SUMMARY OF THE ENERGY AUDIT PERFORMED ON THE MACHINES THAT DEVELOP ALUMINIUM PARTS BY INJECTION

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Abstract: The paper has a structure of four parts. In the first part is justified the concern of the authors regarding the electric energy audit (EEA). In the second part are specified the Al alloy moulding machines that make the contour of the EEA. The third part contains a synthesis of the results, and in the last part are given the conclusions obtained from analyses.

Key words: electric energy audit, energy efficiency, Al alloy moulding, optimization.

1. INTRODUCTION

Targets and means of action of the European Union are clearly defined and regulated [1], aimed, in essence, by 2020, reducing g energy consumption of fossil fuels by 20% and corresponding, increase in the share of renewable energy.

In Romania, energy efficiency is well below that of technologically countries. There are still many processes and services that take place in Romania, at an energy efficiency of [2-3] times higher than similar processes in technologically modernized countries [3÷7]. In the last period legislative and financial efforts [8, 9] are made to align Romania to the European Union standards, both in terms of energy efficiency and in terms of more intense use of renewable resources.

EEA is one of the ways covered [2], to identify ways of improve efficiency of processes of energy conversion. EEA was conducted to an entity that produce pieces of aluminium alloy by melting, injection and hot / cold processing. After specifying the elements that define the contour and some specific aspects of mathematical modelling, there is given the conclusions of the made study with general interest, taking into account, the weight of the electro-thermal processes of Romania and the possibilities to increase the efficiency.

2. CONTOURS AND WAY TO WORK

S.C. Turnătorie Iberica (TI-C) is the industrial consumer choice, to exemplify the results by applying the EEA. The contour is set to perform the EEA at the factory level, with separate assessments on components of the general contour (Table 1.)

We have two types of injecting machines, the significant difference relates to how to load the injecting machines using peripheral device for molten alloy, by doses distribution, or by gravity pouring.

From the records made available by the beneficiary of EEA, August, September and October 2009 shows an average production of 55,994.46 kg pieces made of aluminium alloy per month. Given this schedule of TI-C [120 h continuous work (Monday - 06.00 ÷ Saturday - 06.00)], based on records of those three months, we obtain the average value of output per hour (productivity): 107,68 kg pieces per hour.

Fluctuations in demand from customers, require the use of the injection machines partially (M1 ÷ M9). Reference unit is one hour associated to EEA (hour EEA).

The loading of the equipment during measurements were normal (medium), we specify that the equipment (M9, CP1, CP3, CP4) have not worked this time.

Please note that, furnaces (CP1 ÷ CP4) works with methane gas (basic energy agent), EE is used only as a secondary agent (for ventilation and hydraulic).

Measuring instruments used:

- Network analyser(AR) type C.A. 8334 B (2 pcs.), located in the secondary of the two transformers from each station;
- Protek 307 Clamp Meter Type
- Active and reactive energy meters:-TYPE ENERLUX TCDM, located in the primary of the transformers.

Table 1. Technical characteristics of injection moulding machines, of Al alloy parts

Nr. crt.	Name	Code	Destination and technological characteristics	Structure	Nominal characteristics (furnace / asynchronous engines) f_n=50Hz, n_1 = 1500rot/min				
					R_1	P_n [kW]	$\cos\varphi_n$	η_n	S_c [mm^2]
1.	Machine nr.1 COLOSIO 320	M1	The injection of molten Al alloy to produce parts ϴ=680°C; m=300kg Cycle: [1,5÷3]hours	Furnace resistors		70	1	0,825	50
				Hydraulic pump	0,6353	18,5	0,82	0,87	10
				Press	0,7299	7,5	0,84	0,85	6
				Lubrication machine	0,77548	2,2	0,80	0,79	4
				Peripheral device	0,7686	3	0,81	0,80	4
2.	Machine nr. 2 IDRA 420	M2	The injection of molten Al alloy to produce parts ϴ=680°C; m=300kg Cycle: [1,5÷3] hours	Furnace resistors		70	1	0,825	50
				Hydraulic pump	0,4762	37	0,85	0,90	35
				Press	0,7299	7,5	0,84	0,85	6
				Lubrication machine	0,77548	2,2	0,80	0,79	4
				Peripheral device	0,7686	3	0,81	0,80	4
3.	Machine nr. 3 IDRA 500	M3	The injection of molten Al alloy to produce parts ϴ=680°C; m=600kg Cycle: [1÷2] hours	Furnace resistors		18,5	1	0,825	10
				Hydraulic pump	0,5364	30	0,85	0,90	35
				Press	0,6998	11	0,84	0,87	6
				Peripheral device	0,7686	3	0,81	0,80	4
4.	Machine nr. 5 IDRA 420	M5	The injection of molten Al alloy to produce parts ϴ=680°C; m=300kg Cycle: [1,5÷3] hours	Furnace resistors		70	1	0,825	50
				Hydraulic pump	0,6052	22	0,85	0,89	16
				Press	0,7299	7,5	0,84	0,85	6
				Lubrication machine	0,77548	2,2	0,80	0,79	4
				Peripheral device	0,7686	3	0,81	0,80	4
5.	Machine nr. 8 STP 500	M8	The injection of molten Al alloy to produce parts ϴ=680°C; m=600kg Cycle: [1÷2] hours	Furnace resistors		18,5	1	0,825	10
				Hydraulic pump	0,4762	37	0,85	0,90	35
				Press	0,6998	11	0,84	0,87	6
				Lubrication machine	0,7686	3	0,81	0,80	4
6.	Machine nr. 9 STP 602	M9	The injection of molten Al alloy to produce parts ϴ=680°C; m=600kg Cycle: [1÷2] hours	Furnace resistors		18,5	1	0,825	10
				Hydraulic pump	0,4762	37	0,85	0,90	35
				Press	0,6998	11	0,84	0,87	6
				Lubrication machine	0,7686	3	0,81	0,80	4
				Peripheral device	0,76	4	0,82	0,82	4
				Hydraulic pump	0,7299	7,5	0,84	0,85	6

n_1 – the synchronism speed; R_1 – stator winding resistance; S_c – power supply conductor section; η_n – the nominal efficiency; $\cos\varphi_n$ – rated power factor

In these contours injection machines (M1, M2, M3, M5, M8, M9) and furnaces (CP1 ÷CP4) are included.

• Measurements at COLOSO 320 (M1)

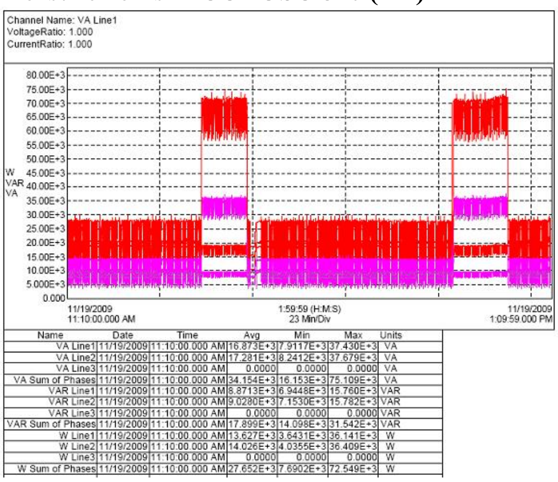
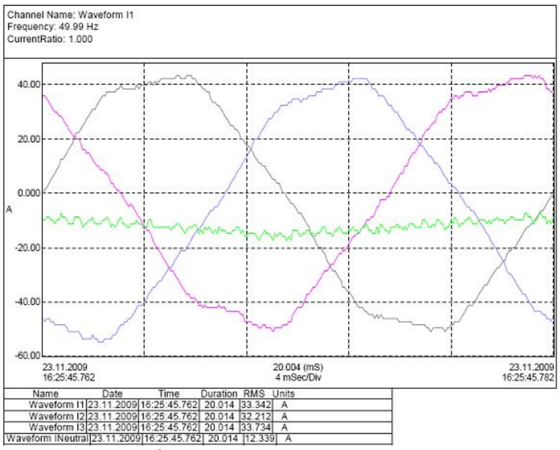
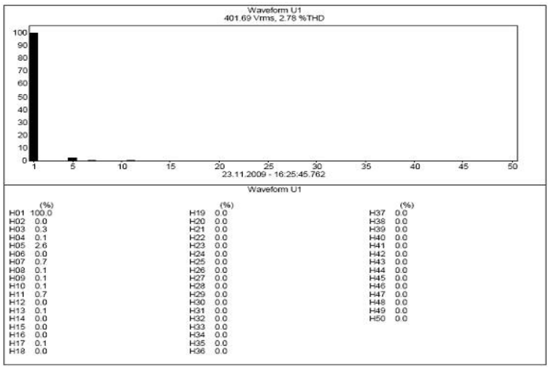


Fig. 1. Load curves for the machine 1(M1)

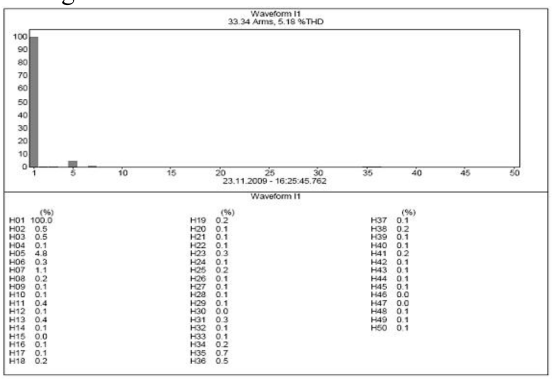
a) voltage waveform



b) current waveform



c) voltage harmonics



d) current harmonics

Fig. 2. EE power quality at machine 1(M1)

Table 2. Measurements recorded for M1

Date	Hour	U1	V1	IR	IS	IT
		V	V	A	A	A
11/19/2009	11:10:00	401.2	231.9	59.5	61.8	60.8
11/19/2009	11:10:01	400.9	231.7	59.7	62	61.1
11/19/2009	11:10:02	401.1	231.9	59.8	62.1	61.1
11/19/2009	11:10:14	402.5	232.6	39.1	41	40.8
11/19/2009	11:10:15	402.4	232.5	42.2	44.2	43.8
11/19/2009	11:10:16	401.6	232	57.6	59.8	59
11/19/2009	11:10:18	401.7	232.2	59	61	60.4
Med. Val.		401.5	232.0	51.3	53.4	52.8

I_m = 52,55A I_{mp} = 53,14A k_f = 1,0113

I_m – average current value
I_{mp} – average square current value
k_f – form factor

• Measurements over the furnace from the machine nr. 1 (CM1)

Load conditions of the furnace are stabilized. Therefore we will present only two load curves: load curves of power and load curves of currents.

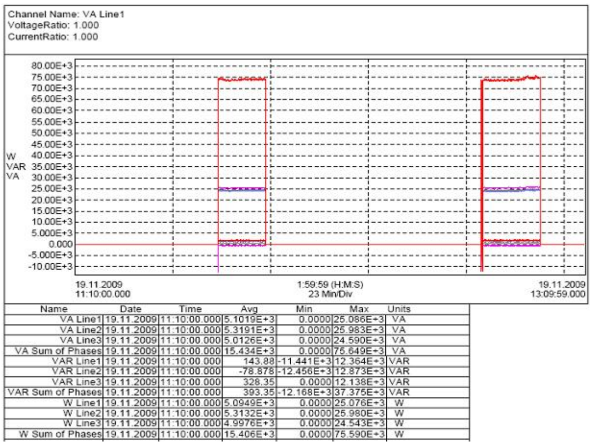


Fig. 3. Power load curves for the machine 1's furnace (CM1)

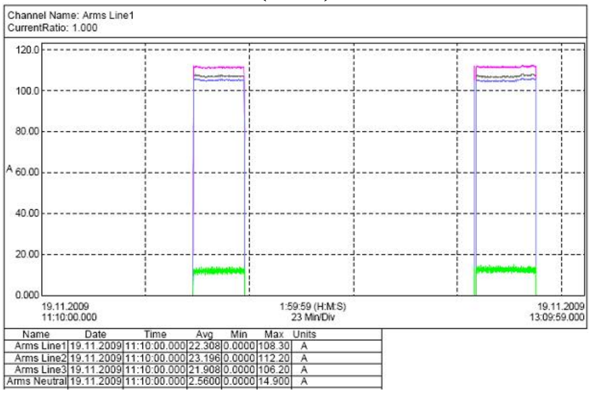


Fig. 4. Current load curves for the machine 1's furnace (CM1)

• Measurements at IDRA 420 (M2)

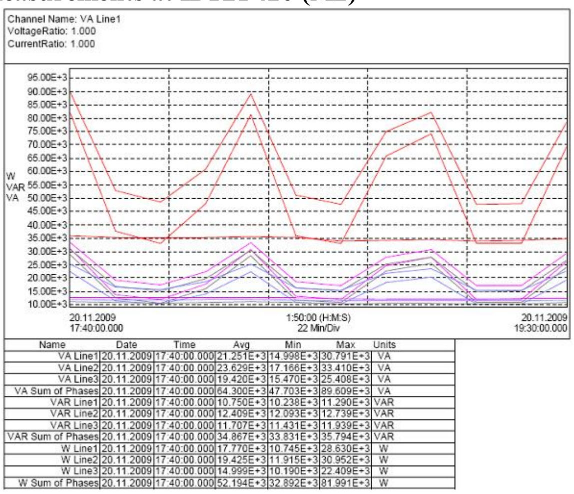
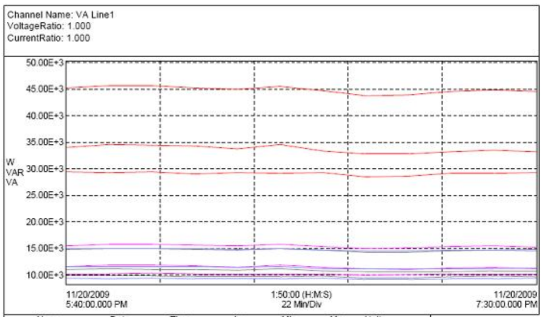


Fig. 5. Load curves for the machine 2(M2)

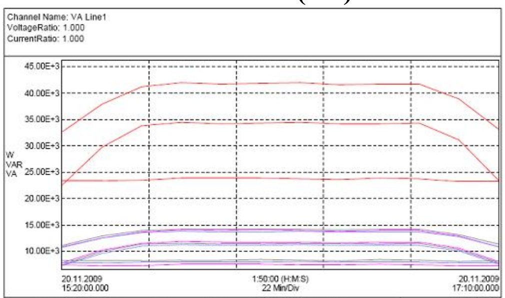
• Measurements over the furnace from the machine nr. 2 (CM2)



Name	Date	Time	Avg	Min	Max	Units
VA Line1	11/20/2009	5:40:00.000 PM	14.690E+3	14.314E+3	14.954E+3	VA
VA Line2	11/20/2009	5:40:00.000 PM	15.462E+3	15.023E+3	15.809E+3	VA
VA Line3	11/20/2009	5:40:00.000 PM	14.803E+3	14.489E+3	15.015E+3	VA
VA Sum of Phases	11/20/2009	5:40:00.000 PM	44.954E+3	43.861E+3	45.733E+3	VA
VAR Line1	11/20/2009	5:40:00.000 PM	10.877E+3	10.573E+3	11.147E+3	VAR
VAR Line2	11/20/2009	5:40:00.000 PM	11.478E+3	11.074E+3	11.848E+3	VAR
VAR Line3	11/20/2009	5:40:00.000 PM	11.366E+3	11.105E+3	11.583E+3	VAR
VAR Sum of Phases	11/20/2009	5:40:00.000 PM	33.722E+3	32.817E+3	34.564E+3	VAR
W Line1	11/20/2009	5:40:00.000 PM	9.6984E+3	9.4588E+3	9.8111E+3	W
W Line2	11/20/2009	5:40:00.000 PM	10.187E+3	9.9213E+3	10.351E+3	W
W Line3	11/20/2009	5:40:00.000 PM	9.2839E+3	9.0994E+3	9.3829E+3	W
W Sum of Phases	11/20/2009	5:40:00.000 PM	29.170E+3	28.479E+3	29.516E+3	W

Fig. 6. Power load curves for the machine nr.2 furnace (CM2)

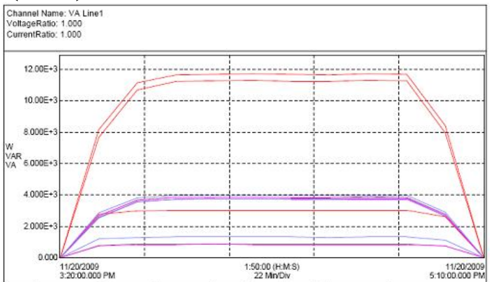
• Measurements at IDRA 500 (M3)



Name	Date	Time	Avg	Min	Max	Units
VA Line1	20.11.2009	15:20:00.000	13.485E+3	11.104E+3	14.223E+3	VA
VA Line2	20.11.2009	15:20:00.000	13.191E+3	10.809E+3	14.031E+3	VA
VA Line3	20.11.2009	15:20:00.000	13.039E+3	10.743E+3	13.801E+3	VA
VA Sum of Phases	20.11.2009	15:20:00.000	39.715E+3	32.657E+3	41.999E+3	VA
VAR Line1	20.11.2009	15:20:00.000	8.2675E+3	8.0980E+3	8.4235E+3	VAR
VAR Line2	20.11.2009	15:20:00.000	7.4207E+3	7.2499E+3	7.5638E+3	VAR
VAR Line3	20.11.2009	15:20:00.000	7.9155E+3	7.8133E+3	8.0117E+3	VAR
VAR Sum of Phases	20.11.2009	15:20:00.000	23.604E+3	23.239E+3	23.936E+3	VAR
W Line1	20.11.2009	15:20:00.000	10.589E+3	7.4603E+3	11.524E+3	W
W Line2	20.11.2009	15:20:00.000	10.852E+3	7.8358E+3	11.826E+3	W
W Line3	20.11.2009	15:20:00.000	10.296E+3	7.3129E+3	11.216E+3	W
W Sum of Phases	20.11.2009	15:20:00.000	31.737E+3	22.609E+3	34.490E+3	W

Fig. 7. Power load curves for the machine (M3)

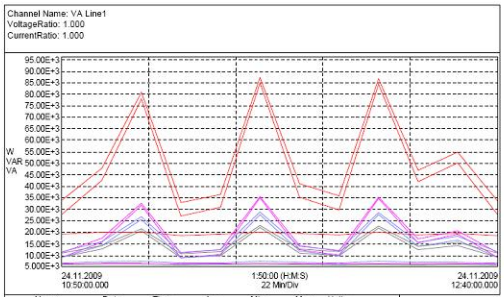
• Measurements over the furnace from the machine nr. 3 (CM3)



Name	Date	Time	Avg	Min	Max	Units
VA Line1	11/20/2009	3:20:00.000 PM	3.0069E+3	0.0000	3.8760E+3	VA
VA Line2	11/20/2009	3:20:00.000 PM	2.9929E+3	0.0000	3.8559E+3	VA
VA Line3	11/20/2009	3:20:00.000 PM	3.1159E+3	0.0000	3.9936E+3	VA
VA Sum of Phases	11/20/2009	3:20:00.000 PM	9.1157E+3	0.0000	11.702E+3	VA
VAR Line1	11/20/2009	3:20:00.000 PM	709.05	0.0000	871.36	VAR
VAR Line2	11/20/2009	3:20:00.000 PM	682.37	0.0000	850.13	VAR
VAR Line3	11/20/2009	3:20:00.000 PM	1.0665E+3	0.0000	1.3215E+3	VAR
VAR Sum of Phases	11/20/2009	3:20:00.000 PM	2.4580E+3	0.0000	3.0293E+3	VAR
W Line1	11/20/2009	3:20:00.000 PM	2.9202E+3	0.0000	3.7768E+3	W
W Line2	11/20/2009	3:20:00.000 PM	2.9126E+3	0.0000	3.7612E+3	W
W Line3	11/20/2009	3:20:00.000 PM	2.9232E+3	0.0000	3.7717E+3	W
W Sum of Phases	11/20/2009	3:20:00.000 PM	8.7560E+3	0.0000	11.287E+3	W

Fig. 8. Power load curves for the machine nr. 3 furnace (CM3)

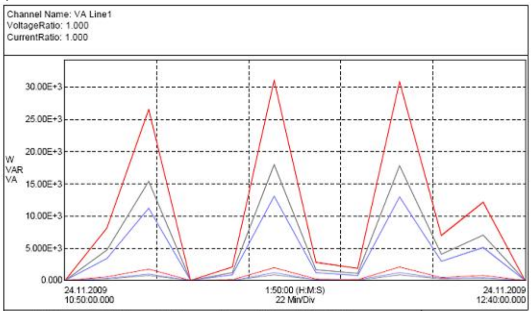
• Measurements at IDRA 420 (M5)



Name	Date	Time	Avg	Min	Max	Units
VA Line1	24.11.2009	10:50:00.000	15.036E+3	10.790E+3	22.999E+3	VA
VA Line2	24.11.2009	10:50:00.000	19.297E+3	11.006E+3	35.535E+3	VA
VA Line3	24.11.2009	10:50:00.000	17.287E+3	11.311E+3	28.792E+3	VA
VA Sum of Phases	24.11.2009	10:50:00.000	51.620E+3	33.107E+3	87.327E+3	VA
VAR Line1	24.11.2009	10:50:00.000	6.0012E+3	5.8178E+3	6.2556E+3	VAR
VAR Line2	24.11.2009	10:50:00.000	6.5022E+3	6.3191E+3	6.7736E+3	VAR
VAR Line3	24.11.2009	10:50:00.000	6.9801E+3	6.5834E+3	7.5041E+3	VAR
VAR Sum of Phases	24.11.2009	10:50:00.000	19.483E+3	18.720E+3	20.255E+3	VAR
W Line1	24.11.2009	10:50:00.000	13.583E+3	9.0391E+3	22.168E+3	W
W Line2	24.11.2009	10:50:00.000	17.703E+3	8.9423E+3	34.918E+3	W
W Line3	24.11.2009	10:50:00.000	15.491E+3	9.1367E+3	27.796E+3	W
W Sum of Phases	24.11.2009	10:50:00.000	46.777E+3	27.118E+3	84.882E+3	W

Fig. 9. Power load curves for the machine 5 (M5)

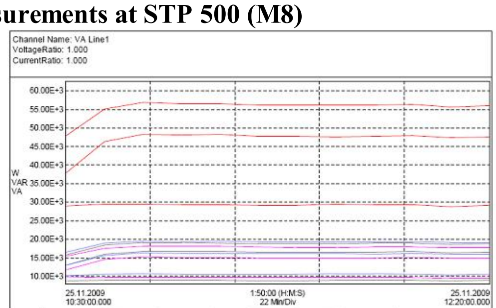
• Measurements over the furnace from the machine nr. 5 (CM5)



Name	Date	Time	Avg	Min	Max	Units
VA Line1	24.11.2009	10:50:00.000	5.9265E+3	0.0000	17.994E+3	VA
VA Line2	24.11.2009	10:50:00.000	0.0000	0.0000	0.0000	VA
VA Line3	24.11.2009	10:50:00.000	4.3160E+3	0.0000	13.107E+3	VA
VA Sum of Phases	24.11.2009	10:50:00.000	10.243E+3	0.0000	31.101E+3	VA
VAR Line1	24.11.2009	10:50:00.000	282.47	0.0000	864.41	VAR
VAR Line2	24.11.2009	10:50:00.000	0.0000	0.0000	0.0000	VAR
VAR Line3	24.11.2009	10:50:00.000	382.85	0.0000	1.1974E+3	VAR
VAR Sum of Phases	24.11.2009	10:50:00.000	665.32	0.0000	2.0618E+3	VAR
W Line1	24.11.2009	10:50:00.000	5.9070E+3	0.0000	17.973E+3	W
W Line2	24.11.2009	10:50:00.000	0.0000	0.0000	0.0000	W
W Line3	24.11.2009	10:50:00.000	4.2884E+3	0.0000	13.050E+3	W
W Sum of Phases	24.11.2009	10:50:00.000	10.195E+3	0.0000	31.023E+3	W

Fig. 10. Power load curves for the machine nr. 5 furnace (CM5)

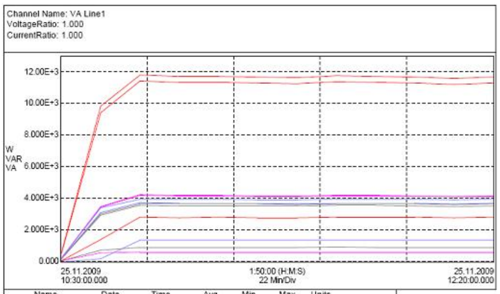
• Measurements at STP 500 (M8)



Name	Date	Time	Avg	Min	Max	Units
VA Line1	25.11.2009	10:30:00.000	18.645E+3	15.831E+3	19.131E+3	VA
VA Line2	25.11.2009	10:30:00.000	17.692E+3	15.438E+3	18.139E+3	VA
VA Line3	25.11.2009	10:30:00.000	19.114E+3	16.621E+3	19.540E+3	VA
VA Sum of Phases	25.11.2009	10:30:00.000	55.451E+3	47.890E+3	56.810E+3	VA
VAR Line1	25.11.2009	10:30:00.000	8.9795E+3	8.8447E+3	9.0871E+3	VAR
VAR Line2	25.11.2009	10:30:00.000	9.6830E+3	9.5086E+3	9.8297E+3	VAR
VAR Line3	25.11.2009	10:30:00.000	10.601E+3	10.263E+3	10.737E+3	VAR
VAR Sum of Phases	25.11.2009	10:30:00.000	29.263E+3	28.838E+3	29.557E+3	VAR
W Line1	25.11.2009	10:30:00.000	16.294E+3	13.057E+3	16.799E+3	W
W Line2	25.11.2009	10:30:00.000	14.750E+3	11.808E+3	15.241E+3	W
W Line3	25.11.2009	10:30:00.000	15.852E+3	12.995E+3	16.305E+3	W
W Sum of Phases	25.11.2009	10:30:00.000	46.897E+3	37.860E+3	48.345E+3	W

Fig. 11. Power load curves for the machine 8(M8)

• Measurements over the furnace from the machine nr. 8 (CM8)



Name	Date	Time	Avg	Min	Max	Units
VA Line1	25.11.2009	10:30:00.000	3.2763E+3	161.25	3.6358E+3	VA
VA Line2	25.11.2009	10:30:00.000	3.7668E+3	193.77	4.2000E+3	VA
VA Line3	25.11.2009	10:30:00.000	3.5471E+3	185.12	3.9328E+3	VA
VA Sum of Phases	25.11.2009	10:30:00.000	10.590E+3	540.14	11.767E+3	VA
VAR Line1	25.11.2009	10:30:00.000	792.61	44.730	887.01	VAR
VAR Line2	25.11.2009	10:30:00.000	528.55	42.560	587.99	VAR
VAR Line3	25.11.2009	10:30:00.000	1.1109E+3	-48.740	1.3401E+3	VAR
VAR Sum of Phases	25.11.2009	10:30:00.000	2.4321E+3	38.550	2.7955E+3	VAR
W Line1	25.11.2009	10:30:00.000	3.1775E+3	147.41	3.5298E+3	W
W Line2	25.11.2009	10:30:00.000	3.7270E+3	178.36	4.1607E+3	W
W Line3	25.11.2009	10:30:00.000	3.3283E+3	162.47	3.6969E+3	W
W Sum of Phases	25.11.2009	10:30:00.000	10.233E+3	488.24	11.387E+3	W

Fig. 12. Power load curves for the machine nr. 8 furnace (CM8)

The way to work at EEA is well known [7, 10÷13].
Thus, assessment is made of the injection machine in the sub contour using the following equation of EEA:

$$W_a = W_U+\Delta W_{TR}+\Delta W_M+\Delta W_{mec}+\Delta W_L \quad (1)$$

where:
W_a - energy absorbed by the machine, determined based on measurements;
W_U - useful energy, determined based on measurements and calculations, with two components:
W_{TRU} - useful thermal energy, as determined by calculating the energy used to bring and maintained Al alloy at a temperature of injection;
W_{MU} - useful mechanical energy, as determined by calculating the energy required in electromechanical drives associated with the injection machine;
ΔW_{TR} – thermal energy loss (primarily by radiation and conduction), determined based on measurements and calculations;
ΔW_M - electric motor power losses related to the injection machine, determined based on measurements and calculations;
ΔW_{mec} - mechanical energy loss on mechanisms associated with injection moulding machines, driven by electric motors;
ΔW_L - energy losses on short lines of the injection machine structure;

EEA components for injection machine, which are of two types

A. Useful energy has two components:
A₁. Thermal component [15]

$$W_{TRU}= [\ m_l\ c\ (\Theta_t - \Theta_i) + m_2\ Q_{sp}\ ]/860\ [kWh] \quad (2)$$

where:
m_l - mass of metal (alloy) melted / heated [kg];
m_2 - mass of metal (alloy) maintained at the melting temperature [kg];
c - average specific heat of metal (alloy) between the initial temperature (Θ_i) and melting temperature (Θ_t) [kcal / kg. deg.];
Q_{sp} - latent heat of melted metal (alloy) [kcal / kg].
For aluminium alloy processed by injection machines from TI-C we will use the following values [15] :

$c = 0{,}210184$ kcal/kg deg ;
$Q_{sp} = 95{,}5383$ kcal/kg ;
$\Theta_m = 20$ °C;
$\Theta_t = 680$ °C.

A₂. Mechanical component

$$W_{MU} = W_{Ma} - \Delta W = W_{Ma} - (\Delta W_M + \Delta W_{mec} + \Delta W_{LM}) \quad (3)$$

where:
W_{Ma} - energy absorbed by the engine determined based on measurements (difference between the energy absorbed by the engine and the energy absorbed by the furnace);
ΔW_M - electric motor power losses related to the injection machine, determined based on measurements and calculations;
ΔW_{mec} - mechanical energy loss on mechanisms associated with injection moulding machines, driven by electric motors;
ΔW_{LM} - energy losses on short lines of the injection machine's engines [obtained as the difference between ΔW_L (on the engine) and ΔW_{LC} (over the furnace)].

B. Energy losses on the injection machine
Thermal energy losses:

$$\Delta W_{TR} = W_{ac} - W_{TRU} \quad (4)$$

W_{ac} – energy absorbed by the furnace from the structure of the injection machine
Energy losses in electric motors from the structure of the injection machine (ΔW_M) determined by applying the model of a group of engines, after calculating the energy absorbed by the group:

$$W_{ae}= W_{aML} - W_{ac} = W_{Ma} \quad (5)$$

W_{aML} – energy absorbed by the machine, (in this case, the injection machine);
Mechanical energy losses on the mechanisms, related to the injection machine (ΔW_{mec}) are calculated:
• If no-load test exists:

$$\Delta W_{mec} = P_0\ \tau - \Delta W_M - \Delta W_{LM0} \quad (6)$$

• If no-load test do not exist:

$$\Delta W_{mec} = k_{mec}\ W_{Ma} \quad (7)$$

where:
P_0 – absorbed power at no-load engine operation from the structure of the injection machine
ΔW_{LM0} – energy losses on short lines of the engines from the structure of the injection machine at no-load operation (it will use no load current - I_0);
k_{mec} – coefficient based on information from scientific literature from other EEA development of operational experience.

3. RESULTS OBTAINED

Based on the nominal characteristics of the equipment, and the results obtained from measurements made and by applying the EEA model the EEA components were determined. The results obtained are displayed in tables and Sankey diagrams - referring to the contour components.
The results obtained from the equipment are presented in two ways (Table 3 – full alloy charge and Table 4 - per hour) and those obtained for all injection moulding machines are presented in Table 6 and Fig. 13.

Table 3. – Real EEA components on a full alloy charge, at the injection machines

EEA component / Injection machine (MI) Full charge time (t_s)	ΔW_{TR} [kWh]	ΔW_M [kWh]	ΔW_{mec} [kWh]	ΔW_L [kWh]
M1 – COLOSIO 320 ts = 63min	8,39	3,05	5,01	0,04
M2 – IDRA 420 ts = 40min	3,15	2,45	0,5	0,09
M3 – IDRA 500 ts = 110min	2,81	10,11	31,25	0,1
M5 – IDRA 420 ts = 30min	0,95	4,39	9,14	0,046
M8 – STP 500 ts = 110min	3,72	14,76	53,17	0,196

Table 3. – Part 2

EEA component / Injection machine (MI) Full charge time (t_s)	W_U		Error	
	W_{TRU} [kWh]	W_{MU} [kWh]	[kWh]	[%]
M1 – COLOSIO 320 ts = 63min	7,02	4,15	1,36	4,7
M2 – IDRA 420 ts = 40min	16,29	12,35	-0,037	-0,1
M3 – IDRA 500 ts = 110min	13,25	0,71	-0,06	-0,1
M5 – IDRA 420 ts = 30min	4,17	4,72	-0,03	-0,13
M8 – STP 500 ts = 110min	15	1,12	-2,42	-2,8

Table 4. – Real EEA components over one hour, for the injection machines

EEA component / Equipment	ΔW_{TR} [kWh]	ΔW_M [kWh]	ΔW_{mec} [kWh]	ΔW_L [kWh]
M1 – COLOSIO 320	8	2,91	4,77	0,038
M2 – IDRA 420	4,73	3,67	0,75	0,135
M3 – IDRA 500	1,53	5,51	17,03	0,054
M5 – IDRA 420	1,9	8,78	18,28	0,092
M8 – STP 500	2,03	8,04	28,98	0,107
Furnace GUINEEA nr.2	-	1,7	1,54	0,002

Table 4. – Part 2

EEA component / Equipment	W_U		Error	
	W_{TRU} [kWh]	W_{MU} [kWh]	[kWh]	[%]
M1 – COLOSIO 320	6,68	3,95	1,29	4,7
M2 – IDRA 420	24,44	18,53	-0,056	-0,1
M3 – IDRA 500	7,22	0,39	-0,033	-0,1
M5 – IDRA 420	8,34	9,44	-0,06	-0,13
M8 – STP 500	8,18	0,61	-1,32	-2,8
Furnace GUINEEA nr.2	-	1,23	-	-

Table 5. Cumulative real EEA results over the injection machines

Feature size	[kWh]	[%]
A. absorbed energy [W_a]	209,409	100
B. output energy [W_i]	209,588	100,09
1. useful energy [W_U]	89,01	42,50
2. losses [ΔW]	120,578	57,58
• thermal [ΔW_{TR}]	18,19	8,68
• on engines [ΔW_M]	30,61	14,62
• mechanical, in mechanisms [ΔW_{mec}]	71,35	34,07
• on short lines [ΔW_L]	0,428	0,21
C. closing error	-0,179	-0,09

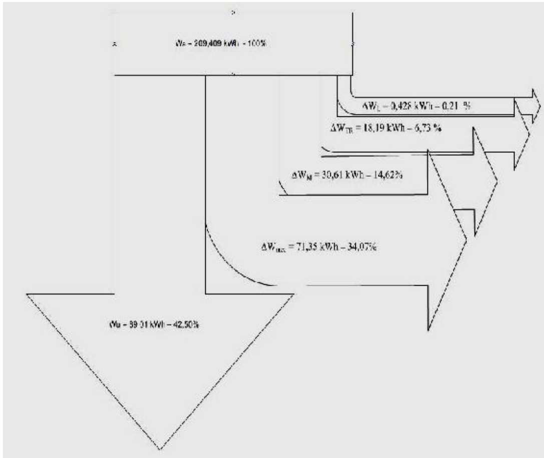


Figure 13 Real EEA Sankey diagram for injection machines

Details regarding the EEA at TI-C level, and of some contour components are presented in [14]

CONCLUSIONS

Measurements and assessments of the EEA of TI-C contour will draw the following conclusions:

Electro-thermal processes, dedicated essentially to maintain molten Al alloy and to inject it for the pieces, is the second category of processes within TI-C in terms of consumption level (209.41 kWh in regard to 218.8 kWh - compressor station).
Is identify, in this category of processes, a substantial reserve of working machines. Thus during the making of EEA only five injection machines operate and an furnace, the other being stopped or defects.
Referring to the five injection machines on which specific EEA measurements and assessments were made we find under energetic aspect:

• A large dispersion of energy efficiency: 19% (M8), 24% (M3), 38% (M1 and M5), 82% (M2);

• A large dispersion of thermal power losses: 29% (M1), below 10% (other machines);

• very high mechanical losses in mechanisms part of the injection machines: 62% (M8), 53% (M3), 39% (M5).

These findings reflect the existence of large reserves of energy efficiency for the injection moulding machines.
The overall efficiency of injection moulding machines is 42.5% below similar processes of the same type and well below of similar processes on which the furnaces are induction type.[15] Mechanical losses in mechanisms (ΔW_{mec}) are extremely high (34.07%), motor losses are high (14.62%), and the heat are very reasonable, except for M1 machine.

In terms of power quality, the records reflect:

• Quality of voltage is good at the terminals corresponding to all injection moulding machines and the furnace analysed (CP2)

• The quality of the current absorbed by all five injection machines (THDI = 6%) and the furnace CP2 (THDI = 7.69%) is good, in terms of current waveform;

• The quality of the current absorbed by the furnace Guinea no. 2 (CP2) in terms of actual values of phases is not good(9.9 A, 9.5 A, 12.3 A, 22.5 A);

Power factor recorded at the injection moulding machines terminals reflect the presence of the furnaces influence over the structure, ranging between 0.81 (M1) and 0.91 (M5). Furnace Guinea (CP2) has a power factor well below neutral (0.55), reflecting significant oversized electric motors, operating in its structure.

Real EEA closing error at the electro-thermal processes is well below the limit allowed [12]: - 0.09%
For the contour, energy efficiency is 42.5% below the characteristic of similar optimized and advanced processes. Energy losses occur mainly in machinery and engines, reflecting their advanced worn-out state, and low loading.

The reducing of the electric energy consumption over the contour, can be achieved mainly through deep maintenance of some machines (Table 6);

Table 6. Estimates of the energy effects of maintenance actions

Working machines	Aims of the maintenance actions	Reduction of energy losses [δ(ΔW)]
Injection machine M1 Colosio 320	Insulation and heat sealing, in order to reduce heat losses	$\delta(\Delta W_{TR})$=4,07kWh
Injection machines M3, M5, M8	Maintenance to the mechanisms to reduce friction and heat losses	$\delta(\Delta W_{mec})$=43,11kWh
Indirect reduction of power losses by reducing consumption		$\delta(\Delta W_L)$=0,097kWh
Total estimated energy effects		$\delta(\Delta W)$=47,417kWh

Applying the measures described above we can obtain a reduction of the absorbed energy
Optimal EEA of the analysed contour is presented in Table 7 and Figure 14:

Table 7. Optimum EEA results over the injection machines

Feature size	[kWh]	[%]
A. absorbed energy [W_a]	162,16	100
B. output energy [W_i]	162,31	100,09
1. useful energy [W_U]	89,01	54,89
2. losses [ΔW]	73,3	45,20
• thermal [ΔW_{TR}]	14,12	8,71
• on engines [ΔW_M]	30,61	18,87
• mechanical, in mechanisms [ΔW_{mec}]	28,24	17,41
• on short lines [ΔW_L]	0,33	0,20
C. Closing error	-0,146	-0,09

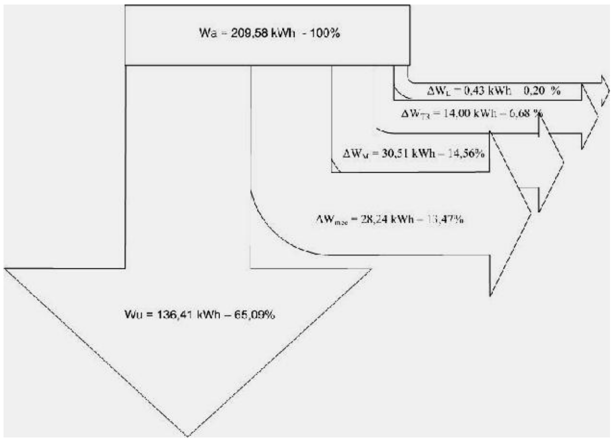


Fig. 14 Optimum EEA Sankey diagram for injection machines

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