DETERMINATION OF EFFICIENCY IN COURSE OF GUARANTEE MEASURMENTS

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(*Received* October 2005*, accepted* January 2006)

ABSTRACT
It is the objective of this thesis to take into account thermal balance of circulating fluidised bed combustors (CFBC), aiming at efficiency assessment, as regards standards, CSN 07 0302, and DIN 1942. It points to differences between calculations along these two different standards, concerning the solution of problems like different comparative temperatures, to which the calculation of physical losses is related to, varying calculation of mean thermal capacity, or problem of electrical motors input.
This article is based on the project GA 617 50 11 solving – „Combine combustion of coal and biomass in fluid boilers".

KEYWORDS: efficiency, boilers, head losses, combustion

1. COMPARISON OF CALCULATIONS ACCORDING TO THE ČSN AND DIN STANDARDS

When the equipment is handed over for operation, it is necessary to verify if the boiler meets parameters that have been guaranteed. The most important thing is if the equipment meets the guaranteed parameters. In the case of large power engineering units this efficiency is determined by indirect methods according to the Czech or German standards (ČSN 07 0302, 1996 and DIN 1942, 1994). The following standards are of concern:

- The Czech standard ČSN 07 0302 „Acceptance Tests of Steam Boilers", issued in October 1996 (herein referred to as „ČSN")
- Deutsche Norm DIN 1942 „Abnahmeversuche an Dampferzeugern", February 1994.
- (herein referred to as „DIN").

With regard to the fact that these standards differ not only as far as a method of calculation is concerned, but also in respect to initial conditions, the resulting efficiency may differ as well as. Which standard to use and in what form, it depends on a contract. The differences relate primarily to the below stated points:

1.1. RELATIVE TEMPERATURE

It is an agreed temperature to which relates the calculation of physical losses. The DIN standard takes into consideration the relative temperature of 25 ^{o}C. The ČSN standards give the temperature of 20 ^{o}C as the relative temperature. The difference of 5 ^{o}C in this temperature to means also the difference in loss by physical heat of waste gases. This difference is around 0.22% at outlet temperature from the stack at 100 ÷ 200 ^{o}C.

1.2. ELECTRIC ENERGY

The DIN standard describes electric energy needed to drive the recirculating ventilator fans, circulating pumps and crushers or mills.This energy belongs to energy supplied which does not depend on the fuel quantity. In the majority of cases, the contracting parties make a mistake when they include the consumers into the calculation that do not enter the system. There is involved electric energy of flue-gas ventilator fans (that operate beyond the boundaries of the system) and air ventilator fans (the inlet energy is included in increased enthalpy of compressed air). In the case of minor electric consumers, the data available are taken, for example, from electric substations or their effect is neglected.

The ČSN standard does not take into consideration the electric energy to determine the efficiency. The effect of electric energy is not very significant in terms of the order of the hundreths of percent. It should be mentioned that the terminal power of consumers is not involved but the coupling power of consumers is of concern. The mentioned output will be smaller by the electric motor efficiency and/or by the efficiency of the gearbox or coupling.

1.3. SPECIFIC HEAT CAPACITIES

The calculation of specific heat capacity of waste gases according to ČSN differs from the calculation according to DIN. At the same time, these calculations differ from thermodynamic tables by Ražněvič that

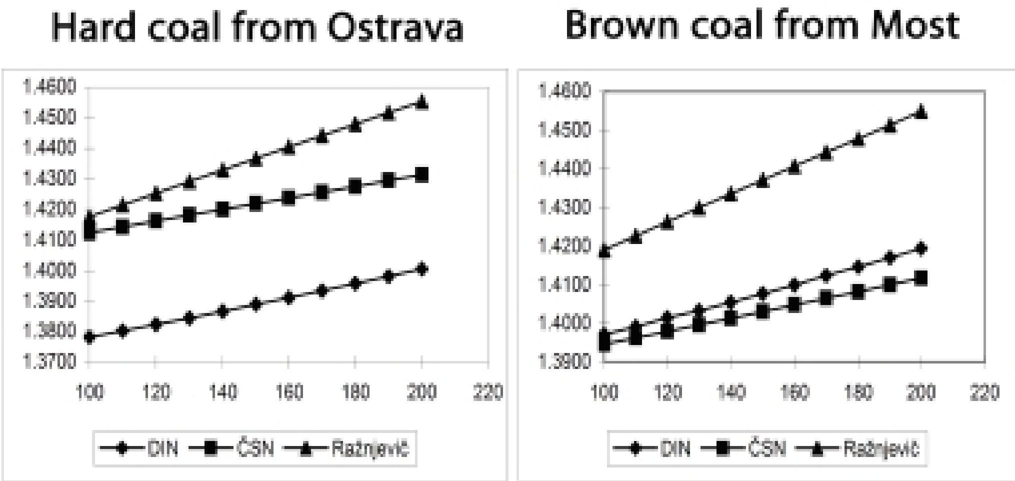

Fig. 1 Comparison of specific heat capacities determined according to values given in the tables, according to ČSN 07 0302 and according to DIN 1942. (on axis x – temperature of waste gases (^oC), on axis y - c_{sp} ($kJ.m^{-3}.K^{-1}$).

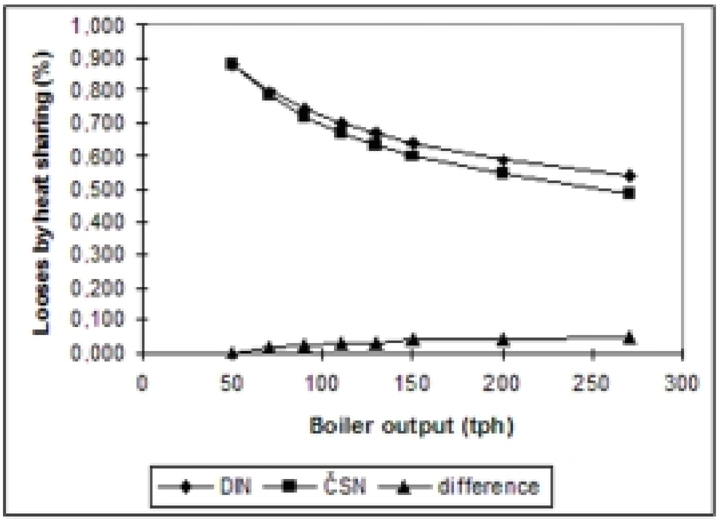

Fig. 2 Comparison of looses by heat sharing with the environment according to ČSN and DIN at various rated outputs of the boiler.

are sufficiently accurate and that are widely used in the field of power engineering. We have converted the values cs determined according to DIN to the same values ($kJ.m^{-3}.K^{-1}$).

The difference between DIN and the table values according to Ražněvič (1984) is smaller than between ČSN and the table values for brown coal (see Fig. 1), while for hard coal from Ostrava the calculation according to ČSN is very similar to that given in the tables according to Ražněvič. With the increased temperature the differences become greater between the table values and those calculated which affects the efficiency.

With regard to stated results, we would speak for simplification of calculation. The calculation according to ČSN is very complicated if one does not use the computer, while the accuracy of results which it gives is comparable with the accuracy, for example, according to DIN (Matouš and Teyssler, 1998).

1.4. LOSSES BY HEAT SHARING WITH THE ENVIRONMENT

The other differences relate to the determination of losses by sharing with the environment, for example, for brown coal there is given the relationship for calculation of losses by sharing with the environment:

$$\check{C}SN: \quad \xi_{svj} = 3.5 \cdot \dot{Q}_{vyrj}^{-0.35} \cdot 10^{-2} \quad (\%)$$

$$DIN: \quad \dot{Q}_{st} = 0.0315 \cdot \dot{Q}_N^{0.7} \quad \text{(MW)}$$

Where:
Q_{vyj}, Q_N - thermal rated output of the boiler in MW.

The difference is in the method of marking. It is apparent from the Fig. 2 that the coincidence of calculation according to ČSN and DIN standards is better for lower outputs. The deviation increases also with the increasing output.

The deviation is 5% for greater outputs. After investigations of heat losses by heat sharing with the environment based on the measurement of surface temperatures carried out on the fluidised-bed boilers in the Czech Republic by the Department of Power Engineering, Technical University of Ostrava, and by calculation of heat flows, it was found out that real losses on fluidised-bed boilers with non-cooled cyclones were significantly greater that the values described in ČSN and DIN.

2. THE EFFECT OF RECIRCULATION OFWASTE GASES ON HEAT BALANCE

The recirculating waste gases in the fluidised-bed boilers keep a fluidised-layer in elevation jointly with the primary air. The inclusion of recirculating waste gases into heat balance is very problematic and it depends on the determination of the so called „boundary limits“ of the system. It is more convenient to keep the entire recirculation inside the boundaries of the system for which the efficiency is to be determined. In this way we may eliminate problems because the recirculating waste gases that enter and leave the system may affect significantly the boiler efficiency.

The recirculating waste gases are taken away behind the heat-exchange surfaces and behind the collector and they are returned by the recirculating ventilator fans back into the combustion chamber to support the production and maintenance of fluidisation. According to ČSN the fluidisation must be taken into account.

A certain quantity of oxygen comes into the boiler with recirculating waste gases, which participates in burning process. Thus the composition of air delivered to the burning zone changes, thereby changing the specific heat capacity and enthalpy of the mixture of air – waste gases. However, there exists an opinion that we must take into consideration the recirculation of waste gases at least from the viewpoint of power energy. With the recirculating waste gases the heat enters the combustion chamber:

$$\Delta Q_{sr} = \Omega_{sr} . \bar{c}_{sr} . (t_{sr} - t_0) \quad (\text{W.kg}^{-1}) \quad (1)$$

Where:
Ω_{sr} - the quantity of recirculating waste gases per 1kg of fuel ($\text{m}^3.\text{kg}^{-1}$),
$\bar{c}_{sr}$ - specific heat capacity of recirculating waste Gates ($\text{m}^3.\text{kg}^{-1}$).

This heat will be added to heat supplied to the system with one kg of fuel, which would mean by itself the increased efficiency. In addition, we must take into consideration the increased volume of waste gases Ω_{sr}, which results again in increased losses by physical heat.

The volume of waste gases in the boiler will be:

$$V_{sr} = V_s + \Omega_{sr} \quad (\text{m}^3.\text{kg}^{-1}) \quad (2)$$

The Fig. 3 shows the efficiency of two identical boilers with similar fuel. The boiler is calculated according to DIN with a 10% recirculation (which is the usual quantity for fluidised-bed), with a 5% recirculation and without recirculation. The efficiency of boilers with calculation according to the system boundaries (a) (see Fig. 4) will decrease by approx. by 0.5 % in comparison with the calculation without recirculation effect, as shown by the system boundaries (b). Fig. 3 shows the dependence on recirculation of waste gases for two identical boilers with similar fuel. With a 10% recirculation the efficiency loss is approx. 0.5% which is clearly very much for the boiler output above 90%. However, the recirculation may be even 20 % (then the efficiency is decreased by up to 1 %).

So, it is apparent that in the case of inappropriately chosen boundaries, especially for calculation of fluidised-bed boilers, it can be very unfavourable for the suppliers or customers and the efficiency may be affected even by one percent. In the majority of cases the recirculated waste gases are

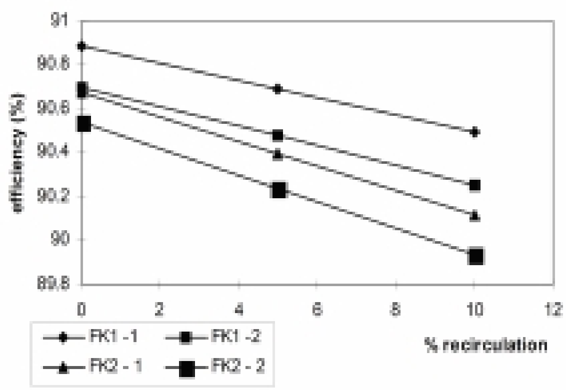

Fig. 3 Dependence of efficiency on percentage of recirculated waste gases.

included in the boiler system in a way as described in DIN (Kadlec and Kolat, 1999).

3. THE EFFECT OF ASH BALANCE ON HEAT LOSSES

The determination of ash balance ranks amongs the crucial problems for the determination of efficiency by indirect method. The following solid residues are taken away during operation :

- Ash entrapped in the cyclones or released from

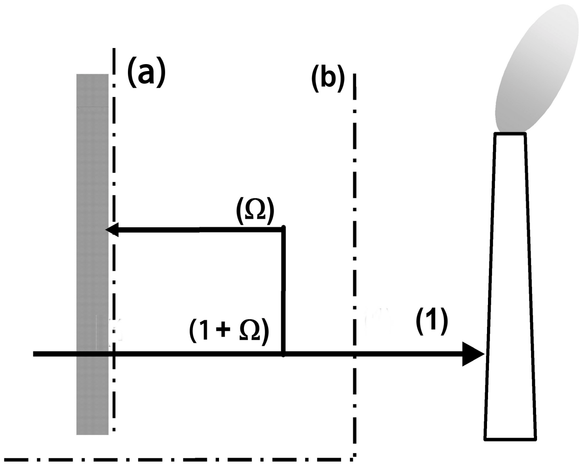

Fig. 4 Chart of inclusion of recirculation in system boundaries **a)** accord. to ČSN, **b)** accord. to DIN.

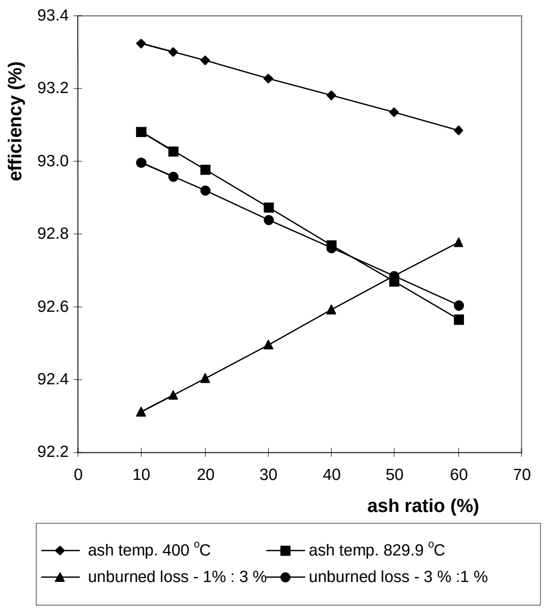

Fig. 5 Effect of ratio ash : fly-ash on boiler efficiency (accord. to DIN).

the fluidised layer via a fluidised ash cooler, identified as the bed ash

- Fly-ash (herein referred to as fly-ash) entrapped in the electric collectors (herein referred to as „EO") or on textile filters.

It is very difficult to determine precisely the quantity of ash taken away from individual outlets of the real equipment.

The inaccurate determination of ratios affects the accuracy of calculation of enthalpy of solid residues and also the loss due to insufficient burning. A ratio of bed ash and fly-ash depends both on a type of boiler and its design and on operated output. The standard specifies a portion of fly-ash (10 ÷ 30%) and a portion of bed ash (even 55 ÷ 80%). In the case of real facilities there a ratio of bed ash and fly-ash varies from 50 % : 50 % up to ratios of 15:85.

With the same temperature of bed ash and fly-ash (120 °C) we have carried out a conversion to the ratio of unburt matter of bed ash – fly-ash 1% : 3% and 3% : 1% (Kadlec, 1996a, b).

An error is apparent from Fig. 5 which we may make provided that the ratio of bed ash : fly-ash is incorrectly determined. Provided that it is not found out by direct measurement of ash quantity, one must reckon with a significant error (approx. 1%) with which the particular calculation of efficiency can be encumbered. Already in stage of the boiler construction one should take into consideration how to determine somehow the quantity of ash or fly-ash.

4. CONCLUSION

Our considerations are based on the knowledge and experience gained in course of guarantee tests on various types of boilers, especially on the fluidised-bed boilers with a circulating fluidised layer. With regard to the perspective of integration of the countries in the EU, we should take the above-mentioned knowledge into account and to attempt to integrate our standardisation activity into the EU legislation. Moreover, any observer may appreciate a reliable calculation of heat balance and heat consumption of the boiler.

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