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RESEARCH ABOUT THE GROUPING OF MAGNETRONS ON THE SAME RESONANT CHAMBER

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Abstract: this paper presents part of the research carried out by the authors in the domain of microwave technologies, which belong to the larger field of the nonconventional technologies; the power emitted by a microwave installation depends on more factors, such as the magnetron nominal output power, the matching degree of the magnetron to the components of the installation, the matching degree of the applicator to the load etc.; as for the microwave production, the output power can be increased either by replacing the original magnetron with a more powerful one, or by using two or more magnetrons grouped on the same resonant chamber.

1. INTRODUCTION

Nowadays, the microwave technologies are more and more widely used in many industrial domains, due to the multiple advantages of the microwave energy: it is pollutant-free and flexible, acts instantaneously on the treated material without any transmission medium, allows the automation of the heating processes, reacts without delay to adjustments and offers very hygienic working conditions.

The demand for useful microwave power can be met by using microwave generators with 200 W ÷ 30 kW nominal power. In the case of 100 W installations, it is best to use more 25 ÷ 30 kW microwave generators which can be connected or disconnected according to the required output power, which may also vary during the heating process. Worldwide, there is a trend for the standardisation of the magnetron nominal power, such as 230 W, 650 W, 800 W, 1.5 kW, 2.5 kW, 5 kW, 30 kW. The microwave frequency for small installations, under 10 ÷ 15 kW, is 2.45 GHz, and 915 MHz for big installations [1, 2, 6].

2. CALCULATION RELATIONS

The electrical power absorbed by the operating microwave device was calculated by measuring of the input voltage and current, by means of the well-known calculation formula:

$$P_{abs} = U_{input} \cdot I_{input} \tag{1}$$

adapted for the time-division of the microwave emission:

$$P_{abs} = U_{input} \cdot I_{off} \cdot \frac{t_{off}}{t_{on} + t_{off}} + U_{input} \cdot I_{on} \cdot \frac{t_{on}}{t_{on} + t_{off}} \tag{2}$$

where:

P_{abs}	:	electrical power absorbed by the device [W]
U_{input}	:	input voltage of the microwave device [V]
I_{on}	:	current absorbed with microwave emission [A]
I_{off}	:	current absorbed without microwave emission [A]
t_{on}	:	duration of enabled emission, in one on/off cycle [s]
t_{off}	:	duration of disabled emission, in one on/off cycle [s]

Taking into account that the main purpose of the microwave installations is to heat the treated object, the direct calorimetric measurement method proves itself to be the most adequate in our case. Because we used glass recipients with known water quantities as loads, the calculation formulas are also well-known:

$$Q_{water} = m \cdot c_{water} \cdot \Delta T \qquad (3)$$

$$P_{water} = \frac{Q_{water}}{t} \qquad (4)$$

where

Q_{water}	:	energy absorbed by the water sample [J]
P_{water}	:	power absorbed by the water sample [W]
c_{water}	:	water specific heat, 4187 J/(kg·degree)
m	:	mass of the water sample [kg]
ΔT	:	temperature rise by treatment [ºC]
t	:	microwave treatment duration [s]

The energy efficiency of the microwave device under study is:

$$\eta = \frac{P_{water}}{P_{abs}} \qquad (5)$$

The efficiency of a microwave installation depends greatly on the efficiency of the magnetron itself, but also on the matching between the magnetron, waveguides, applicator and load. As a matter of facts, the microwave power absorbed by the load may vary between the magnetron nominal power at perfect matching, and zero at total mismatch, when all the microwave power reverses towards the magnetron, with the risks of overheating, arcing etc. In the usual cases, the existence of mismatch situations is accepted, so the magnetron and the additional devices are designed to withstand such operating conditions, and the installation comprises a thermal safety device in thermal contact with the magnetron, which cuts out the power supply if the overheating becomes too drastic. So, the microwave device efficiency varies also with the load matching [2, 6].

3. EXPERIMENTAL DEVICE

Along other measuring techniques of the emitted microwave power emitted, we carried out efficiency measurements on a Sharp R-8680(W)A microwave oven, modified in order to add another magnetron along with its original one. Thus, now there are two waveguides attached to the resonant chamber (fig.1), which bring microwaves from the two magnetrons (fig.2) [3, 4, 6].

The microwave oven is fitted with a rotary table, driven by a small AC motor, in order to even the microwave absorption into the treated material.

In order to carry out our experiments, we used the oven original electronic command device, along with a volt-ammeter scheme for the absorbed electrical power (fig.3). Because of the intense supply currents, exceeding 10A, which could endanger the existing measuring devices, we mounted a 0.1Ω shunt in series with the entire installation, and we measured the across it by means of an electronic auto scaling voltmeter.

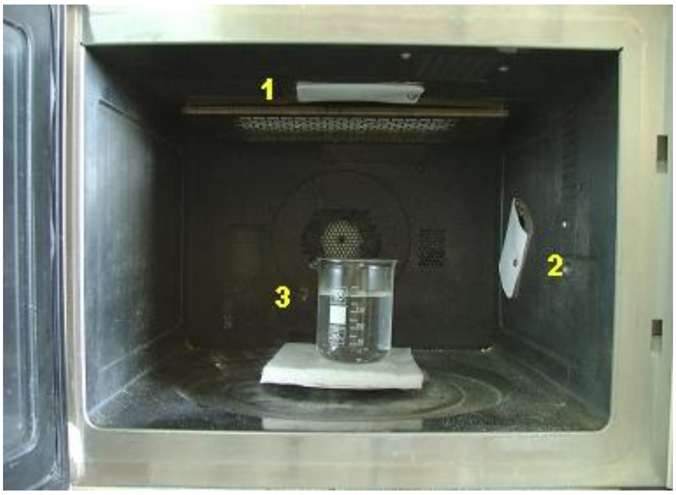

Fig.1. Resonant chamber of the R-8680(W)A microwave oven, modified, with two waveguides; 1 – initial waveguide, 2 – added waveguide, 3 – beaker.

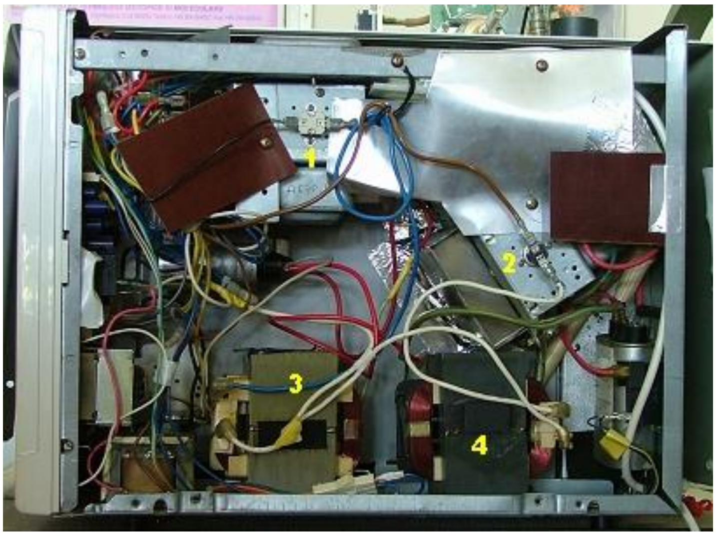

Fig.2. Interior of the two-magnetron oven; 1 – original magnetron, 2 – added magnetron, 3 – transformer of the original magnetron, 4 – transformer of the added magnetron.

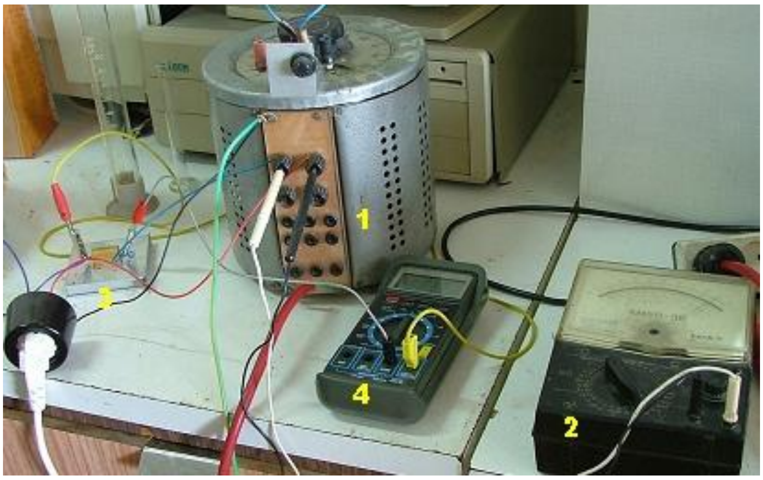

Fig.3. Measurement of the electrical absorbed power; 1 – autotransformer, 2 – voltmeter, 3 – 0.1Ω power shunt, 4 – electronic voltmeter.

4. EXPERIMENTAL MEASUREMENTS

We performed direct calorimetric power measurements by means of a glass beaker filled with 200 ml distilled water, on a 60 s time interval [5]. Because the magnetron filaments are fed together with their anodes, we carried out the efficiency measurements only according to the emission time division factor, with both magnetrons enabled, then with one magnetron enabled and the other one disabled. The supply voltage was maintained at 220 V by means of the autotransformer.

The results are shown in tab.1. Fig.4 shows the diagram of the device efficiency, fig.5 shows the water sample temperature rise, and fig.6 shows the electrical power absorbed by the device and the microwave power absorbed by the water sample.

Tab.1. Results of the measurements carried out on the two-magnetron microwave oven.

I_{on} (A)	I_{off} (A)	ΔT (°C)	Q_{water} (J)	P_{water} (W)	t_{on} (s)	t_{off} (s)	Q_{abs} (J)	P_{abs} (W)	η (%)	
11.7	0.38	5.0	4'187.00	69.78	5	25	29'920.00	498.67	13.99	1+2
11.7	0.38	18.3	15'324.42	255.41	12	18	64'785.60	1'079.76	23.65	
11.7	0.38	25.9	21'688.66	361.48	16	14	84'708.80	1'411.81	25.60	
11.7	0.38	42.3	35'422.02	590.37	22	8	114'593.60	1'909.89	30.91	
11.7	0.38	58.8	49'239.12	820.65	30	0	154'440.00	2'574.00	31.88	
6.5	0.35	3.4	2'847.16	47.45	5	25	18'150.00	302.50	15.69	1
6.5	0.35	11.2	9'378.88	156.31	12	18	37'092.00	618.20	25.29	
6.5	0.35	14.3	11'974.82	199.58	16	14	47'916.00	798.60	24.99	
6.5	0.35	19.1	15'994.34	266.57	22	8	64'152.00	1'069.20	24.93	
6.5	0.35	29.3	24'535.82	408.93	30	0	85'800.00	1'430.00	28.60	
5.5	0.33	2.7	2'260.98	37.68	5	25	15'730.00	262.17	14.37	2
5.5	0.33	10.7	8'960.18	149.34	12	18	31'653.60	527.56	28.31	
5.5	0.33	14.5	12'142.30	202.37	16	14	40'752.80	679.21	29.80	
5.5	0.33	19.6	16'413.04	273.55	22	8	54'401.60	906.69	30.17	
5.5	0.33	32.2	26'964.28	449.40	30	0	72'600.00	1'210.00	37.14	

According to our measurements, magnetron 2 heated more efficiently the water sample. The maximum efficiency of this device is 37.12% for magnetron 2, 28.60% for magnetron 1 şi 31.88% for both magnetrons, which is approximately the sum of the single magnetrons efficiencies.

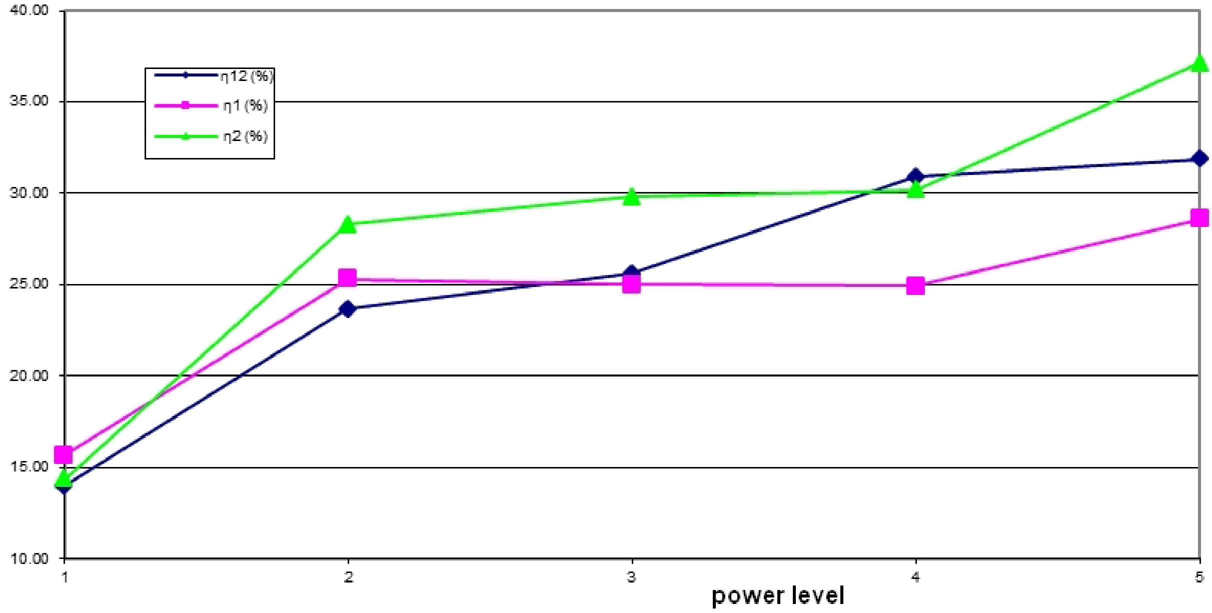

Fig.4. Efficiency of the two-magnetron microwave oven, versus the power level.

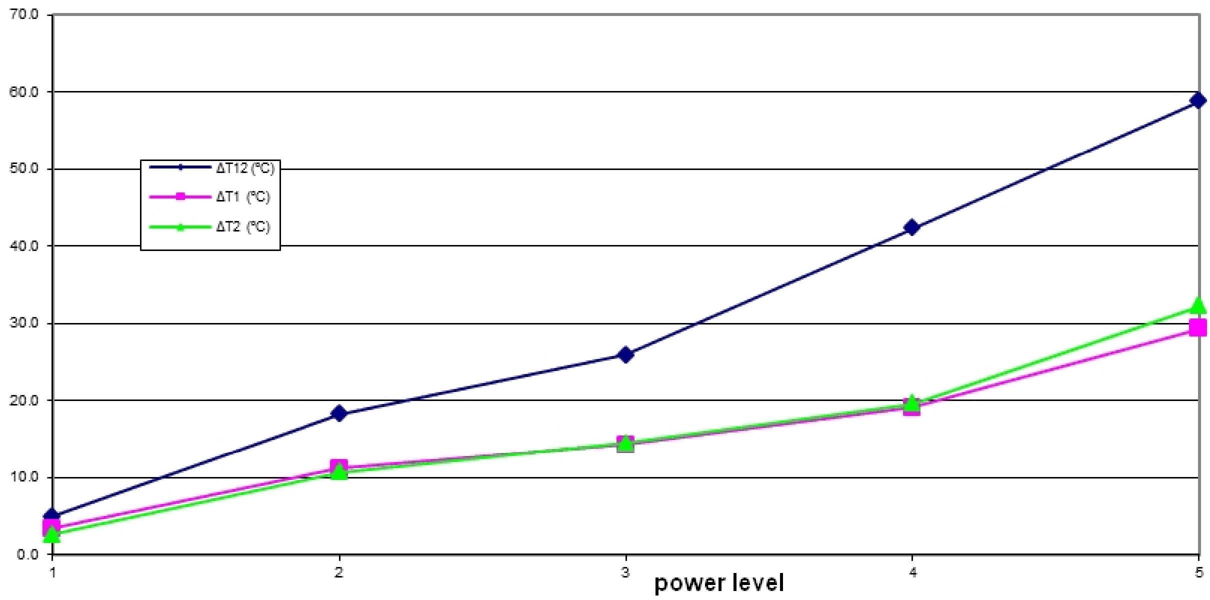

Fig.5. Temperature rise versus power level.

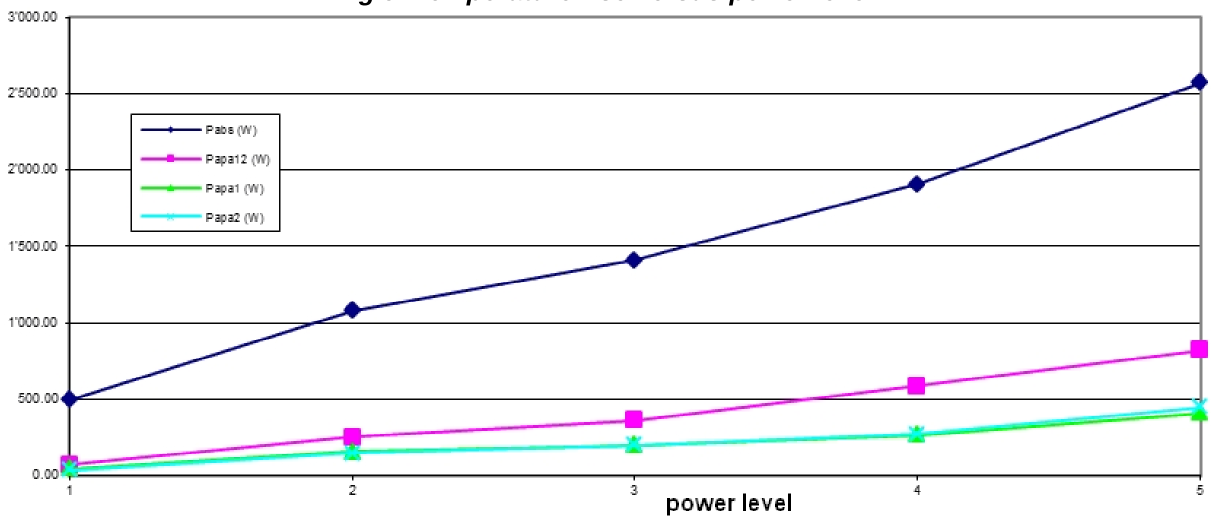

Fig.6. Electrical power absorbed by the device and microwave power absorbed by the water sample, versus power level.

The maximum magnetron powers are 408.93 W and 449.40 W respectively, and the device maximum power is 820.65 W, which is approximately the sum of the single magnetrons powers.

5. CONCLUSIONS

The power of a given microwave installation can be increased by simply adding one additional magnetron or even more of them, because the total power of the device is approximately the sum of the single magnetron powers, while the efficiency remains approximately the same, especially if the magnetrons are identical. Of course, the waveguides must be positioned in such manner that the magnetrons do not emit microwaves directly to each other.

We mention that, for electrical security, series connection of the magnetrons is out of the question, because their anodic voltages of 4.5 kV should be connected in series, which raises insulation issues.

Also, magnetrons cannot be connected in parallel either, because of the magnetron parameters dispersion, which can lead to the short-circuiting of the entire group by the magnetron with the smallest initiation voltage and then the cascade destruction of the entire group of magnetrons. The solutions of equalizing the currents of the parallel transistors cannot be applied here. In the same time, different operating currents and voltages make problematic or even impossible the pin-to-pin connection of the magnetrons. Thus, the only viable solution for using multiple magnetrons remains their grouping on the same resonant chamber or waveguide, by simply adding several assemblies magnetron & power supply and electrically connecting their anodes together.

Because of the same electrical safety reasons, added to the protection of the operating personnel against microwave leakage, it is recommended to use a group of smaller power than one single powerful magnetron. Also, there are several complex microwave treating devices, fitted with conveyors, which use several different microwave irradiation patterns, in which each section magnetron & waveguide & power supply can be separately enabled and disabled automatically, according to the special treatment profile, and only at the proper moment when the load is passing in front of the applicator, which also ensures important electrical energy savings.

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