

COMPARISON OF DRAFT ISO- AND CEN-STANDARDS TO DETERMINE EFFICIENCY AND EMISSIONS OF SOLID FUEL BURNING APPLIANCES

C. K. Gaegauf and Y. Macquat
Centre of Appropriate Technology and Social Ecology
Laboratories for Sustainable Energy Systems
Schwengstrasse 12, CH-4438 Langenbruck, Switzerland
Fon +41(0)62-38731-26 or -37, Fax +41(0)62-390 16 40
gaegauf@oekozentrum.ch

ABSTRACT: There are two draft standards for type tests supplying *test methods* and *test procedures* to determine efficiency and emissions of solid fuel burning appliances. The *Comité Européen de Normalisation* (CEN/TC 295, prEN 13240) proposes test methods to determine efficiency by stack loss method and carbon monoxide emissions measured in the flue gases. The *International Organization for Standardization* (ISO/TC 116 SC 3, DIS 13336) suggests the measurement of efficiency and power output by means of a calorimeter room and emissions by total suspended particulates (TSP) in a dilution tunnel. To compare the reliability of the two different test methods, a continuous burning appliance has been tested for efficiency and emissions with wood logs. The tests have been conducted simultaneously according to ISO- and CEN-standards. Applying the same test procedure the test results for efficiency and emissions showed just small variation within the accuracy range of the test set-up. The CEN- and ISO-test methods to determine efficiency and emissions are equivalent provided that the test procedures are identical. Due to different test procedures, data of actual CEN- and ISO-type tests are not comparable. For equivalence of test results, the test procedures need further harmonization.

1 OBJECTIVES

1.1 Introduction

There is a large variety of solid fuel burning appliances available on the market such as cookers, roomheaters, inserts, and boilers. In addition some of these appliances supply hot water to the central heating system. Considering the variety of these appliances, it is important to obtain transparent performance data, not least in view of the consumer protection.

The *Comité Européen de Normalisation* (CEN/TC 295) and the *International Organization for Standardization* (ISO/TC 116 SC 3) presently work out standards for type testing of residential solid fuel appliances.

The CEN/TC 295 draft prEN 13240 (1) is based on measurements of efficiency and flue gas emissions at nominal burning rate. The emission factors are based on concentration measurements of the pollutants in the flue gas. The efficiency is calculated indirectly by the flue loss method taking into account the thermal flue gas losses (sensible heat) and the chemical losses (combustible gases, here as carbon monoxide, CO).

The ISO/TC 116 SC 3 draft ISO/DIS 13336 (2) is based on measurement of the Total Suspended Particles (TSP) in a dilution tunnel, where the flue gas is diluted with ambient air at constant flow (Constant Flow Sampling, CFS). As an option carbon monoxide emissions can also be measured in the dilution tunnel. The power output and efficiency are directly measured in an enclosed, isolated chamber (Calorimeter room), which is cooled with ambient air. With the ISO/DIS standards the appliances are tested at three different burn rates (minimum, medium and maximum burn rate).

1.2 Scope

The objective of this research work is the comparison of reliability of the CEN/prEN and ISO/DIS draft standards by evaluation of a typical example of the continuous burning appliances. Priority is given to the measurement of

efficiency and emissions, whereby judgements shall be made on the reproducibility of the results as well as on the reliability and feasibility of laboratory praxis of both test methods.

The investigations shall supply data and facts as a basis for a possible future harmonization of the CEN and ISO standards.

2 MATERIALS AND METHODS

2.1 Test rig

The *Centre of Appropriate Technology and Social Ecology* has a test rig in its *Laboratories for Sustainable Energy Systems* with the possibility to test burning appliances in accordance with the draft standards CEN/prEN and ISO/DIS (3). The test rig includes a calorimeter room and a dilution tunnel. The CEN/prEN and the ISO/DIS measurements can be realized simultaneous. This allows a comparison of the data and the test methods at the same burn cycle with identical combustion parameters.

2.1.1 Calorimeter room

Power output in the range of 0.1 till 16 kW can be measured in the calorimeter room. The room is designed with little thermal mass and is insulated with a 15 cm thick insulation, corresponding to a thermal resistance of 2.86 m²K/W. The pressure in the room is controlled with a tolerance of ± 0.5 Pa.

The room is vented with air in order to extract the heat released. An additional electrical heater and a temperature control keep the room at constant temperature. This compensation method excludes inaccuracies due to heat losses of the construction. A very accurate weighing scale with an accuracy of ± 10 grams allows the measurement of the burn rate.

2.1.2 Dilution tunnel

Flue gas and ambient air are mixed in the *dilution tunnel* at constant flow conditions. Mass flow of emissions are known at any time of the burn cycle and emissions factors can be determined, based on weighted mean value calculations.

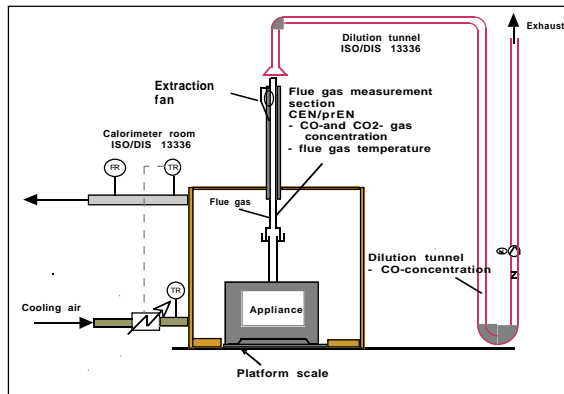


Figure 1: Test rig to test appliances in accordance with the draft ISO/DIS and CEN/prEN test standards.

2.1.2 Set-up for CEN/prEN test standard

The measurements of flue gas temperature, carbon dioxide (CO₂) and carbon monoxide (CO) are used to determine efficiency and emissions according to CEN/prEN. The measuring section in the flue duct is designed in accordance with CEN/prEN test standards. The efficiency is based on the flue loss method taking into account the thermal and chemical losses in the flue gas.

2.1.3 Test appliances

For the evaluation following typical example of a continuous burning appliances was used:

Manufacturer	Jøtul, Norway
Type	3R (CB)
Combustion chamber dimensions (width x length x height)	46 x 29 x 23 cm
Usable fuel chamber volume	29 liter
Weight of the appliance	125 kg

2.2 Tests

2.2.1 Test program

Extensive measurements of power output, efficiency and CO-emissions on the before mentioned appliance were the emphasis of the tests. The program included measurements at nominal burn rates in accordance with CEN/prEN 13240 and at three different burn rates in accordance with ISO/DIS 13336.

Special attention was given to following aspects:

- Direct measurement of the efficiency in the calorimeter room
- Determination of the efficiency by the flue loss method
- CO emissions measurement in the dilution tunnel
- CO emissions measurement in the flue duct

In total 8 test cycles were performed, each comprising 2 to 3 burn cycles used for conditioning, followed by 3 to 4 consecutive burn cycles for the measurements. The burn rate was the key process variable and was set by the combustion air control device.

All measurements for the comparison of CEN/prEN and ISO/DIS test methods were done simultaneously in order to exclude possible deviations due to parameter variations.

2.2.2 Test procedure

As foreseen in both draft standards the burn cycles were determined with the weighing scale. The test cycle started with the refueling and ended as soon as the residual ember bed had obtained the starting weight, corrected with the ash of the burnt fuel. The time elapsed corresponds with one burn cycle. The data of an entire test cycle are calculated from the mean values of all performed burn cycles. The ash content was assumed with 0.5 % of the fuel mass.

The ISO/DIS standard requires three burning cycles with identical burn rates ($\pm 15\%$) per test. Accordingly, the adjustment of the combustion air remained constant during the complete test.

The tests were performed with natural draught in accordance with ISO/DIS.

All test parameter were continuously monitored, registered and evaluated. The combustion period for each fuel load was between 0.8 and 1.7 hours, depending on test series.

Figure 2 shows the power output of a test run.

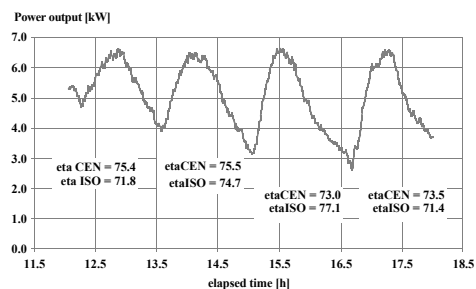


Figure 2: Course of the heat release to the calorimeter room over four burn cycles. Efficiencies are indicated according to direct measurement (ISO/DIS) and flue loss method (CEN/prEN).

3 RESULTS

3.1 Efficiency according to CEN/prEN and ISO/DIS

The efficiencies evaluated by both methods vary only marginal at all tested burn rates. The maximum deviation is 2.7 % points, corresponding to a relative deviation of 3.8 %. The differences are within the accuracy of the test methods.

Table 2: Comparison of test results according to ISO/DIS and CEN/prEN. Survey of combustion parameters and efficiencies.

Test cycle	Burn rate [kg/h]	Excess air ratio [-]	Flue gas temperature [°C]	eta _{CEN} [%]	eta _{ISO} [%]
1	2.62	2.48	314	69.0	68.0
2	2.18	3.08	272	67.7	70.4
4	1.92	2.49	265	73.2	74.3
5	3.92	2.95	405	56.6	56.2
6	2.82	2.44	366	66.0	68.3
7	2.11	2.44	271	73.7	74.6
8	2.07	2.63	268	72.6	71.9
9	2.49	2.74	311	69.6	67.7

The mean values of all measured efficiencies of ISO/DIS are in the average 0.4 % points higher than those of CEN/prEN.

The standard deviation of the ISO/DIS method within an entire test cycle comprising 3 to 4 burn cycles is higher, typically 6.25 % compared to the flue loss method according to CEN/prEN, which is typically 0.93 %.

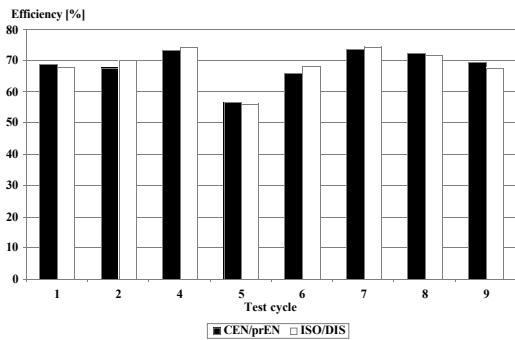


Figure 3: Comparison of efficiencies measured according to ISO/DIS and CEN/prEN.

3.2 Emission factors according to CEN/prEN. and ISO/DIS

Comparing the different measuring methods the emission factors (in grams CO related to dry fuel) vary $\pm 3\%$. This variation is within the accuracy of the measuring methods. The emission factors averaged over 3 to 4 burning cycles are shown in Table 4.

Table 4. Emission factors according to ISO/DIS and CEN/prEN.

Test cycle	Burn rate kg/h	Exc. air ratio [-]	CEN/prEN		ISO/DIS	
			Efact _{CO/kr} (g/kg)	Efact _{CO/krWh} (g/kWh)	Efact _{CO/kr} (g/kg)	Efact _{CO/krWh} (g/kWh)
1	2.62	2.48	27.2	8.4	29.7	9.0
3	2.16	2.45	30.2	9.0	34.3	9.5
5	3.92	2.95	15.3	5.8	14.8	5.7
8	2.07	2.63	46.9	13.7	44.2	13.0
9	2.48	2.75	30.5	9.4	29.1	9.2

The emission factors based on heat output, which take into account the efficiency figures do vary just very little.

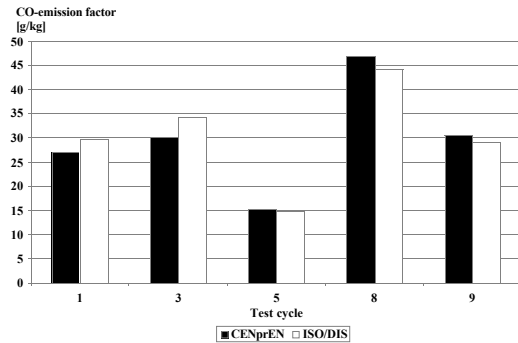


Figure 4: Comparison of the emission factors determined according ISO/DIS and CEN/prEN based on heat output.

The mean values of all emission factors of ISO/DIS are in the average 1.2 % higher than those of CEN/prEN.

4 DISCUSSION

Based on the investigations of a typical continuous solid fuel-burning appliance the test methods of ISO/DIS and CEN/prEN for determination of efficiencies and emission factors can be considered as equivalent.

The test set-up of ISO/CEN is easily traceable. The ISO/DIS results are weighted mean values over a burn cycle with its changing parameters. Even though the ISO/DIS test method does not show any advantages in practice over the CEN/prEN test method. The variation of the results is within the accuracy of both methods.

In practice it seems that the CEN/prEN test method is less demanding from a technical point of view. The method is tolerant to parameter variations. Possible errors in the temperature differential measurement between ambient air and flue gas do not effect the results very much, because of the relatively large temperature differences. Where as the calculations of the efficiencies according ISO/DIS are sensitive to errors in measurements of temperature differences and flow in the calorimeter room. In order to avoid faults due to different heat accumulation in the appliances during a single burn cycle, the end of the burn cycle has to be observed very accurately applying the ISO/DIS test method.

With small CO emissions the measurements in the dilution tunnel result in very low concentrations. Possible problems with the accuracy of the instruments cannot be excluded.

The dilution tunnel is very suitable for the measurements of particulates, which is proposed by ISO/DIS.

The hardware requirements are somewhat higher for ISO/DIS. Especially the expenditure for the calorimeter room is of importance.

5 CONCLUSION

For the first time the test methods of international and European type test standards, presently available as draft, have been compared with simultaneous measurements with a typical continuous solid fuel burning appliance.

The measurements show that the *test method* with direct determination (calorimeter room) and the indirect determi-

nation (flue gas) can be considered as equivalent. The same can be concluded for the measurements of emissions in the flue gas and the dilution tunnel.

Provided that the *test procedures* are identical for both standards, equivalent results for efficiencies and emissions are obtained.

In view of a possible harmonization of the standards, it is necessary to perform extensive examinations of other typical continuous solid fuel appliances. It is suggested that the results shall be confirmed with round robin tests in order to check the reproducibility and transferability of the results.

With a harmonization of the ISO/DIS and CEN/prEN test set-ups and test procedures the equivalence of the test methods would be fulfilled. If this equivalence can be demonstrated, the ISO accepts with their *Equivalence of Methods* other test standards for determination of emissions and efficiency. At the moment the results from the ISO/DIS and CEN/prEN test standards cannot be directly compared, due to differences in test procedures.

The now available comparative examinations of determination methods for efficiency are a meaningful basis for a possible future harmonization between the ISO and CEN test standards. In view of manufacturers, traders and consumers, it would be very desirable to have harmonized international type test standards.

ACKNOWLEDGEMENTS

The Swiss Federal Office of Energy (BFE) funded the investigations.

REFERENCES

- [1] CEN/prEN 13240, Final draft, Residential solid fuel burning appliances, Roomheaters, Requirements and test methods, European Committee for Standardisation (1999)
- [2] ISO/DIS 13336, Draft International Standard (DIS), Solid fuel burning appliances - Test method for determining power output, efficiency and flue gas emissions, International Organization for Standardization (1997)
- [3] C. Gaegauf, Y. Macquat, Die europäischen und internationalen Prüfnormen für Feuerstätten, Bundesamt für Energie (BFE), Switzerland, Final report November 1999
- [4] P.E. Denyer, D. Wilkins, Further investigations into the use of a flue loss method for measurement of the thermal efficiency of wood-burning roomheaters, CRE Group Ltd., Gloucestershire GB, F&AT Report no. 70 (1994)
- [5] E. Karlsvik, ed. al., Round robin test of a wood stove - emissions, International Energy Agency (IEA), Report February 1995