improvement
806	22	650	87.6%	91.1%	3.5%
808	37	575	88.3%	92.5%	4.2%
810	52	550	88.6%	92.8%	4.2%
812	75	515	89.1%	93.5%	4.4%
814	110	500	90.4%	94.2%	3.8%
816	150	480	91.3%	94.8%	3.5%
818	185	435	91.8%	95.0%	3.2%

The efficiencies listed in Table 12 are for rated conditions according to the standard. DC motors operating at half and quarter speed will have significantly lower efficiencies because they are basically the same motor operated at lower voltages. The AC mill-duty motors are always higher efficiency than the equivalent DC mill-duty motor.

Motor Design Ratings — Each motor frame has designs corresponding to the equivalent 460 VDC, 230 VDC and 115 VDC ratings. They are labeled Standard, Medium and Low speed in Table 13. The rotor is the same design, but the stator winding connections are modified for approximately the same VAC and therefore high efficiency.

Table 13

AC Mill-Duty Design Ratings

Frame no.	Speed	Design ratings: kW	RPM	VAC	Amps	Hertz
806	Standard	44	1,314	370	96	65.7
	Medium	22	664	370	50	33.2
	Low	11	336	350	30	16.8
808	Standard	74	1,164	370	160	58.2
	Medium	37	586	370	80	29.3
	Low	14.8	240	350	38	12.0
810	Standard	104	1,110	370	230	55.5
	Medium	52	560	370	120	28.0
	Low	20.8	230	350	52	11.5
812	Standard	150	1,040	370	315	52.0
	Medium	75	526	370	160	26.3
	Low	30	226	350	70	11.3
814	Standard	220	1,010	360	480	50.5
	Medium	110	510	360	240	25.5
	Low	44	210	340	110	10.5
816	Standard	300	970	360	640	48.5
	Medium	150	490	360	325	24.5
	Low	60	200	340	150	10.0
818	Standard	370	880	370	760	44.0
	Medium	185	442	370	400	22.1
	Low	74	180	340	185	9.0

Responsive induction motor control requires that the motor voltage goes higher than the nameplate rating to force the torque-producing component of stator current to rapidly pick up load. This is especially true in the constant torque range of Figure 5. Some motor manufacturers may list the maximum voltage on their nameplates, but in general this statement is true. Therefore to get the maximum rating and performance, all 21 of the ratings in Table 13 would be driven by an inverter capable of 420–460 VAC output at 70 hertz.

It is also worth noting that these motors are designed for variable speed applications and that none of the frames happens to fall on either the 50 or 60 Hz line frequencies. The following formula is for 3-phase motor synchronous speed:

$$RPM = (120 \times Hertz) / Number\ of\ Poles \qquad \text{(Eq. 1)}$$

There is an important distinction between synchronous speed and rated speed in the application of induction motors. Using Equation 1 and Table 13, one can determine that frame 818 is a 6-pole design (6 = 120 x 44/880). Referring back to Table 10, we find a frame 818 rating of 870 rpm. This 10-rpm difference corresponds to the induction motor slip frequency required to produce torque. One can therefore determine that the slip frequency at rating conditions of 100% load requires approximately 1.4% slip (10/880). The motor nameplate will reflect the 870-rpm rated condition at 100% load.

Bearings — Roller bearings are used for the drive end, and ball bearings for the non-drive end. The non-drive end bearing includes a grounding brush for additional protection against unwanted shaft currents caused by inverter switching (Figure 7). In addition, frames 808 and above use insulated brackets for both bearings. A special labyrinth seal is also optionally available, as shown in Figure 8.

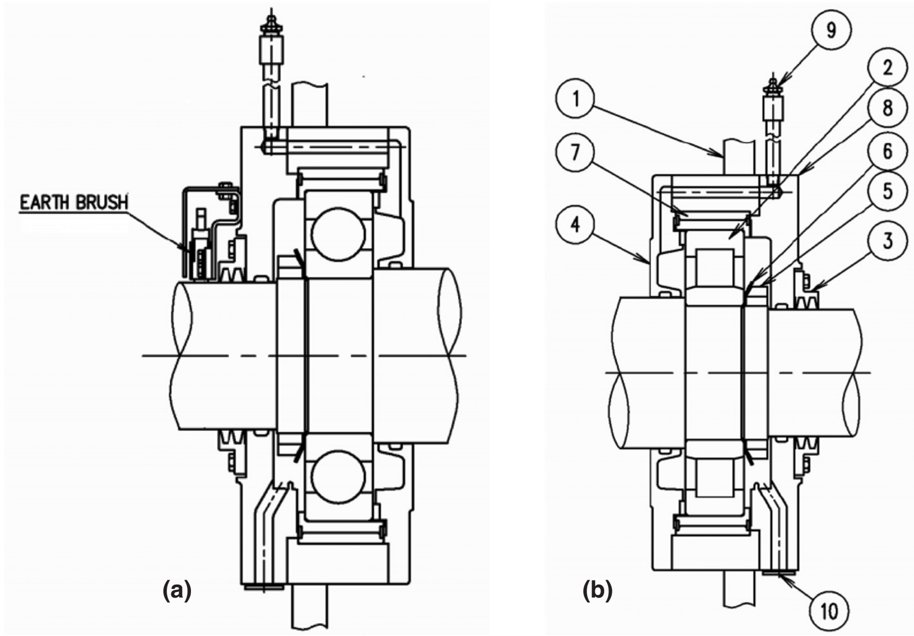
Conclusion

An AC mill-duty motor in frames 806–818 is now available to replace existing DC mill-duty motors conforming to AIST Standard No. 1. They are ideally suited to replace table motors and may be used in other variable speed applications as well. The user must take care to understand the application of the existing DC motor, as the nameplate may not reflect actual usage.

References

1. *DC Mill Motors,* AIST Standard No. 1, September 1968.

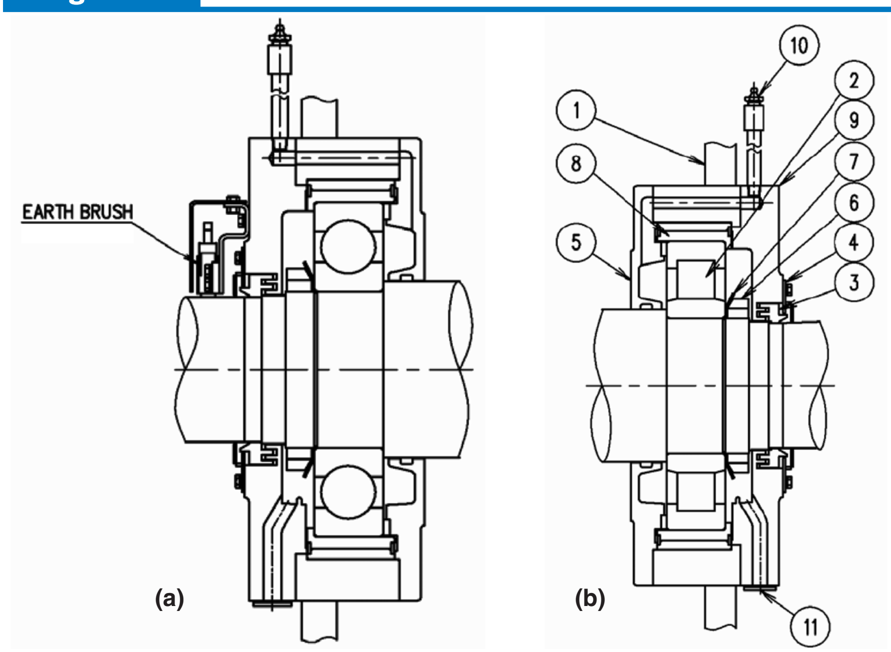
Figure 7



1. Bracket
2. Antifriction bearing
3. Standard seal
4. Inner bearing cover
5. Bearing nut
6. Bearing washer
7. Bearing insulation brush
8. Outer bearing cover
9. Grease inlet
10. Grease outlet

Standard bearing arrangements: (a) non-drive end, (b) drive end.

Figure 8



1. Bracket
2. Antifriction bearing
3. Labyrinth seal
4. Labyrinth cover
5. Inner Bearing cover
6. Bearing nut
7. Bearing washer
8. Bearing insulation brush
9. Outer bearing cover
10. Grease inlet
11. Grease outlet

Labyrinth bearing arrangements: (a) non-drive end, (b) drive end.

2. General Electric, "Armored Motor Application Manual," December 1969.

3. General Electric, "MD 800 Armoured Mill Motor Buyer's Guide," GEP-620, December 1978.

4. L.S. Sherman, "Understanding Motor Temperature Ratings," *Plant Engineering,* February 1969.

5. R.I. Tessendorf, AIST 2005 DC Machines and Drives Technology Seminar. ✦

This paper was presented at AISTech 2008 — The Iron & Steel Technology Conference and Exposition, Pittsburgh, Pa., and published in the Conference Proceedings.