MOTOR LOAD AND EFFICIENCY

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ABSTRACT

This article decribes the efficiency and the usage of induction motor for energy conservation. The motor rotating speed calculation, simple speed reduction method and variable speed drive (VSD) are discussed. The full load amperage and average efficiency at various percent of full load taken from the references are shown in the attached tables. In absence of the partload efficiency tables, a method of partload efficiency estimation is also presented. The Slip Method for motor partload and efficiency calculation is strongly discouraged. The power saving by employing VSD for centrifugal fans, centrifugal pumps and air compressors is also recommended.

1. Objective of Motor

Motor is an appliance to covert electrical energy into mechanical energy in order to move or to operate a machine e.g. compressor, fan or pump. The efficiency of energy convertion is an answer to the energy conservation.

2. Popular kind of Motor used

The most popular kind of motor used, is induction type. There are two type widely used:

- Open Drip Proof (ODP) is easily noticed by its visible winding.The price is economical.

- Totally Enclosed Fan Cooled (TEFC), as its name implies, it is enclosed in a casing preventing from dust getting in and attached with a cooling fan. It is more expensive than the former.

3. Motor Rotating Speed

Induction motor has a theoretical or so called Synchronous Speed, N_S as folllows:

N_S = 120F/P..(1)

N_S = Synchronous speed, RPM (Revolutions per minute)

F = Frequency, in Thailand, Japan and United Kingdoms are 50 Herz, USA using 60 Hz :

Thailand, Japan and United Kingdoms

N_S = 6,000/P..(1a)

USA N_S = 7,200/P.......................................(1b)

P = Magnetic Poles (2, 4, 6,.........................)

Therefore in Thailand, Japan and United Kingdoms the motor synchronous speeds in RPM are 6,000/2 = 3,000, 6,000/4=1,500, 6,000/6=1,000.....for 2, 4, 6.....poles respectively.

The actual rotating speed will be about 1%-4% less, due to electrical slip. All manufacturers will show the actual or rated speed in motor nameplate. As an example for a motor nameplate: 7.5 kW,380/50/3, 1450 RPM is a 4 poles motor with an actual speed of 1450 RPM. The electrical slip is (1500-1450)/ 1500 = 3.3%. In actual installation, a motor is very often operate at a partload. The speed varies inversely as the load. Since the variation is only a few percentage, therefore in mechanical point of view it is considered as approximately constant. As an example a motor rated at 10 HP(7.5 kW), 1450 RPM is used to drive a small pump required 5 HP brake power. This is a 50% load, the actual speed found to be 1470 RPM. The variation of speed due to load is only = (1470-1450)/ 1450*100 = 1.4% which is not significant. This is the reason why it is not possible to increase water flowrate by using a larger motor with a same number of poles. The motor speed can be changed by having numbers of poles change as in small air conditioning fan. However the variation of poles is limited. In the past, varying the speed of an induction motor was very difficult. Today, variable speed drive (VSD) can vary motor speed with an unlimited speeds. VSD is expensive but not as expensive as before. VSD is working by varying the electrical frequency (F) as mentioned above the speed is 120F/P. Therefore the rotating speed varies linearly as frequency.

4. Motor Efficiency

Motor Efficiency $\eta_m = W_B/W_E$ often multiplied by 100 into percent.............................(2)

$Q_{LOSS} = W_E - W_B = [(1/\eta_m)-1]\ W_B$................(3)

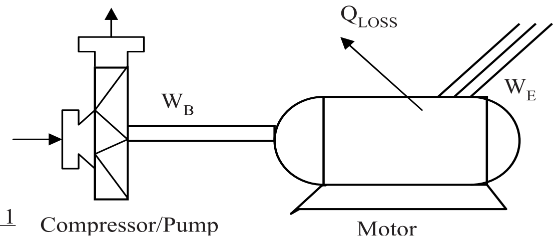

Fig. 1

W_B = Brake/Shaft Power or rated Power in HP(Horse Power) is also Nominal power, in S.I. Unit is kW (Kilowatt). The followings are standard rating in HP(kW in the bracket) 0.5(0.37), 0.75(0.55), 1(0.75), 1.5(1.1), 2(1.5), 3(2.2), 4(3), 5.5(4), 7.5(5.5), 10(7.5), 15(11), 20(15), 25(18.5), 30(22), 40(30), 50(37),60(45), 75(55), 100(75), 150(110), 200(150), 250(187), 300(220), 400(300), 500(373)..................................

W_B is measured by Dynamometer it is not practical in doing on site. Therefore accurate field measuring motor effficiency is not possible. Indirect way of finding can be done by mearuring fluid flowrate and pump/ fan head provided that accurate Characteristic Curve is known.

W_E = Electrical power input can be directly measured in the field.

$W_E = V.I.Cos\theta$ single phase........................(4)

$W_E = 1.732\ V.I.Cos\theta$ 3 phase ....(5)

$Cos\theta$ = Power Factor which can be found as:

$Cos\theta = (W_B/\eta_m)/(1.732*V.I/1000)$..................(6)

The motor efficiency at full or rated load and at various partloads can be obtained from manufacturers, if not available Table 2 and Table 3 can be used as an average value. They are from NEMA and FACT Sheet of a program of the U.S. Department of Energy.

The percentage of rated load can be approximated as percentage of rated power input (W_E) which is:

Percent rated load = $[(1.732*V*\ I*Cos\theta)/(1.732*V*\ I*Cos\theta)_{rate}]*100$ ....(7)

Percent rated load = $[(1.732*V*\ I*Cos\theta)/W_{Erated}]*100$..(8)

At percent rated load not less than 50% and actual voltage equals rated voltage, normallly the power factor ($Cos\theta$) varies insignificantly. The percent rated load can be simplified as:

Percent rated load = $(I/I_{rated})*100$....................(9)

Example 1 An open drip proof (ODS) motor is identified as a 30HP(22kW),380V/3/50,950 RPM. The electrician makes the average measurements as 22 Amperes, 380V. What are the percentage of Full-load, Fulll Load efficiency and partload efficiency?

Solution Rated current (Irated)can be taken from Table 1 as 44 Amp.

Percent rated load = $(I/\ I_{rated})*100$ = (22/44)*100 = 50% Full Load

From Table 2 (From NEMA) Full Load efficiency is 89.8% and

from Table 3 an ODS motor,900 RPM at full load is 89.9% and at 50% Load efficiency is 90.2% which is a little better than full load efficiency.

An existing standard efficiency motor larger than 1.5 HP(1.1kW) operating at half load is not recommended to replace with a smaller standard efficiency motor. The high efficiency motor with a smaller size may be used providing that the payback period is worth.

Most electric motors are designed to run at 50% to 100%. Maximum efficiency is normally near 75% of rated load. The optimum operating range is between 60% and 80% of rated load. Partload efficiency of a motor smaller than 1.5 HP(1.1 kW) decreases significantly with the load decreases.The efficiency reduction rate will be very high when the load is less than 50%.

In case of Table 3 (Part load efficiency) is not available. Partload efficiency may be estimated from motor power loss(Q_{LOSS}). Motor power losses consist of 2 parts. The first losses are core, friction and windage which called fixed lossses. They do not depend on load but vary as the square of the voltage. They are about 30% of the total lossses. The second loss is a copper loss which varies as load or square of VI. It is about 70% of the total losses. By means of equation(3), total losses can be written as:

Q_{LOSS} = $(1/\eta_{m\text{-}rated}\text{-}1)\ W_B\ [0.3(V/V_{rated})^2 + 0.7 (VI/(V_{rated}I_{rated}))^2]$..(10)

The partload efficiency of a motor, η_m will be:

$\eta_m = \{1\text{-}(1/\eta_{m\text{-}rated}\text{-}1)W_B[0.3(V/V_{rated})^2+0.7 (VI/(V_{rated}I_{rated}))^2]/(1.732^*VICos\theta/1000)\}^*100$......(11)

If actual voltage equals rated voltage. The partload efficiency can be simplified as:

$\eta_m = \{1\text{-}(1/\eta_{m\text{-}rated}\text{-}1)W_B[0.3+0.7(I/I_{rated})^2]/ (1.732^*VICos\theta/1000)\}^*100$..................................(12)

Example 2 An ODP motor, 30HP(22kW) 380V/ 3/50, 950 RPM, the rated load efficiency is 89.9%. The measured average current and voltage are 22 Amp. and 380V respectively. Assume that Table 3 is not available. What is motor partload efficiency?

Solution From Table 1, Rated current (I_{rated}) = 44 Amp. and power factor ($Cos\theta_{rated}$) can be obtained from equation(6)

$Cos\theta_{rated}$ = (22/0.899)/(1.732*380*44/ 1000)= 0.85

Assuming power factor remain constant or

$Cos\theta = Cos\theta_{rated} = 0.85$

By means of equation (11)

η_m = {1-(1/0.899-1)*22*[0.3(380/380) 2+0.7(380*22/(380*44)) 2]/(1.732*380*22*0.85/ 1000)}*100

η_m = 90.46%

If using equation (12)

η_m = {1-(1/0.899-1)*22*[0.3+0.7(22/44)2]/ (1.732*380*22*0.85/1000)}*100=90.46%

Compare the result to Table 3 at 50% load efficiency of motor is 90.2%.

It should be noted that the calculated value is close to the actual value due to the assumed power factor being close to the actual value. In actual partload power factor must be measured. The error will be large if actual power factor diviates from the assumed value.

The Slip Method

The Slip Method for estmating motor load in the field is not recommended by the author. In actual field measurement, a lot of unacceptable error has been found by this method. The Slip method is as shown below:

Percentage of Rated Load = $(N_S\text{-}N) / (N_S\text{-}N_{rated})^*100\%$..(13)

N_S = Synchronous speed =120F/P

N = actual speed measured in RPM

N_{rated} = rated speed from manufacturer in RPM

The error mainly comes from the measurement. Since the percentage difference between actual speed and synchronous speed is minimal about 1-4% only and the variation of speed with the load is so small as mentioned above. Therefore a little error in measuring of speed can magnify into a large error.

5. Brake/Shaft Power from a motor

Brake or Shaft output power of a motor depends on a load. It does not depend on the rated power of the motor. As an example a 100 HP(75 kW), 1460 RPM motor is connected to drive a pump required 10 HP(7.5kW), 1460

RPM. The power output from the motor will be 10 HP(7.5 kW) not 100 HP. If the motor efficiency remains constant the power input (Power consumption) will be exactly the same. However in actual condition a motor operating at 10% load the effficiency will be lower, power consumption will be higher. Two motors driving the same load, power consumptions can be written as:

$$W_{E2} = W_{E1}\ (\eta_{m1}/\eta_{m2})$$

Example 3 A motor, 25 HP(18.5 kW), 950 RPM with a rated load efficiency of about 88.6% is driving a pump with a measured motor power input of 20 kW. If it is replaced with a 100 HP(75 kW), 950 RPM motor which is about 25% load. From Table 3 the partload efficiency is 85.8%. What is the new motor power comsumption?

Solution New motor power consumption, $W_{E2}=W_{E1}\ (\eta_{m1}/\eta_{m2}) = 20\ (0.886/0.858) = 20.7$ kW

Normally, the load of a pump or a fan varies when its speed varies. A directly driven machine speed can be varied by using VSD as mentioned before. A fan driven with pulleys and belt, its speed can be changed easily and economically by changing the size of a pulley.

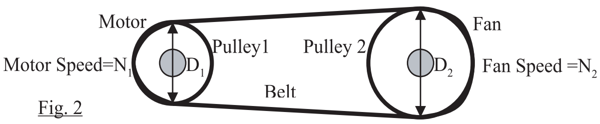

Fig. 2

The relation between motor speed and fan speed can be derived as:

$$\pi D_1 N_1 = \pi D_2 N_2 \quad D_2 = D_1 N_1 / N_2 \text{ ....(14)}$$

If it is required to change fan speed from N_2 to N_3, the pulley diameter will be D_3. The diameter can be derived as shown below:

$$\pi D_1 N_1 = \pi D_2 N_2 = \pi D_3 N_3$$

$$D_3 = D_2 N_2 / N_3 \text{ ....(15)}$$

It should be noted that motor speed always remains constant.

Example 3 A motor with a speed of 1450 RPM is driving a fan with a speed of 600 RPM. The fan pulley size is 200 mm. It is required to increase fan speed to 800 RPM. What is the new pulley required?

Solution New pulley size, $D_3 = D_2 N_2 / N_3 = 200(600)/800 = 150$ mm

In this example motor speed remains constant at 1450 RPM but fan speed is increased. The load will be increased. If originally the motor was at rated load, it will be overloaded. It should be noted that a motor load is a machine load.

6. Machine Load

Machine load depends on 2 factors : (1) Characteristics or performance of Machine and (2) System.

(1) **Characteristics of Machine** depends on each type and each machine and it must be tested by the manufacturer. Fortunately for a centrifugal pump or a centrifugal fan there is a common law. It is called Affinity or Fan or Pump Laws as shown below:

$$Q_2/Q_1 = N_2/N_1 \text{ ....(16),}$$

$$P_2/P_1 = (Q_2/Q_1)^2 = (N_2/N_1)^2 \text{ ....(17),}$$

$W_2/W_1 = (Q_2/Q_1)^3 = (N_2/N_1)^3$ ....(18)

Q = fluid flow rate

P = Head or pressure increase

W = Theoretical(Ideal) Power

N = Speed

This law enables a manufacturer to draw a characteristic or performance curve of a pump or a fan at various speeds based on only one tested speed.

(2) **System** is a mass fluid flow and energy required to move the mass. Considering for a fan the energy required to move a mass is only friction. The air flow in most system is turbulent,the friction varies directly as the sqaure of the mass or volume flowrate:

$Frict_2/Frict_1 = (Q_2/Q_1)^2$..................................(19)

Since fan head or pressure increase is friction. Equaton (19) coincides with equation (17). The theoretical power required in equation (18) $W_2/W_1 = (Q_2/Q_1)^3$ can be used. The theoretical power can be replaced by brake power (W_B) if efficiency of a fan remains constant. It can be replaced by power consumption (W_E) if motor efficiency is also constant.

Water pump delivers water from a storage tank to another on the same level. The energy required to move a mass just like a fan is also due to friction only. The water pumping in air conditioning system is also applicable to the above equation [$W_2/W_1 = (Q_2/Q_1)^3 == (N_2/N_1)^3$].

In practice, the variation of fan or pump efficiency due to speed change is not much for a system having only friction. The equation telling that the energy or electricity can be conserved tremendously if speed is reduced.

Example 4 A centrigal fan operates at a speed of 1200 RPM. The fan speed is changed to 600 RPM. What is the new brake power required in term of the existing brake power.

Solution $W_2 = (Q_2/Q_1)^3\ W_1 = (N_2/N_1)^3\ W_1 = (600/1200)^3\ W_1 = (1/8)\ W_1 = 0.125\ W_1$

New brake power required is only 12.5% of the existing. The energy saving is 87.5%.

System with Potential Energy (Elevation or height)

In a system consists of not only a friction but also potential energy (Elevation or height), the above power rule may not be used. The reason is that the energy required is Friction and Potential energy. The potential energy or height remains constant regardless of the mass or volume flow only the friction varies as the square of the flow. The power required is governed by the system. In a system essentially consists of potential head (height) the power varies directly as the mass flow or $W_2 = (Q_2/Q_1)W_1$. It is obvious the pump power rule does not coincide with the system power. In practice the efficiency of a pump also changes. The Pump/Fan Law equation (16) $Q_2/Q_1 = N_2/N_1$ cannot be used. This means to increase a water flow rate from 1 m^3/s to 2 m^3/s the pump speed is not required to increase twice but much less than twice.

Example 5 A centrigal pump delivers water from underground storage tank to a roof tank at 100 m high at the rate of 2 m^3/s. The flow rate is decreased to 1 m^3/s by a VSD (Variable Speed Drive) changing to a lower speed. What is the new brake power required in term of the existing brake power. Assuming friction is negligible.

Solution $W_2 = (Q_2/Q_1)W_1 = (1/2)\ W_1 = 0.5\ W_1$ New theoretical power required is a half or 50% of the existing. Assume that pump efficiency change from 80% to 75%. The new bake power will be 0.5 *(80/75) W_{B1} = 0.53 W_{B1} or 0.53 time of the existing. Again assuming motor efficiency change from 90% to 85%, the motor power input will be 0.53* (90/85) W_{E1} = 0.56 W_{B1} or 0.56 time of the existing. The saving is not as much as in the previous example.

Pump and Hydronic System Curves

In fact Affinity or Pump Laws can be used regardless of system with friction head or potential head. Since Affinity Laws are used to estimate pump performance at different rotating speeds based on a pump with known characteristics at one speed. The required rotating speed will be governed by the system. The correct speed is necessary. Thr practical method is to plot both system curve and pump curve on the same graph. The intersection of the two curves (Fig. 3) is the operating point. From Example 5 system consists of only a potential energy or the height of 100 m and the flow rate of 2 m^3/s. Since system with only the potential energy which is constant. The system curve will be horizontal line as shown in the figure. Assume a known pump characteristic curve at speed N1 from manufacturer and point 1 is the original operating point. It is required to reduce flow rate to 1 m^3/s. The new operating point 2 will be governed by system curve. The pump curve passing through this point is operating at a speed of N_2. The N_2 curve can be found from Affinity Laws. It should be noted that N_2 is not equal to $N_1(Q_2/Q_1)$ or N_2 is not N1/2. This is the reason why the ideal power is not $(1/2)^3$ =1/8 =0.125 of the original power as mentioned in example 5.

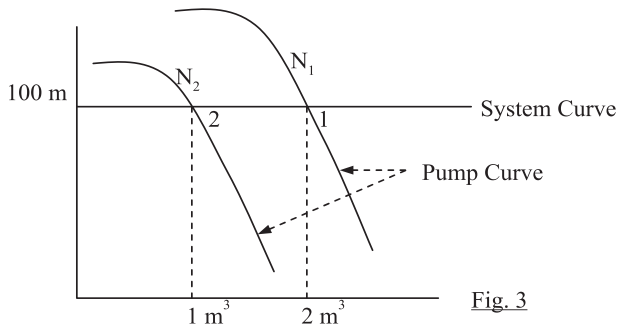

Fig. 3

In order to simplify, both hydronic system curve and pump curve must be plotted on the same graph. From Example 5 if the head of 100 m consists of 80 m of potential head and 20 m of friction head. The system curve will be as shown in Fig. 4. The pump curve at a new speed N_{2b} which can be found from Affinity Laws. It also should be noted that N_{2b} is not equal to $N_1(Q_2/Q_1)$ either.

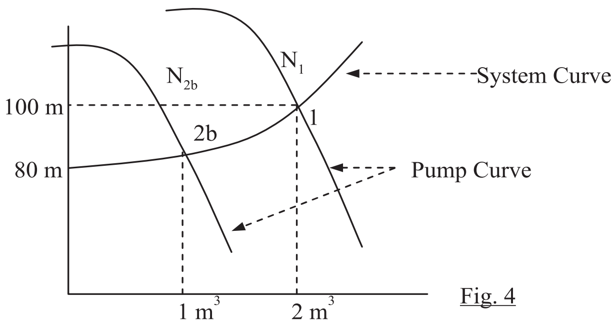

Fig. 4

Once the flow rate ,the head and the rotating speed are known, actual power can be obtained.

7. Variable Speed Drive (VSD)

As mentioned above the motor directly drive a fan or a pump is practical to use VSD to vary the speed. A fan or a pump operating without potential head, a flow rate varies directly as the speed ($Q_2/Q_1 = N_2/N_1$) and power or torque varies directly as the cube of the speed [$W_2/W_1 = (N_2/N_1)^3$]. The VSD varies an electrical frequency (F). Thus, power or torque also varies directly as the cube of the frequency [$W_2/W_1 = (F_2/F_1)^3$]. The energy saving is extremely high in reducing the frequency by VSD. The efficiency of a VSD must also be considered. The VSD efficiencies are shown in Table 4. It should be noted that the VSD efficiencies reduce considerably with motor load for small motor (Motor less than 5HP). For example a 5 HP motor, the speed reduced to 75% of rated speed, the motor load will be reduced to 42% according to Power Law. The VSD efficiency will be 83.3% as shown in Table 4. In this case the actual power required will be 42% / 0.833 = 50.4% of rated power. It is also indicated in the table that at 100% load the VSD effciency is 92.4% not 100%. At 100% load bypass magnetic contactors can be used to eliminate VSD losses. The net energy saving must consider not only VSD efficiency but also motor efficiency as mentioned before.

VSD for Air Compressor

In a compressed air system employing reciprocating(piston) air compressors, a required pressure is controlled by stopping the air compressor by a presssure switch. Using VSD cannot save any energy. Thus, using VSD is not recommended. In a system using screw compressors the pressure is controlled by unloading or shutting off a solenoid valve. VSD can save some energy but not as much as in the centrifugal fan case. The energy required by the system is a pressure difference or gage pressure which is constant. Thus, the power required varies directly as the flow rate only not as the cube of the flow rate.

References

1. Fact Sheet : A Program of The U.S. Department of Energy “Determining Electric Motor Load and Efficiency”
2. James A. Rooks.P.E. and Alan K. Wallace, Ph.D “Energy Efficiency of Variable Speed Drive Systems”
3. NEMA: Partload Efficiency and Amperage of Motor.

Table 1 Approximate Fulload Current for Motors

Electricity 380/50/3									Electricity 220/50/1		
Rated Power		Current	Rated Power		Cuurent	Rated Power		Current	Rated Power		Current
kW	HP	Ampere	KW	HP	Ampere	kW	HP	Ampere	kW	HP	Ampere
0.37	0.5	1.1	7.5	10	16.5	75	100	142	0.37	0.5	3.1
0.55	0.75	1.6	11	15	23.0	90	125	170	0.55	0.75	4.8
0.75	1	2.0	15	20	30.0	110	150	207	0.75	1	6.0
1.1	1.5	2.8	18.5	25	37.0	150	200	280	1.1	1.5	7.8
1.5	2	3.6	22	30	44	187	250	335	1.5	2	10.4
2.2	3	5.0	30	40	60	224	300	402	2.2	3	15.1
3	4	6.8	37	50	73	300	400	561	3	4	20.0
4	5.5	8.5	45	60	87	373	500	584	4	5.5	25.1
5.5	7.5	11.5	55	75	105						

Table 2 Efficiencies for Standard and High Efficiency Motors at Rated Load

Rated Power		Standard Efficiency Motor	High Efficiency Motor
HP	kW		
1	0.75	75.2	82.5
1.5	1.1	77.0	84.0
2	1.5	78.5	84.0
3	2.2	81.5	87.5
5	4	84.3	87.5
7.5	5.5	84.8	89.5
10	7.5	85.6	89.5
15	11	87.4	91.0
20	15	88.3	91.0
25	18.5	88.9	92.4
30	22	89.8	92.4
40	30	90.4	93.0
50	37	91.0	93.0
60	45	91.5	93.6
75	55	92.0	94.1
100	75	92.0	94.5
125	90	92.2	94.5
150	110	92.8	95.0
200	150	93.3	95.0
250	187	93.5	95.0
300	224	93.5	95.4
400	300	93.8	95.4
500	373	94.0	95.8

Table 3 Average Efficiencies for Standard Efficiency Motors at Various Load Points

Efficiencies for 900 rpm, Standard Efficiency Motors								
Motor Size HP	Load Level In Percent							
	ODP				TEFC			
	100%	75%	50%	25%	100%	75%	50%	25%
10	87.2	87.6	86.3	78.3	86.8	87.6	86.8	77.3
15	87.8	88.8	88.2	79.6	87.5	88.7	88.1	79.1
20	88.2	89.2	88.0	81.8	89.2	89.9	89.2	82.6
25	88.6	89.2	88.0	83.0	89.7	90.3	89.1	78.6
30	89.9	90.7	90.2	84.5	89.6	90.5	86.5	84.1
40	91.0	91.8	91.7	86.2	90.5	91.4	85.5	85.0
50	90.8	91.9	91.1	87.1	90.2	91.0	90.2	84.9
75	91.7	92.4	92.1	86.5	91.6	91.8	91.0	87.0
100	92.2	92.2	91.8	85.8	92.4	92.5	92.0	83.6
125	92.9	92.3	91.7	86.9	93.0	93.1	92.1	87.9
150	93.3	93.1	92.6	89.5	93.0	93.4	92.5	NA
200	92.8	93.5	93.1	NA	93.7	94.1	93.4	NA
250	93.1	93.5	93.0	NA	91.7	94.8	94.5	NA
300	93.1	93.7	92.9	92.7	94.4	94.2	93.7	NA

Efficiencies for 1200 rpm, Standard Efficiency Motors								
Motor Size	Load Level In Percent							
	ODP				TEFC			
	100%	75%	50%	25%	100%	75%	50%	25%
10	87.3	86.9	85.7	78.5	87.1	87.7	86.4	80.3
15	87.4	87.5	86.8	80.8	88.2	88.1	87.3	80.7
20	88.5	89.2	88.8	84.1	89.1	89.7	89.4	82.8
25	89.4	89.7	89.3	85.0	89.8	90.5	89.8	83.5
30	89.2	90.1	89.8	87.6	90.1	91.3	90.7	84.6
40	90.1	90.4	90.0	85.8	90.3	90.1	89.3	85.3
50	90.7	91.2	90.0	86.9	91.6	92.0	91.5	86.7
75	92.0	92.5	92.3	88.6	91.9	91.6	91.0	87.2
100	92.3	92.7	92.2	87.4	92.8	92.7	91.9	86.5
125	92.6	92.9	92.8	87.9	93.0	93.0	92.6	88.7
150	93.1	93.3	92.9	89.7	93.3	93.8	93.4	91.1
200	94.1	94.6	93.5	91.5	94.0	94.3	93.6	NA
250	93.5	94.4	94.0	91.9	94.6	94.5	94.0	NA
300	93.8	94.4	94.3	92.9	94.7	94.8	94.0	NA

Table 3 (Cont.) Average Efficiencies for Standard Efficiency Motors at Various Load Points

Efficiencies for 1800 rpm, Standard Efficiency Motors								
Motor Size HP	Load Level In Percent							
	ODP				TEFC			
	100%	75%	50%	25%	100%	75%	50%	25%
10	86.3	86.8	85.9	80.0	87.0	88.4	87.7	80.0
15	88.0	89.0	88.5	82.6	88.2	89.3	88.4	80.7
20	88.6	89.2	88.9	83.3	89.6	90.8	90.0	83.4
25	89.5	90.6	90.0	86.6	90.0	90.9	90.3	83.4
30	89.7	91.0	90.9	87.3	90.6	91.6	91.0	85.6
40	90.1	90.0	89.0	86.3	90.7	90.5	89.2	84.2
50	90.4	90.8	90.3	88.1	91.6	91.8	91.1	86.3
75	91.7	92.4	92.0	87.7	92.2	92.5	91.3	87.1
100	92.2	92.8	92.3	89.2	92.3	92.1	91.4	85.5
125	92.8	93.2	92.7	90.7	92.6	92.3	91.3	84.0
150	93.3	93.3	93.0	89.2	93.3	93.1	92.2	86.7
200	93.4	93.8	93.3	90.7	94.2	94.0	93.1	87.8
250	93.9	94.4	94.0	92.6	93.8	94.2	93.5	89.4
300	94.0	94.5	94.2	93.4	94.5	94.4	93.3	89.9

Efficiencies for 3600 rpm, Standard Efficiency Motors								
Motor Size	Load Level In Percent							
	ODP				TEFC			
	100%	75%	50%	25%	100%	75%	50%	25%
10	86.3	87.7	86.4	79.2	86.1	87.2	85.7	77.8
15	87.9	88.0	87.3	82.8	86.8	87.8	85.9	79.5
20	89.1	89.5	88.7	85.2	87.8	89.6	88.3	79.7
25	89.0	89.9	89.1	84.4	88.6	89.6	87.9	79.3
30	89.2	89.3	88.3	84.8	89.2	90.0	88.7	81.0
40	90.0	90.4	89.9	86.9	89.0	88.4	86.8	79.7
50	90.1	90.3	88.7	85.8	89.3	89.2	87.3	82.0
75	90.7	91.0	90.1	85.7	91.2	90.5	88.7	82.5
100	91.9	92.1	91.5	89.0	91.2	90.4	89.3	83.8
125	91.6	91.8	91.1	88.8	91.7	90.8	89.2	82.6
150	92.0	92.3	92.0	89.2	92.3	91.7	90.1	85.6
200	93.0	93.0	92.1	87.9	92.8	92.2	90.5	84.9
250	92.7	93.1	92.4	87.1	92.7	92.5	91.2	90.3
300	93.9	94.3	93.8	90.4	93.2	92.8	91.1	89.9

Table 4 VSD Efficiency (in percent) as a function of Percentage of Full Operating Speed and corresponding Percentage of Power

VSD Rating HP(kW)	Percent of Full Operating Speed			
	25%	50%	75%	100%
	Percent of Power / Torque			
	1.6%	12.5%	42%	100%
1(0.75)	9.4%	44.2%	70.5%	82.5%
5(3.7)	29.6%	74.7%	83.3%	92.4%
10(7.5)	35.3%	79.0%	90.3%	93.5%
25(18.5)	35.6%	79.4%	90.6%	93.8%
50(37)	43.3%	83.5%	92.1%	94.4%
100(75)	54.8%	89.1%	95.0%	96.6%
200(150)	61.2%	91.3%	96.1%	97.3%