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Optimization of Operational Method to improve sustainable Energy Efficiency of Auxiliaries in a CFBC coal fired Boiler- Result Analysis

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ABSTRACT

The research paper provides details of the sultry dihydrogen monoxide heating system for power consumption such as aliment pump, victual pump motor, control valves etc; withal, details cognate to the test of the subsisting system power utilizing the 3-element mode method to control the drum level. Includes details about the sundry energy test equipment used during the potency test to quantify the sundry parameters such as flow, head, power haste, temperature and vibration. This study was conducted with the avail of 2 boiler and turbine engineers and 3 operators where there is an inch switch. During the study of the parameter sundry parameters were accumulated and designations were accumulated and the calculation was predicated on brake vigor and pressure disunion. In order to calculate it is consequential that one situation is sometimes engendered under the circumstances of each task. In cases of full volume, the drum pressure is customarily kg/cm^2 above the maximum pressure. This denotes that when the total smoke load maximum pressure is ninety kg/cm^2, then the corresponding drum pressure will be 100 kg/cm^2. Ergo, while competitive calculations always engender the assurance that the pressure to aliment the victual in an economic rest area or aliment supply center is much more preponderant than the high pressure of the boiler drum suppleness for harmless operation.

Keywords: Boiler Feed pump, Energy efficiency, Auto Scoop, Boiler auxiliary, Differential pressure, Drum level control

I. INTRODUCTION

The research paper provides details of the sultry dihydrogen monoxide heating system for power consumption such as aliment pump, victual pump motor, control valves etc; withal, details cognate to the test of the subsisting system power utilizing the 3-element mode method to control the drum level. Includes details about the sundry energy test equipment used during the potency test to quantify the sundry parameters such as flow, head, power haste, temperature and vibration. This study was conducted with the avail of 2 boiler and turbine engineers and 3 operators where there is an inch switch. During the study of the parameter sundry parameters were accumulated and designations were accumulated and the calculation was predicated on brake vigor and pressure disunion. In order to calculate it is consequential that one situation is sometimes engendered under the circumstances of each task. In cases of full volume, the drum pressure is customarily kg/cm² above the maximum pressure. This denotes that when the total smoke load maximum pressure is ninety kg/cm², then the corresponding drum pressure will be 100 kg/cm². Ergo, while competitive calculations always engender the assurance that the pressure to aliment the victual in an economic rest area or aliment supply center is much more preponderant than the high pressure of the boiler drum suppleness for harmless operation.

Energy preserving on this nonessential BFP performance of high loads is another option adopted. This approach utilized the advantages of BFP speed control utilizing the subsisting scoop control system. In the incipient BFP scoop control manual it is set to the default mode that would maintain the Differential pressure throughout the FRS as a set point while the FRS control valve will maintain that drum level as required for the 3rd phase control (50%) control. There are no adscititious costs or tangible assets as all arrangements are in place and provided in the subsisting system. It is withal recommended to lock the control valves at the FRS station to operate between 0% (min) - 75% (max) open position to ascertain that the sensitivity of the control valves is maintained. The only change required was the rectification of the BFP scoop signs. Since this method uses subsisting equipment, no adscititious funding is required. Withal, because all the indispensable requisites were in place in time from a divergent perspective on the authentic implementation of the project was inhibited. This betokened paramount savings of perpetual working hours.

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II. ENERGY AUDIT INSTRUMENTS

The instruments used in the feedwater system for the purpose of measurements are,

TABLE I

INSTRUMENTS OF MEASUREMENTS

Parameter	Instrument	Accuracy
Flow	Magnetic Flow Meter	± 1 %
Head	Bourdon Tube Pressure Gauge and	± 0.5 %
Power	3-phase watt transducer in	± 0.5 %
Speed	Electronic Revolution Centre	± 0.1 %
Temperature	Resistance temperature	± 1°C
Vibration	Spectrum analyzer with accelerometer	± 5 %

The flow transmitter and the flow element are provided at the cessation of the Boiler supply pump. While the flow element maintains the required permeate the victual line the flow conductor measures the flow of the victual line. Two transmitters are provided in the dihydrogen monoxide supply system. One transfer is near the cessation of the boiler victual pump discharge i.e., afore the aliment supply station and other transfers are provided abaft the aliment control station near the economic inclusion. These transmitters transmit pressure readings to the control systems distributed in the control room and avail in perpetual monitoring away from the field. Similarly, a pressure gauge is provided at the terminus of the Boiler pump for pressure monitoring. A component of the heat and temperature of the gauge is provided at the terminus of the pump cooling outlet of the boot to quantify the temperature of the engenderer source. In integration to the above implements, the same arrangement of the three flow valves is withal provided in the victual line connecting the victual control channel. The main purport of the aliment control station is to maintain the pressure required for the victual dihydrogen monoxide to be relinquished against the pressure of the drum. A detailed procedure and diagram for the installation of the dihydrogen monoxide supply system is provided in the appendices.

TABLE II
ENERGY CONSUMPTION AND ENERGY GENERATION OF SINGLE UNIT PER DAY

Sr. No	**Parameters**	**UOM**	**Design Value**	**Operating Value**
1	Generation	MWH	1476.00	1444.00
2	Net Power Export	MWH	1321.02	1251.62
3	Net Power Import	MWH	-	0.00
4	Load on Station Transformer	MWH	-	101.69
5	Auxiliary Consumption	MWH	-	82.59
6	UAT	MWH	-	81.40
7	Total Unit Auxiliary Consumption	MWH	154.98	163.99
8	Total Unit Auxiliary Consumption	%	10.50	11.36
9	Running Hours of Generator	Hrs	24.00	24.00
10	Average Load (Running Hrs. Basis)	MW	61.50	60.17
11	Plant Load Factor	%	100	97.83
12	Plant Availability Factor	%	100	100
13	Total Steam at Boiler Outlet	TPD	5760.12	5627.31
14	Steam Inlet to Turbine	TPD	5712.12	5442.38
15	Steam Consumption per KWH	Kg / KWH	3.87	3.77
16	Turbine Heat Rate	Kcal /KWH	2218	2231.84
17	Station Heat Rate	Kcal /KWH	2650	2688.96
18	Running Hours Boiler	Hrs	24.00	24.00
19	Raw Water Consumption	Cu. M	20599.00	5924.00
20	DM Water Consumption	Cu. M	< 180	60.00
21	Coal Consumption	MT	1220.00	1153.69
22	G.C.V of feed coal	Kcal / Kg	3432.00	3711.00
23	Specific Coal Consumption	Kg / KWH	0.83	0.80

TABLE III

TECHNICAL SPECIFICATION OF EQUIPMENTS OF FEED WATER SYSTEM

Details	**Technical Specifications**	
Boiler Feed Pump	No of stages	14
	Liquid handled	Boiler feed water
	Diff. Head/ ham	1505 m
	NPSH r	7.2 m
	Speed	2905 rpm (+ 5% slippage)
	Efficiency	81%
	Power	1142 kw
	Suction temp.	158.1 °C
	Suction pressure	6.0 kg/cm^2
	Discharge pressure	142 kg/cm^2
	Discharge temp.	160.1 ^{0}C
	Discharge flow	300 m^3/hr
Boiler Feed Pump Motor	Type	Squirrel cage motor
	Rated voltage	6600v
	Frequency	50 hz.
	Connection	Star
	Phase	3
	Speed	2985 rpm
	Power factor	0.88
	Current	166 amps
	Efficiency	96.1%
	Rated power output	1600 kw

TABLE IV

ENERGY AUDIT OF BOILER FEED PUMP IN 3- ELEMENT METHOD

PERFORMANCE TEST RECORD (3 – Element Method)			
Equipment	Boiler	Date	11/08/2020
Model No	MD 100-	Serial No	386620
Suction/Discharge NB (mm)	400 / 125	Impeller	297
Driver KW	1600	RPM	2905
STANDARD OPERATING PARAMETERS			
Liquid Duty		**Liquid Data**	
Flow (m^3 / hr)	300	Specific Gravity	0.909
TDH (mwc)	1505	Temperature (°C)	158.1
Pump Input (KW)	1442	Viscosity	0.15 P
Efficiency (%)	81	Ke: 1	Kh: 1 Kq: 1
NPSH r (mwc): 7.20 H atm (mwc) : 10.2 Shut Off Head (mwc) : 1884			

Speed		RPM	2734	2708	2726	2726	2772.51
Flow		m^3/hr	0.00	80.10	161.00	242.70	281
Suction	Gaug	Bar	5.8	5.8	5.8	5.8	5.8
	Corr	M	0.70	0.70	0.70	0.70	0.70
	Hs	mwc	59.86	59.86	59.86	59.86	59.86
Disch.	Gaug	Bar	164.30	161.00	153.70	141.00	137.61
	Corr	M	0.70	0.70	0.70	0.70	0.70
	Hd	mwc	1676.5	1642.90	1568.44	1438.9	1404.32
TDH		mwc	1616.6	1583.02	1508.56	1379.02	1344.44
Voltage		volts	6600	6600	6600	6600	6600
Current		Amps	69.60	99.20	115.63	131.20	137.18
Wattmeter		KW	8.75	12.47	14.54	16.49	17.24
Multi factor			80	80	80	80	80
Motor Input		KW	700.15	997.92	1163.20	1319.83	1379.95
Motor Efficiency		%	95.23	95.36	95.57	96.01	96.34
Pump Output		KW	0.00	345.50	661.79	911.95	1029.39
Pump Efficiency		%	0.00	25.53	63.43	79.88	80.85
Performance Corrected to Rated Speed: 2905 RPM							
Flow		m^3/hr	0.00	85.92	171.57	258.63	294.42
TDH		mwc	1825.23	1821.71	1713.18	1566.06	1476.00
Pump Input		KW	0.00	980.13	1098.51	1222.67	1269.89
Efficiency		%	0.00	25.53	63.43	79.88	80.85
Ambient Temperature: 30.23 ^{0}C Bearing Temperature: D.E – 43.00 ^{0}C N.D.E – 55.00 ^{0}C Noise level including surrounding Noise: 93 dBa at 1m							

			V	H	A
Velocity (mm/sec)	D.E	DP	1.87	1.80	1.01
		MF	1.43	2.36	0.85
	N.D.E	DP	0.68	2.20	0.92
		MF	0.99	2.33	1.19

III. ENERGY AUDIT OF BOILER FEED PUMP BY DP AUTO SCOOP METHOD

TABLE V

PERFORMANCE TEST RECORD OF SYSTEM IN DP AUTO SCOOP MODE

PERFORMANCE TEST RECORD (DP Method with Scoop in AUTO Mode)			
Equipment	Boiler Feed	Date	15/06/2021
Model No	MD 100-300 /	Serial No	386620
Suction/Discharge NB (mm)	400 / 125	Impeller Diameter	297
Driver KW	1600	RPM	2905
STANDARD OPERATING PARAMETERS			
Liquid Duty		**Liquid Data**	
Flow (m^3 / hr)	300	Specific Gravity	0.909
TDH (mwc)	1505	Temperature (^0C)	158.1
Pump Input (KW)	1442	Viscosity	0.15 P
Efficiency (%)	81	Ke : 1 Kh : 1	Kq : 1
$NPSH_r$ (mwc) : 7.20	H atm (mwc) : 10.2	Shut Off Head (mwc) : 1884	

Speed		RPM	2653	2657	2655	2650	2660
Flow		m^3/hr	277	280	281	270	285
Suctio	Gauge	Bar	5.8	5.8	5.8	5.8	5.8
	Correction	M	0.70	0.70	0.70	0.70	0.70
	Hs	mwc	59.86	59.86	59.86	59.86	59.86
Disch.	Gauge	Bar	125.35	122.63	117.67	120.31	118.16
	Correction	M	0.70	0.70	0.70	0.70	0.70
	Hd	mwc	1279.27	1251.52	1201.02	1227.86	1205.93
TDH		mwc	1219.39	1191.64	1141.14	1167.98	1146.05
Voltage		volts	6600	6600	6600	6600	6600
Current		Amps	105.38	110.10	108.52	103.98	115.71
Wattmeter		KW	13.25	13.84	13.64	13.07	14.55
Multi factor			80	80	80	80	80
Motor Input		KW	1060.09	1107.57	1091.68	1046.01	1164.01
Motor Efficiency		%	96.40	96.50	96.50	96.40	96.60
Pump Output		KW	920.35	909.15	873.73	859.27	889.98
Pump Efficiency		%	86.25	86.40	86.75	86.80	86.55
Performance Corrected to Rated Speed : 2905 RPM							
Flow		m^3/hr	303.31	306.13	307.45	295.98	311.25
TDH		mwc	1462.04	1424.47	1366.16	1403.57	1366.88
Pump Input		KW	1067.07	1052.25	1007.18	989.94	921.30
Efficiency		%	86.25	86.40	86.75	86.80	86.55
Ambient Temperature : 31.50 ^0C			Bearing Temperature : D.E – 46.00 ^0C			N.D.E –	

NOTE :

From the above readings, the feed water flow in the DP method (scoop in AUTO mode) that matches the feed water flow from the readings obtained in the 3-element method is used for computation and analysis. Hence, the readings corresponding to the flow of 281 m^3/hr is used in the calculations and extrapolations.

IV. CALCULATION FOR EXISTING SYSTEM

Rated Speed, N= 2905 RPM
Test Speed, N1 = 2772.51 RPM
Rated Flow = 300 m3/hr
Test Flow, Q = 281 m3/hr
Operating Temperature To= 158.1 0C
Suction NB, Ds= 400 mm
Discharge NB, Dd = 250 mm
Elevation difference between suction gauge and pump centre, HS= 0.7 m
Elevation difference between Discharge gauge and pump centre, HD = 0.7 m
Atmospheric Pressure, Ha = 10.2 mwc
Vapour Pressure, Hv = 59.62 mwc
Density of water at operating temperature = 0.9093 kg/m^2

A) Suction Head, Hs = Ps x 10.2 ± HS
= 5.8 x 10.2 + 0.7
Hs = 59.86 mwc

B) Discharge Head, Hd = Pd x 10.2 ± HD
= 137.61 x 10.2 + 0.7
Hd = 1404.32 mwc

C) Suction Velocity Head,

$K1 = 6.382 \times 10^{-9} \times \{1 / (Ds)^4\} \times Q^2$
$= 6.382 \times 10^{-9} \times \{1 / (0.4)^4\} \times (281)^2$
K1 = 0.01968 mwc

D) Net Velocity Head,
$K = 6.382 \times 10^{-9} \times [\{1/ (Dd)4\} - \{1 / (Ds)^4\}] \times Q2$
$= 6.382 \times 10^{-9} \times [\{1/(0.25)4 -\{1 / (0.4)^4\}] \times (281)^2$
K = 0.109 mwc

E) Total Differential Head,
TDH = Hd – Hs + K
= 1404.32 – 59.86 + 0.109
TDH = 1344.56 mwc

F) NPSH a = Ha + Hs + K1 – Hv
= 10.2 + 59.86 + 0.01968 – 59.62
NPSH a = 10.45 mwc

G) Power Output of Pump,
Pout = Q x TDH / 367
=281x 1344.56/ 367
Pout = 1029.49 KW

H) Power Input to motor,
Pm = Wattmeter X Multi factor
= 17.24 x 80
Pm = 1379.95 KW

I) Brake Kilowatt,
$bKw = Pm \times \eta m \times \eta c$
= 1379.95 x 0.9610 x 0.96
bKw = 1273.09 KW

J) $bKw\ Hot = bKw \times \rho / \eta\ Hot$
= 1273.09 x 0.9093 / 0.80
bKw Hot = 1447.02 KW

K) Efficiency of Pump,
$\eta_p = (Pout / bKw) \times 100$
= (1029.49 / 1273.09) x 100
$\eta_p = 80.86\ \%$

Correction to Rated speed

I. Flow, Q rated = (N / N1) x Q
= (2905 / 2772.51) x 281
Q rated = 294.42 m3 / hr

II. Total Differential Head,
$TDH\ rated = (N / N1)^2 \times TDH$
$= (2905 / 2772.51)^2 \times 1344.44$
TDH rated = 1476.00 mwc

III. $NPSH\ a\ rated = (N / N1)^2 \times NPSH$

= $(2905 / 2772.51)^2$ x 10.45

NPSH a rated = 11.47 mwc

IV. bKw rated = $(N / N1)^3$ x bKw

= $(2905 / 2772.51)^3$ x 1447.02

bKw rated = 1664.53 KW

V. CALCULATION FOR PROPOSED SYSTEM

Rated Speed, N= 2905 RPM

Test Speed, N1 = 2772.51 RPM

Rated Flow = 300 m3 / hr

Test Flow, Q = 281 m3 / hr

Operating Temperature To= 158.1 0C

Suction NB, Ds= 400 mm

Discharge NB, Dd = 250 mm

Elevation difference between suction gauge and pump centre, HS= 0.7 m

Elevation difference between Discharge gauge and pump centre, HD = 0.7 m

Atmospheric Pressure, Ha = 10.2 mwc

Vapour Pressure, Hv = 59.62 mwc

Density of water at operating temperature= $0.9093 kg/m^2$

A) Suction Head, Hs = Ps x 10.2 ± HS

= 5.8 x 10.2 + 0.7

Hs = 59.86 mwc

B) Discharge Head, Hd = Pd x 10.2 ± HD

= 117.67 x 10.2 + 0.7

Hd = 1201.02 mwc

C) Suction Velocity Head,

K1 = 6.382 x 10 -9 x $\{1 / (Ds)^4\}$ x Q^2

= 6.382 x 10 -9 x $\{1 / (0.4)^4\}$ x $(281)^2$

K1 = 0.01968 mwc

D) Net Velocity Head,

K = 6.382 x 10 -9 x$[\{ /(Dd)^4 \} - \{1/(Ds)^4 \}]$ x Q^2

= 6.382 x 10-9 x $[\{1/(0.25)^4\} -\{1/(0.4)^4\}]$ x $(281)^2$

K = 0.109 mwc

E) Total Differential Head,

TDH = Hd – Hs + K

= 1201.02 – 59.86 + (- 0.019)

TDH = 1141.141 mwc

F) NPSH a = Ha + Hs + K1 – Hv

= 10.2 + 59.86 + 0.01968 – 59.62

NPSH a = 10.45 mwc

G) Power Output of Pump,

Pout = Q x TDH / 367

= 281 x 1141.141 / 367

Pout = 873.73 KW

H) Pump Input to motor,

Pm = Wattmeter X Multi factor

= 14.55 x 80

Pm = 1091.68 KW

I) Brake Kilowatt,

bKw = Pm x ηm x ηc

= 1091.68 x 0.9610 x 0.96

bKw = 1007.14 KW

J) bKw Hot = bKw x ρ / η Hot

= 1007.14 x 0.9093 / 0.80

bKw Hot = 1144.74 KW

K) Efficiency of Pump,

η_p = (Pout / bKw) x 100

= (873.73 / 1007.14) x 100

η_p = 86.75 %

The above calculations are made at operating conditions and hence need to be extrapolated to rated conditions to determine the exact effect of the modification on the system operation. The corrections to rated conditions are calculated below.

Correction to Rated Speed:

I. Flow, Q rated = (N / N1) x Q
= (2905 / 2655) x 281
Q rated = 307.45 m3 / hr

II. Total Differential Head,
TDH rated = (N / N1) 2 x TDH
= (2905 / 2655)2 x 1141.141
TDH rated = 1366.16 mwc

III. NPSH a rated = $(N / N1)^2$ x NPSH
= $(2905 / 2655)^2$ x 10.45
NPSH a rated = 12.51 mwc

IV. bKw rated = (N / N1) 3 x bKw
= (2905 / 2655)3 x 1007.14
bKw rated = 1319 KW

VI. CALCULATION FOR ENERGY SAVINGS

BFP rating: 6600 Volts, 1600KW
Power Factor: 0.88

Reduction in BFP current: 28.66 Amps
Cost of 1KWH unit: Rs4.35 (inclusive of coal cost, water cost and auxiliary consumption cost)
Savings = √3 VI Cos Ø

= 1.732 x 6600 x 28.66 x 0.90 x 24/1000 KWH /day
= 7076.56 KWH/day (in terms of units per day)
= 7076.56 x365 x 6.35 x 4 (in terms of Rupees/annum)
= Rs. 6, 65, 06, 787.76 per year (For 4 Units)
= Rs. 1, 64, 01, 696.94 per year (Per running unit)

VII. RESULT ANALYSIS

TABLE VI
COMPARATIVE OF POWER CONSUMPTION OF EXISTING AND PROPOSED SYSTEM

Power Consumption of Existing System		
Feed Water eco inlet pressure (after Feed control station)	Kg/cm^2	108.50
Feed Water pressure before Feed control station	Kg/cm^2	137.61
Scoop % (Command)	%	67
Scoop % (Actual)	%	73.25
Control Valve opening position	%	53
Differential Pressure across Feed Control Station	Kg/cm^2	29.12
Boiler Feed Pump Speed	Rpm	2772.51
BFP Current	AMP	137.18
BFP Power Consumption (Per day)	**KWH**	**33871.65**
Power Consumption of Proposed System (Based on Theoretical Calculations, Motor and Pump Efficiency Curves)		
Feed Water eco inlet pressure (after Feed control station)	Kg/cm^2	108.50
Feed Water pressure before Feed control station	Kg/cm^2	117.67
Scoop % (Command)	%	70
Scoop % (Actual)	%	70
Control valve opening position	%	73
DP Set point for BFP scoop control	Kg/cm^2	10
Differential Pressure across Feed Control Station	Kg/cm^2	10
Boiler Feed Pump Speed	Rpm	2655
BFP Current	AMP	108.52
BFP Power Consumption (Per day)	**KWH**	**26795.09**

For the calculations it is imperative that one condition is always fulfilled under every operating load conditions. The feed water discharge pressure at the economiser inlet is always greater than the boiler drum pressure. If this condition is reversed then it might lead to tube ruptures of the economiser due to overheating. At full load conditions the drum pressure is always 10 kg/cm^2 above the main steam pressure i.e. at full load condition the maximum allowable main steam pressure is 90 kg/cm^2, therefore the corresponding drum pressure will be 100 kg/cm^2. Hence, while considering the calculations it is always made sure that the feed water discharge pressure at the economiser inlet or the feed regulation station outlet is above the maximum pressure range of the boiler drum for safe operation. The rest of the calculations are completely dependent on only the power requirement and consumption of the boiler feed pump corresponding to the discharge pressure. The power consumption and the discharge pressure are in direct proportion i.e., an increase in discharge pressure increases the power consumed and a decrease in discharge pressure decreases the power consumed. The calculations are provided below.

VIII. ACTUAL NET SAVINGS FROM NEW SYSTEM

Since, all the instruments and equipments for controlling and monitoring the experimentation are already installed in the system, no extra cost of purchasing and installation is required. Therefore, the payback is immediate. Also, the success of the experiment provides both tangible and intangible benefits. It is very robust control and can be used during varying loads without any major drum level fluctuation. With decreased DP across FRS life of control valve also increases. Life of a bearing is inversely proportional of the seventh power of its speed hence as the speed of BFP decreases its bearing life also increases.

TABLE VII
ACTUAL NET SAVINGS FROM NEW SYSTEM

Actual Net Energy Savings:		
Cost Benefits		
BFP Current	=	108.52 amps
BFP Power Consumption (Per		26795.09
Annual Energy Saving Potential	=	33871.65 – 26795.09
	=	7076.56 KWH/day
Annual Cost Saving	=	7076.56 x 365 x 4.35 x
	=	Rs. 44943232.56 per year (For 4 Units)
Investment	=	Nil
Simple Payback	=	Immediate

IX. CONCLUSION

In the calculation it is paramount that one condition is continually slaked under all working situations. The pressure of the dihydrogen monoxide supply in the feeder installation area remains higher than the pressure of the boiler tank. If this situation is inverted it could lead to economic collapse due to overheating. In cases of total load, the pressure of the drum remains at 10 kg/cm^2 above the maximum pressure of the smoke i.e., in the full case the maximum allowable load is 90 kg/cm^2, so the corresponding drum pressure will be 100 kg/cm^2. Ergo, when considering the calculation, it is always ascertained that the pressure of the victual discharge from the economic centre or supply law station is more preponderant than the width of the boiler drum pressure so that it can operate safely.

Therefore, from the calculations for the proposed modification in system it is clear that the

- NSHP a for the proposed system is greater than the NSHP a for the existing system and will always be greater than NPSH r under operating conditions.
- The changes in Flow and Head are small compared to the previous system.

- The efficiency of the pump increases by 5.9 % compared to the previous system.
- The power input to the motor decreases by 288.27 KW compared to the previous system
- The efficiency of the motor more or less remains the same with respect to Power factor as a component of load and speed.

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