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WASTE HEAT POTENTIAL IN POLYETHYLENE PRODUCTION PROCESS

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ABSTRACT
Heat energy flow in the process of high pressure production of (L)ow (D)ensity (P)oly(E)thylene (LDPE) is analyzed. This process occurs at very high pressures, from 122 to 303MPa and temperatures from 130 to 350°C, consuming 0,9 kg of process steam per kg of product (LDPE). Process steam condenses during process creating condensate with significant waste heat potential. Proposed model for condensate waste heat recovery shows that lowering of heat energy consumption up to 18,7% is possible.
Keywords: LDPE production, heat energy flow, condensate waste heat recovery

1. INTRODUCTION
It is impossible to conceive modern life without polymers. More than hundred years long history of polymers promoted them in inevitable part of most products in common life as well as those of most sophisticated design. Plastics represent one group of polymers consisting of big variety of products such as polyvinylchloride (PVC), polypropylene (PP)**,** polystyrene (PS), polyethylene and many other. Polyethylene itself creates important group of plastics consisting of two basic forms. These are High Density PolyeEthylene (HDPE) and Low Density PolyEthylene (LDPE). They differ in density, LDPE has density between 0,912 and 0,925 g/cm^3 while HDPE has density between 0,926 and 0,940 g/cm^3 [1]. They also differs in form of their molecules, HDPE creates long, straight chains while LDPE creates chains with smaller branches on both sides. They have common monomer unit CH_2. Form of molecules defines their mechanical, physical and chemical properties. LDPE due to its softness, low melting point and semirigid form, is used for making of plastic bags, food packaging films etc. and HDPE opposite to LDPE posses rigid structure and is used for bottle caps, toys, pipes, casings for computers and televisions etc. [2]. Beside these two groups there also exist other forms of polyethylene such as Linear Low Density PolyEthylene (LLDPE), UltraHigh Molecular Weight PolyEthylene (UHMWPE) and modified polyethylenes. These forms are result of more or less different technologies offering great variety of their structures, properties and fields of application [1]. In further discussion production of LDPE from energy consumption point of view will be presented.

2. LDPE PRODUCTION
Production of LDPE is characterized by temperatures ranging from 130 to 350°C, and very high pressures ranging from 122 up to 303MPa [1]. Process also requires significant quantities of heat and

electric energy Heat energy is supplied by superheated steam. Figure 1. shows detailed LDPE production process scheme. Also, process steam data with their temperatures and rates delivered to certain stage of process are included in figure.

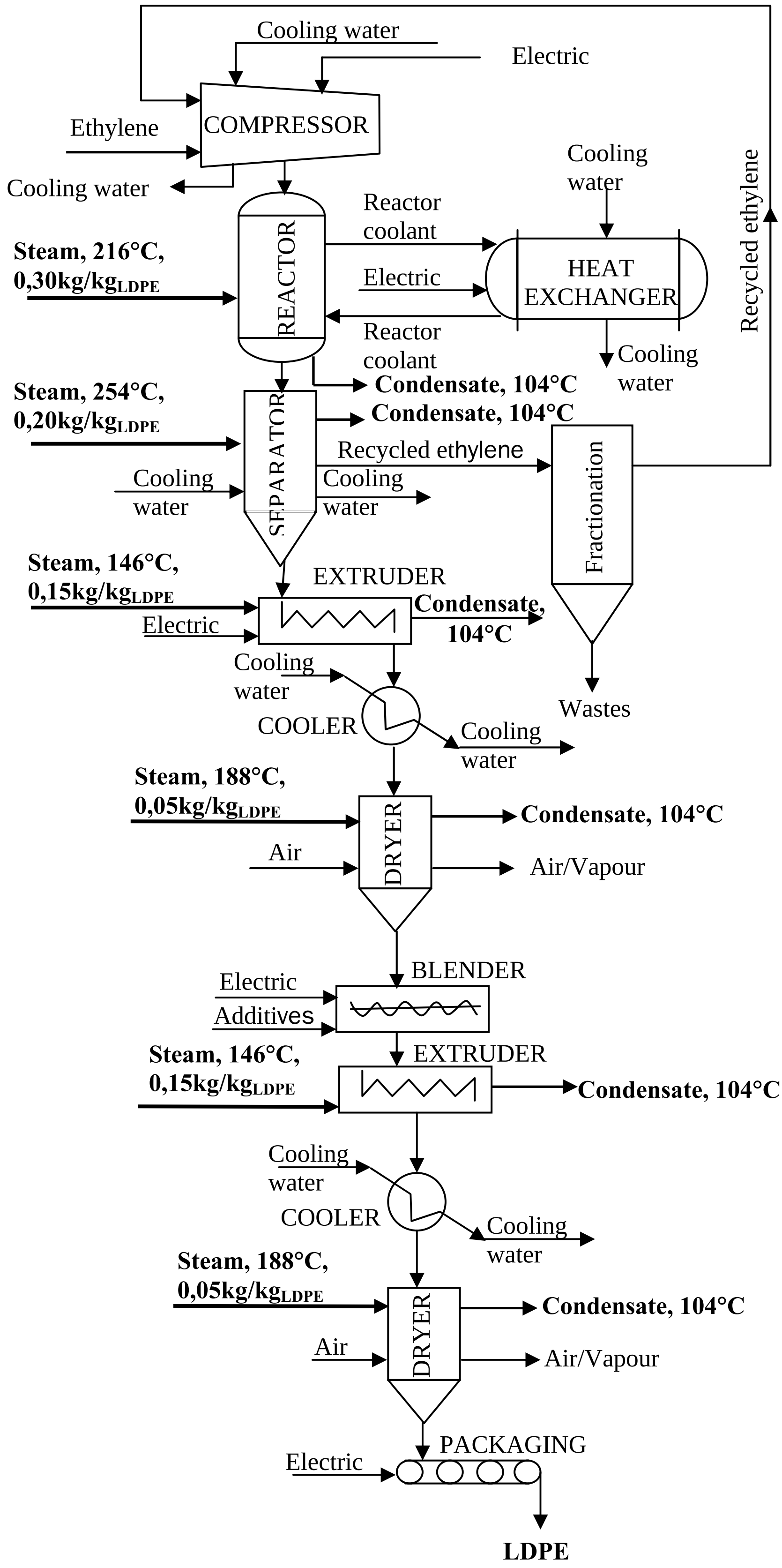

Figure 1. Scheme of LDPE production process

3. WASTE HEAT POTENTIAL ANALYSIS

LDPE production is continuous process with continuous steam supply. After being delivered to certain stage of process by means of appropriate pressure, temperature and rate, steam condensates creating condensate. This condensate with the temperature of 104°C represents valuable source of waste heat energy [3].

Table 1. shows summary data for process steam at different temperature levels and for condensate all expressed as specific value i.e. per mass unit of product [4].

Table 1. Process steam and condensate parameters

Process steam			Condensate		
Temp., °C	Rate, d_S, kg/kg_{LDPE}	Specific energy, *e*, kJ/kg_{LDPE}	Temp., °C	Rate, d_C, kg/kg_{LDPE}	Specific energy, *e*, kJ/kg_{LDPE}
254,4	0,200	564,3	104,4	0,900	396,0
215,6	0,300	845,9			
187,8	0,100	280,4			
146,1	0,300	828,1			

4. CONDENSATE WASTE HEAT RECOVERY

Technically, to make possible to reuse waste heat of condensate it has to be collected first. Figure 2. shows generalized scheme for condensate waste heat recovery. Condensate from all stages of polymerization process (as shown in Figure 1.) is collected first in mixing tank, presumed ideally isolated. Y is part of reused condensate, its value varies from 0 to 1 (i.e. from 0 to 100%) for any reason. The rest, up to full quantity of condensate is compensated by adding fresh water in amount of 1-Y.

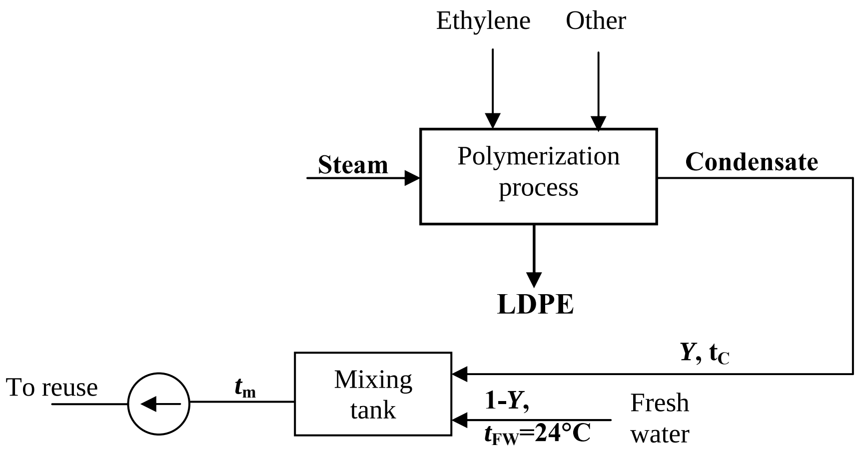

Figure 2. Condensate waste heat recovery scheme

Heat balance for mixing tank is:

$$c_{pC}\cdot Y\cdot d_S\cdot(t_C-t_m)=c_{pFW}\cdot(1-Y)\cdot d_S\cdot(t_m-t_{FW}) \quad (1)$$

where c_{pC} and c_{pFW} are specific heat of condensate and fresh water, presumed equal 4,187kJ/kg.

From equation (1) mixing temperature in °C can be calculated as:

$$t_m=t_C\cdot Y+t_{FW}\cdot(1-Y) \quad (2)$$

Mixing temperature as well as heat energy saving is proportional to the amount of returned condensate *Y*. Energy saving as result of condensate waste heat recovery in kJ/kg_{LDPE} is:

$$q_C=Y\cdot d_C\cdot h_C=396{,}0\cdot Y \quad (3)$$

where is h_C=440,0kJ/kg enthalpy of condensate.

Heat energy available from process steam (Table1.) having temperature *t*=254,4°C and enthalpy h_S=2799kJ/kg is:

$$q_S=d_S\cdot(h_S-h_C)=2123{,}1kJ/kg_{LDPE} \quad (4)$$

Dividing (3) by (4) percentage of energy saving can be calculated as follows:

$$q_{C\%} = \frac{q_C}{q_S} = 0{,}1865 \cdot Y [\%] \qquad (5)$$

The results of calculation according to equations (2), (3) and (5) for several values of *Y* are given in table 2.

Table 2. Summary results of condensate waste heat recovery

Y, %	t_m, °C	q_C, kJ/kg$_{LDPE}$	$q_{C\%}$, %
100	104,0	396,0	18,7
80	88,0	316,8	14,9
50	64,0	198,0	9,3
20	40,0	79,2	7,5
0	24,0	0	0

5. CONCLUSION

Presented analysis of heat energy flow in process of LDPE production has shown significant condensate waste heat potential. Recovering this waste heat, savings up to 18,7% are possible resulting directly in fuel saving and lower environmental impact. For instance, in Croatia in year 2004., 193430 ton [5] of LDPE was produced. With maximal possible saving by condensate waste heat recovery it makes $7{,}66 \cdot 10^{10}$ kJ less heat energy produced.

6. REFERENCES

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