

Addenda to ANSI Z21.40.4-1996 • CGA 2.94a-M96

AMERICAN NATIONAL STANDARD/CANADIAN GAS ASSOCIATION STANDARD
FOR

PERFORMANCE TESTING AND RATING OF GAS-FIRED, AIR-CONDITIONING AND HEAT PUMP APPLIANCES



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PREFACE

The standards set forth herein apply to the first edition of the Standard for Performance Testing and Rating of Gas-Fired, Air-Conditioning and Heat Pump Appliances, ANSI Z21.40.4-1996 · CGA 2.94-M96, and supersede corresponding standards therein. Following their preparation by the supervising subcommittee, they were accepted by ANSI, and the Interprovincial Gas Advisory Council, and subsequently approved.

NOTE: Changes, other than editorial, are denoted by a vertical line in the margin.

On June 30, 1997, the Canadian Standards Association (CSA) acquired International Approval Services (IAS) which was until then a joint venture of the American Gas Association (A.G.A.) and the Canadian Gas Association (CGA). Under this agreement CSA acquired the complete range of IAS standards administration, certification and registration products and services for appliances and accessories fueled by natural and liquefied petroleum gases.



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Addenda to
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APPENDIX A

METHODS OF DETERMINING EFFICIENCY RATINGS AND OPERATING COSTS OF GAS-FIRED, HEAT PUMPS FOR SPACE-CONDITIONING PERFORMANCE

(This Appendix is informative and is not part of the standard.)

SECTION 1

SCOPE

This appendix presents methods of determining efficiency ratings and operating costs of gas-fired, heat pumps for space-conditioning performance. The procedures in this appendix apply to factory-made, space-conditioning, unitary heat pumps which utilize gas as the primary fuel. This includes engine-driven heat pumps, absorption-cycle heat pumps, desiccant-type heat pumps, and other gas-fired heat pumps. The heat source/sink for the heat pumps may be outdoor air, ground water, or closed-loop water. The heat pumps provide the functions of year-round space conditioning either by direct heating and cooling of air or indirectly by the production of heated and chilled water. The heat pump may include other functions.

Appropriate portions of this appendix can be applied to heat pumps which have a gas input that varies so that the output matches the cooling or heating load, to heat pumps which have a single level gas input which varies as a function of ambient conditions, to heat pumps which have a constant gas input regardless of load or ambient conditions, and to heat pumps with several discrete levels of gas input.

In addition to applying to heat pumps which provide year-round space conditioning, portions of this appendix can be applied to heat pumps which provide space cooling only or space heating only. Also, the procedures in this appendix are provided for evaluating and rating water-cooled air conditioners and water-cooled chillers which reject condenser heat with a cooling tower, air- and water-cooled condensing units, and desiccant ventilation-air dehumidifiers.

Section 2 covers calculation procedures for determining steady-state efficiency ratings for the appliance operating in the cooling mode.

Section 3 covers calculation procedures for determining steady-state efficiency ratings for the appliance operating in the heating mode.

Section 4 covers calculation procedures for determining cooling-mode energy costs and efficiency ratings for appliances suitable for installation in residential applications. The steady-state cooling ratings from Section 2 are required as inputs for these determinations. A sample calculation is provided in **Annex A**.

Section 5 covers calculation procedures for determining heating-mode energy costs and efficiency ratings for appliances suitable for installation in residential applications. The steady-state heating ratings from Section 3 are required as inputs for these determinations. A sample calculation is provided in **Annex B**.

Section 6 covers calculation procedures for determining annual energy costs for appliances suitable for installation in residential applications.

Section 7 covers calculation procedures for determining cooling-mode energy costs and efficiency ratings for appliances suitable for installation in commercial applications. A sample calculation is provided in **Annex C**.

Annex D provides procedures for determining the annual energy consumption of other residential space-heating/space-cooling appliances.

SECTION 2

STEADY-STATE COOLING EFFICIENCY RATINGS

2.1 NET COOLING CAPACITY AND INPUT RATINGS. Net cooling capacity, cooling-mode gas input, and cooling-mode electric input ratings shall be determined in accordance with the procedures of *ANSI Z21.40.4 CGA 2.9, American National Standard/Canadian Gas Association Standard for Performance Testing and Rating of Gas-Fired Air-Conditioning, and Heat-Pumping Appliances.*

2.2 COOLING-MODE GAS COP. The cooling-mode gas COP ratings, COP_{CG} , shall be obtained by dividing the net cooling capacity rating by the corresponding net cooling-mode gas input rating, as measured at the rating conditions specified in Section 2 of the Standard.

When used for rating purposes, values of Cooling-Mode Gas COP shall be expressed in the nearest multiple of 0.02. When the cooling-mode gas COP is quoted, it should be accompanied by the corresponding cooling-mode electric input rating for the same rating conditions.

2.3 COST EER. Cost Energy Efficiency Ratio (Cost EER) is defined as the cooling-mode EER required of an all-electric air conditioner or heat pump to match the hourly rate of energy cost of the combined gas and electric input of a gas-fired heat pump. It is calculated as follows:

$$\text{Cost EER} = \frac{1}{1 / (3.413 \times COP_{CG} \times FCR) + 1/EER_{CE}}$$

where COP_{CG} is as determined in 2.2 and EER_{CE} is calculated by dividing the net cooling capacity rating by the corresponding net cooling-mode electric input rating. FCR, the fuel cost ratio is calculated as follows:

$$FCR = 29.3 \times (\$/\text{kWh}) / (\$/\text{therm})$$

where:

$$\begin{aligned} \$/\text{kWh} &= \text{cost of electric energy per kilowatt-hour} \\ \$/\text{therm} &= \text{cost of gas per therm (100,000 Btu)} \end{aligned}$$

The same energy cost figures used to calculate annual energy costs should be used in the preceding equation for FCR.

The value of FCR usually ranges from 3 to 5 with the national average in recent years being approximately 4.

When used for rating purposes, values of Cost EER shall be expressed in the nearest multiple of 0.05.

2.4 SOURCE FUEL EER. Source Fuel Energy Efficiency Ratio (Source Fuel EER) is defined as the cooling-mode EER required of an all-electric air conditioner or heat pump to match the source fuel consumption rate of the gas and electric cooling-mode input of a gas-fired heat pump for the case where the electric generating plant is fueled by gas. It is calculated as follows:

$$\text{Source Fuel EER} = \frac{1}{\text{SER}/(3.413 \times \text{COP}_{\text{CG}}) + 1/\text{EER}_{\text{CE}}}$$

where COP_{CG} is defined in 2.2, EER_{CE} is defined in 2.3, and SER, the composite of electric source fuel efficiency and gas source fuel efficiency, as defined below:

$$\text{SER} = \text{ESFE}/\text{GSFE}$$

where

SER	= Source Energy Ratio
ESFE	= Electric Source Fuel Efficiency
GSFE	= Gas Source Fuel Efficiency

Unlike the $\text{ESFE} = 1/3.37$ developed by DOE, no such value has been developed for GSFE. The value of ESFE typically ranges from 0.25 to 0.35. Unless evidence is provided to support a different value, a value of $\text{ESFE} = 1/3.37$ shall be used in the preceding equation for Source Fuel EER.

When used for rating purposes, values of Source Fuel EER shall be expressed in the nearest multiple of 0.05.

SECTION 3

STEADY-STATE HEATING EFFICIENCY RATINGS

3.1 NET HEATING CAPACITY AND INPUT RATINGS. Net heating capacity, heating-mode gas input, and heating-mode electric input ratings shall be determined in accordance with the procedures of ANSI Z21.40.4, American National Standard for *Performance Testing and Rating of Gas-Fired Air-Conditioning, Heat-Pumping, and Like Appliances*.

3.2 HEATING-MODE GAS COP. The heating-mode gas COP ratings, COP_{HG} , shall be obtained by dividing the net heating capacity rating by the corresponding net heating-mode gas input rating, as measured at the rating conditions specified in Section 3 of the Standard.

When the heating-mode gas COP is quoted, it should be accompanied by the corresponding heating-mode electric input rating for the same rating conditions.

3.3 COST COP. Cost Coefficient of Performance (Cost COP) is defined as the heating-mode COP required of an all-electric heat pump to match the hourly rate of energy cost of the combined gas and electric input of a gas-fired heat pump. It is calculated as follows:

$$\text{Cost COP} = \frac{1}{1/ (COP_{HG} \times FCR) + 3.413/EER_{HE}}$$

where COP_{HG} is as determined in 3.2 and EER_{HE} is calculated by dividing the net heating capacity rating by the corresponding net heating-mode electric input rating. FCR, the fuel cost ratio is defined in 2.3.

3.4 SOURCE FUEL COP. Source Fuel Coefficient of Performance (Source Fuel COP) is defined as the heating-mode COP required of an all-electric heat pump to match the source energy consumption rate of the gas and electric heating-mode input of a gas-fired heat pump for the case where the electric generating plant is fueled by gas. It is calculated as follows:

$$\text{Source Fuel COP} = \frac{1}{SER/COP_{HG} + 3.413/EER_{HE}}$$

where COP_{HG} is defined in 3.2, EER_{HE} is defined in 3.3, and SER, is the composite Source Energy Ratio as defined in 2.4.

3.5 ROUNDING OF EFFICIENCY RATING VALUES. When used for rating purposes, values of COP shall be expressed in the nearest multiple of 0.02.

SECTION 4

COOLING SEASONAL EFFICIENCY RATINGS AND OPERATING COSTS OF RESIDENTIAL AIR-SOURCE APPLIANCES

4.1 LIMITATIONS. The procedures of this section for the determination of seasonal cooling-mode energy costs and seasonal cooling-mode efficiency parameters is limited to air-source (air-to-air and air-to-water) heat pumps with a maximum rated cooling capacity less than 65,000 Btu/h.

4.2 SEASONAL COOLING OUTPUT AND ENERGY CONSUMPTION. The seasonal cooling output, the seasonal cooling gas energy consumption, and the seasonal electric energy consumption shall be determined in accordance with the procedures of *ANSI Z21.40.4 · CGA 2.94*, American National Standard/Canadian Gas Association Standard for *Performance Testing and Rating of Gas-Fired Air-Conditioning, and Heat-Pumping Appliances*.

4.3 SEASONAL COOLING ENERGY COSTS. The cost of operating the gas-fired heat pump for the cooling season can be determined as follows:

$$\text{Seasonal cooling costs} = [(\text{SCGEC}/100,000) \times (\$/\text{therm})] + [(\text{SCEEC}/1000) \times (\$/\text{kWh})]$$

where:

SCGEC	=	Seasonal cooling gas energy consumption, Btu
\$/therm	=	cost of gas per therm (100,000 Btu)
SCEEC	=	Seasonal cooling electric energy consumption, watt-hour
\$/kWh	=	cost of electric energy per kilowatt-hour

4.4 GAS SEASONAL COP - COOLING. The Gas Seasonal Coefficient of Performance - Cooling (Gas SCOP_C) for gas-fired heat pumps based on seasonal cooling output and seasonal cooling gas energy consumption can be calculated as follows:

$$\text{Gas SCOP}_C = \text{SCO} / \text{SCGEC}$$

where:

SCO	=	Seasonal cooling output
SCGEC	=	Seasonal cooling gas energy consumption

When used for rating purposes, values of SCOP shall be rounded to the nearest multiple of 0.02.

4.5 COST SEER. Cost Seasonal Energy Efficiency Ratio (Cost SEER) is defined as the SEER required of an all-electric air conditioner or heat pump to match the cooling energy cost of a gas-fired heat pump. It is calculated as follows:

$$\text{Cost SEER} = \frac{\text{SCO}}{\text{SCGEC} / (3.413 \times \text{FCR}) + \text{SCEEC}}$$

where:

SCO = Seasonal cooling output
SCGEC = Seasonal cooling gas energy consumption
SCEEC = Seasonal cooling electric energy consumption
FCR = Electric-to-Gas Fuel Cost Ratio

The Fuel Cost Ratio is calculated as follows:

$$\text{FCR} = 29.3 \times (\$/\text{kWh}) / (\$/\text{therm})$$

where:

\$/kWh = cost of electric energy per kilowatt-hour
\$/therm = cost of gas per therm (100,000 Btu)

The value of FCR usually ranges from 3 to 5 with the national average in recent years being approximately 4.

When used for rating purposes, values of Cost SEER shall be rounded to the nearest multiple of 0.05.

4.6 SOURCE FUEL SEER. Source Fuel Seasonal Energy Efficiency Ratio (Source Fuel SEER) is defined as the SEER required of an all-electric air conditioner or heat pump to match the source fuel consumption of the gas-fired heat pump when cooling for the case where the electric generating plant is fueled by gas. It is calculated as follows:

$$\text{Source Fuel SEER} = \frac{\text{SCO}}{\text{SCGEC} \times \text{SER} / 3.413 + \text{SCEEC}}$$

where:

SCO = Seasonal cooling output
SGEC = Seasonal cooling gas energy consumption
SCEEC = Seasonal cooling electric energy consumption
SER = Source Energy Ratio

SER, the composite of electric source fuel efficiency and gas source fuel efficiency, is defined in 2.4.

When used for rating purposes, values of Source Fuel SEER shall be rounded to the nearest multiple of 0.05.

SECTION 5

HEATING SEASONAL EFFICIENCY RATINGS AND OPERATING COSTS OF RESIDENTIAL AIR-SOURCE APPLIANCES

5.1 LIMITATIONS. This procedure for the determination of seasonal heating-mode energy costs and seasonal heating-mode efficiency parameters is limited to air-source (air-to-air and air-to-water) heat pumps with a maximum rated cooling capacity less than 65,000 Btu/h (or with a maximum rated heating capacity less than 65,000 Btu/h for heating-only heat pumps).

5.2 SEASONAL HEATING OUTPUT AND ENERGY CONSUMPTION. The seasonal heating output, the seasonal heating gas energy consumption, and the seasonal electric energy consumption shall be determined in accordance with the procedures of *ANSI Z21.40.4 · CGA 2.94*, American National Standard/Canadian Gas Association Standard for *Performance Testing and Rating of Gas-Fired Air-Conditioning, and Heat-Pumping Appliances*.

5.3 HEATING ENERGY COSTS. The cost of operating the gas-fired heat pump for the heating season can be determined as follows:

$$\text{Seasonal heating costs} = [(\text{SHGEC}/100,000) \times (\$/\text{therm})] + [(\text{SHEEC}/1000) \times (\$/\text{kWh})]$$

where:

SHGEC	=	Seasonal heating gas energy consumption, Btu
\$/therm	=	cost of gas per therm (100,000 Btu)
SHEEC	=	Seasonal heating electric energy consumption, watt-hour
\$/kWh	=	cost of electric energy per kilowatt-hour

5.4 GAS SEASONAL COP - HEATING. The Gas Seasonal Coefficient of Performance - Heating (Gas SCOP_H) for gas-fired heat pumps based on seasonal heating output and seasonal heating gas energy consumption can be calculated as follows:

$$\text{Gas SCOP}_H = \text{SHO} / \text{SHGEC}$$

where:

SHO	=	Seasonal heating output
SHGEC	=	Seasonal heating gas energy consumption

When used for rating purposes, Gas Seasonal COP shall be rounded to the nearest multiple of 0.02.

5.5 ANNUAL FUEL UTILIZATION EFFICIENCY. Annual Fuel Utilization Efficiency (AFUE) is used as a measure of space heating efficiency for residential gas-fired furnaces and gas-fired boilers. It is the ratio of heat delivered over a heating season divided by the heat equivalent of the gas input during the heating season plus any standby gas energy consumption during the non-heating season. Auxiliary electric energy consumption is not included in the efficiency term, so the annual auxiliary electric kWh consumption is often provided along with the AFUE rating.

Comparable efficiency terms can be developed for the heating mode of gas-fired heat pumps as follows:

Heat pumps that provide heating and cooling:

$$\text{AFUE (in \%)} = 100 \times \{ \text{SHO} / [\text{SHGEC} + (\text{N}_S/2) \times \text{SGECR}] \}$$

Heat pumps that provide heating only:

$$\text{AFUE (in \%)} = 100 \times \{ \text{SHO} / [\text{SHGEC} + (\text{N}_S + \text{N}_C) \times \text{SGECR}] \}$$

where SGECR is the hourly standby gas energy consumption rate in Btu/h. N_C , the number of bin hours per year that cooling is required, and N_S , the number of bin hours per year that neither cooling or heating is required, vary by the U.S. Department of Energy (DOE) climate regions. These regions are defined in Figure 5-1 and the values for N_C and N_S are listed in Table 5-1.

Table 5-1
BIN HOURS

Climate Regions	N_H	N_C	N_S
Region I	1,826	6,720	214
Region II	3,148	5,040	572
Region III	4,453	3,360	947
U. S. National Average Rating Value	5,216	2,800	744
Region IV	5,643	2,240	877
Region V	6,956	1,120	684
Region VI	6,258	560	1,942

When used for rating purposes, Annual Fuel Utilization Efficiency shall be rounded to the nearest multiple of 0.1.

The related annual auxiliary space heating energy consumption, ASHEC, in KWh, shall be calculated as follows:

Heat pumps that provide heating and cooling:

$$\text{ASHEC (in kWh)} = [\text{SHEEC} + (\text{N}_S/2) \times \text{SEECR}] / 1000$$

Heat pumps that provide heating only:

$$\text{ASHEC (in kWh)} = [\text{SHEEC} + (\text{N}_S + \text{N}_C) \times \text{SEECR}] / 1000$$

where SEECR is the hourly standby auxiliary electric energy consumption rate in watts.

5.6 COST HSPF. Cost Heating Seasonal Performance Factor (Cost HSPF) is defined as the HSPF required of an all-electric heat pump to match the heating energy cost of a gas-fired heat pump. It is calculated as follows:

$$\text{Cost HSPF} = \frac{\text{SHO}}{\text{SHGEC} / (3.413 \times \text{FCR}) + \text{SHEEC}}$$

where FCR = Electric-to-Gas Fuel Cost Ratio

The Fuel Cost Ratio is calculated as follows:

$$\text{FCR} = 29.3 \times (\$/\text{kWh}) / (\$/\text{therm})$$

where:

$$\begin{array}{ll} \$/\text{kWh} & = \text{cost of electric energy per kilowatt-hour} \\ \$/\text{therm} & = \text{cost of gas per therm (100,000 Btu)} \end{array}$$

The value of FCR usually ranges from 3 to 5 with the national average in recent years being approximately 4.

When used for rating purposes, Cost HSPF shall be rounded to the nearest multiple of 0.05.

5.7 SOURCE FUEL HSPF. Source Fuel Heating Seasonal Performance Factor (Source Fuel HSPF) is defined as the HSPF required of an all-electric heat pump to match the source fuel consumption of the gas-fired heat pump when heating for the case where the electric generating plant is fueled by gas. It is calculated as follows:

$$\text{Source Fuel HSPF} = \frac{\text{SHO}}{\text{SHGEC} \times \text{SER} / 3.413 + \text{SHEEC}}$$

where SER = Source Energy Ratio, the composite of electric source fuel efficiency and gas source fuel efficiency, as defined in 2.4.

When used for rating purposes, Source Fuel HSPF shall be rounded to the nearest multiple of 0.05.

DOE CLIMATE REGIONS



SECTION 6

ANNUAL OPERATING COSTS OF RESIDENTIAL AIR-SOURCE APPLIANCES

6.1 LIMITATIONS. This procedure for the determination of annual energy costs is limited to air-source (air-to-air and air-to-water) heat pumps with a maximum rated cooling capacity less than 65,000 Btu/h (or with a maximum rated heating capacity less than 65,000 Btu/h for heating-only heat pumps).

6.2 ANNUAL GAS ENERGY CONSUMPTION AND ANNUAL ELECTRIC ENERGY CONSUMPTION. The annual gas energy consumption and the annual electric energy consumption shall be determined in accordance with the procedures of *ANSI Z21.40.4 · CGA 2.94*, American National Standard/Canadian Gas Association Standard for *Performance Testing and Rating of Gas-Fired Air-Conditioning, and Heat-Pumping Appliances*.

6.3 ANNUAL ENERGY COSTS. The cost of operating the gas-fired heat pump for the year can be determined as follows:

$$\text{Annual energy costs} = [(\text{AGEC}/100,000) \times (\$/\text{therm})] + [(\text{AEEC}/1000) \times (\$/\text{kWh})]$$

where:

AGEC = Annual gas energy consumption, Btu

\$/therm = cost of gas per therm (100,000 Btu)

AEEC = Annual electric energy consumption, watt-hour

\$/kWh = cost of electric energy per kilowatt-hour

SECTION 7

COOLING EFFICIENCY RATINGS AND OPERATING COSTS OF COMMERCIAL APPLIANCES

7.1 LIMITATIONS. This procedure for the determination of cooling integrated part load value (IPLV) parameters is limited to air-source (air-to-air and air-to-water) heat pumps with a maximum rated cooling capacity of 65,000 Btu/h or higher and to water-cooled air conditioners and chillers which reject condenser heat with a cooling tower.

7.2 INTEGRATED PART LOAD VALUES. The average cooling output per hour of operation (IPLV_Q), the average gas input per hour of operation (IPLV_G), and the average electric input per hour of operation (IPLV_E) shall be determined in accordance with the procedures of *ANSI Z21.40.4 · CGA 2.94*, American National Standard/Canadian Gas Association Standard for *Performance Testing and Rating of Gas-Fired Air-Conditioning and Heat-Pumping Appliances*.

7.3 SEASONAL COOLING ENERGY COSTS. The cost of operating the gas-fired heat pump, air conditioner, or chiller for the cooling season can be determined as follows:

$$\begin{aligned}\text{Seasonal cooling cost} &= \{\text{Annual hours of operation}\} \times \{\text{average operating cost per hour}\} \\ &= \{(\text{Annual cooling load}) / \text{IPLV}_Q\} \\ &\quad \times \{[(\text{IPLV}_G / 100,000) \times (\$/\text{therm})] + [(\text{IPLV}_E / 1000) \times (\$/\text{kWh})]\}\end{aligned}$$

where the annual cooling load in Btu is determined by an accepted computation method for the structure and climate in which the appliance is installed.

7.4 GAS SEASONAL COP - COOLING. The Gas Seasonal Coefficient of Performance - Cooling (Gas SCOP_C) for gas-fired heat pumps, air conditioners, or chillers can be calculated as follows:

$$\text{Gas SCOP}_C = \text{IPLV}_Q / \text{IPLV}_G$$

7.5 COST IPLV. Cost Integrated Part Load Value (Cost IPLV), in Btu/watt-hour, is defined as the IPLV required of an all-electric heat pump, air conditioner, or chiller to match the cooling energy cost of a gas-fired heat pump, air conditioner, or chiller. It is calculated as follows:

$$\text{Cost IPLV} = \frac{\text{IPLV}_Q}{\text{IPLV}_G / (3.413 \times \text{FCR}) + \text{IPLV}_E}$$