Additional Information on Proposed Methodology

"Energy Saving by Introduction of High-efficiency Inverter Type Multi-Stage Oil-Free Air Compressor"

1. Specific Power (SP)[1] Values of the Reference Air Compressors

1.1 Market Condition of Air Compressors in Viet Nam

According to the interviews with the major compressor suppliers and trading company in Viet Nam, there are no official statistics on air compressors. Table 1 shows the summary of interviews with major suppliers concerning air compressor market share in Viet Nam.

Table 1 Summary of the air compressor market survey in Viet Nam

Company	Summary of interview concerning boiler market share in Viet Nam
A	● In the factory where strict air quality management is required in the production processes, only oil-free compressors are introduced so that the air quality requirement is met.
B	● Air compressors made by Japanese and Swedish manufacturers are mainly introduced in Viet Nam.
C	● Japanese and Swedish manufacturers are dominant in the oil-free air compressor market. ● For oil-lubricated air compressors, Taiwan manufacturer is also one of the main players.
D	● Air compressors made by Japanese manufacturers are mainly introduced in Viet Nam.

Source: Based on interview results

1.2 Research on the SP Value of Inverter Type Oil-Free Air Compressors in Viet Nam

1.2.1 Catalogue Air Compressors Efficiency Values

Based on the result of the market survey shown in 1.1, some major compressor manufacturers who have a certain market share of oil-free type compressor in Viet Nam are identified.

Because the proposed methodology is applied to the project in which inverter-type air compressor is introduced, the reference compressor should also be the inverter-type compressor to ensure comparability of efficiency.

[1] SP (Specific Power): An indicator of efficiency of air compressor, calculated with electric motor power [kW] and free air delivery [m^3/min] of the air compressor under the specific conditions of discharge pressure at 0.7MPa(gauge pressure) and suction air temperature of 20 degrees Celsius, 0% relative humidity.

Taking into consideration the above information, catalogue values of efficiency of inverter type oil-free air compressor whose capacity is less than 300 kW sold in Viet Nam by the major manufacturers are collected from the web.

1.2.2 Calculation of SP values and identification of the type of the reference compressor

SP values of inverter type oil-free air compressor marketed in Viet Nam are calculated from values of the obtained 52 catalogue data with the equation as indicated in the proposed methodology. The calculated SP values are plotted in Figure 1 below. It is noted that the air compressors with smaller SP value are more efficient.

As shown in the figure, multi-stage air compressors have higher efficiency than that of single-stage air compressors. In order to ensure conservativeness, the reference compressor in the proposed methodology is identified as inverter type multi-stage oil-free air compressor.

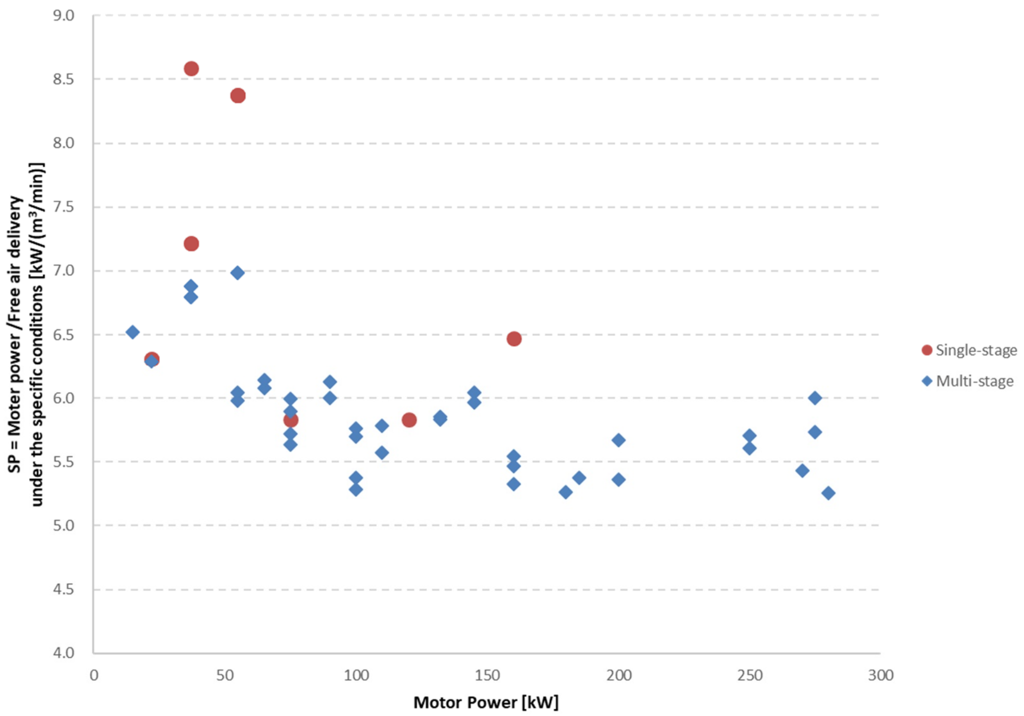

Figure 1 SP values of inverter type oil-free air compressors

1.2.3 Determination of the reference SP value

SP values of inverter type multi-stage oil-free air compressor marketed in Viet Nam are calculated from values of the obtained 19 efficiency catalogue data with motor power ranging from 37 kW to 160 kW with the equation as indicated in the proposed methodology. The calculated SP values are plotted in Figure 2 below.

Since different air compressors having the same motor power have different SP values, the lowest value is selected as the reference SP value for each motor power in order to ensure conservativeness, hence net emission reductions.

The default SP values are determined as shown in Table 2 below.

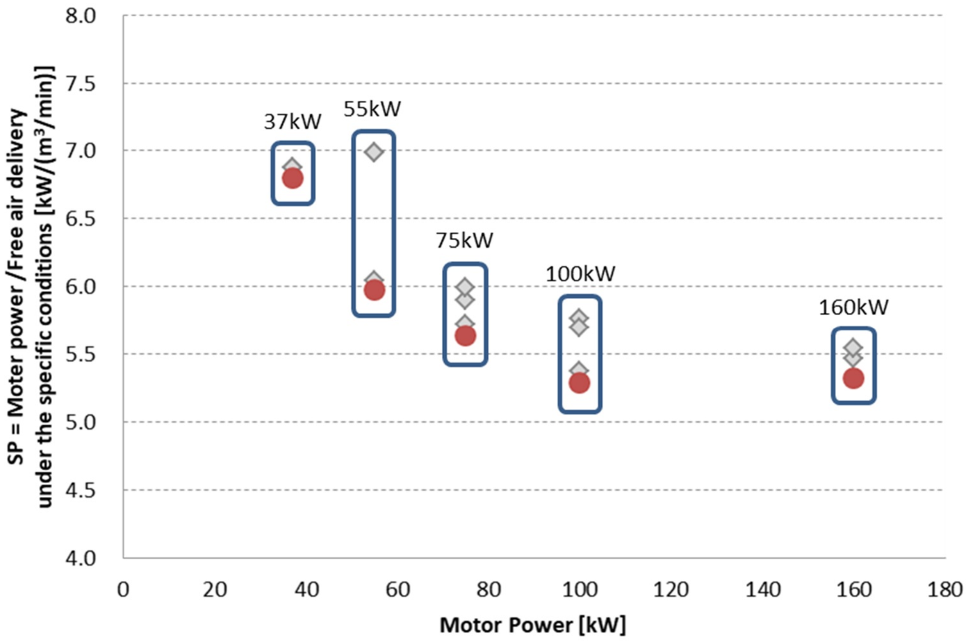

Figure 2 SP values of inverter type multi-stage oil-free air compressors

Table 2 The reference SP values set as default values in this methodology

Motor Power [kW]	Reference SP
37	6.80
55	5.98
75	5.63
100	5.28
160	5.32

2. Equation to Derive SP Value under the Specific Conditions[2]

Since the conditions of performance test (the project specific conditions) can be different on each air compressor, the equation in order to convert the SP value under the project specific conditions to that under the specific conditions is defined in the proposed methodology. The equation is derived from the formula for theoretical power in adiabatic compression process with an ideal gas.

2.1 Theoretical Adiabatic Power of Air Compressor

The theoretical power is generally given by:

$$L_{ad} = \frac{\mathrm{mk}}{k-1} \times \frac{P_S Q_S}{0.06} \times \left[\left(\frac{P_d}{P_s} \right)^{\left\{ \frac{k-1}{mk} \right\}} - 1 \right] \qquad \text{[Equation 1]}$$

where,

L_{ad} Theoretical adiabatic power [kW]

m Number of compression stages

k Heat capacity ratio (Dried Air) = 1.4

P_s Suction pressure at the first compression stage [MPa(a)]

P_d Discharge pressure [MPa(e)]

Q_s Discharge flow rate converted to the suction condition [m^3/min]

2.1 Specific Power (SP)

SP is defined as follows in the proposed methodology:

$$\mathrm{SP} = \frac{\text{Motor power [kW]}}{\text{Free air delivery capacity [m}^3\text{/min]}} \qquad \text{[Equation 2]}$$

Assuming that “Motor power” is equal to “L_{ad}” and “Free air delivery” is equal to “Q_s”, the equation for L_{ad} can be rearranged to provide SP by dividing both sides of the equation by Q_s.

$$\mathrm{SP} = \frac{\mathrm{mk}}{k-1} \times \frac{P_s}{0.06} \times \left[\left(\frac{P_d}{P_s} \right)^{\left\{ \frac{k-1}{mk} \right\}} - 1 \right] \qquad \text{[Equation 3]}$$

Then the SP value under the project specific conditions and the specific conditions can be derived with the following equations respectively:

[2] Ambient temperature = 20 degrees Celsius, Ambient pressure = 0 MPa(Gauge pressure), Relative humidity = 0%, Cooling water/air = 20 degrees Celsius, Effective working pressure at discharge valve = 0.7 MPa (Gauge pressure), specified in ISO 1217:2009.

$$\mathrm{SP}_{PJ} = \frac{\mathrm{mk}}{k-1} \times \frac{P_{s,PJ}}{0.06} \times \left[\left(\frac{P_{d,PJ}}{P_{s,PJ}} \right)^{\left\{ \frac{k-1}{mk} \right\}} - 1 \right] \qquad \text{[Equation 4]}$$

$$\mathrm{SP}_{PJ,sc} = \frac{\mathrm{mk}}{k-1} \times \frac{P_{s\_PJ} \frac{T_{s,PJ,sc}}{T_{s,PJ}}}{0.06} \times \left[\left(\frac{P_{d,PJ,sc}}{P_{s,PJ,sc}} \right)^{\left\{ \frac{k-1}{mk} \right\}} - 1 \right] \qquad \text{[Equation 5]}$$

where,

SP_{PJ} SP of project air compressor under the project specific conditions [kW・min/m3]

m Number of compression stages

k Heat capacity ratio (Dried Air) = 1.4

$P_{s,PJ}$ Suction pressure of project air compressor under the project specific conditions [MPa(a)]

$P_{s,PJ,sc}$ Suction pressure of project air compressor under the specific conditions [MPa(a)]

$P_{d,PJ}$ Discharge pressure of project air compressor under the project specific conditions [MPa(Gauge pressure)]

$P_{d,PJ,sc}$ Discharge pressure of project air compressor under the specific conditions [MPa(a)]

With Equation 4 and 5, SP value under the specific conditions can be rewritten as:

$$\mathrm{SP}_{PJ,sc} = \mathrm{SP}_{PJ} \times \frac{\frac{\mathrm{mk}}{k-1} \times \frac{P_{s,PJ} \frac{T_{s,PJ,sc}}{T_{s,PJ}}}{0.06} \times \left[\left(\frac{P_{d,PJ,sc}}{P_{s,PJ,sc}} \right)^{\left\{ \frac{k-1}{mk} \right\}} - 1 \right]}{\frac{\mathrm{mk}}{k-1} \times \frac{P_{s,PJ}}{0.06} \times \left[\left(\frac{P_{d,PJ}}{P_{s,PJ}} \right)^{\left\{ \frac{k-1}{mk} \right\}} - 1 \right]} \qquad \text{[Equation 6]}$$

Then, the equation which is defined in the proposed methodology is determined as:

$$\mathrm{SP}_{PJ,sc} = \mathrm{SP}_{PJ} \times \frac{T_{s,PJ,sc}}{T_{s,PJ}} \times \frac{\left[\left(\frac{P_{d,PJ,sc}}{P_{s,PJ,sc}} \right)^{\left\{ \frac{k-1}{mk} \right\}} - 1 \right]}{\left[\left(\frac{P_{d,PJ}}{P_{s,PJ}} \right)^{\left\{ \frac{k-1}{mk} \right\}} - 1 \right]} \qquad \text{[Equation 7]}$$