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FUEL CONSUMPTION FOR THE ATTACHMENTS OF STEAM GENERATOR INSTALLATIONS OF TECHNOLOGICAL TRANSPORT

The article is devoted to the analysis and specification of fuel consumption for the operation of the attachment of steam-generating instalations of the PPUA type, which actuate the steam boiler that produces the steam-water mixture. It is performed the analysis of information sources on fuel consumption for the operation of the heat generator and unreasonable overspending. There were described disadvantages in calculating fuel consumption per hour of operation of the steam-generating installation. Based on the analysis of normative data on fuel consumption accounting per hour of operation, a calculation model was proposed to calculate the actual fuel consumption for the work performed on the preparation of the steam- water mixture in different modes of operation of the installation. During the calculation, it was proposed to calculate the power losses of the internal combustion engine to drive the attachment during their operation in different modes of preparation of the steam-water mixture.

The main purpose is to determine the power loss of the internal combustion engine for each device that ensures the operation of the heat generator and the total power lost, find the amount of fuel to perform the steam-water mixture in the selected mode of operation. Knowing the total power loss and specific fuel consumption for a given engine, it is possible to determine the actual fuel consumption in the selected mode of operation of the steam generator.

The proposed will allow operators to get rid of unreasonable fuel costs to obtain a steam-water mixture with the necessary parameters for performance, pressure and temperature.

Keywords: steam generator, attachments, fuel consumption, internal combustion engine (ICE), power losses, steam-water mixture.

INTRODUCTION

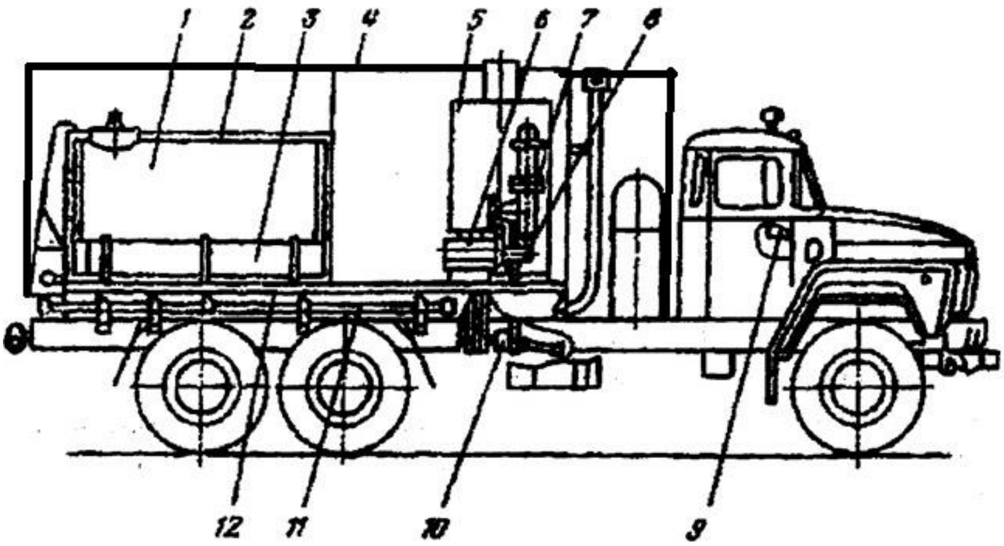
Nowadays, the use of fuel and energy resources is one of the most important economic problems. Dozens of steam generating units are used in the state oil and gas sector: ППУА (PPUA)-1200/100, ППУА (PPUA)-1600/100, ППУА-1800/100, which are installed on the chassis of cars: КрАЗ, УрАЛ, КамАЗ (KrAZ, UrAL, KAMAZ) and others. The steam generator is driven by attachments, which are connected to the internal combustion engine (ICE) of the vehicle through the power take-off. Technologically and structurally, steam generators have not undergone significant changes for decades. [1-3].

ANALYSIS OF LITERATURE DATA AND PROBLEM STATEMENT

It should be noted that at the same time, the manufacturers of steam generating units, planned the fuel consumption for their operation at the nominal capacity, which was given in the operating instructions of the units. Initially, ППУА (PPUA) industrial steam mobile units were intended for dewaxing wells, later they began to be used for heating underground and ground oil and gas equipment, as well as for steaming and cleaning pipelines, tanks and other household needs.

According to the ППУА (PPUA) operating instructions, fuel consumption was given per hour of steam generator operation with initial data for stage I - (Q - 110 kg / h, P-9,81 MPa and t-310 oC) and stage II - (Q - 35 kg / h, P-0.78 MPa and t-175 oC) and separately for devices (attachments), which is driven by the car engine [4]. Regulatory data on fuel consumption Q, for the operation of the steam generator unit in other modes (temperature and pressure of the steam-water mixture) are not provided by the operating instructions. Due to the fact that the loss of power of the internal combustion engine to drive the attachments (pumps and fan) at lower modes will be less than at maximum modes, for which there are regulatory data on fuel consumption per hour of operation of the installation, therefore, it will be less fuel consumed per hour of equipment operation than provided by the regulatory document at the nominal (maximum) mode of operation. The lack of standards for calculating fuel consumption during the operation of the steam generator at lower modes, does not allow operators to calculate the actual fuel consumption for the work performed to obtain a steam-water mixture, which creates certain conditions in unreasonable fuel consumption.

Picture 1 shows a schematic diagram of a mobile steam generator ППУА (PPUA), which is a mobile mini-boiler on the chassis of the car.



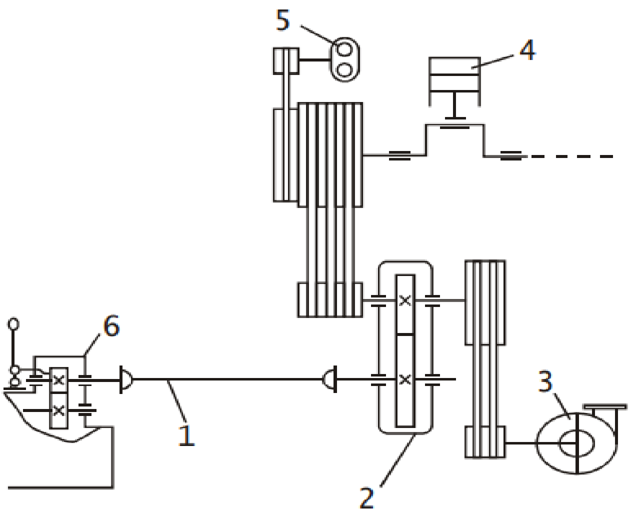
Picture 1 - Schematic diagram of the unit ППУА (PPUA) 1600/100

According to the design, the unit consists of: water tanks 1, tank shelters 2, fuel tanks 3, body (kung- {body - van}) 4, a steam generator 5, a water pump to power 6 the steam generator 5; a high pressure fan 7 for supplying air to the boiler of the steam generator 5; gear pumps 8 for supplying fuel to the injectors of the boiler of the steam generator 5; electrical equipment, control and measuring devices with automatic control of the technological process 9, the mechanical drive 10 of the pumps 6, 8 and the fan 10; main pipelines 11, mounting frame 12.

The operation of the steam generator is carried out from a set of auxiliary equipment shown in **Picture 2**, which is driven by the internal combustion engine of the vehicle on which the steam generator unit is installed.

PURPOSE AND OBJECTIVES OF THE RESEARCH

Fuel consumption accounting during the operation of the units is carried out separately for the steam generator (boiler) and attachments, which serves to ensure the operation of the steam generator and is actuated through the power take-off from the traction engine of the car.



Picture 2-Kinematic diagram of the attachment of the ППУА (PPUA) unit

1- cardan shaft, 2- reducer, 3- fan, 4- pump (pump), 5- gear pump, 6- box power take-off.

Regarding information on fuel consumption, in the operation of ППУА (PPUA) in different modes of operation of the steam generator, it should be noted that currently, the author has no information on specific standards on this issue, and operators use their industry standards, which in some way do not correspond to reality, as they calculate the cost per hour of operation of the steam generator, rather than the work performed.

RESEARCH RESULTS

In industry standards [5,6,7] fuel consumption rates differ in some way from each other, for example, according to the industry document [5] for the operation of the boiler of the steam generator per hour consumes 56 liters (stage I, mode: Q - 110 kg / h, P-9.81 MPa and t-310 oC table 1) and 30.6 liters (stage II, mode Q - 35 kg / h, P-0.78 MPa and t-175 oC table 1), for the same hour of work according to the document [6] 69,1 liters (degree not specified) and according to the document [7] 133,3 liters (degree I) and 42,4 liters (degree II). According to this information [5], 8 liters are consumed for the operation of the internal combustion engine from which the attachment is actuated (Picture 2), which is defined for the operation of the steam generator (supply to the coil of the boiler water, supply to the furnace of the boiler fuel, supply to the furnace of the boiler air needed to burn fuel, consumption for electricity extracted from the ICE generator). In addition, consumption is restored here for the operation of navigation equipment, which ensures the operation of the internal combustion engine (fan, compressor, generator, etc.)

In the factory standards for ППУА (PPUA) [4,8,9] for the production of steam at nominal (maximum) power consumed fuel (stage I): Q - 110 kg per hour at (P-9.81 MPa and t-310 oC) and (degree II): Q - 35 kg / h, at (P-0.78 MPa and t-175 oC).

As can be seen from the above, in different industry and factory standards there is a big difference in fuel consumption, which indicates an incorrect accounting and calculation of fuel consumption to obtain an equivalent amount of steam-water mixture at the same output parameters (temperature and pressure).

In all the above standards there is no data on fuel consumption at lower modes, which can run the steam generator. **Table 1** presents the possible modes of operation of the steam generator, recommended in the operating instructions PPUA [4,10].

Table 1 - Recommended modes of operation of the steam generator [4,10]

Absolute vapor pressure, P, MPa, (kgf / cm^2)	Saturation temperature, t_s,°C	Absolute vapor pressure, P, MPa, (kgf / cm^2)	Saturation temperature, ts, °C	Absolute vapor pressure, P, MPa, (kgf / cm^2)	Saturation temperature, t_s,°C
Stage I				Stage II	
1,96 (20)	213,85	5,39 (55)	269,84	0,098 (1)	119,62
2,06 (21)	216,23	5,88 (60)	275,36	0,196 (2)	132,88
2,16 (22)	218,53	6,37 (65)	280,55	0,29 (3)	142,92
2,25 (23)	220,75	6,86 (70)	285,44	0,39 (4)	151,11
2,35 (24)	222,9	7,35 (75)	290,08	0,49 (5)	158,08
2,45 (25)	224,99	7,84 (80)	294,48	0,59 (6)	164,17
2,94 (30)	234,57	8,33 (85)	298,69	0,69 (7)	169,61
2,43 (35)	243,04	8,82 (90)	302,71	0,79 (9)	174,53
3,92 (40)	250,64	9,31 (95)	306,56		
4,41 (45)	257,56	9,81 (100)	310,26		
4,90 (50)	263,93				

The values [11] of fuel consumption in the modes presented in Table 1 , which is consumed by the steam boiler in each of the modes are calculated in this work [11]. It should be noted that these fuel consumption is much lower than when operating at nominal modes, which are calculated by operators. That is, operators, due to the lack of recommendations, calculate fuel consumption for all modes per hour of operation, both for stage I with maximum power and parameters (Q - 110 kg / h, P-9.81 MPa and t-310 °C) and for stage II with maximum power with parameters (Q - 35 kg / h, P-0.78 MPa and t-175 °C).

Analyzed indicates an incorrect determination of fuel consumption in the manufacture of steam-water mixture with lower initial parameters than (stage I - P-9.8 MPa and t-310 °C) and (stage II -P-0.78 MPa and t-175 °C).

The obtained difference in fuel consumption in different modes between really burned and accounting, shows the unreasonableness of accounting for fuel consumption per hour of operation of the steam generator in their accounting. As for the attachments of the steam generator (pumps for supplying water to the boiler coil, pumps for supplying fuel to the furnace of the boiler, fan for supplying air to the boiler, etc.), according to industry standards, fuel consumption rates also differ between operators.

According to [5], for the operation of the internal combustion engine, which works to ensure the operation of the steam generator (together with the consumption for the operation of the internal combustion engine) it is consumed Qn - 8 kg / h regardless of P - MPa and t-ºC in any technological mode referred to in Table 1. In the characteristics on ППУА (PPUA) 1600/100 [8], it is stated that the fuel consumption in the operating mode is 10 kg / h. As you can see, these data vary up to 2 kg / h.

In the technical characteristics on ППУА (PPUA) 1600/100 [9] it is specified that the maximum power which is taken away from traction internal combustion engine of the car on work of the hinged equipment (attachments) of the steam generator makes 40 kW. Knowing the power loss and specific fuel consumption for a diesel engine, you can find the fuel consumption. In this case, it is about 10 kg / h, which is approximately correlated with the above figures.

However, it should be noted that steam generators installed on different brands of cars, which are equipped with different technical characteristics of the internal combustion engine, will have different specific fuel consumption g / kWh and different fuel consumption for the same work performed to prepare the steam mixture.

Taking into account the fact that the operation of the steam generator uses different pressures and flow rates of liquids (power supply of the steam generator) and the air used to burn fuel, you can determine the power consumed by the internal combustion engine to drive pumps and fans. Let's call the above system hydropneumatic.

The hydropneumatic system of the ППУА (PPUA) steam generator (Picture 2) is equipped with two hydraulic pumps: a plunger for water supply to the coil and a gear for supplying fuel to the nozzles of the heat generator boiler.

Pumps

As can be seen from Table 1, ППУА (PPUA) steam generators operate in different modes, which correspond to constant pressures P - MPa and saturation temperature t-ºC. In the end, the power that the pump consumes at constant pressure and constant performance is determined by the known formula [12,13]:

$$N_H = P \cdot Q, \text{ kW}, \qquad (1)$$

where P is the pressure, MPa;

Q - productivity (consumption), l / s.

Knowing the power of the pumps, you can determine the power consumed by the internal combustion engine to drive the pumps by the formula [12,14]:

$$N_{ДН} = \frac{N_H}{\eta_н \cdot \eta_{п_н}}, \text{ kW}, \qquad (2)$$

where $\eta_н$ – coefficient of the pumps efficiency;

$\eta_{п_н}$ – coefficient of the drive efficiency.

Fan

To supply air to the furnace of the steam boiler in the hydropneumatic system of the unit, a high pressure fan is installed (Figure 2), which provides efficient (complete) combustion of fuel in the furnace of the boiler of the steam generator.

During operation, the fan consumes the following power [12]:

$$N_B = Q_в \cdot P_в, \text{ kW}, \qquad (3)$$

where $Q_в$ - fan capacity, m3 / s;

$P_в$ – full pressure of the fan, Pa.

Having the power of the fan, you can determine the power consumed by the internal combustion engine to drive the fan by the formula [12,14]:

$$N_{ДВ} = \frac{N_В}{\eta_в \cdot \eta_{n_в}}, \text{ kW}, \quad (4)$$

де $\eta_в$ – coefficient of the fan efficiency;
$\eta_{n_в}$ – coefficient of the fan drive efficiency.

Electrical equipment

For the operation of the steam generator unit according to the instructions for technical operation, the power, that is consumed by electrical equipment and the burner, is not more than 220 W, with short-term operation of the igniter (20-sec) - not more than 500 W [4]. The method of determining the power consumption of internal combustion engines on the drives of automotive generators, that produce the current to power electrical equipment, that provides the operation of the steam generator is described in works [12,14]. Due to the small values of power consumption, the calculation is impractical and the power consumption of the internal combustion engine to drive the generator is taken according to the operating instructions [4].

Knowing the power consumption of the internal combustion engine to drive the above units, as well as the specific fuel consumption for this engine, you can determine the hourly fuel consumption for the operation of auxiliary equipment of the steam generator in the selected mode.

$$G_T = \sum(N^{П}{}_{ДВ} + N^{Ш}{}_{ДВ} + N^{В}{}_{ДВ} + 0{,}22) \cdot q_e, \text{ kg/h}, \quad (5)$$

where $N^{П}{}_{ДВ}$ - power consumption of the internal combustion engine to drive the plunger pump for water supply to the boiler coil of the heat generator, kW

$N^{Ш}{}_{ДВ}$ - power consumption of the internal combustion engine to drive a gear pump for fuel supply to the nozzles of the furnace of the heat generator boiler, kW;

$N^{В}{}_{ДВ}$ - power consumption of the internal combustion engine for the fan drive, kW;

0,22 - power consumption of the internal combustion engine to drive the generator, we accept according to [4], kW;

q_e - estimated specific fuel consumption at a given engine crankshaft speed, g / (kWh).

DISCUSSION OF RESEARCH RESULTS

Preliminary calculations of fuel consumption for the operation of attachments due to power consumption show that lower modes will consume less fuel, as far as energetically, the attachments at lower modes will consume less power, and at the same time the internal combustion engine will burn less fuel. Operators do not take this moment into account, but accept the normative value, which is determined for the nominal (maximum) power of the heat generator.

From the above, we can conclude that the current fuel consumption rates are imperfect, as they do not reflect the fuel consumption required for the operation of the steam generator.

CONCLUSIONS

For more accurate control of fuel consumption, various types of information technologies, computer equipments, meters, FMS and SCRT systems and more are currently used. However, for their implementation it is necessary to have a developed method of calculating fuel consumption at different stages and modes of operation of the steam generator.

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Богатчук М.І.. **Витрати палива на роботу навісного обладнання парогенераторних установок технологічного транспорту**

Стаття присвячена аналізу і уточненню витрат палива на роботу навісного обладнання парогенераторних установок типу ППУА, які приводять в дію паровий котел, що виробляє пароводяну суміш. Виконано аналіз інформаційних джерел з витрат палива на приведення в дію теплогенератора і необґрунтованих перевитратах. Охарактеризовано недоліки з підрахунку витрат палива за годину роботи установки. На основі аналізу нормативних даних з обліку витрат палива за годину роботи запропоновано розрахункову модель для обчислення дійсної витрати палива за виконану роботу з підготовки пароводяної сумі на різних режимах експлуатації установки. При розрахунку запропоновано обчислення вести за втратами потужності двигуна внутрішнього згоряння на привід навісного обладнання при їх роботі на різних режимах підготовки пароводяної суміші.

Основна суть полягає в тому, що визначають втрати потужності ДВЗ для кожного пристрою, який забезпечує функціювання теплогенератора і по сумарній втраченій потужності, знаходять кількість палива на виконання пароводяної суміші на вибраному режимі експлуатації установки. Знаючи сумарні втрати потужності і питому витрату палива для даного двигуна визначають дійсну витрату палива на вибраному режимі експлуатації парогенератора. Запропоноване позволить експлуатаційникам позбутися необґрунтованих витрат палива на отримання пароводяної суміші з необхідними параметрами по продуктивності, тиску і температурі.

Ключові слова: парогенератор, навісне обладнання, витрати палива, двигун внутрішнього згоряння (ДВЗ), втрати потужності, пароводяна суміш.

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