Scientific results, theses

1. During the course of the experiments, I established that increasing gas use does not go together with a drop in specific grinding energy to the merits (Diagram number 1). In the 50 – 80^{o}C exit air temperature range, W_f specific energy hardly changes, hardly drops, and the extent of the drop does not cover the significant increase of energy consumption originating from gas consumption.

?t Term h	Q Mill Production t/h	Exit Temperature C^{o}	Mill Electricity consumption kWh
2	50	37.8	687
2	50	50.0	644
2	50	60.0	642
2	50	70.0	630
2	50	80.0	614
2	50	90.0	528

Table 1: Mill electricity consumption

1.1. Diagram number 2 proves that, in spite of the stagnation or decrease of specific grinding electric energy, total specific energy is increasing drastically due to the consumption of natural gas. The use of gas energy is superfluous and groundless from the aspect of grinding. It has a role only in drying.

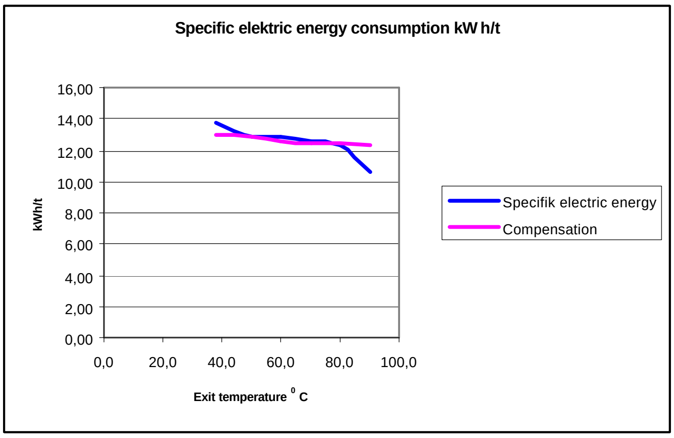

Diagram 1: Specific electric energy consumption

Y = -0.04966220204 * X + 15.68983366

Relative standard deviation: 7.75 %

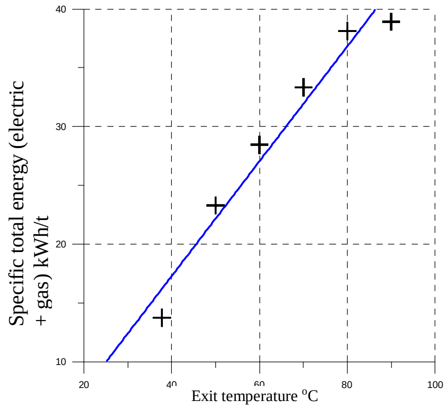

Diagram 2: Specific total electric energy consumption

Y = 0.4884610433 * X - 2.259198763

2. I have proved that, regardless of the fact that grindability hardly improves with the increase in the temperature of the grinding space, there is a lower limit value from the aspect of temperature that has to be met. This limit value is necessary so that, in the dust filter separating the dust-air mixture, the pressure difference emerging as the result of the extent of adhesion be continuously lower than the value specified by the manufacturer and not endanger the undisturbed operation of the technology.

Date / time	1	2	3	4	5	6	7	8	9	10	11	12	13
Loading	62	62	62	62	62	62	62	62	62	62	62	62	62
Dust-filtering pressure 1 mbar	8.8	11.9	11.1	11.3	11.5	11.1	11.2	10.7	10.5	9.7	9.5	8.8	8.1
Interim pressure	36.9	39.2	38.8	40.2	40.0	41.4	40.7	34.1	36.2	37.4	36.7	39.1	37.0
Temperature ^{o}C	30	35	40	45	50	55	60	65	70	75	80	85	90

Date / time		1	2	3	4	5	6	7	8	9	10
Loading		62	62	62	62	62	62	62	62	62	62
Dust-filtering pressure 2 mbar		11.1	11.0	11.2	11.2	11.4	10.5	8.2	10.2	10.5	10.7
Interim pressure		40.5	39.6	38.5	37.8	35.1	41.7	49	35	41.1	47
Temperature ^{o}C		35	40	45	50	55	60	65	70	75	80

Table 2: Dust-filtering pressure

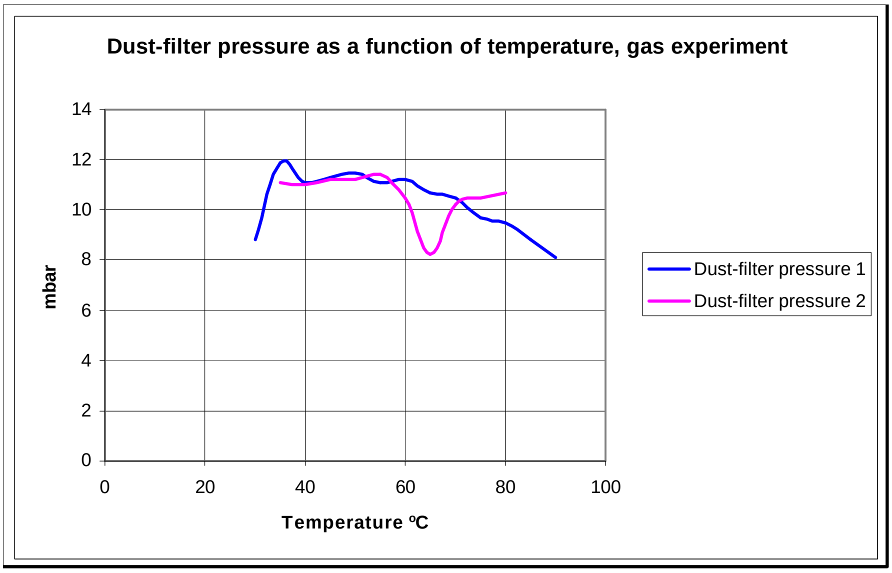

Diagram 3: Dust-filtering pressure

Dust-filter pressure 1 mbar: Y = -5.26048951 + 0.814536297 * X - 0.01226373626 * pow(X,2) + 5.431235431E-005 * pow(X,3)

Relative standard deviation: 11.28 %

Dust-filter pressure 2 mbar: Y = -18.65547786 + 1.773286713 * X - 0.03358041958 * pow(X,2) + 0.0002004662005 * pow(X,3)

Relative standard deviation: 8.29 %

The threshold value of temperature: 35°C.

The temperature of the grinding space has a dual threshold value.
The threshold value that is necessary for keeping the pressure difference in the first dust-filter under the limit value, which is of a technical nature and secures the undisturbed operation of technology.
The second threshold value is defined by the humidity contents of the finished product. With the experiments, I established that this temperature is 37.8°C (Table 1).
It is always the higher threshold value that is to be set for the undisturbed operation of the technology.

3. I have established that there is a linear functional relationship between the loading performance of the mill (capacity) and the specific grinding energy need.
The performance of the mill can be varied within wide borders. The lower and upper limits of the quantity of material flow are defined by the thickness of the grinding bed.
The lower limit value is regulated by the vibration speed of the mill.
The upper limit value is defined by the throttling down of the mill, through the increase of energy consumption.
Table 3 contains the measurement results, which are presented in Diagram 4 in a diagram form.

Loading	[t/h]	48	49	50	51	52	53	54	55	56	57	58
Specific electric energy consumption	[kW/t]	13.1	13.0	12.4	12.8	12.5	12.3	12.2	12.2	13.0	11.7	11.7

Loading	[t/ó]	59	60	61	62	63	64	65	66	67	68
Specific electric energy consumption	[kW/t]	11.7	11.4	12.1	11.5	11.1	10.4	10.5	10.6	10.2	9.7

Table 3: Specific electric energy

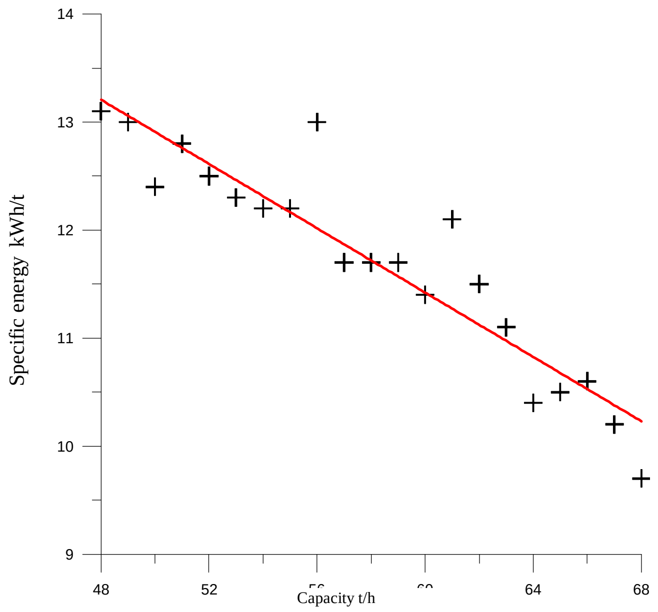

Diagram 4: Specific electric energy

The correlation factor of the measuring points can be described in the form of 0.86262 and the function, and is suitable for the execution of preliminary calculations.

$$Y = -0.1488311688 * X + 20.35125541$$

Relative standard deviation: 8.28 %

4. With the help of grindability examinations, I established that the grindability of pure limestone with low humidity contents is not influenced by the temperature; fluctuation is within the margin of error.

   The measurements executed have proven that within the relationship of grindability, humidity contents, drying temperature and dead rock, the dead rock contents has a defining effect on grindability.

	Humidity contents [%]	**Bond work index calculated from stress measurement** [kWh/t]	**Bond work index calculated from Hardgrove number** [kWh/t]
100 % limestone	0	9.83	13.39
5 % dead-rock	0.22	8.31	13.16
10 % dead-rock	0.44	7.89	12.92
100 % dead-rock	4.44	3.92	8.71

Table 4: Grinding work-need upon varying dead-rock contents

5. It can be established that stress measurement presents the changes of grindability more finely than the Hardgrove-index or the Bond work index, calculated from that.
   Upon the evaluation of the results, it must be taken into account that I was not able to achieve identical grinding circumstances on every occasion. Upon 0.12 – 0.14 % humidity contents, temperature was 40°C, with the exception of the Bond examination, where we worked at room temperature.

	On the basis of the Hardgrove examination		On the basis of plant measurements	On the basis of Bond examination
	Calculated from Hardgrove number	Calculated from stress measurement		
Bond work index [kWh/t]	13.66	9.83	10.02	8.71

Table 5: The faring of Bond work indices (pure limestone)

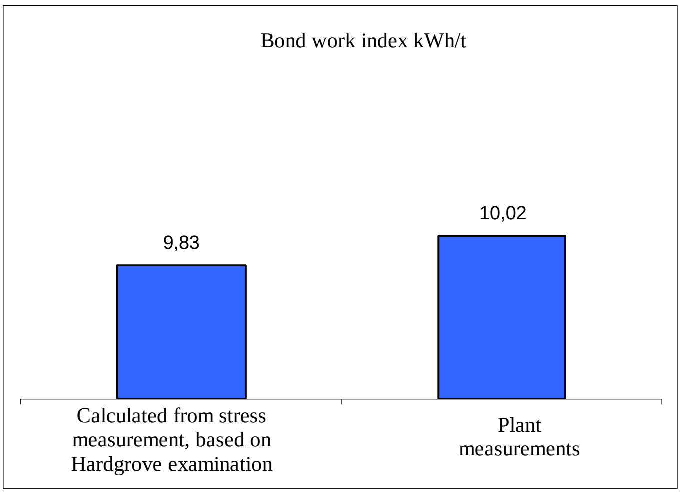

Diagram 5: Bond work indices

In spite of the divergence of the sample material, the results prove that stress measurement is more precise, is in more harmony with the plant result.

6 a.) With the help of experiments, I established what portion of the electric energy input for grinding is used for drying:

$$Q_{vsz} = k\ Q_{vill}$$

k – the factor defined from the energy model, which shows what portion of the electric energy input is used for drying.

b.) I defined the formula of the energy at my disposal for drying:

$$Q_{sz} = Q_{lev} + k\ Q_{vill.en.}$$

Q_{lev} – change of the heat contents of the air passing through the grinding space.

7. For the automation of the process control, from the drying energy formula and the momentary measured parameters of the loaded material, I defined the necessary drying energy

$$\mathbf{Q_{aszp} = Q_{1\ (loaded\ material\ heat\ change)} + Q_{2\ (loaded\ material\ evaporation)}}$$

Q_{aszp} – The drying energy defined on the basis of the momentary material parameters

a.) if $Q_{aszp} > Q_{szár}$

the input of exterior, natural gas energy is necessary, the extent of which can be defined with the 34 MJ/m^3 = 9.4455 kWh value, from the difference.

b.) if $Q_{aszp} < Q_{szár}$

there is superfluous energy in the system (e.g. summer heat – high material temperature), which we can utilise through the loading of extra material.

? Q – the size of the plus energy of the system

$$? Q = Q_{szár} - Q_{aszp}$$

In the knowledge of ? Q and plant Bond work index, the extent of extra material loading can be defined

$$m_{üz} = \frac{?Q}{W_{ü\,iB}}$$

8. I have established that if we compare the plant Bond-index with the parameters of the material loaded and the air drawn through (temperature, humidity contents), we can establish that the Bond index is hardly affected by these parameters, while the mill engine performance is significantly affected by them.

	Bond-index [kWh/t]	Electric performance [kWh]	Loading [t/h]	m^2/g	Humid.cont. [%]
1st experiment	10.08	658.86	56	1.6	0.69
2nd experiment	10.44	679.91	54	1.6	0.97
3rd experiment	10.43	727.28	58	2.2	1.43
4th experiment	10.03	673.77	56	1.6	0.80
Difference of extreme values:		4 %		~ 10.4 %	

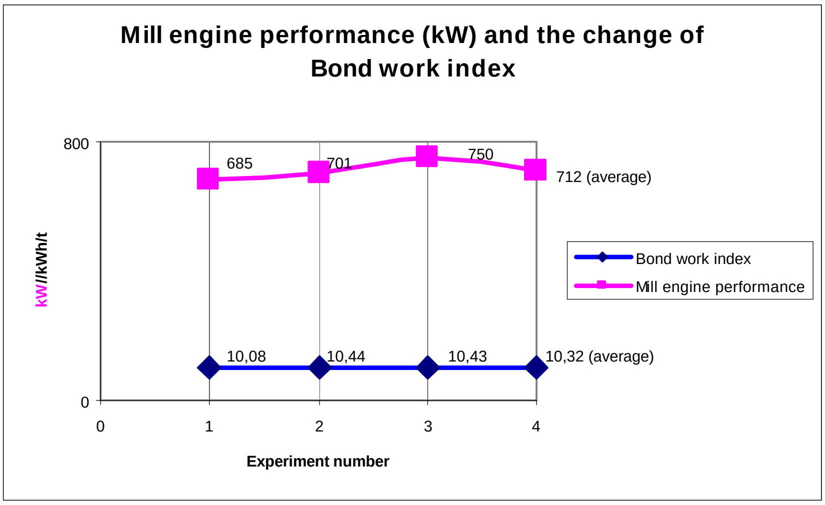

Diagram 6: Electric energy Bond-index / experiment

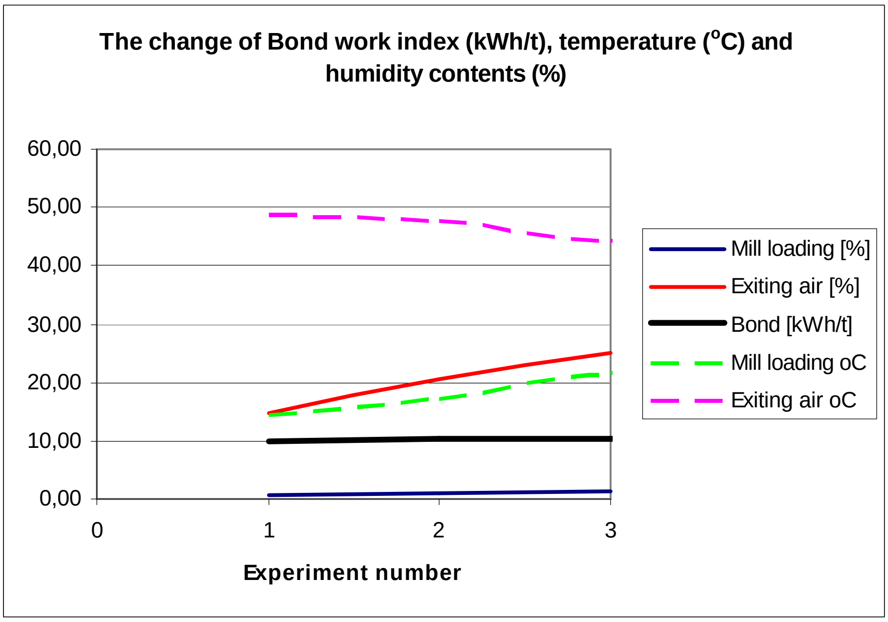

Diagram 7: Bond dry and wet L_G

9. With the laboratory experiments, we were able to prove that the number of micro cracks emerging in the rocks during the course of explosions as compared to non-exploded limestone, and this affects grinding energy, decreasing that. This manifested itself in a striking manner when we increased grinding temperature.