New approaches to testing innovative gas heating appliances automatically

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Testing new heating systems like heat pumps (HP) and combined heat and power units (CHP) implies that new requirements have to be met. Small-scale systems have low water flow rates and lower levels of heat and power output and often they can be operated at part load. In many cases, modern heating systems are equipped with smart meter interfaces allowing transmission of internal data and communication to building automation controllers. The new devices will be developed for the world market (mass market), which means they will have to satisfy country-specific conditions and requirements.

For this purpose, E.ON Technologies established its Automatic Test Center (ATC). The test rig is equipped with high-resolution sensors and appropriate piping to be able to reproduce country-specific conditions, e.g. resulting from different gas qualities. The automatic control system is capable of testing equipment using test methods set out in different national and international standards or country-specific heat and power profiles (central heating, hot water production, power demand). The control system is based on pMeter, a software product developed by E.ON, and a programmable logic Controller (PLC) system of Beckhoff.

Introduction

The German government and governments of other countries have set efficiency targets and voiced the need for a greater variety of residential heating systems on the market. As a result, many new appliances have been developed such as small- and medium-scale CHP systems, based on fuel cells, combustion engines or gas turbines, and heat pumps (driven by electricity or gas). Also, integrated solar thermal collectors or PV systems are becoming increasingly popular and, in some countries, have even been included as basic technology in relevant legislation.

This new trend involves increasingly complex heating systems. As a consequence, system evaluation has also become more complex and the requirements to be met in the process are more challenging, calling for new evaluation methods.

Test rig requirements

The requirements to be met by an automatic test rig for testing new heating systems are listed below:

- Evaluation of the heating systems is based on different national standards.
- Appliances are tested with different gas qualities.
- Appliances are operated at part load where a modulating system has been implemented; other systems are tested in a cyclic mode.
- The measurement system must be capable of accurately recording low flow rates and small temperature differentials.
- The system must be capable of processing discontinuous volume flow.
- Appliances generate heat and power.
- Systems may be combined appliances requiring selective control of individual units.
- Own consumption of electricity is a criterion.
- The test run must be highly flexible.
- The system must be designed to support smart meter communication.
- Reproducibility must be high.
- The system must be suitable for 24-hour endurance testing.

Technical description of ATC

To meet all these requirements an appropriate automation system is needed. Data processing was fully implemented on the basis of E.ON's pMeter software. pMeter has been employed in numerous projects for test rigs and field measurements. A Beckhoff programmable logic controller system (PLC) has been used for process interfacing and implementation of a large number of controllers.

Basically, the test rig represents the heating system of a home for the purpose of testing.

A test method needs to be defined in a first step. The standards used are specified and provided by standardization authorities and test institutes. Tests are stationary or dynamic. In stationary tests, appliances are selectively operated in defined operating modes, for example 100% nominal load, 60% part load, or 30% part load. Steady-state conditions are to be identified and analyzed. In dynamic tests, new setpoints for appliance operation are entered into the test rig down to a resolution of a single minute.

In a second step, the test rig is adjusted depending on the test method applied. For example, water piping is switched, the desired type of gas selected, and a cooling method activated. The appliance to be tested will then respond to the heat requirements transmitted by the test rig and start operation. The control system transmits the test rig settings via setpoints to the actuators such as controllers, valves or pumps. Once the starting conditions have been established, closed-loop control circuits are supplied in parallel with setpoint values. A simple spreadsheet structure is used for this purpose that contains in its first column time information and the controller setpoint addresses in the following columns (Fig. 1).

Time	Setpoint t_Flow	Setpoint t_Return	Setpoint Q_heat
00:00	57,47	47,26	70
00:01	57,42	47,26	80
00:02	57,36	47,17	70
00:03	57,32	47,21	90
00:04	57,27	47,14	60
00:05	57,23	47,13	70
00:06	57,19	47,09	90
00:07	57,15	47,04	60
00:08	57,06	46,99	70
00:09	57,02	47,02	80
00:10	56,91	46,82	70
00:11	56,84	46,74	90
00:12	56,75	46,69	60
00:13	56,68	46,56	70
00:14	56,62	46,45	90
00:15	56,52	46,33	60
00:16	56,48	46,24	70
00:17	56,37	46,1	90

Fig. 1: Example of setpoint testing.

If several setpoints have been set, the setpoints may be activated virtually simultaneously and they can be reached independently of each other; this is necessary, for example, where setpoint values have been entered for electricity and heat demand as well as for hot water production.

Actuators and sensors must be adjusted as required to ensure proper functioning. The response times of control runs should be as short as possible. Actuators should therefore best be fitted with direct position feedback. Regarding sensors, high-resolution measurement signals should be provided. A critical factor is, of course, behavior of the test run as such comprised of the pipework with corresponding cross sections and pipe lengths. Water volume influences the dead times of the control run; adjustment is possible by connection of hot water storage devices. Fig. 2 shows the test rig piping diagram.

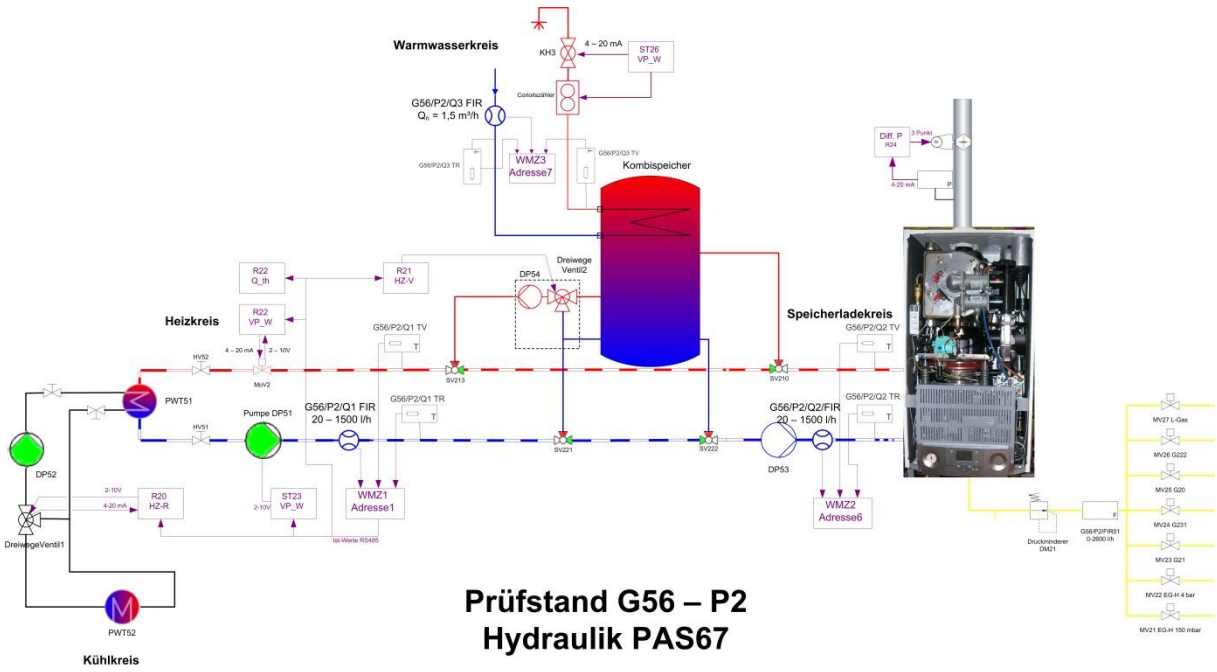

Fig. 2: Automatic test rig piping.

The figure shows several water circuits, basically a heating circuit, a storage charging circuit, a hot water circuit, and a cooling circuit.

Test methods

It is not possible to fully explain all test methods mentioned in this paper; they are too complex and a large number of variants exist. Some relevant curves will be compared below for clarification.

Test method according to DIN 4709

DIN 4709 [1] is used for determining standard efficiency factors for µCHP systems. Once nominal output has been determined, a daily curve consisting of 12 time step is specified for determining standard efficiency, the shortest time step being 0.75 h. The load stages used are 63%, 48%, and 30% of the nominal load, see Fig 3. The different load stages are set via the heat requirements.

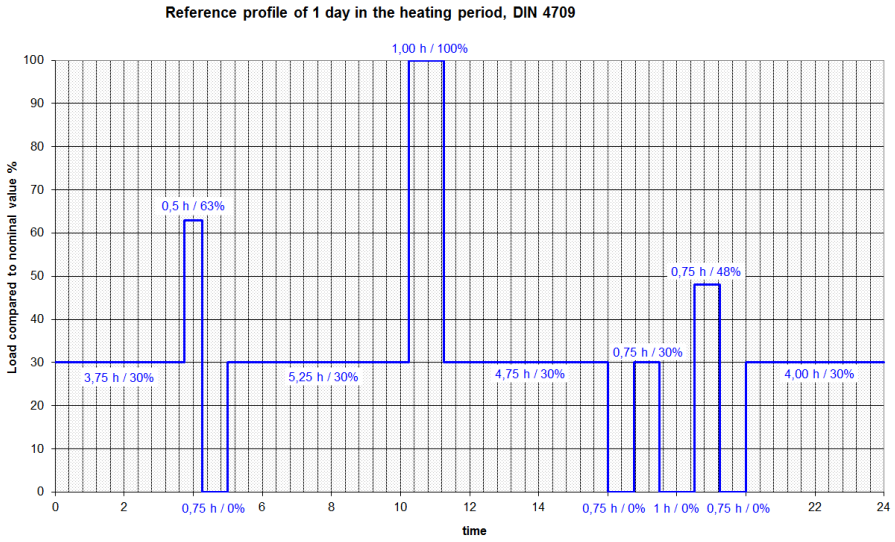

Fig. 3: Test sequence according to DIN 4709.

Test method according to Gaskeur

The next example refers to the Dutch Gaskeur quality standard for determining efficiency and comparing it with the reference data provided by manufacturers. The method proceeds from a CHP unit that is operated in a stationary mode under the following load conditions:

- MP 1: CHP unit and boiler running at nominal conditions
  (MP = Measurement point)
- MP 2: CHP unit running at nominal conditions
- MP 3: CHP unit running at 20% of nominal conditions

More detailed information is provided in documents published by KIWA [2].

Fig. 4 shows the measurement points.

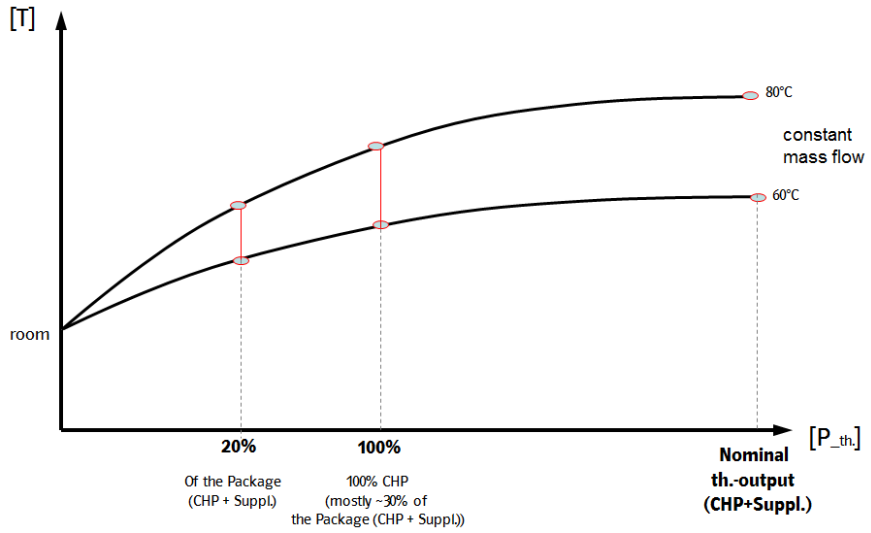

Fig. 4: Test points according to Gaskeur.

Test method according to PAS 67

Another example is test rig testing with respect to British Standard PAS 67 [3]. Fig. 5 shows a bi-modal operation curve. The system is operated at 30% heat load over a period of 24 h. Over a day, two periods are specified for cyclic operation. Efficiencies will be calculated for these periods using a method defined in the standard.

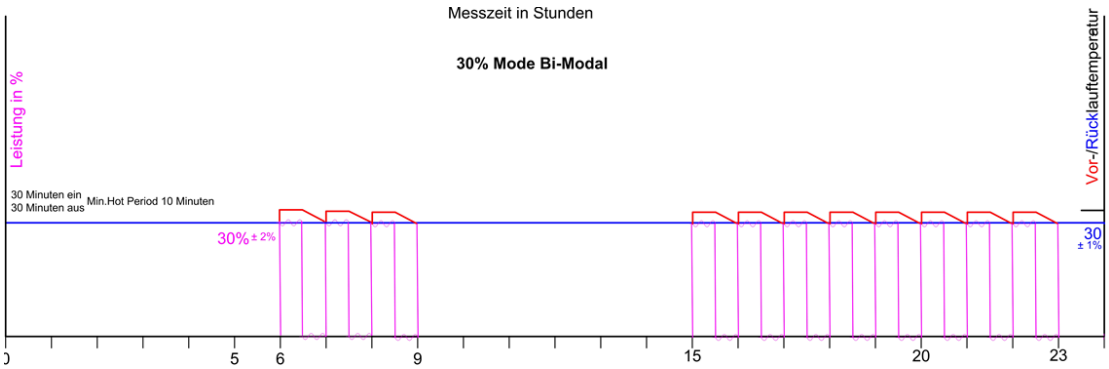

Fig. 5: Test sequence according to British Standard PAS 67.

E.ON-specific test method

The following two diagrams show E.ON tests performed on the test rig. Fig. 6 shows a real heat and power demand profile using a one-minute resolution. Fig. 7 shows a hot water demand profile also using a one-minute resolution.

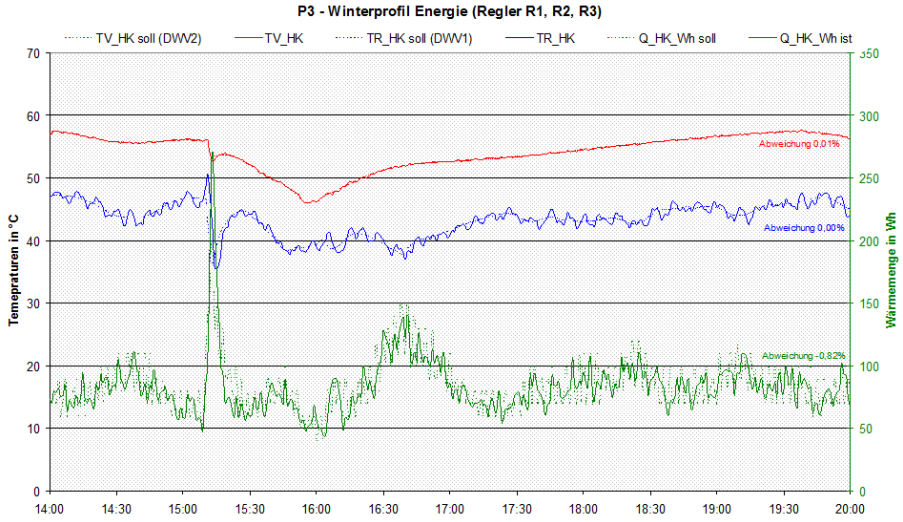

Fig. 6: Winter profile using a one-minute resolution.

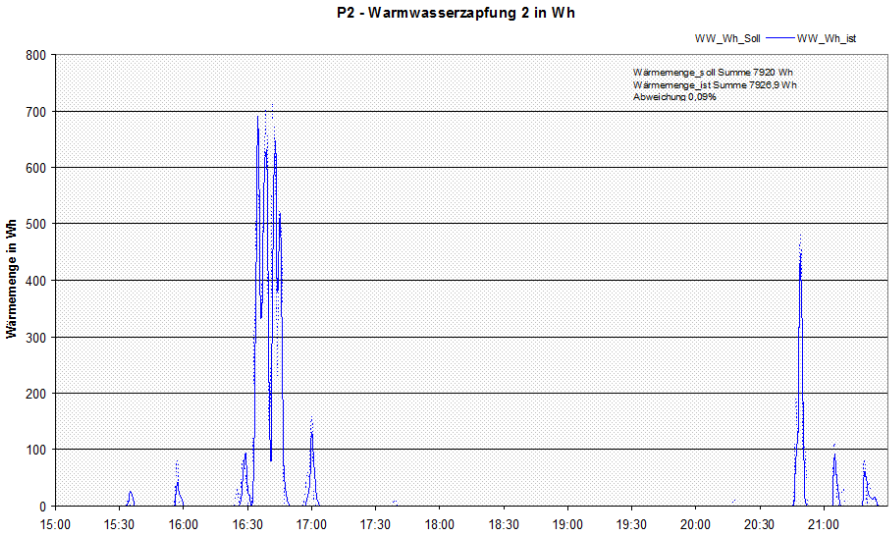

Fig. 7: Hot water demand profile using a one-minute resolution.

General comments / next activities

The ATC investigates and evaluates new domestic heating systems, mainly systems based on combined heat and power units. To ensure a flexible test system, a modular structure was designed allowing scaling to different power ranges.

The ATC provides E.ON with additional, impartial information about heating appliances. Different test standards can be set and compared with each other or tailored to E.ON-specific test scenarios. The results obtained are important for E.ON's business.

E.ON has shifted focus to distributed energy generation. Key issues in this respect are communication, system integration, and handling of available flexibilities including CHP systems. Within cooperation projects, the ATC can support the development of new products for the market.

References

[1] DIN 4709: Determination of the standard efficiency factor for micro-CHP appliances of nominal heat input not exceeding 70 kW, November 2011.

[2] Evaluation Guideline regarding the product certificate for the Gaskeur Label HRe (high efficiency, electricity):2010 for central heating appliances, KIWA Nederland B.V., Feb 1, 2011.

[3] British Standard PAS 67: Laboratory tests to determine the heating and electrical performance of heat-led micro-cogeneration packages primarily intended for heating dwellings, October 2008.