What do you have in your toolbox?

What happen to the Basic Engineering Skills?
Energy Baseline EnB
Quantitative reference(s) providing a basis for comparison of energy performance

Energy Performance Indicator EnPI
Quantitative value or measure of energy performance, as defined by the organization
Some questions on company level

How can we implement e.g. ISO 50001 with a very limited number of meters (which has never been calibrated)?

How can we convince the company that energy management is for all companies no matter of the level of information and data available? (can be improved later)

How can we get attention from the staff in the company?

How can we make the staff part of the process?

How can we combine EnPI and “operational control”?

How can we learn about the process?

How can we find out where to put up more meters?

How can we break down the barrier that Regression Analysis is complicated to use?

How can we “sneak in” better EnPI (maybe based on regression analysis) through the “backdoor”?
Heat (energy) balance

Use what you know:

- Steam flow.
- Feedwater flow (= steam flow approximately).
- Fuel flow (heat flow = fuel flow * efficiency).
- Gas bills.
- Hot water flow and temperature difference (dT) (Q = m*Cp*dT).

Build up a balance:

- Heat in = heat out.
- If you have a significant gap, you may need to measure it.
- Ultrasonic flow meters, portable heat meters.
Heat energy in air drying

A food containing 80% water is to be dried at 100°C down to moisture content of 10%. The initial temperature of the food is 21°C. The specific heat capacity of the food (original matter) is 3.8 kJ kg⁻¹ °C⁻¹.

Basic Engineering knowledge:

- The latent heat of vaporization of water at 100°C and at standard atmospheric pressure is 2,257 kJ kg⁻¹.
- The specific heat capacity of water is 4,186 kJ kg⁻¹ °C⁻¹.

Calculating for 1 kg food:

Initial moisture = 80% (800 g moisture are associated with 200 g dry matter).
Final moisture = 10% (100 g moisture are associated with 900 g dry matter).

Therefore, (100 x 200) / 900 g = 22.2 g moisture are associated with 200 g dry matter.

1 kg of original matter must lose (800 - 22) g moisture = 778 g = 0.778 kg moisture.

Heat energy required for 1 kg original material:

Start temp.: 21°C
End temp.: 100°C
The latent heat of vaporization: 2,257 kJ kg⁻¹
Heat capacity of food: 3.8 kJ kg⁻¹ °C⁻¹

= heat energy to raise temperature to 100°C + latent heat to remove water
= (100 - 21) x 3.8 + 0.778 x 2,257

Production per year (drying): 1000 tonnes
Energy consumption per year (drying): 2,055,644.444 kJ or 571,469 kwh or 74,217 Nm3 or 0.000278 (kJ → kWh) or 11 (kWh/Nm3 natural gas) or 0.7 (boiler efficiency)
Measuring plant performance can be difficult, and experience has shown that two complementary monitoring strategies give the best results in ensuring maximum plant efficiency.

These are:
Strategy 1: Indirect Assessment of Plant Faults

This involves assessment of the performance of individual items of plant, such as condensers, in order to identify specific types of fault that need to be remedied. This involves taking a "snapshot" of instantaneous data (e.g. temperatures and pressures) and comparing this with "expected values".

Strategy 2: Direct Monitoring of Performance

This involves measuring the power input into the plant over fairly long periods of time (e.g. weekly), and estimating the amount of cooling done in the same period by direct measurement or through calculation. This strategy allows you to build a comprehensive picture of plant performance over time.

Ideally, you should adopt both strategies, although Strategy 1 can often be adopted more quickly and with less investment in metering.

SEU – Cooling Plants – Strategy 1

Compare Data Snapshot with Expected Values

This is often the most difficult step because you may be uncertain about expected values. Expected values for each snapshot parameter can vary with ambient temperature, cooling load and product temperature.
SEU – Cooling Plants – Strategy 1

Look for Fault Symptoms
The data collected should be assessed and a fault check should be developed. Each part of the plant can be considered separately.

Example – Condensers: Probably the most common faults are those linked to condensers – and they are usually fairly easy to spot. Inefficiencies linked to condenser problems always result in a compressor discharge pressure that is too high.

A high discharge pressure reduces the system efficiency whilst at the same time it also reduces the amount of cooling being done. Most condenser faults are associated with a heat transfer problem that causes the condenser to operate inefficiently.

SEU – Cooling Plants – Strategy 2

Direct Monitoring of Performance
The direct assessment methodology uses “integrated data” measured over long periods of time e.g. kWh consumption of compressors. This data is used to estimate plant efficiency which can be compared to expected values.

How We Measure Refrigeration Plant Performance
We can calculate the plant efficiency in terms of the ratio of cooling carried out to power consumed (Q/P). This is known as the COP or Coefficient of Performance.
SEU – Cooling Plants – Strategy 2

Is Your COP Good or Bad?
Once you have measured your refrigeration plant COP, how do you know whether the performance is good or bad? Ideally we want the COP to be as high as possible, because that means we are getting more cooling for each kW of power input.

<table>
<thead>
<tr>
<th>Plant Cooling Load</th>
<th>Ambient Temperature [°C]</th>
<th>Expected Best COP</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 (%)</td>
<td>25</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>5.9</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>7.0</td>
</tr>
<tr>
<td>50 (%)</td>
<td>25</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>6.5</td>
</tr>
<tr>
<td>25 (%)</td>
<td>25</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>4.8</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>5.5</td>
</tr>
</tbody>
</table>

Using Strategy 2, Direct Measurement of Plant Performance, seems a simple and effective approach.

But:
Unfortunately measuring the cooling load is not always so easy to do – and sometimes is virtually impossible! For example if your main cooling load is a cold store, how do you measure the amount of cooling? You would need to measure the air flow and temperature difference across each cooling coil.

This is impossible to do accurately and very expensive – that is why no industrial cold store users try to do it!
SEU – Cooling Plants – Strategy 2

Problems:
- In some cases it is virtually impossible to measure the cooling load,
- COP does only tell us how efficient we produce the cooling; not how much of the cooling we waste in the production area, and
- (Cold store) The energy consumption of the cooling plant may be very little influenced by the production; more influenced by the outdoor temp.
**SEU – Compressed Air**

**Compressed Air Systems – Supply, Storage and Distribution**

**Supply**

- Air Compressor 1
- Air Compressor 2 (Variable Speed)

**Storage**

- Wet Receiver
- Dry Receiver

**Focus on demand first!**

**Demand:**

- Actual production demand
- Artificial demand
- Leaks

---

**SEU – Compressed Air – Baseline**

**Company name:** Myanmar Mix Ltd.

**Tag Number:** M1

**Year:** 1997

**Brand Name:** Ingersoll-Rand

**Air Flow (7 bar):** 414 [CFM] 11,7 [m³/min]

**Loaded:** 87 [kW]

**Power:** 100 [hp] 73,5 [kW]

**Idling:** 24,8 [kW]

**Air/Water Cooled:** Air

**Connected to:** Main

**Table:**

<table>
<thead>
<tr>
<th>Date</th>
<th>Days</th>
<th>Hours</th>
<th>Load</th>
<th>Load</th>
<th>Load out</th>
<th>Run</th>
<th>Run</th>
<th>Run</th>
<th>Load</th>
<th>Operation</th>
<th>Load</th>
<th>Operation</th>
<th>Load</th>
<th>Operation</th>
<th>Energy consumption (average)</th>
<th>Energy consumption (average/unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>26-04-14</td>
<td>14</td>
<td>25</td>
<td>285</td>
<td>251</td>
<td>97,19%</td>
<td>78,35%</td>
<td>4,8</td>
<td>165</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15-04-14</td>
<td>14</td>
<td>12</td>
<td>308</td>
<td>251</td>
<td>97,19%</td>
<td>78,35%</td>
<td>4,8</td>
<td>165</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-04-14</td>
<td>14</td>
<td>13</td>
<td>305</td>
<td>251</td>
<td>97,19%</td>
<td>78,35%</td>
<td>4,8</td>
<td>165</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23-04-14</td>
<td>14</td>
<td>16</td>
<td>323</td>
<td>251</td>
<td>97,19%</td>
<td>78,35%</td>
<td>4,8</td>
<td>165</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28-04-14</td>
<td>14</td>
<td>12</td>
<td>68</td>
<td>56</td>
<td>82,35%</td>
<td>89,29%</td>
<td>8,8</td>
<td>128</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>04-04-14</td>
<td>14</td>
<td>17</td>
<td>730</td>
<td>251</td>
<td>97,19%</td>
<td>78,35%</td>
<td>4,8</td>
<td>165</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---
Theoretical horsepower required to compress one cubic foot of free air (atmospheric pressure).

\[ HP = \frac{144 \times P1 \times V \times k}{33000 \times (k - 1)} \times \frac{(P2 / P1)^{(k - 1)/N}}{N} \]

- \( P1 \): Absolute initial atmospheric pressure (psi) (14.7 psi at sea level)
- \( P2 \): Absolute final pressure after compression (psi)
- \( V \): Volume of air at atmospheric pressure (cfm)
- \( N \): Number of compression stages
- \( k \): Adiabatic expansion coefficient (1.41)

Convert:
- 14.69594876 [psi] -> 1,01325 [bar]
- 125,0225298 [psi] -> 0,199465 [hp/cfm]
- 413,887888 [cfm] -> 11,72 [Nm3/min.]

Specific:
- 0,190465 [hp/cfm]
- 14,20 [kW/100 cfm]

Comparison with A1:
+ 47.9%
### SEU – Compressed Air – Baseline

**COMPRESSOR DATA SHEET**

**Rotary Compressor: Fixed Speed**

<table>
<thead>
<tr>
<th>Model</th>
<th>Data</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Manufacturer: Atlas Copco</td>
<td>Screw</td>
</tr>
<tr>
<td>2</td>
<td>Model Number</td>
<td>GA140-7.5-50Hz</td>
</tr>
<tr>
<td>3</td>
<td>Rated Capacity at Full Load Operating Pressure</td>
<td>565</td>
</tr>
<tr>
<td>4</td>
<td>Full Load Operating Pressure</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>Maximum Full Flow Operating Pressure</td>
<td>7.5</td>
</tr>
<tr>
<td>6</td>
<td>Drive Motor Nominal Rating</td>
<td>140</td>
</tr>
<tr>
<td>7</td>
<td>Drive Motor Nominal Efficiency</td>
<td>96.2</td>
</tr>
<tr>
<td>8</td>
<td>Fan Motor Nominal Rating of Application</td>
<td>3 x 4.0</td>
</tr>
<tr>
<td>9</td>
<td>Fan Motor Nominal Efficiency</td>
<td>85.0</td>
</tr>
<tr>
<td>10</td>
<td>Total Package Input Power at Zero Flow</td>
<td>47</td>
</tr>
<tr>
<td>11</td>
<td>Total Package Input Power of Rated Capacity and Full Load Operating Pressure</td>
<td>183.5</td>
</tr>
<tr>
<td>12*</td>
<td>Specific Package Input Power of Rated Capacity and Full Load Operating Pressure</td>
<td>36.1</td>
</tr>
</tbody>
</table>

### SEU – Compressed Air – Baseline

**Average kW vs Average Capacity with Load/Unload Capacity Control**

Lubricant Injected Rotary Screw Compressor

![Graph showing average kW vs average capacity with load/unload capacity control]
**SEU – Compressed Air – Baseline**

<table>
<thead>
<tr>
<th></th>
<th>Flow [cfm]</th>
<th>Specific Power [kw/100 cfm]</th>
<th>Load factor [%]</th>
<th>Power factor [%]</th>
<th>Operation [h]</th>
<th>Power [kWh/year]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total demand</td>
<td>600</td>
<td>21.0</td>
<td>100%</td>
<td>100%</td>
<td>3000</td>
<td>260.820</td>
</tr>
<tr>
<td>Comp. A</td>
<td>414</td>
<td>21.0</td>
<td>100%</td>
<td>100%</td>
<td>3000</td>
<td>187.790</td>
</tr>
<tr>
<td>Comp. B</td>
<td>186</td>
<td>33.7</td>
<td>45%</td>
<td>72%</td>
<td>3000</td>
<td>165.186</td>
</tr>
<tr>
<td>Trim comp.</td>
<td>200</td>
<td>33.0</td>
<td>48%</td>
<td>76%</td>
<td>2500</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>613.796 [kWh/year]</strong></td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>92.069 [USD/year]</strong></td>
</tr>
</tbody>
</table>

**SEU – Compressed Air – EnB, EnPI**

Compressed air systems can be managed by setting specific EnPIs that relate to the energy performance of the system. Like any SEU, this management is done by measuring specific elements of the system within a specific measurement boundary.

For compressed air systems, this means keeping track of the energy going into air compressors and treatment equipment and measuring what comes out — the compressed air flow.
System Specific Power (SSP): This is a measurement of the production efficiency of a compressed air system, and is a ratio of the power input compared to the compressed air output.

Total Energy Consumption: This is simply the energy consumption in kWh of a system.

Specific Energy Consumption: This metric is the ratio of energy consumption divided by some specific production output.

Portion of Non-Productive Usage: This is the proportion of the airflow during nonproductive periods divided by the average airflow, calculated in percent.
Waste? – How much?

Diesel Generator Set

100 [units]

Efficiency: 0.3

Waste [units]

Compressor

30 [units]

Efficiency:

End User

End Use 70% [units]

Waste 30% [units]

Leakage Loss
Pressure Drop
Artificial Use
Inappropriate Use

Thank you for your attention!