Energy Saving through Promotion of Cooling Seasonal Efficiency CSPF

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Contents:

1. EER and CSPF (or SEER)
2. Evaluation of inverter unit by CSPF
3. Effect of local load and hour fraction
4. Promotion of CSPF in ASEAN
5. Case study of LCCP (or TEWI)
6. Conclusion
1. EER and CSPF (or SEER)

1) Definition

EER: Energy Efficiency Ratio

\[ \text{EER} = \frac{\text{Cooling capacity}}{\text{Power input}} \]

(usually only at 35°C)

CSPF: Cooling Seasonal Performance Factor

(SEER: Seasonal Energy Efficiency Ratio)

\[ \text{CSPF} = \frac{\text{Total cooling load}}{\text{Total power consumption}} \]
1. EER and CSPF (or SEER)

2) Difference

**EER: One point efficiency at 35°C outdoor temperature**
- Higher efficiency at medium temperatures is not evaluated.

**CSPF: Average efficiency for all operating temperatures**
- Reduction of efficiency by on-off operation is considered.
- Advantage of inverter unit which continuously operates at medium temperatures is evaluated.

Diagram:
- Heat Radiation
- Outdoor Unit (Condenser)
- Expansion Device
- Compressor
- Indoor Unit (Evaporator)
- Cooling

Inverter can continuously change compressor speed
1. EER and CSPF (or SEER)
3) Features of inverter air conditioner

- **Energy saving:** Low power consumption
- **Comfort:** Low indoor temperature variation

**Part load operation**

- **Low energy consumption**
- **Quick response and low fluctuation**
1. EER and CSPF (or SEER)

4) History of CSPF

1992: SEER was adopted in USA.

2005: APF (Annual Performance Factor: cooling and heating) was adopted in Japan.


2012: EU-Ecodesign regulation using SEER was published.

2013: ISO 16358-1, 2, 3 were published.

(-1 for cooling, -2 for heating and -3 for annual efficiency)

2014-2016: Japan promoted adoption of CSPF in national standard and installation to local regulation in ASEAN.

2017: Amendment draft adding T3 high ambient calculation was released and is under process for approval.
1. EER and CSPF (or SEER)

5) Conventional EER and CSPF

EER35 is used here to distinguish from operating EERs under 35°C.

Conventional EER cannot evaluate efficiency in majority zone.

CSPF is a kind of average of actual EER for all operating temperatures.

![Graph showing EER35 and operating EER](image)

Majority zone

- **Good**
- **Bad**

![Bar graph showing operating hours](image)

- **Operating hours**
- **Outdoor temperature (°C)**
- **Operating hours**
- **Outdoor temperature (°C)**
2. Evaluation of inverter unit by CSPF

1) Fixed speed and inverter

**Fixed speed unit**

- Load and capacity/ Full capacity at 35°C
- EER and actual EER/ EER35

Actual EER decreases from full EER by on-off under 35°C.

CD: Degradation coefficient = 0.25

**Inverter unit**

- Load and capacity/ Full capacity at 35°C
- EER and actual EER/ EER35

Actual EER increases from full EER by capacity change from 35°C to tc, and decreases from half EER under tc.

tc: Cross temperature of load and half capacity (°C)
2. Evaluation of inverter unit by CSPF

2) CSPF ratio to EER35

[CSPF/EER35] is a kind of average of [Actual EER/EER35] weighted by [Load ratio x Hour fraction].

CSPF/EER35 of fixed speed unit is constantly 1.062 for ISO load and hours.

CSPF/EER35 of inverter unit changes by half EER ratio. It is usually 30 to 50% higher than fixed speed.
2. Evaluation of inverter unit by CSPF

3) Global sales and percentage of inverter unit

Global sales in 2017: 111 M-units

- **xx%**: Residential A/Cs with Inverter
- **yy%**: Commercial A/Cs with Inverter (without VRF)

Market proportion of inverter unit is about 50% or less in ASEAN countries except Singapore. There is no technology other than inverter which is more effective for energy saving.
3. Effect of local load and hour fraction

1) No load temperature

ISO load is 0 at 20°C. Load for Hong Kong, Taiwan and India is 0 at 23°C.

When no load temperature becomes higher, reduction rate of actual EER in on-off zone becomes greater. However, reduction rate of CSPF is same for all types of unit. Relative evaluation of unit efficiency does not change by no load temperature.
3. Effect of local load and hour fraction

2) Temperature shift hours

- **ISO and +2°C hour fraction**
- **Actual EER/EER35**
- **Relative CSPF vs ISO hours**

CSPF decreases by +2°C shift, because actual EER at higher temperature side is lower than at lower side. Reduction of CSPF by +2°C shift for inverter unit is 3 to 5% greater than fixed speed.

Reduction of CSPF for ASEAN climate is smaller than this case. This is shown next.
3. Effect of local load and hour fraction

3) Singapore (Typical ASEAN climate) and India hours

ISO, Singapore and India hour fraction

Actual EER/EER35

Relative CSPF vs ISO hours

Hour fraction = Hours/Total hours
EER35 = Full EER at 35°C (conventional EER)

R = [Half EER/Full EER] at 35°C
= usually 1.2 to 1.4

Mean temperature for Singapore is higher than ISO. However, reduction of CSPF is small, because hours are concentrated with no hour over 35°C. For ASEAN, CSPF practically will not change from ISO hours.

Reduction of CSPF for India is much greater. ISO hours may be unsuitable for India.
3. Effect of local load and hour fraction
4) Proposed ISO T3 calculation (Amendment draft)

ISO T3 load and hours represent Middle East. Although test points and load are different from T1 climate, characteristics of actual EER is similar.

Fixed speed unit
Load and capacity/ Full capacity at 46°C

Inverter unit
Load and capacity/ Full capacity at 46°C

EER and actual EER/ EER46

Actual EER decreases from full EER by on-off under 46°C.

CD: Degradation coefficient = 0.27

Actual EER increases from full EER by capacity change from 46°C to tc, and decreases from half EER under tc.

tc: Cross temperature of load and half capacity (°C)
3. Effect of local load and hour fraction

5) CSPF by T1 and T3 calculation

ISO T3 hours are based on average temperatures of Riyadh, Saudi Arabia and Abu Dhabi, UAE.

ISO T1 and T3 hour fraction

CSPF/EER46 (ISO T3 hours)

Actual EER/EER46

Hour fraction = Hours/ Total hours

EER46 = Full EER at 46°C (conventional T3 EER)

R = [Half EER/Full EER] at 35°C  
= usually 1.2 to 1.4

In T1 calculation, inverter unit cannot increase capacity over 35°C. This will not match actual unit selection. In T3 calculation, CSPF for inverter unit is 30 to 50 % higher than fixed speed at usual half EER ratio.

Energy saving effect of inverter is almost same for any climate if unit capacity is correctly selected for load.
## 4. Promotion of CSPF in ASEAN

**METI Project on Adoption of international standard and installation to local regulation (IS-INOTEK/JEMA, FY2014 to 2016)**

- Promotion of new international standard (ISO16358-1) to ASEAN countries
- Training program and round robin tests by JATL (Testing Laboratory)
- Harmonization of standards among ASEAN countries

<table>
<thead>
<tr>
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<th>2015</th>
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▲Initiation ◆Completion

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5. Case study of LCCP (or TEWI)

1) Case of cooling only in summer daytime

**LCCP (CO2-ton %)

<table>
<thead>
<tr>
<th></th>
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<th>Direct emission</th>
<th>Indirect emission</th>
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<td>Inverter R32</td>
<td>43</td>
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**Air Conditioners**

- Full capacity: 4.0 kW
- Full EER: 4.0 (fixed), 5.0 (inverter)
- Half EER ratio: 1.2 (inverter)
- Refrigerant charge: R22-1.4 kg/
  - R410A-1.1 kg/
  - R32-1.0 kg
- GWP: R22-1810/ R410A-2090/ R32-675

**Conditions**

- Emission factor: 0.49 CO2-kg/kWh
- Life: 12 years
- Operation: 1817 hours/year (ISO T1)
- ISO T1 hour fraction
- Leakage: 0 %/year
- Refrigerant recycle: 30 %

**LCCP: Life Cycle Climate Performance**
- TEWI: Total Equivalent Warming Impact
- Direct emission: based on GWP of refrigerant
- Indirect emission: based on Power consumption in operation

In order to correctly evaluate power consumption, seasonal efficiency CSPF must be used instead of EER.
5. Case study of LCCP (or TEWI)
1) Case of all year round cooling

LCCP: Life Cycle Climate Performance
TEWI: Total Equivalent Warming Impact
Direct emission: based on GWP of refrigerant
Indirect emission: based on Power consumption in operation

For regions to use cooling all year round, operating power consumption has major effect for total emission. Higher efficiency may be more effective than lower GWP to reduce total emission in these regions.
6. Conclusion
1) Conclusions

- Conventional EER evaluates efficiency only at 35°C, but CSPF evaluates average efficiency for all operating temperatures.
- CSPF for inverter unit is usually 30 to 50% higher than fixed speed unit.
- For high ambient T3 climate, load and calculation method are different, but energy saving effect of inverter unit is almost same.
- For the purpose of LCCP study, seasonal efficiency CSPF must be used instead of EER in order to correctly evaluate power consumption.
- Higher efficiency may be more effective than lower GWP to reduce total emission in regions to use cooling all year round.
6. Conclusion

2) Advantages of CSPF

- Consumer: More selection for energy efficient products in actual use.
- Government: More measures to reduce power consumption and climate impact in actual use.
- Manufacturer: More opportunity to fairly demonstrate energy saving products

Thank you!