

INTELLIGENT EQUIPMENT FOR ELECTRIC ARC WELDING

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Inverter, rectifier, C.C. generator, resonant intelligence, MIG/MAG welding, standard, synergy, pulsing current

SUMMARY

The development and the evolution of power sources for electric arc welding has depended and continues to depend on the users' demands, as well as on the technological level of the producers. If we were to consider as a criterion only the modality to control the power provided to the electric arc, welding equipments would fall into two big categories:

- a- with electromagnetic control
- b- with electronic control

The first category includes welding sources of the following types: generator, transformer and non- commanded rectifiers, while the second category includes: commanded rectifiers, simple and double inverters as well as those of the generation using for command the 'INTELLIGENT RESONANT' option.

Practically, nowadays all inverters for electric arc welding are equipped with MOSFET and IGBT electronic devices for power.

This paper presents a concise history regarding the development of electric arc welding sources, the main functions with which 'INTELLIGENT RESONANT' type commanded sources are equipped, 'HYBRID' high productivity equipments, as well as the influence of certain functions on the features of the arc welded seam, respectively on the exploitation of welding equipments.

1. SOURCES OF POWER FOR ELECTRIC ARC WELDING

The power source along with the welding electric arc form a dependent and mutual energetic system. It is in the characteristics of this system that the features of the arc welded seam mostly depend on (mechanical and geometrical features).

The essential prerequisites of an electric arc welding source can be narrowed down mainly to the type of its external feature, as well as to the possibilities to adjust the output parameters, tension- current: according to the welding procedure, of the material to weld, and last but not least, according to the position of the seam.

The evolution in time, according to the technical features and to the possibilities to adjust the parameters of the welding method are presented in image 1. These sources belong to the first category, that of the electromagnetic control. The main parameters of these sources are presented in chart 1.

By running an analysis of the possibilities for adjustment presented in images 2 and 3 it can be inferred that for covered electrode welding, the features obtained according to image 2c are the so called 'ideal' ones (for reduced welding currents high empty running voltage). Each source in image 1 is built for a single welding procedure, namely: 1a, b, d for electric arc welding with covered electrodes, while 1c is for welding in protective gas environment, MIG/MAG using short or spray arc transfers.

The external features of welding sources such as those displayed in 3 a and b are recommended for electric arc welding under flux layer and in a protective gas environment. These features are valid for classic sources, as well as for the inverter type. For the features in image 3a, the use of a function called hot start is needed, in order to fuse the electric arc.

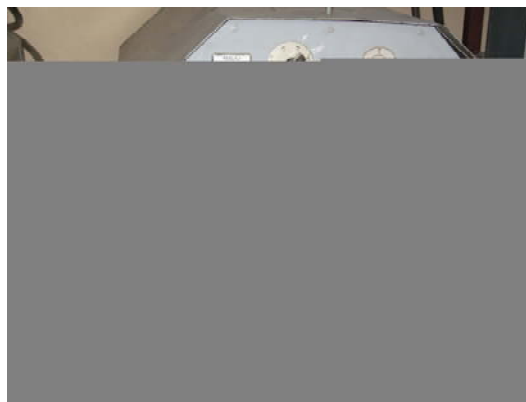
*a**b**c**d*

Fig.1. Sources for electric arc welding: a,b,c of C.C. ; d – of C.A.

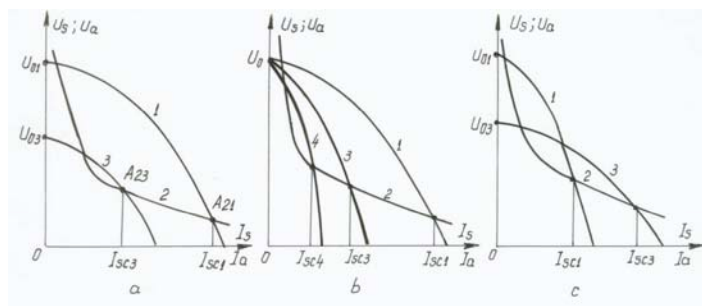


Fig. 2 Adjustment of the welding current through modifying the shape of the external features: a – fine adjustment; b – gradual adjustment; c – mixed adjustment (ideal)

Fig.3 The shape of external features: a- for the SF procedure; b- for the MIG/MAG procedure

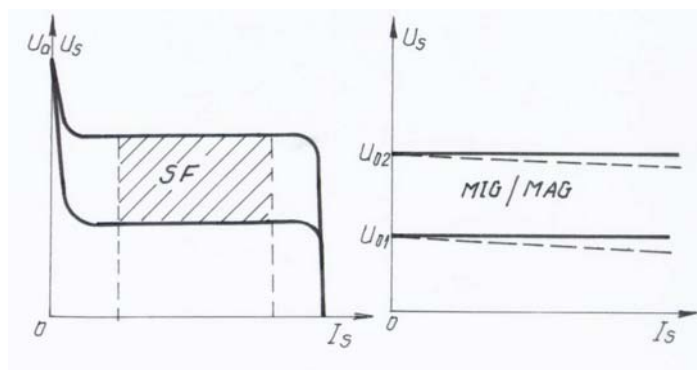


Table 1. Main features of the welding sources

Nr. crt.	Param. Type	U_1 [V] 50 Hz	U_{S0} [V]	Range of welding current [A]	Ratio [%]	Weight [Kg]	Procedure
1	Generator of C.C.	3x400	80	25÷625	0,45÷0,65	850	111-SE
2	Transformer	230 400	75	50÷500	0,6÷0,8	350	111-SE
3	Rectifier	3x400	80	0 – 1500	0,5÷0,9	650	111-SE și/sau 135- MAG

The adjustment of the working method for these sources it is mainly done through modifying the shape and the gradient of the external feature, but the quality of the welded seam depends on the dynamic behavior of the source, on the level of qualification of the welding operator, as well as on the control of the arc in the case of mechanized or semi mechanized welding equipments. The laws of functioning and the considerations referring to the analysis of stability of the electric arc welding process in a mechanized and semi mechanized protective gas environment are presented in chart 2.

Table 2. Main features of welding with: $v_{ae}=ct.$; $v_{ae}=f(U_a)$; $v_{ae}=f(I_a)$

System	Gen eral law	Laws of functioning	Adjustment of the arc's voltage	Adjustment of the current	Obs.
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				through the arc	
$V_{ae} = ct$	$dl_a = V_{te} - V_{ae}$	$V_{ae} = k_i I_a - k_u U_a$ $k_i = C \frac{I_a}{d_c^2}$ $\Delta I_a = \Delta I_{a0} e^{-\frac{t}{T_{ar}}}$	From the source the $U_a = ct \pm 2\%$ variation maintained by the source.	From the feeding device wire by modifying V_{ae} $I_a = I_{a0} \pm \Delta I_{ai}$ $\Delta I_{ai} \geq 60A$	$K_s > 0$ $T_{ar} > 0$, but small -SF, $U_0 = (1,5-2)U_a$ -MIG/MAG $U_s \cong U_a$
$V_{ae} = f(U_a)$		$V_{ae} = k_{au}(U_a - U_r)$ $\Delta I_a = \Delta I_{a0} e^{-\frac{t}{T_{au}}}$	From the feeding device wire-electrode $U_a = U_0 + \Delta U_0 \pm 0,8V$	From the source $I_a = ct \pm 2\%$ Maintained by the source	$K_s > 0$ $T_{au} > 0$, but small
$V_{ae} = f(I_a)$		$V_{ae} = k_{ai}(I_a - I_r)$ $\Delta I_a = \Delta I_{a0} e^{-\frac{t}{T_{ai}}}$	From the source the variation $U_a = ct \pm 2\%$ maintained by the source	From the feeding device wire by modifying V_{ae} $I_a = I_{a0} \pm \Delta I_a$ $\Delta I_a \approx 5-10A$	$K_s > 0$ $T_{ai} > 0$, but small, it is recommended for Sf welding

2. INVERTER TYPE WELDING SOURCES

Welding sources with inverter – figure 4 – allow for an electronic control of the power supplied to the electric arc, and moreover, an intelligent control.

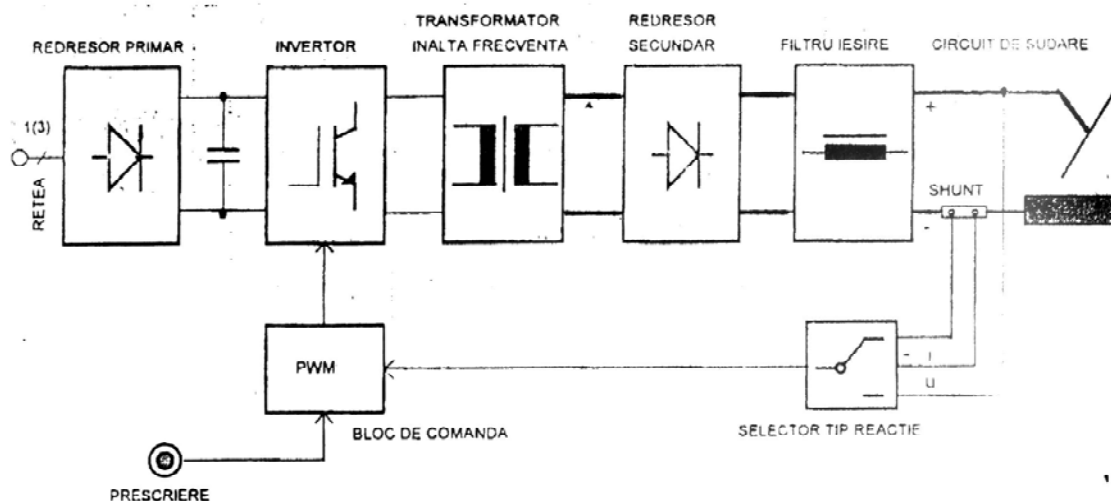


Fig.4 Electrical flow-chart of a welding block

The development of inverter welding sources is strongly connected with the evolution and characteristics of power semi-conductors, whose basic characteristics are presented in table 3 and which are capable to work at high frequency. These sources have totally shifted the mentality about welding equipments, both as construction, adjustment possibilities and applicability for two or more procedures.

Table 3. Basic characteristics of power semi-conductors

<i>Disp. Param.</i>	<i>Rapid controlled rectifier</i>	<i>Bipolar transistor</i>	<i>MOSFET tranzistor</i>	<i>IGBT transistor</i>	<i>Remark</i>
<i>Working current [A]</i>	400**	600**	100*	600**	* satisfactory ** good *** very good
<i>Backing-off voltage [V]</i>	2500	1200	500	1200	
<i>Switching time [μs]</i>	20*	50**	0,3***	1***	
<i>Command</i>	<i>Forced switch *</i>	<i>In the current **</i>	<i>In the voltage***</i>	<i>In the voltage***</i>	
<i>Switching frequency</i>	≤25 kHz	50kHz	125kHz	100kHz	

The inverter, whose image is presented in figure 5, closely reflects the usage of electronic circuits and devices in the conversion of direct current electrical energy into alternating current energy, at a different frequency than that of the industrial mains.

Due to the high primary switch frequency (100 kHz), the overall size and weight of the equipment are considerably reduced, there is a short reaction time, a very good dynamics and implicitly a good stability of the electric arc. Thus, the liquid metal drop is transferred without spatters.

Currently, the new generation inverters can be “MULTIPROCES”, which use the “INTELLIGENT REZONANT” variant to regulate the welding parameters, which results in: a high reaction speed, reduced size with lower power transistors.

If we compare only some characteristics of the inverters presented in table 4 with those of the classical sources presented in table 1, we will notice a clear progress in the field of electric arc welding. Moreover, applying the synergy for the standard and pulse variants (fig.6) in the case of MIG/MAG, SE, TIG processes, allows that the modification of one parameter permits the other ones to be changed, so that the welding regime can remain stable. The relation (1) indicates the mathematic formula of this adjustment:

$$F(V_{ae}, I_s, U_a, a, s)=0 \quad (1)$$

Where: V_{ae} – feed rate of the electrode wire, I_s – welding current, U_a – arc voltage, a – thickness of the corner joint, s – head to head thickness.



Fig. 5 Welding inverter

By the synergic control of the electric arc MIG/MAG welding process – but not only – we understand any system with a stub or locked loop by which a significant parameter of the system modifies the others, so that the balance condition of the working regime can be maintained.

The new generation of welding inverters, type TPS – 5000 or TIME-5000 digital, whose features are presented in table 4, are part of the multi-process welding equipments and can be used for welding of the types:

- MIG/MAG – manual, standard or pulse (synergic), figure 7;
- WIG – inert wolfram gas with LIFT-ARC starting, figure8
- SE – manual DC welding for any kind of electrode, figure 9.

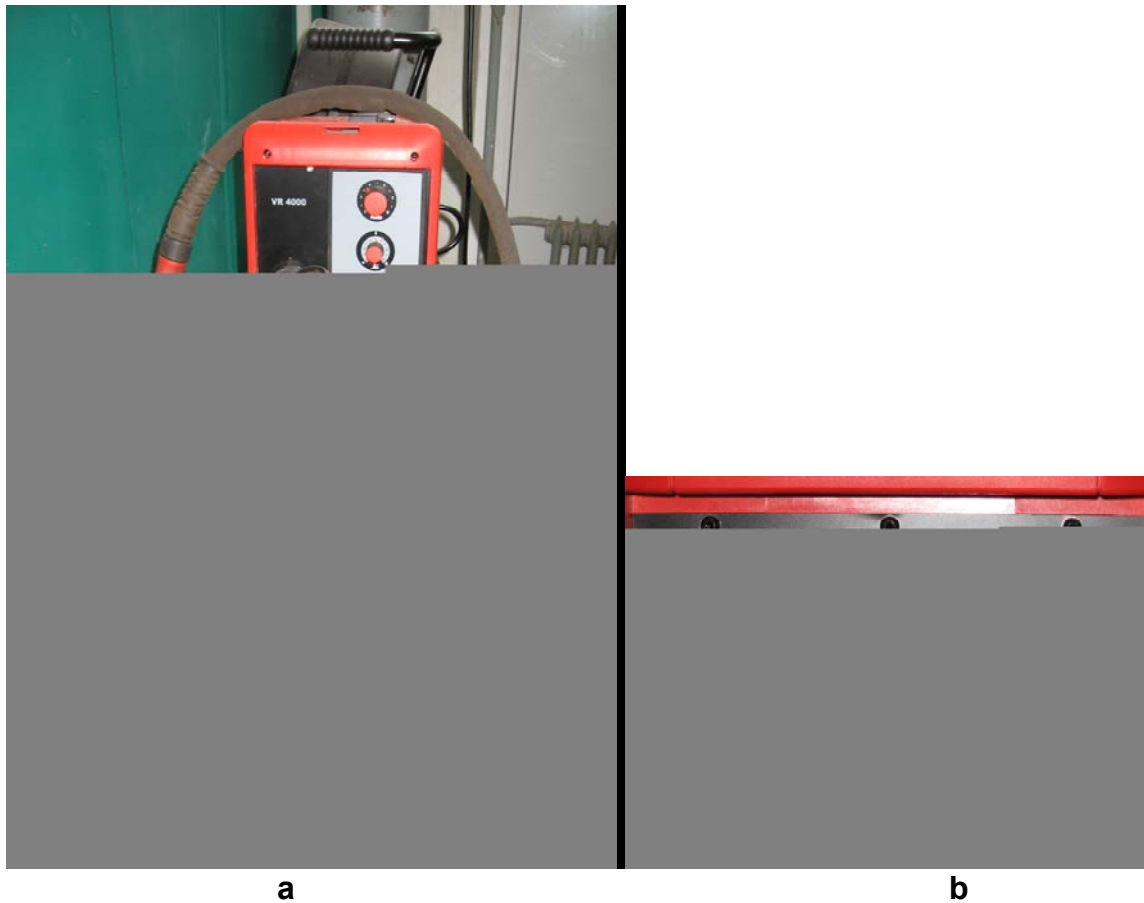


Fig. 6 Multi-process welding equipment: a - general view; b - command desk

Inverters are of the “DIGITAL” type, commanded through microprocessors and equipped with a series of standard or optional functions for improving the transfer of the liquid material drop through the arc, in order to reduce splatters, to increase the stability of the source-arc energetic system and to improve the features of welded joints. Table 5 presents the most important functions that “INTELLIGENT REZONANT” inverters have, as well as their role in the welding process selected by the digital panel of the source.

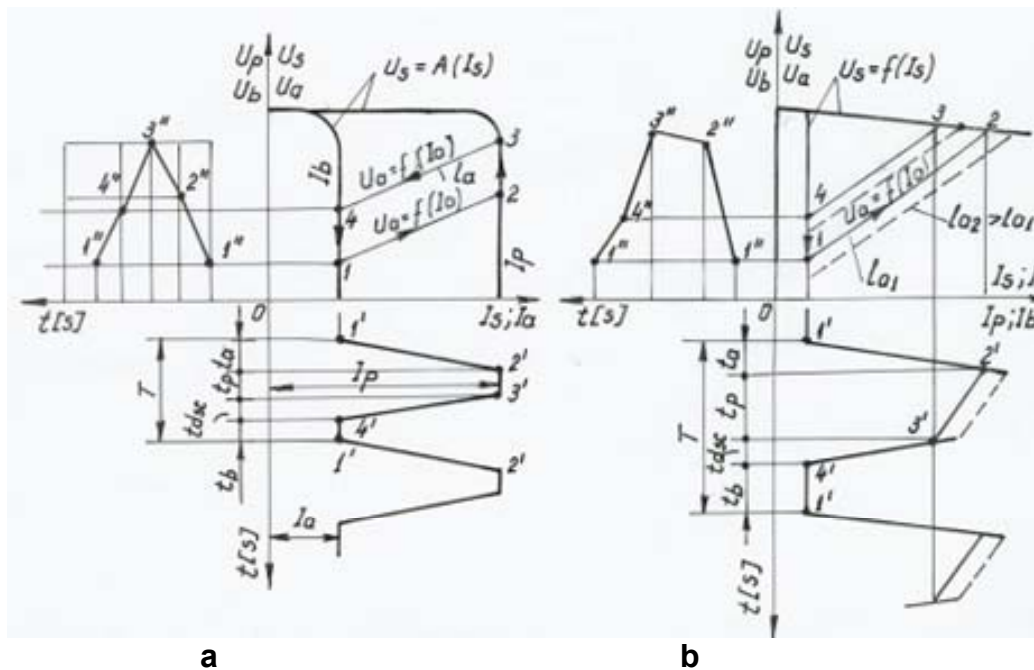


Fig.7 Shape of the current pulse in MIG/MAG welding:
a- I/I system ; b- U/I system

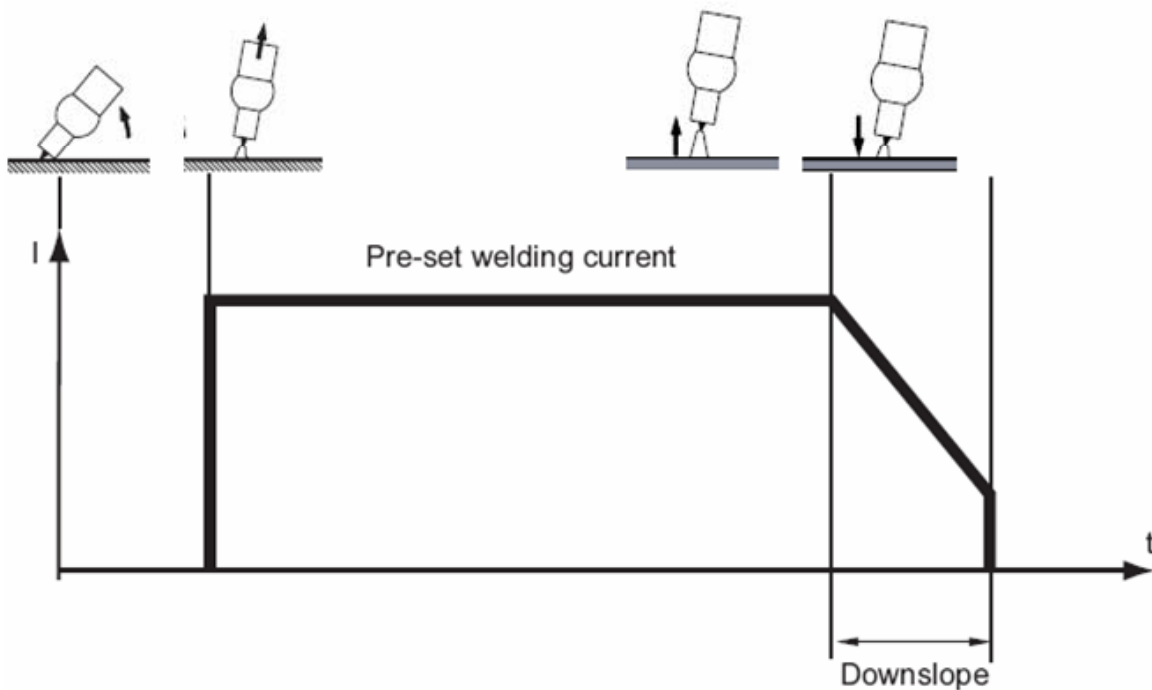


Fig 8. Welding cycle for WIG variant

If we analyse the characteristics presented in figure 9 and the possibilities of selecting them within the electric arc welding process, with covered electrodes, as well as their corresponding dynamics, we recommend the following usages:

- "cone" feature for rutile electrode welding;
- „0,1-20 A/V" feature for alkali electrode welding;

- „P” feature for cellulose electrode welding;

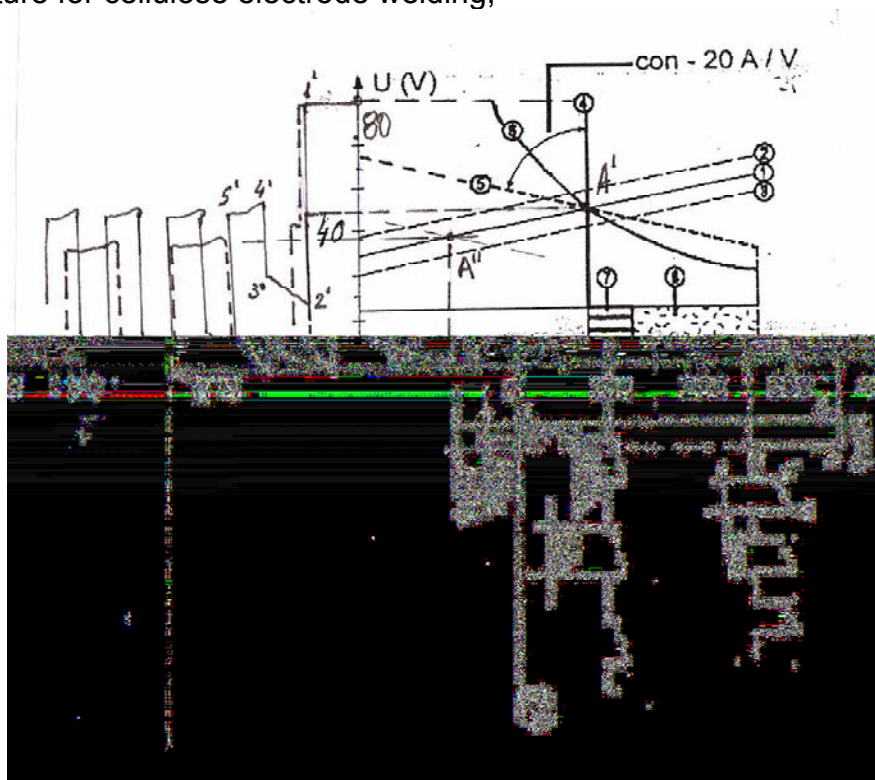


Fig. 9 Selecting the "Eln" feature for SE welding

Table 4. Basic parameters of the TPS 5000 and digital TIME 5000 inverters

Parameters	U ₁ [V] (50Hz)	U _s [V]	Dom. Welding current [A]	Arc voltage [V]	Mas s [Kg]	Welding procedure	Remarks
Inv. type							
TPS-5000	3x380-460	70	3-500	14,2-39	35,6	MIG/MAG	Welding of steels, inox, alluminum and MIG hard joining. OL joining with AL (weld-brazing)
			10-500	20,4-40		SE	
			3-500	10,1-30		TIG	
TIME 500 Digital	3x380-460	70	3-500	28,0-48,0	37,4	TIME	Virtual welding without spatters
			3-500	14,2-39		MIG/MAG	
			10-500	20,4-40,0		SE	
			3-500	10,1-30,0		TIG	

Table 5.
The main functions of the inverters by the „INTELLIGENT

REZONANT" variant

Crt.	Prod.	With	MIG/MAG 135	TIG	Symbol	Role of	Adjustment
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No.	Function	covered electrode	Manual	Standard	Pulse			function	
1	Arc-Length correction	-	-	*	*	-	AL.C	Arc length correction	
2	Electric arc	-	-	*	*	-	Arc	Eliminates arc stop	Off 0,01-2 sec
3	Anti-Stick	*	-	-	-	-	ASt	Elim. electrode sticking effect	Isc min= 5-10A Tsc≤1.0-1,5s
4	Burn-back-time	-	*	*	*	-	Bbc	Back burn	Off 0,1-2 sec
5	Cooling unit cut-out		*	*	*	*	C-C	Torch protection	Aut. On Off
6	Comfort stop Sensitivity					*	CSS	Welding cycle gradient	
7	Dynamic	-	-	-	*	-	dYn	Corrects arc dyn.	Soft Hard
8	Electrode-line	*	-	-	-	-	EIn	Select feature	Con 0,1-20A/V P
9	Hot-start current	*	-	-	-	-	HCU	Starting current impulse	0-200% 0-100%
10	Hot-current time	*	-	-	-	-	Hti	Time of cur. Impulse	0-3 sec
11	Arc force	*	-	-	-	-	ACF	Adjusts short-circuit cr.	0-100 R,B<50 C>50
12	Ignition Time-Out	-	-	*	*	-	It ₀	Disconnect source dep. On adjusted length	Off 5-100 mm 8-10 mm
13	Lift-arc	-	-	-	-	*	LAC	Starting by short-circuit	Isc.= 5-15A

4. „EXIAL”—ARC/LASER HYBRID WELDING INSTALLATIONS

The **EXIAL** system comes as a package that can be easily adapted or matched with any Nd-YAG laser equipment or CO₂. The package includes a pistol that is fixed on the laser beaming head.

The modular pistol, by the mere changing of the nozzles, becomes a hybrid welding pistol: plasma / laser, TIG/laser, MIG/laser, figure 10.

The resulting welding combines two characteristics:

- those of a TIG or MIG plasma seam, but with laser speed;
- those of a welding bath enlarged at its top part, because of the electric arc.

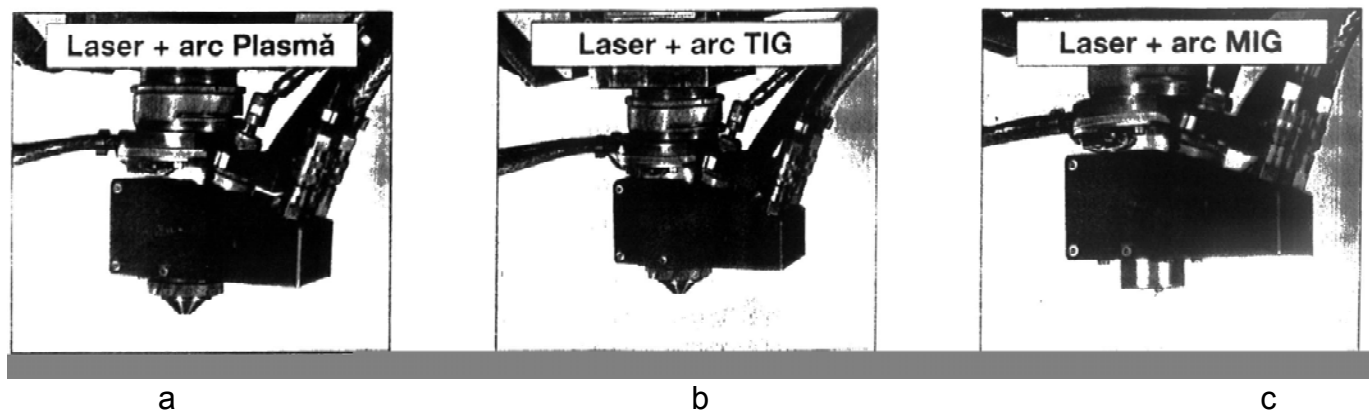


Fig.10. Multi-process external pistol: a-plasma, b-TIG, c- MIG.

The Flowchart of a „hybrid” MIG-laser equipment is presented in figure 11.

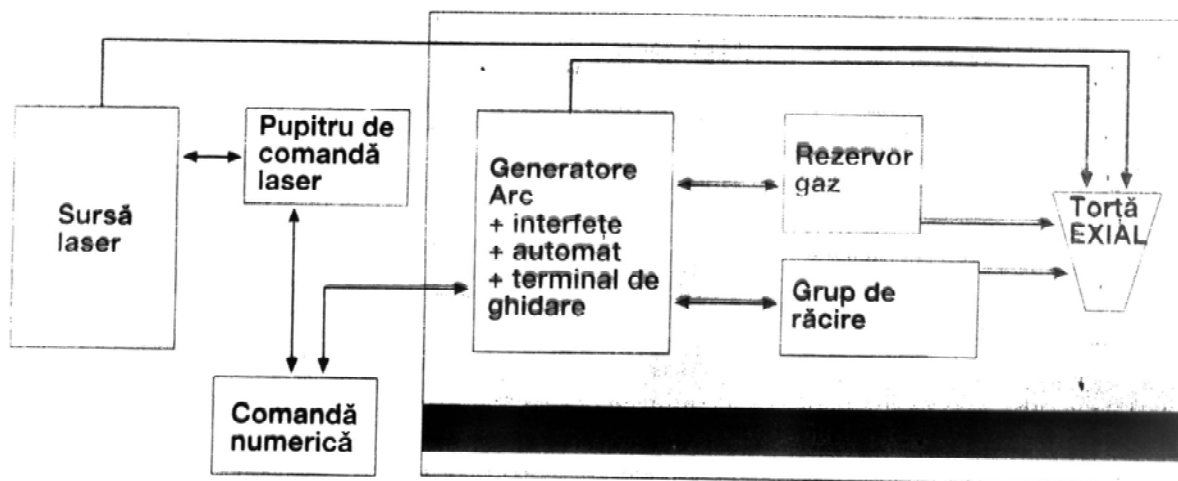


Fig.11. The flowchart for „laser – welding equipment with electric arc.”

2. CONCLUSIONS

The current sources of the generation that uses adjustment by the „INTELLIGENT REZONANT” variant are completely digital, commanded by micro-processors and ensure a high degree of flexibility.

These devices are « MULTI-PROCESS » and can be adapted to any situation.[4],[2]

If correctly programmed, these equipments can weld almost any kind of material and in any position, from PA to PG.

Experiments have proven the capacity of these equipments of being adjusted by the central control system, together with the digital signal processor that finally regulates the entire welding process.

The influence of the FI function over the interruption and re-start of the welding process is represented in figure 6.

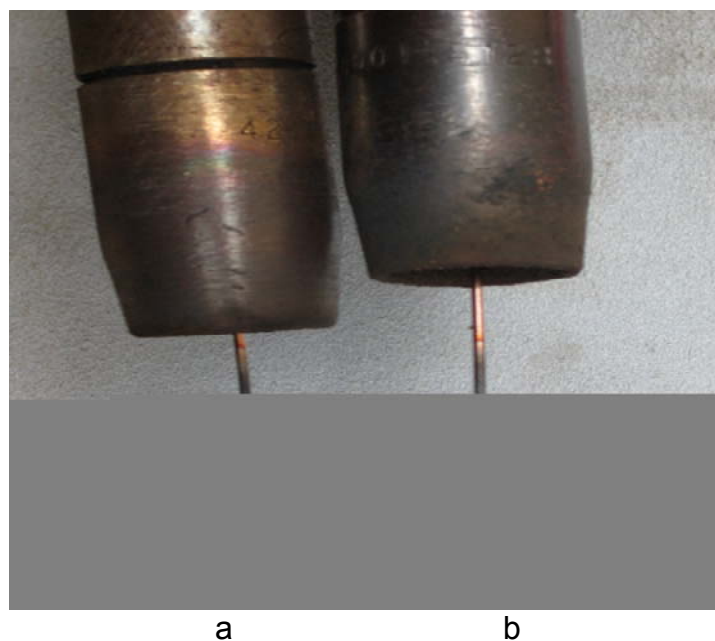


Fig. 6 Influence of the FI function on the electrode tip: a- ON; b- OFF

During the welding process, the five parameters of the synergic programme are continuously measured and other parameters can be corrected.[4],[1]

The equipment reacts, by the mentioned functions, to any modification of the welding process. Thus, one can obtain: a good and precise structure, where the results can be easily and exactly reproduced and easily exploited.[1],[2],[3]

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