Study of Evaluation Method for New CO_2 Heat Pump Water Heater

Background

Heat pump water heater technology using CO_2 as a refrigerant (ECO CUTE technology) is attracting attention for its ability to save energy and reduce greenhouse gas emissions. The government support program has been introduced with a target to increase total installation to 5.2 million by 2010. There are several problems to hinder progress toward the goal, for example large footprint, degradation of COP in cold regions and so on. To overcome these problems, technical development projects have been conducted since 2005 on the initiative of NEDO (development subjects include downsizing and improving performance in cold regions). There is no appropriate evaluation method for new developed heat pump water heaters, so it is essential to study new evaluation methods of heat pump water heaters.

Objectives

In order to establish a performance evaluation method for a standard family for new CO_2 heat pump water heater, the following subjects were carried out; (1) reviewing existing performance evaluation methods, (2) extracting necessary evaluation items according to development subjects, (3) investigating testing facilities necessary for the performance evaluation, and (4) studying test procedures for extracted evaluation items.

Principal Results

1. Reviewing existing performance evaluation methods

Table 1 shows the characteristics of existing performance evaluation methods. It is found that JRA 4050:2005 that is voluntary standard of JRAIA *1, is de facto standard.

2. Extraction of necessary evaluation item according to development subjects

It is found that “two-axis evaluation” is necessary to evaluate the new heat pump water heater appropriately. Two axes are “performance" and “function and ability that should be secured” (hereinafter abbreviated to “F&A”). Table 2 shows necessary evaluation items organized according to development subjects and the two-axis. For “performance”, it is necessary to evaluate “performance of a heat pump”*2 that has been conventionally evaluated, in addition, we proposed that “annual performance of heat pump system with supplying standard hot water tapping profile *4”*3 (hereinafter abbreviated to “annual system performance”) should to be evaluated because it is comprehensible to users. For “F&A”, we also proposed it is necessary to evaluate and we extracted items in consideration of new equipment's usability and of technologies that would be applied, for example, using small storage tank and large compressor for downsizing.

3. Investigation of test facilities necessary for the performance evaluation

In order to carry out the evaluation, a testing chamber in the artificial environment room that keeps all temperature conditions (hereinafter abbreviated to “TC”) for a long time, hot water load equipment that can control time-dependent load minutely and a high accuracy measurement system that ensures traceability are required.

4. Studying test procedures for extracted evaluation items

Performance evaluation methods were built based on JRA4050. New tapping and heating profiles, testing procedures and so on were proposed in this report for additional evaluation items not included in JRA4050. “F&A” evaluation methods were newly built. New quantitative testing procedures were proposed in this report (Table 3).

Future Developments

It is necessary to keep observation on the movement of other performance evaluation methods and hot water supplying mode (modified M1 mode *10 etc.) and to improve continually the proposed procedure and method.

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Reference

K. Hashimoto, et.al., 2006, “Study of Evaluation Method for New CO_2 Heat Pump Water Heater”, CRIEPI Report M05020 (in Japanese)

Table 1 Characteristics of the existing evaluation methods for heat pump water heater

Standards	Heat pump efficiency*2	Annual system efficiency*3	Remarks	Latest
JRA Standard "Residential heat pump water heaters JRA4050: 2005" in Japan	- TCs and permissible temperature fluctuation. - Procedures for measuring performance under intermediate, summer and winter TCs (Remarks: measuring COP need to be over 90% of one on brochure) - Procedures for measuring availability of de-frosting operation and cold winter with low temperature TC.	- "Guidance" (not "regulation") - Using standard hot tapping profile for standard family (IBEC*8-L mode) - Power consumptions are measured under intermediate, summer and winter TC - Annual system performance was calculated as a heating-load-days*6 weighted average of power consumption and standard hot tapping load.	Include: strength and electrical safety codes	2005/5
BL*7 Certification Standard for Quality Housing Components "Electric water heaters" in Japan	Ref. "JRA4050: 2002"	---	Include: safety, durability, environmental availability	2005/12
IEA HPP Annex 28*9 in EU, US and Japan (9 countries)	Discussion about proposals from EU (EN255-3), US (ARI470) and Japan (JRA4050).	Agreement only in EU - Using hot water tapping and heating combined mode	---	2005/11

Table 2 Extracted evaluation items according to development subjects

Development Subjects	Performance (heating capacity, power consumption and COP)	Function & Ability
"Downsizing"	- Heat pump performance (under intermediate, summer winter and defrosting TCs) - Annual system performance for warm regions	- Continuous hot water tapping capacity - Maximum hot water tapping capacity - Intermittent hot water tapping capacity
"Improving performance in Cold region"	- Heat pump performance (under intermediate, summer, winter, defrosting, cold winter with high temperature heating TCs) - Annual system performance for cold regions - Annual combined (hot water tapping and floor heating) system performance for cold regions	- Continuous hot water tapping capacity - Maximum hot water tapping capacity - Black-out durability in cold regions - Available operation in cold regions

Table 3 Newly proposed evaluation items, tables and test procedures

TEST NAME	Proposed items
Heat pump performance - Testing procedures are given*11 - New TCs	- CO_2 heat pump water heaters classification - Out-going temperature from heat pump according to classification (New TC array) - Measuring items under new TCs (for example, COP under defrosting and cold winter with high temperature output TCs) - Discussion about auto defrosting operation - Waiting time for stable state and measuring time
Annual system performance - Testing procedures are almost given*11 - New TCs - New heating-load-days for cold regions	- TC and heating-load-days for estimating annual system performance for cold regions - TC, heating-load-days, combined load profile and testing procedure for estimating annual combined system performance
Newly proposed testing method for F&A	- Testing procedure for continuous hot water tapping capacity - Testing procedure for maximum hot water tapping capacity - Testing procedure for re-heating to hot water in bath - Testing procedure for black-out durability in cold regions - Intermittent hot tapping profile

＊1：Japan Refrigeration and Air Conditioning Industry Association.
＊2：Heating capacity (capacity of water supplying), power consumption and COP (coefficient of performance) which measured under each TC＊5.
＊3：Hot water supplying system includes heat pump and storage tank. Each seasons' system performance is measured under summer, winter and intermeditate TCs＊5 in artificial environmental room with meeting standard tapping profile＊4 (IBEC-L mode). Annual system performance is calculated as a heating-load-days＊6 weighted average.
＊4：It includes start time of tapping, tapping duration, tapping temperature and tapping flow rate. There is IBEC-L mode in the typical one.
＊5：TC is a kind of array which include seasonal average ambient dry-bulb temperature, wet-bulb temperature, tapping temperature and out-going temperature from heat pump.
＊6：It is deemed running days of each TCs.
＊7：Better Living Foundation
＊8：the Institute for Building Environment and Energy Conservation in Japan.
＊9：In order to discuss world wide standard of evaluation method for multi functional heat pump (2003/6-2005/6).
＊10：New hot water tapping profile proposed by the book "Design guideline to independence circulation type house" (IBEC supervision).
＊11：Testing procedure is "given" in JRA 4050:2005