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Lower heating value

Laboratory of metrology

(M-8)

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1. PURPOSE OF THE EXERCISE

The purpose of the exercise is to acquainted with the method of determination the high heating value and the lower heating value of gaseous and liquid fuels, using the Junkers calorimeter, as well as a practical determination of these values.

2. INTRODUCTION

Types of fuels could be distinguish a natural and synthetic fuels, as well as a gaseous, liquid and solid fuels. Liquid and gaseous fuels (in comparison to solid fuels) have many advantages. The most important are: 1) easy and fast transmission through pipelines over long distances without reloading and loss; 2) high lower heating values; 3)easy and complete combustion at low excess air ratio.

The advantages include the combustion of residues such as the bottom ash, the fly ash and the coke breeze, so that the heating surfaces and the combustion chamber are always clean. Easily setting of the fuel supply, as well as obtaining the high thermal loads in the combustion chamber is possible by the use of gaseous fuel.

3. HIGH HEATING VALUE AND LOWER HEATING VALUE

The most important feature of all fuels is its lower heating value. In the estimation of usefulness of solid fuel, the many of quantities are also taken under consideration, such as: the high heating value, the water content, the combustible volatiles, an ash, the granularity characteristics, the ability of the combustion and the melting temperature of the bottom ash.

The **high heating value - *HHV*** (W_g - in polish nomenclature) is the amount of heat generated with the total and complete combustion of fuel, at assumption that the combustion products are cooled to the initial temperature of the components involved in the combustion process, and the water condenses.

The **lower heating value - *LHV*** (W_d - in polish nomenclature) is numerically equal to difference between the high heating value and the amount of heat required to the separation of water contained in fuel, and also the water produced in the hydrogen combustion process. In technique, the water vaporization heat at 0 °C is 2500 kJ/kg.

$$LHV = HHV - 2500 \cdot m_w \qquad , \text{kJ/kg}$$

where: m_w - is whole of amount of water, produced by the combustion of 1 kg of fuel, kg.

Another form of this equation is used:

$$LHV = HHV - 25 \cdot (8,94 \cdot h + w) \quad , \text{kJ/kg}$$

where: w - is percentage concentration of water in fuel,
   h - is percentage concentration of hydrogen in fuel.

The high heating value and the lower heating value could be determined indirectly, based on results of elementary analysis of the fuel.

4. DETERMINATION OF THE LOWER HEATING VALUE OF GASEOUS AND LIQUID FUELS

The Junkers calorimeter (Fig. 1.) is the most convenient equipment to the performing of measurement of the lower heating value of gaseous fuels and light liquid fuels with the low boiling temperature.

The principle of the measuring method is based on the measurement of the temperature increase of the known mass of cooling water with the weak intensity, flowing through the overcoat of the calorimeter. The water is heated by the flue gases produced in the combustion process a known amount of fuel burned in a continuous manner.

Essential elements of calorimeter are:

- a special gas burner for combustion,
- a combustion chamber surrounded by a double-walled cylindrical water jacket,
- exhaust pipe system directing the flue gas through the water jacket to the outlet,
- cylindrical housing the nickel-plated from the outside to reduce heat transfer by radiation.

The cooling water from the water supply network enters to the overcoat, by the overflow vessel (1), the valve A and the cylindrical chamber, in which the temperature sensor (7) is located.

The thermometer shows the temperature of the water at the inlet into the calorimeter. The cooling water flowing through the jacket, receives heat generated by combustion a known amount of fuel. Next the water is leaving the water jacket, and flows through the mixing device and the second chamber, in which the temperature sensor (8) is located, to an overflow vessel (2). The thermometer (8) shows the temperature of the water heated, at the outlet of calorimeter. The water amount, which flowed through the overcoat from the beginning time to the moment of completion the measurement, is directed to the tared vessel (7), by the turn of cock below the overflow. Then this water is weighted.

The task of the overflow vessels (1 and 2) is to provide the constant pressure, and therefore the steady cooling water flow through the water jacket, independently of the pressure changes of the water from the water supply network. The water flow is controlled by the valve at the inlet in that way, so that the arithmetic mean of values of the inlet and outlet water temperature was equal to the ambient temperature. Optimal accuracy of the measurement is obtained, by the temperature difference of 6-12 °C. The thermometers scale (7 and 8) is with accuracy of 0,1 °C. These thermometers are located next to one another, what is helpfully in the omitting an amendment of protruding mercury column. Analyzed gas is supplied to the burner through the gas meter and a special bell-apparatus. This appliance provides constant pressure, and therefore a steady flow of burned gas.

Flow amount is regulated by two sinkers, with watching indications of differential pressure gauge, at the same time. The air supply to the burner is controlled so as to tested the gas could be completely combusted (i.e. the flame without the blue color). The outlet of the burner is located in the combustion chamber of the water jacket. In order to control the flame, the mirror is used. This make possible the regulation of the air supply. The gas combustion in the glowing flame (reducing flame) is incomplete, and also causes secretion of soot on the calorimeter walls.

The gas behind the gas meter and the bell-apparatus, could be considered as a saturated vapor in the room-temperature. The flue gases hovers upwardly in the first combustion chamber and then fall in down through the tubes passing through the water jacket to the lower chamber and then are discharged by the outlet (5). In the lower chamber, the water condensed from the flue gas is discharged by the outlet (6). This water is gathered into the tared vessel and then is weighed. The temperature of flue gas discharged from the calorimeter is lower than the ambient temperature of about few degrees of Celsius. So the resulting error is small and negligible in the calculations.

5. METHODOLOGY OF MEASUREMENT

The order of the procedure at measurement is as follows:

1) turn on the cooling water circuit flowing through the calorimeter,

2) open the gas valve and light the Bunsen burner and adjust the amount of air flowing to the burner that way, so the gas would be burned as in the complete and total combustion,

3) adjust the streams of cooling water and condensate by the valve at the inlet,

4) weighed empty and dry vessels for receiving condensate and cooling water,

5) for each complete cycle - offside fixed dose of fuel:

   - read the water temperature at the inlet of the calorimeter,
   - read the water temperature at the outlet of the calorimeter,
   - read the flue gas temperature at the outlet of the calorimeter,
   - read the temperature of gas in gas meter,
   - read the over-pressure in the U-pipes, located on the gas meter.

6) after the nine cycles, weighed the vessels with the condensate and the cooling water,

7) repeat the operations of points 5. and 6.,

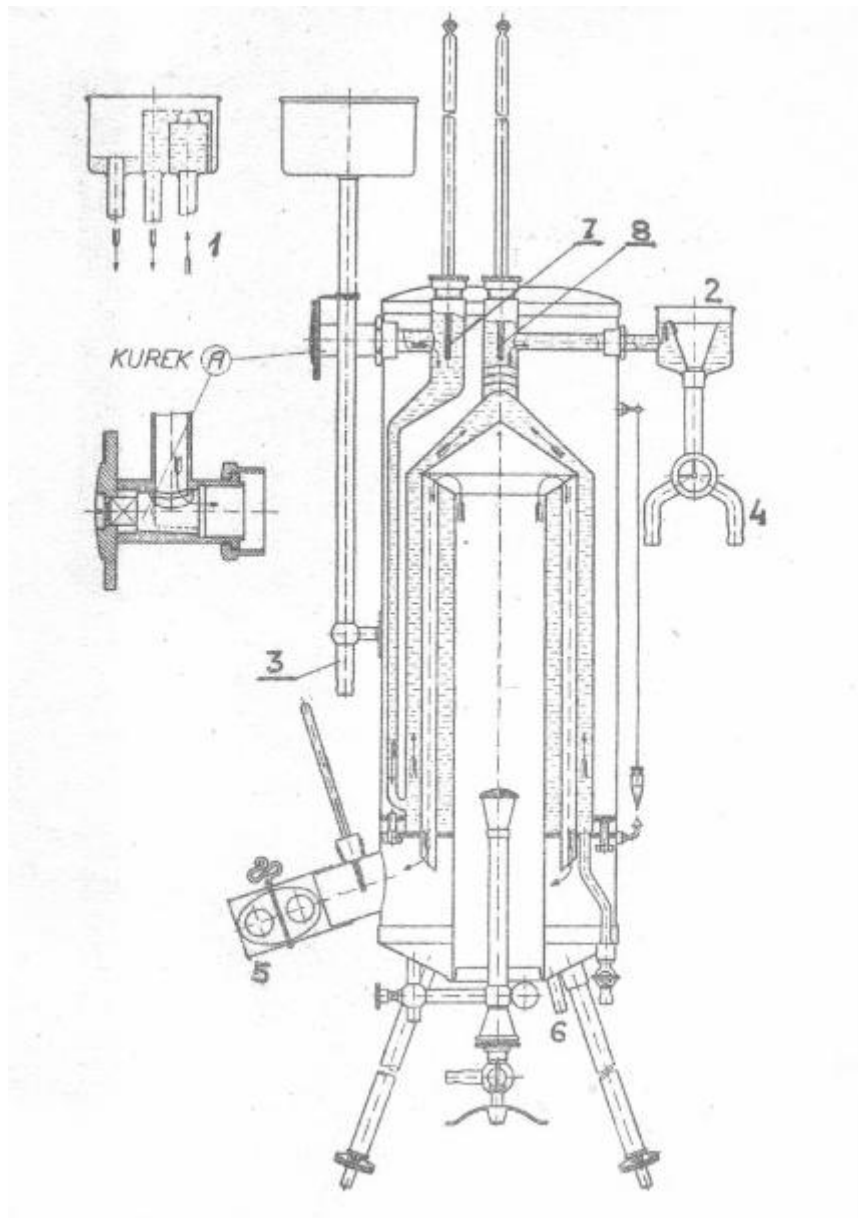8) read the values of the ambient temperature and pressure of the barometer.

Fig. 1. The scheme of Junkers calorimeter

1 - overflow of water supplied to the calorimeter
2 - overflow of water discharged out the calorimeter
3 - water supply to the calorimeter
4 - water discharge from the calorimeter
5 - flue gas outlet
6 - tube to drain the water from the flue gas
7 and 8 - temperature sensors

6. DEVELOPMENT OF MEASUREMENT RESULTS

Symbols:

t_0 - ambient temperature, °C

t_{w1} - temperature of water supplied to the calorimeter, °C

t_{w2} - temperature of water at the outlet of the calorimeter, °C

t_s - flue gas temperature at the outlet of the calorimeter, °C

t_g - the temperature of the combustible gas, **15 °C**

h_g - under-pressure of the measurement gas, mmH$_2$O

b - condition of the barometer, mm Hg

h_p - water vapor pressure, mm H$_2$O

V_g, V_{gk} - the actual amount of wet burned gas, m^3

G_w - amount of water from the calorimeter, kg

G_k - amount of condensate, kg

HHV - the high heating value, kJ/m^3

LHV - the lower heating value, kJ/m^3

"av" - the average value

The condition of the barometer at the pressure of 1 at and different mercury temperature values:

t, °C	0	15	20	30
b_1	733,5	737,4	738,0	739,3

The reduction of the barometric pressure to the temperature of 0 °C:

$$b_o = \frac{b}{b_1} \cdot 735{,}5 \qquad , \qquad \text{mmHg}$$

measurement read	t_1, °C	t_2, °C	t_s, °C	G_w, kg	G_k, kg
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
Total:					
Average:					

The saturated vapor pressure h_p for different temperature t_o:

t , °C	h_p , mmH₂O	t , °C	h_p , mmH₂O
0	62,26	17	197,55
5	88,96	18	210,42
10	125,20	19	224,02
11	133,84	20	238,40
12	143,01	21	253,56
13	152,69	22	269,56
14	162,97	23	286,44
15	173,86	24	304,23
16	185,37	25	322,98

Measuring the amount of burned gas:

measurement read	the initial indication of the gas meter V_g , m³	the final indication of the gas meter V_g , m³	the difference of indications of the gas meter V_g , m³
I			
II			

The high heating value: $$HHV = \frac{G_w \cdot (t_{2,av} - t_{1,av}) \cdot 4,19}{V_g}$$, kJ/m³ the wet gas

The lower heating value: $$LHV = HHV - 2500 \cdot \frac{G_k}{V_{gk}}$$, kJ/m³ the wet gas

Reduction of the high heating value and the lower heating value of the gas to the dry and normal conditions:

The reduction coefficient: $$R = \frac{273}{273 + t_g} \cdot \frac{h_0 + \frac{(h_g - h_p)}{13,5}}{760}$$, -

$$HHV_n = \frac{HHV}{R}$$, kJ/m_n^3 $$LHV_n = \frac{LHV}{R}$$, kJ/m_n^3

7. THE REPORT SHOULD INCLUDE:

- title page (date of the exercise and its number, names of the participants),
- short introduction,
- measuring table,
- development of measurement results (exemplary calculations)
- summary (conclusions)