

Energy Audits / Energy Saving Opportunities

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Energy Management

- *“The judicious and effective use of energy to maximize profits (minimize costs) and enhance competitive positions.”*
 - To minimise energy costs / waste without affecting production & quality
 - To minimise environmental effects.
-
- HOW MUCH?
 - WHERE?
 - HOW?

Energy Cost Reduction

- Energy cost is the most controllable variable
- Rising fast
- Easier to reduce than
 - Material
 - Labour
 - Interest
 - Depreciation

Indian Scenario

■ Good Practices

- Most of the latest commercial and industrial complexes are equipped with latest technology equipments.
- Energy Efficient systems have been installed in most of the new establishments.

■ Room for Improvement

- Not much attention is being paid to fine tune the installed systems for efficient operation based on requirement.
- No monitoring and management of energy consumption.

Way to achieve energy efficiency

■ Identification

- Monitor, study and Identify potential areas with measured data and analysis
- Evaluate Energy cost reduction and investments

■ Implementation

- Implement with detail engineering of measures
- Performance testing

■ Measurement and Verification

- Measure and Verify potential savings
- Look for further optimization opportunities

Energy Conservation Opportunities

- Electrical System (Transformers, PF, Capacitors)
- Electric Motors
- Pumps, Fans and Blowers
- Compressed Air system
- Boilers / Hot water generator / Thermic Fluid Heater
- Air Conditioning System
- Lighting system

Electrical system

■ Scope

- Distribution, Voltage level and Cable losses
- Transformer loading pattern and losses
- Demand management
- Power factor control (capacitors performance)

■ Measurements

- Electrical parameters (V, I, PF, Hz, kW, kVA, kWh) will be measured and logged as per requirement
- Capacitors current

Capacitor Selection Chart

TABLE 1: MULTIPLIERS TO DETERMINE CAPACITOR KVAR REQUIRED FOR POWER FACTOR CORRECTION

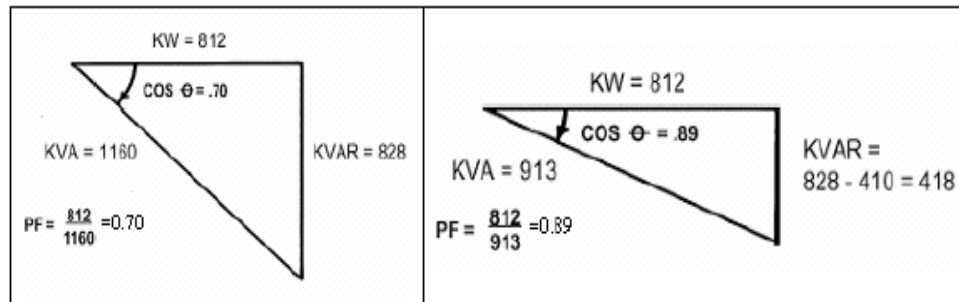
Original Power Factor	Desired Power Factor																				
	0.80	0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.88	0.89	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99	1.0
0.50	0.982	1.008	1.034	1.060	1.086	1.112	1.139	1.165	1.192	1.220	1.248	1.276	1.306	1.337	1.369	1.403	1.440	1.481	1.529	1.589	1.732
0.51	0.937	0.962	0.989	1.015	1.041	1.067	1.094	1.120	1.147	1.175	1.203	1.231	1.261	1.292	1.324	1.358	1.395	1.436	1.484	1.544	1.687
0.52	0.893	0.919	0.945	0.971	0.997	1.023	1.050	1.076	1.103	1.131	1.159	1.187	1.217	1.248	1.280	1.314	1.351	1.392	1.440	1.500	1.643
0.53	0.850	0.876	0.902	0.928	0.954	0.980	1.007	1.033	1.060	1.088	1.116	1.144	1.174	1.205	1.237	1.271	1.308	1.349	1.397	1.457	1.600
0.54	0.809	0.835	0.861	0.887	0.913	0.939	0.965	0.992	1.019	1.047	1.075	1.103	1.133	1.164	1.196	1.230	1.267	1.308	1.356	1.416	1.559
0.55	0.769	0.795	0.821	0.847	0.873	0.899	0.926	0.952	0.979	1.007	1.035	1.063	1.093	1.124	1.156	1.190	1.227	1.268	1.316	1.376	1.519
0.56	0.730	0.756	0.782	0.808	0.834	0.860	0.887	0.913	0.940	0.968	0.996	1.024	1.054	1.085	1.117	1.151	1.188	1.229	1.277	1.337	1.480
0.57	0.692	0.718	0.744	0.770	0.796	0.822	0.849	0.875	0.902	0.930	0.958	0.986	1.016	1.047	1.079	1.113	1.150	1.191	1.239	1.299	1.442
0.58	0.655	0.681	0.707	0.733	0.759	0.785	0.812	0.838	0.865	0.893	0.921	0.949	0.979	1.010	1.042	1.076	1.113	1.154	1.202	1.262	1.405
0.59	0.619	0.645	0.671	0.697	0.723	0.749	0.775	0.802	0.829	0.857	0.885	0.913	0.943	0.974	1.006	1.040	1.077	1.118	1.166	1.226	1.369
0.60	0.583	0.609	0.635	0.661	0.687	0.713	0.740	0.766	0.793	0.821	0.849	0.877	0.907	0.938	0.970	1.004	1.041	1.082	1.130	1.190	1.333
0.61	0.549	0.575	0.601	0.627	0.653	0.679	0.706	0.732	0.759	0.787	0.815	0.843	0.873	0.904	0.936	0.970	1.007	1.048	1.096	1.156	1.299
0.62	0.516	0.542	0.568	0.594	0.620	0.646	0.673	0.699	0.726	0.754	0.782	0.810	0.840	0.871	0.903	0.937	0.974	1.015	1.063	1.123	1.266
0.63	0.483	0.509	0.535	0.561	0.587	0.613	0.640	0.666	0.693	0.721	0.749	0.777	0.807	0.838	0.870	0.904	0.941	0.982	1.030	1.090	1.233
0.64	0.451	0.474	0.503	0.529	0.555	0.581	0.608	0.634	0.661	0.689	0.717	0.745	0.775	0.806	0.838	0.872	0.909	0.950	0.998	1.068	1.201
0.65	0.419	0.445	0.471	0.497	0.523	0.549	0.575	0.602	0.629	0.657	0.685	0.713	0.743	0.774	0.806	0.840	0.877	0.918	0.966	1.026	1.169
0.66	0.388	0.414	0.440	0.466	0.492	0.518	0.545	0.571	0.598	0.626	0.654	0.682	0.712	0.743	0.775	0.809	0.846	0.887	0.935	0.995	1.138
0.67	0.358	0.384	0.410	0.436	0.462	0.488	0.515	0.541	0.568	0.596	0.624	0.652	0.682	0.713	0.745	0.779	0.816	0.857	0.905	0.965	1.108
0.68	0.328	0.354	0.380	0.406	0.432	0.458	0.485	0.511	0.538	0.566	0.594	0.622	0.652	0.683	0.715	0.749	0.786	0.827	0.875	0.935	1.078
0.69	0.299	0.325	0.351	0.377	0.403	0.429	0.456	0.482	0.509	0.537	0.565	0.593	0.623	0.654	0.686	0.720	0.757	0.798	0.845	0.906	1.049
0.70	0.270	0.296	0.322	0.348	0.374	0.400	0.427	0.453	0.480	0.508	0.536	0.564	0.594	0.625	0.657	0.691	0.728	0.769	0.817	0.877	1.020
0.71	0.242	0.268	0.294	0.320	0.346	0.372	0.399	0.425	0.452	0.480	0.508	0.536	0.566	0.597	0.629	0.663	0.700	0.741	0.789	0.849	992
0.72	0.214	0.240	0.266	0.292	0.318	0.344	0.371	0.397	0.424	0.452	0.480	0.508	0.538	0.569	0.601	0.635	0.672	0.713	0.761	0.821	964
0.73	0.186	0.212	0.238	0.264	0.290	0.316	0.343	0.369	0.396	0.424	0.452	0.480	0.510	0.541	0.573	0.607	0.644	0.685	0.733	0.793	936
0.74	0.159	0.185	0.211	0.237	0.263	0.289	0.316	0.342	0.369	0.397	0.425	0.453	0.483	0.514	0.546	0.580	0.617	0.658	0.706	0.766	909
0.75	0.132	0.158	0.184	0.210	0.236	0.262	0.289	0.315	0.342	0.370	0.398	0.426	0.456	0.487	0.519	0.553	0.590	0.631	0.679	0.739	882
0.76	0.105	0.131	0.157	0.183	0.209	0.235	0.262	0.288	0.315	0.343	0.371	0.399	0.429	0.460	0.492	0.526	0.563	0.604	0.652	0.712	855
0.77	0.079	0.105	0.131	0.157	0.183	0.209	0.236	0.262	0.289	0.317	0.345	0.373	0.403	0.434	0.466	0.500	0.537	0.578	0.626	0.685	829
0.78	0.052	0.078	0.104	0.130	0.156	0.182	0.209	0.235	0.262	0.290	0.318	0.346	0.376	0.407	0.439	0.473	0.510	0.551	0.599	0.659	802
0.79	0.026	0.052	0.078	0.104	0.130	0.156	0.183	0.209	0.236	0.264	0.292	0.320	0.350	0.381	0.413	0.447	0.484	0.525	0.573	0.633	776
0.80	0.000	0.026	0.052	0.078	0.104	0.130	0.157	0.183	0.210	0.238	0.266	0.294	0.324	0.355	0.387	0.421	0.458	0.499	0.547	0.609	750
0.81		0.000	0.026	0.052	0.078	0.104	0.131	0.157	0.184	0.212	0.240	0.268	0.298	0.329	0.361	0.395	0.432	0.473	0.521	0.581	724
0.82			0.000	0.026	0.052	0.078	0.105	0.131	0.158	0.186	0.214	0.242	0.272	0.303	0.335	0.369	0.406	0.447	0.495	0.555	698
0.83				0.000	0.026	0.052	0.079	0.105	0.132	0.160	0.188	0.216	0.246	0.277	0.309	0.343	0.380	0.421	0.469	0.529	672
0.84					0.000	0.026	0.053	0.079	0.106	0.134	0.162	0.190	0.220	0.251	0.283	0.317	0.354	0.395	0.443	0.503	646
0.85						0.000	0.027	0.053	0.080	0.108	0.136	0.164	0.194	0.225	0.257	0.291	0.328	0.369	0.417	0.477	620
0.86							0.000	0.026	0.053	0.081	0.109	0.137	0.167	0.198	0.230	0.264	0.301	0.342	0.390	0.450	593
0.87								0.000	0.027	0.055	0.083	0.111	0.141	0.172	0.204	0.238	0.275	0.316	0.364	0.424	567
0.88									0.000	0.028	0.056	0.084	0.114	0.145	0.177	0.211	0.248	0.289	0.337	0.397	540
0.89										0.000	0.028	0.056	0.086	0.117	0.149	0.183	0.220	0.261	0.309	0.369	512
0.90											0.000	0.028	0.056	0.089	0.121	0.155	0.192	0.233	0.281	0.341	484
0.91												0.000	0.030	0.061	0.093	0.127	0.164	0.205	0.253	0.313	456
0.92													0.000	0.031	0.063	0.097	0.134	0.175	0.223	0.283	426
0.93														0.000	0.032	0.066	0.103	0.144	0.192	0.252	396
0.94															0.000	0.034	0.071	0.112	0.160	0.220	363
0.95																0.000	0.037	0.079	0.126	0.186	329
0.96																	0.000	0.041	0.089	0.149	292
0.97																		0.000	0.048	0.108	251
0.98																			0.000	0.060	0.203
0.99																				0.000	0.143
																					0.000

Benefits of PF improvement

Reduced maximum demand charges (avail rebates from SEB).

Eg.: A chemical industry had installed a 1500kVA Transformer.

- The initial demand was 1160 kVA with a PF of 0.70. The % loading was around 77.8 %.
- To avoid penalty, the unit had added capacitors of 410kvar at the load end.
- This improved the PF to 0.89 and reduced the required kVA to 913 thereby avoiding penalty.



Electric Motors

- **Scope**

- Motor loading and Power Factor
- Control of motors

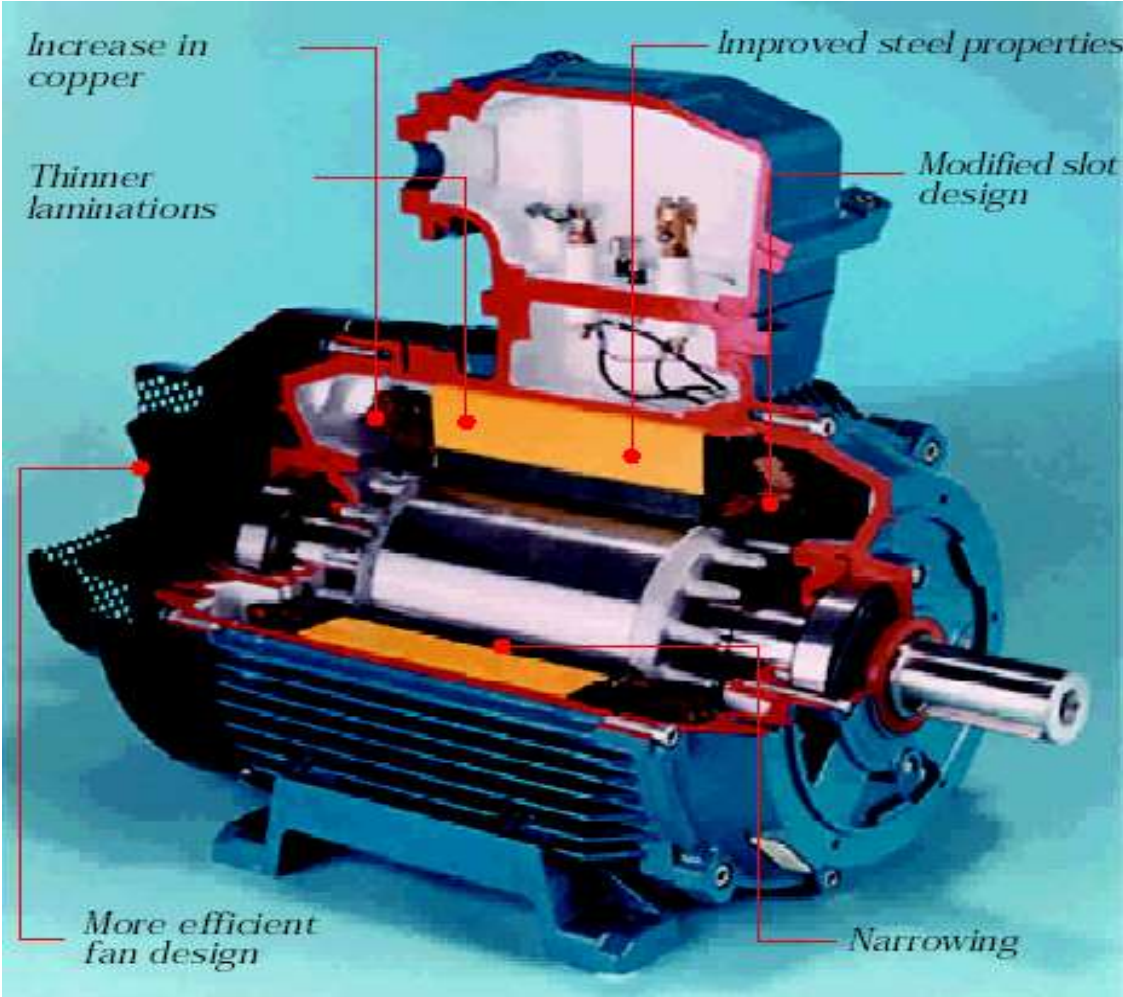
- **Measurements**

- Electrical parameters (V, I, Pf , Hz. , kW, kVA, kWh) will be measured and logged as per requirement
- Type of control of motors

Energy Efficient Motors (EEM)

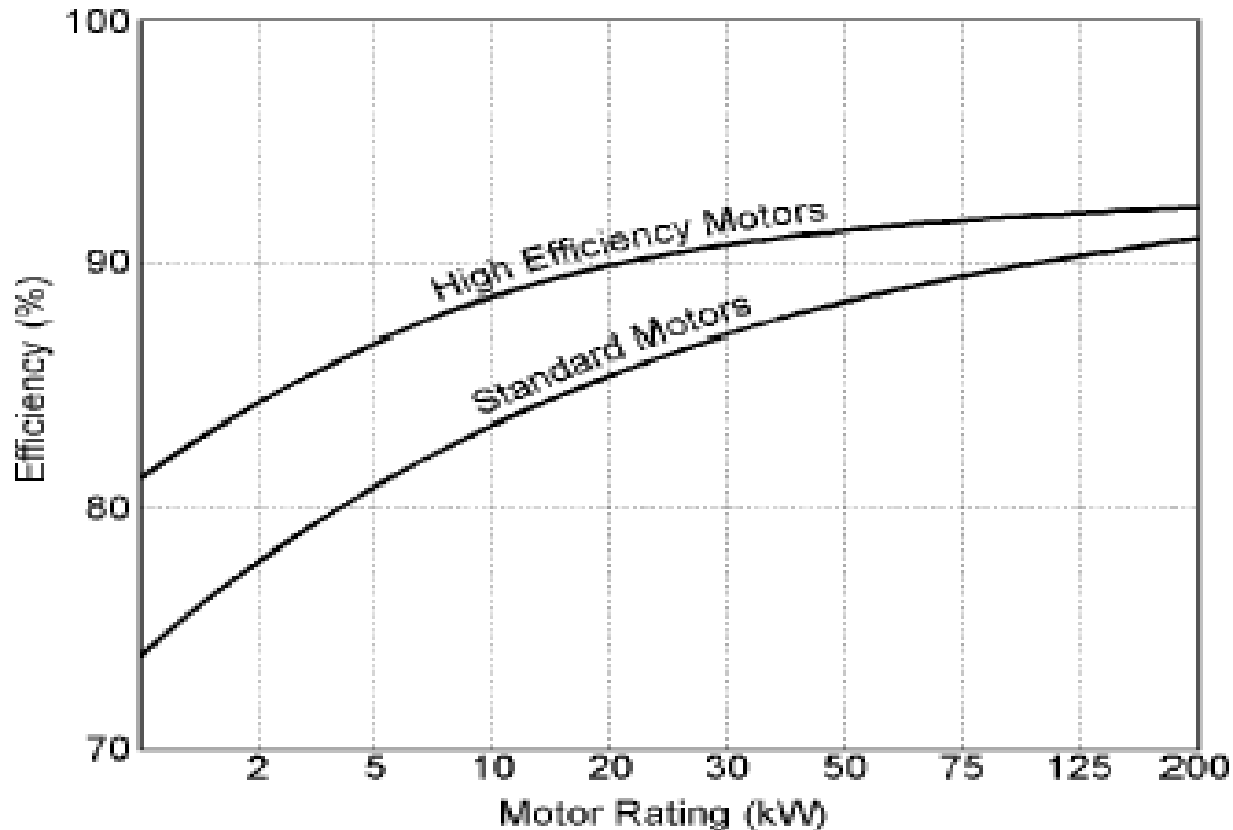
- Stator & rotor made of high grade silicon steel with a std. core loss of 3.3w/kg as against a conventional loss of 6.6w/kg.
- Thinner laminations & better insulation b/w laminations reduces eddy loss.
- 35-40% more conductor volume to reduce winding resistance.
- Modified slot design.
- Reduced air gap.
- Improved rotor insulation.
- Efficient means of cooling - better cooling.
- Efficient fan design - smaller fan, less windage loss & less noise.

Energy Efficient Motor



Standard vs High Efficiency Motors

**STANDARD vs HIGH EFFICIENCY MOTORS
(Typical 3-Phase Induction Motor)**



Cranes

- Cranes operation - Load transfer and Booming operation
- Regenerative type Cranes uses generated energy in the crane itself and extra energy generated is fed back to the substation.
- Specific Energy Consumption is the indicator

Pumps, Fans and Blowers

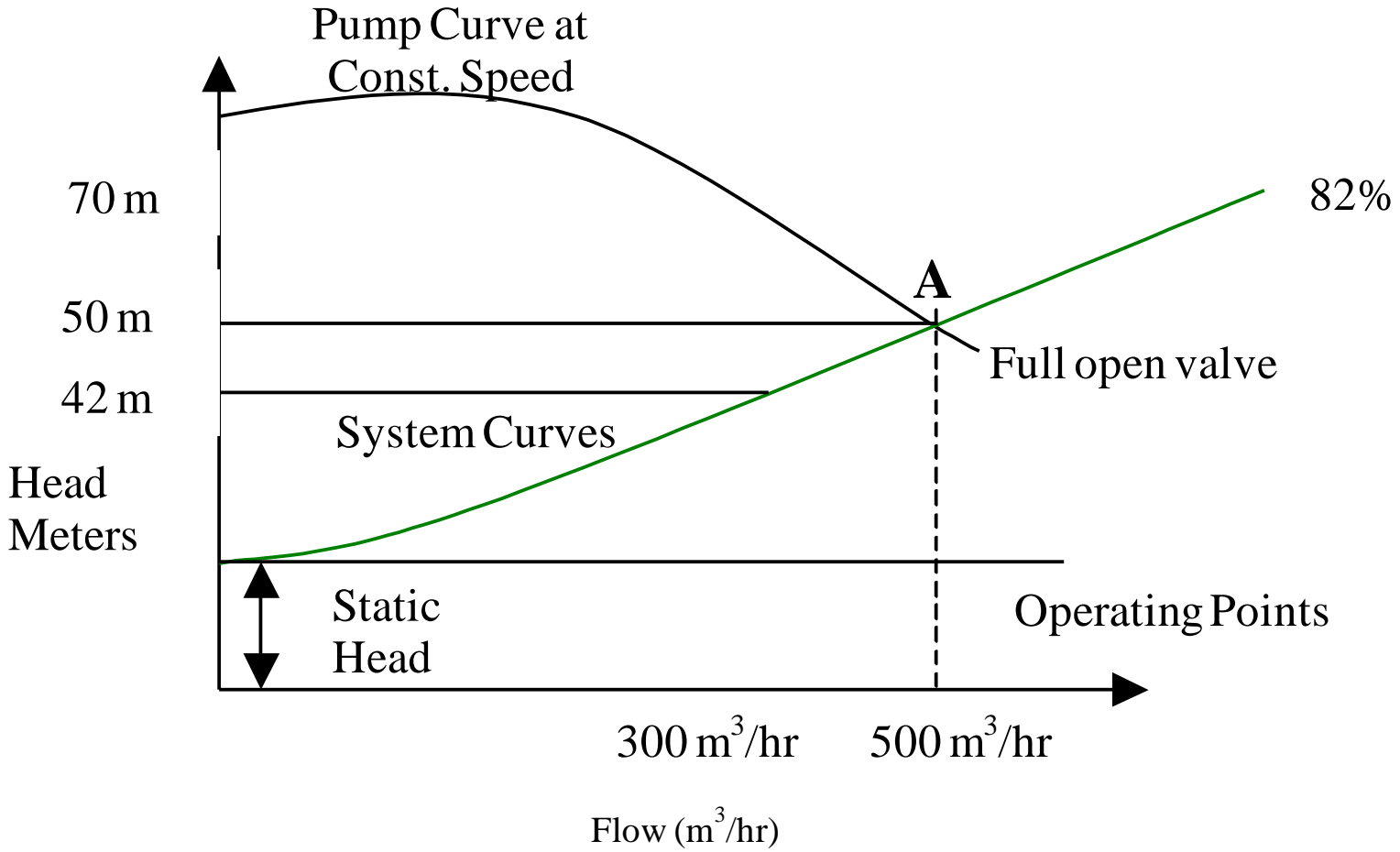
■ Scope

- Performance of the Pump, Fans (Efficiency)
- Analysis of Flow Control method of Pumps, Fans

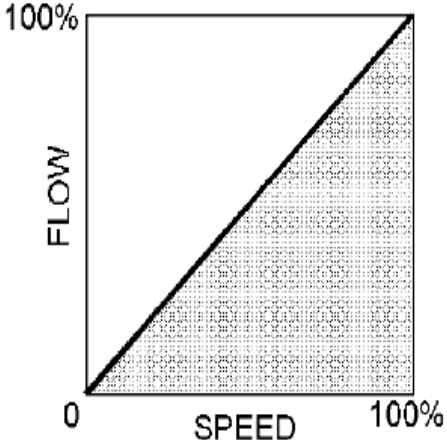
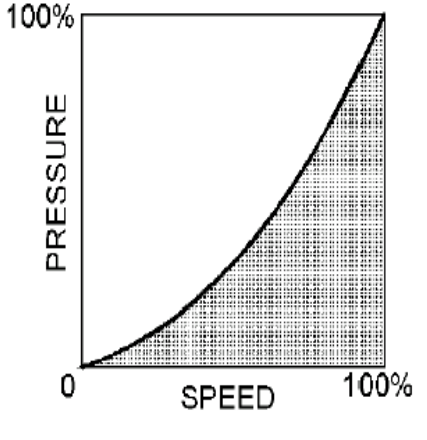
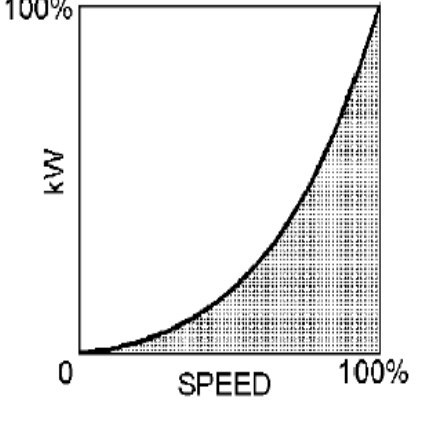
■ Measurements

- Electrical parameters (V, I, Pf , Hz. , kW, kVA, kWh) will be measured and logged as per requirement
- Flow, Head/pressure developed by Pumps, Fans

Pump Curve



Affinity Laws

Flow ? Speed	Pressure ? (Speed) ²	Power ? (Speed) ³
		
$\frac{Q_1}{Q_2} = \frac{N_1}{N_2}$	$\frac{SP_1}{SP_2} = \left(\frac{N_1}{N_2} \right)^2$	$\frac{kW_1}{kW_2} = \left(\frac{N_1}{N_2} \right)^3$
<p><i>Varying the RPM by 10% decreases or increases air delivery by 10%.</i></p>	<p><i>Varying the RPM by 10% decreases or increases the static pressure by 19%.</i></p>	<p><i>Varying the RPM by 10% decreases or increases the power requirement by 27%.</i></p>

Where Q – flow, SP – Static Pressure, kW – Power and N – speed (RPM)

Compressed Air system

■ Scope

- Free air delivery assessment
- Leakage survey
- Distribution study
- Study of Air dryer, receiver system and utilization points

■ Measurements

- Electrical parameters (V, I, Pf , Hz. , kW, kVA, kWh) will be measured and logged as per requirement
- Compressed Air FAD test
- Network pressure at various sections
- Leakage survey

Air Conditioning System

■ Scope

- Evaluating the performance of chillers, AHU's, Pumps
- Evaluating the effectiveness of Cooling Towers
- Estimation of KW / TR

■ Measurements

- Electrical parameters (V, I, PF, Hz, kW, kVA, kWh) will be measured as per requirement
- Air flow / water flow
- DBT, RH measurements
- Insulation survey

Best Operating Practices

- Maintain Comfort condition as 25 deg. C and 55% RH.
- Avoid Part Load Operation
- Maintain Chilled water temperature (inlet 7 deg. C, outlet 12 deg.C)
- Maintain Condenser water temperature (inlet 30 deg. C, outlet 35 deg.C)
- Check for Pressure drop in evaporator and condenser
- Specific Energy Consumption, kW/TR
- Cold insulation

Lighting system

- **Scope**

- Illumination Level and comparison with standards
- Lighting distribution

- **Measurements**

- Electrical parameters (V, I, PF, Hz, kW, kVA, kWh) will be measured and logged as per requirement
- Lux level at each section

Best Operating Practices

- Upgrade Lighting technologies
- Daylight harvesting
- Energy management in lighting controls
- Occupancy sensors
- Optimising Voltage in lighting circuit

Recommended Lux Levels

Situation	Recommended Level
Fine work and Inspection	600 Lux
Laboratories, Sorting- Medium Work	400 Lux
Office Work	320 Lux
Filing and storage rooms- Course work	240 Lux
Large Scale Assembly /Storage with occational reading	160 Lux
Passage Ways/ Toilet Blocks	80 Lux
Dead Storage- Bulk Items	40 Lux

Boilers/ Hot water generators / Thermic Fluid Heaters

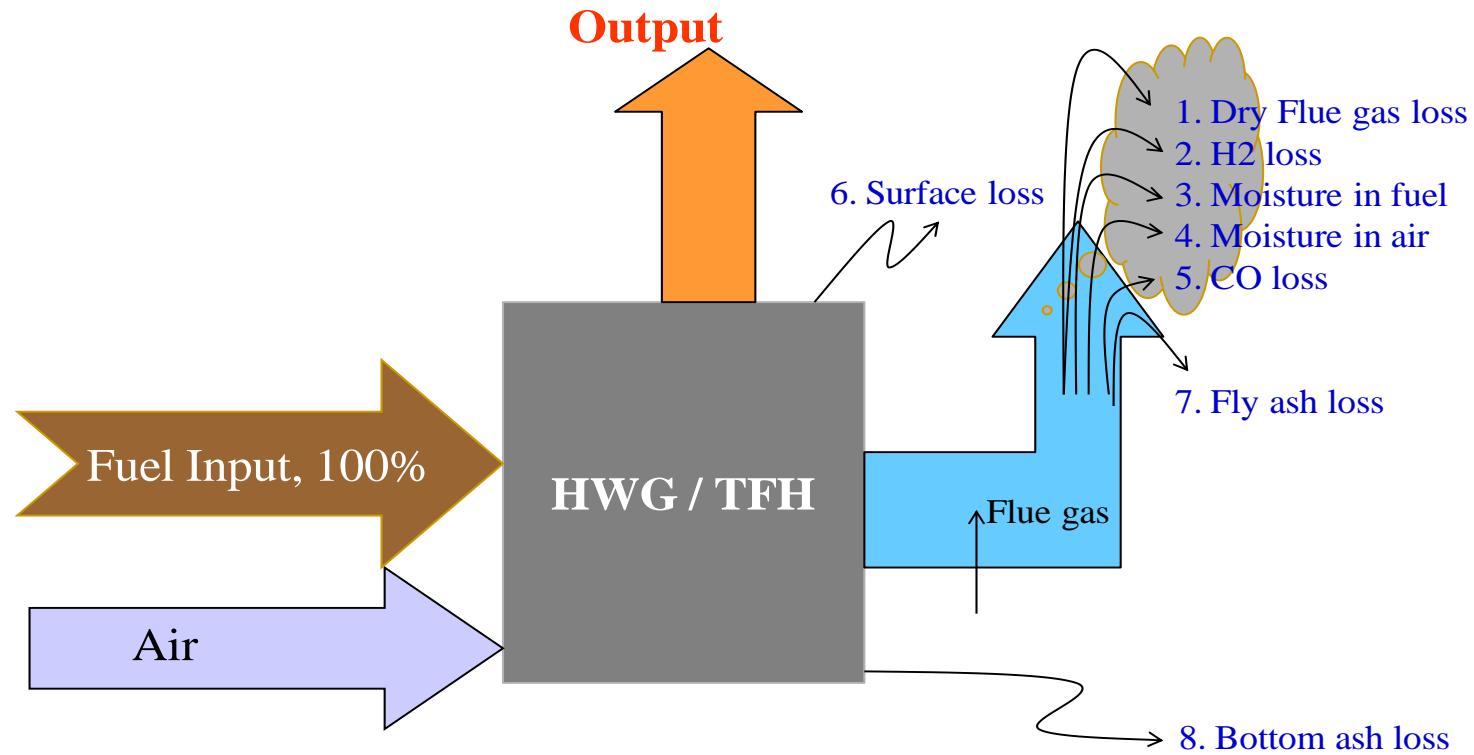
■ Scope

- Efficiency evaluation
- Monitoring and Instrumentation

■ Measurements

- Electrical parameters (V, I, PF, Hz, kW, kVA, kWh) will be measured as per requirement
- Combustion Air / Flue gas flow rate, Fuel flow rate
- Flue gas analysis at exit of gas
- Temperature of all fluids in and out of system (fuel, air)
- Insulation survey

Efficiency of Boilers / HWG / TFH



$$\text{Efficiency} = 100 - (1+2+3+4+5+6+7+8)$$

(by In Direct Method)

Best Operating practices

- Optimize air used for combustion
- Clean equipment heat transfer surfaces
- Install heat recovery equipment (Feed water economizers and/ or combustion air pre heaters)
- Proper insulation
- Ensure steam traps in proper working condition
- Condensate recovery

Energy Conservation Measures

- Reduce compressed air set pressure from 6 bar to 5 bar
- Arrest compressed air leak in compressed air system
- Reduce the excess air in Thermic fluid heater
- Operate Mobile conveyors in star mode
- Heat the FO by using flue gas instead of electric heaters in hot water boiler
- Install timer based operation to window and split A/C.
- Operate chillers as per working hours

Energy Conservation Measures

- Replace 40 W FTL with copper choke with T-5 (28W) with electronic Choke
- Replace 125 W MV lamps with 70W SV Lamps
- Install lighting energy savers in identified lighting feeders
- Install VFD to pumps to avoid recirculation flow in liquid section
- Increase the air conditioning set temperature in server room
- Remove or re arrange fixtures to achieve optimum Lux levels in working areas

Make the most of your Energy



Schneider
Electric