Additional Information on the Proposed Methodology
"Energy Saving by Introduction of Multi-stage Oil-Free Air Compressor"

1. Specific power (SP)[1] values of the reference air compressors

1.1 Market share of Oil-Free Air Compressor in Thailand

In Thailand, the American, Swedish and Japanese manufacturers are dominant in the oil-free air compressor market according to market specialists.

1.2 Research on the SP values of non-inverter oil-free air compressors in Thailand

1.2.1 Catalogue air compressor efficiency values

Catalogue values of efficiency of non-inverter type oil-free air compressor whose capacity is equal to or less than 200 kW sold in Thailand by the major manufacturers are collected on the web. 17 efficiency data in total with motor power ranging from 55 kW to 200 kW is obtained.

1.2.2 Calculation of SP values and determination of the reference SP value

SP values of non-inverter type oil-free air compressor marketed in Thailand are calculated from values of the obtained 17 catalogue data with the equation as indicated in the proposed methodology. The calculated SP values are plotted in Figure 1 as below. It is noted that the air compressors with smaller SP value are more efficient.

It is observed that air compressors used in the manufacturing process of semiconductors are manufactured at certain motor power as shown in Figure 1. 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 Table 1 as below.

[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.

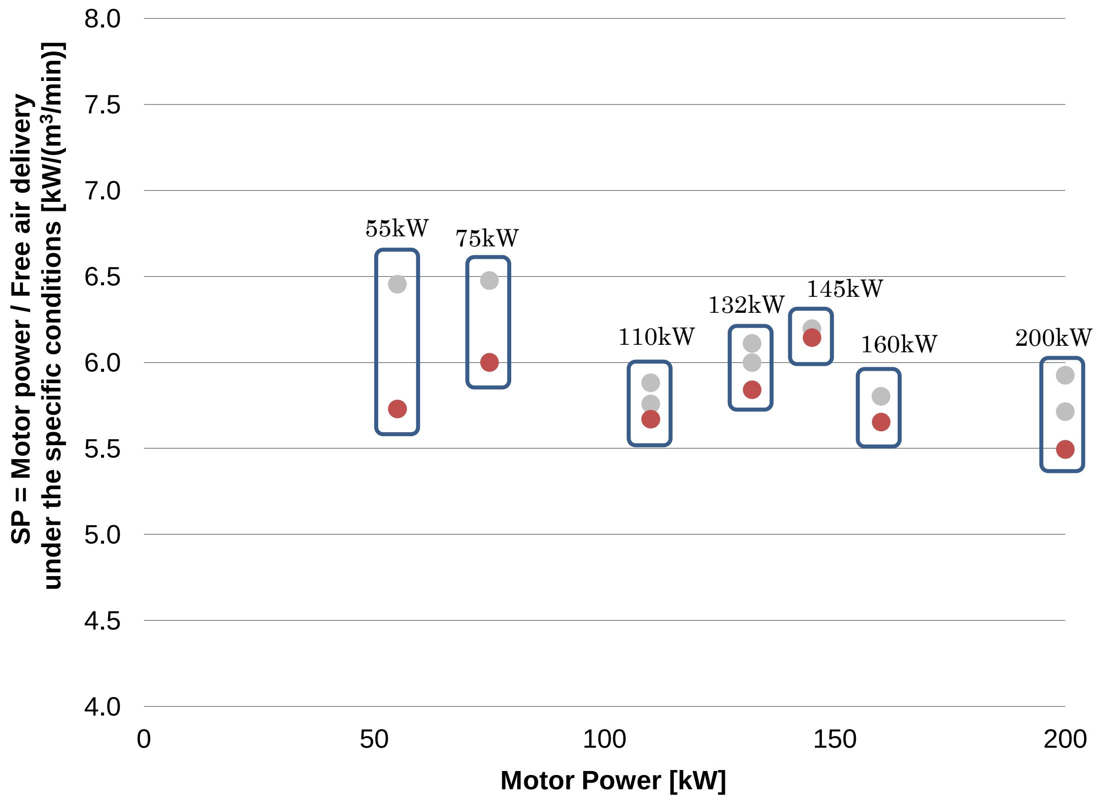

Figure 1: SP values of non-inverter type oil-free air compressor.

Table 1: The reference SP values set as default values in this methodology

Motor Power [kW]	Reference SP
55	5.73
75	6.00
110	5.67
132	5.84
145	6.14
160	5.65
200	5.49

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:

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

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]

2.2 Specific power (SP)

SP is defined as follows in the proposed methodology:

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

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.

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

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[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

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

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

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

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:

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

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

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