COMPARISON OF INTERNALLY PARALLEL SECONDARY AND INTERNALLY SERIES SECONDARY TRANSGUN TRANSFORMERS.

BY

Kurt A. Hofman
Stanley F. Rutkowski III
Mark B. Siehling
Kendall L.Ymker

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RoMan Manufacturing, Inc.
861 47th Street S.W.
Grand Rapids, Mi. 49509
(616) 530-8641

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ABSTRACT

COMPARISON OF INTERNALLY PARALLEL SECONDARY AND INTERNALLY SERIES SECONDARY TRANSGUN TRANSFORMERS

The purpose of this paper is to compare the strengths and weaknesses of "transgun" style resistance welding transformers that have internally parallel secondaries or internally series secondaries.

Since the 1980's, the popularity of transguns has rapidly increased. While there are many different sizes and shapes of transgun transformers, the secondary construction of the transgun transformer is one of two methods - internally parallel secondaries or internally series secondaries. This study will examine the effects that the secondary construction has on the following characteristics: secondary voltage, impedance matching between weld gun and transformer, duty cycle, primary and secondary currents, size, and weight.

There is not a "good" or "bad" style transformer. An understanding of the welding application and how the transformer affects the application will allow the best choice of transformer style.

INTRODUCTION

Transgun style transformers have been in large scale use for the past 10 years. The concept of the transgun transformer is for the transformer to be integrally mounted to a welding gun, forming the transgun assembly. In many applications, the transgun assembly is manipulated with a robot.

The application of robotic transguns has created some challenging design requirements for the transformer. These requirements include, but are not limited to the following: light weight, compact size, secondary voltage that is capable of driving automotive weld currents through weld guns that vary in size, shape, and configuration, a thermal or KVA rating of the transformer that allows maximum production rate (spots per minute) at the selected weld current; minimize primary demand current on the power system.

A review of the above design criteria indicates that as one criteria is optimized it may have a negative effect on another criteria. This contradiction of design requirements raises the question, "Should we design a transformer that compromises many criteria and attempts to meet all applications or should the application drive a style of transformer that best meets the specific process requirements?"

The intent of this paper is to provide technical data on the two different styles of transformers, internally parallel secondaries or internally series secondaries . The parallel or series configuration of the transformer secondary affects different application parameters.

BACKGROUND

The transformers that were used in this research have the following characteristics:

Primary 460 Volt 60 Hz. 1 (phase) AC

KVA	R Parallel	42 KVA	@ 50%	Duty Cycle
	R Series	45 KVA	@ 50%	Duty Cycle
	H	70 KVA	@ 50%	Duty Cycle

Insulation Class: 155 °C (Class F)

Secondary Voltages:

R parallel (Rp)	6.05
R series (Rs)	10.70
H parallel (Hp)	5.22
H series (Hs)	10.44

For this research two different styles of transformers were used to compare the parallel and series configurations. In the R transformer, an internally series secondary construction was used and the physical dimensions of the transformer were held the same as the parallel secondary R. The internal series bar occupies space which would otherwise be occupied by magnetic core material, thus reducing the amount of core in the series transformer. A reduction in magnetic core reduces the allowed secondary voltage. (See Appendix A Drawings 1 and 2) The effects of this decision show in the physical size vs. secondary voltage. It is expected that the series secondary would result in doubling the secondary voltage, whereas, in the R, the secondary voltage went from 6.05 (parallel) to 10.70 (series) or an increase of 77%, a direct result of the reduced magnetic core.

The second approach to comparing the parallel secondary to the series secondary was done with the H transformer. With the H transformer, the secondary assembly was lengthened to allow room for the series bar which maintained the same magnetic core area for both transformers, resulting in a secondary voltage that doubled from parallel to series. The parallel transformer has a secondary voltage of 5.22 and the series has a secondary voltage of 10.44. The additional secondary length in the series transformer changes the physical dimensions comparing a parallel transformer to a series transformer (See Appendix A drawings 3 and 4). The two approaches to the series and parallel configuration were driven by current practice.

IMPEDANCE MATCHING

Impedance matching is the determination of transformer impedance combined with weld gun impedance to produce a total impedance of the transgun assembly. Chart 1 shows the impedance in rectangular coordinates of the four test transformers. For this investigation three weld gun sizes are used denoted as “S” small, “M” medium, and “L” large. Chart 2 shows the measured gun impedance and physical size.

Transformer	Resistance R (μΩ)	Reactance Xl (μΩ)	Impedance Z (μΩ)
H- Parallel	30	24	38.42
H-Series	120	96	153.67
R-Parallel	58	34	67.23
R-Series	213	65	222.70

Chart 1. Transformer Impedance Values

Gun	Resistance R (μΩ)	Reactance Xl (μΩ)	Impedance Z (μΩ)	Size (In.)
S	60	75	96.05	5.0 x 7.0
M	110	150	186.01	9.2 x 11.4
L	160	300	340.00	16.1 x 41.0

Chart 2. Gun Impedance Values

Total impedance of the transgun assembly and the transformer secondary voltages are shown in Chart 3 located on the following page.

TX-Gun	Z (μΩ)	Vsec

HP-L	375.60	5.22
HP-M	223.33	5.22
HP-S	133.79	5.22
HS-L	484.99	10.44
HS-M	336.77	10.44
HS-S	248.28	10.44
RP-L	398.85	6.00
RP-M	249.16	6.00
RP-S	160.64	6.00
RS-L	521.88	10.70
RS-M	388.01	10.70
RS-S	306.80	10.70

Chart 3. Total Impedance and Secondary Voltage

The application of Ohm's law for AC circuits (V = I x Z) weld current, I, can be solved by taking the secondary voltage and dividing it by the total impedance. The maximum tip to tip (no work) current of the transgun assemblies using the H transformer is shown in Chart 4 and graphically displayed in Figure 1.

Gun	HP-L	HP-M	HP-S	HS-L	HS-M	HS-S
Iweld	13898	23374	39015	21526	31000	42050

Chart 4. Weld Currents for H Transformer with Gun

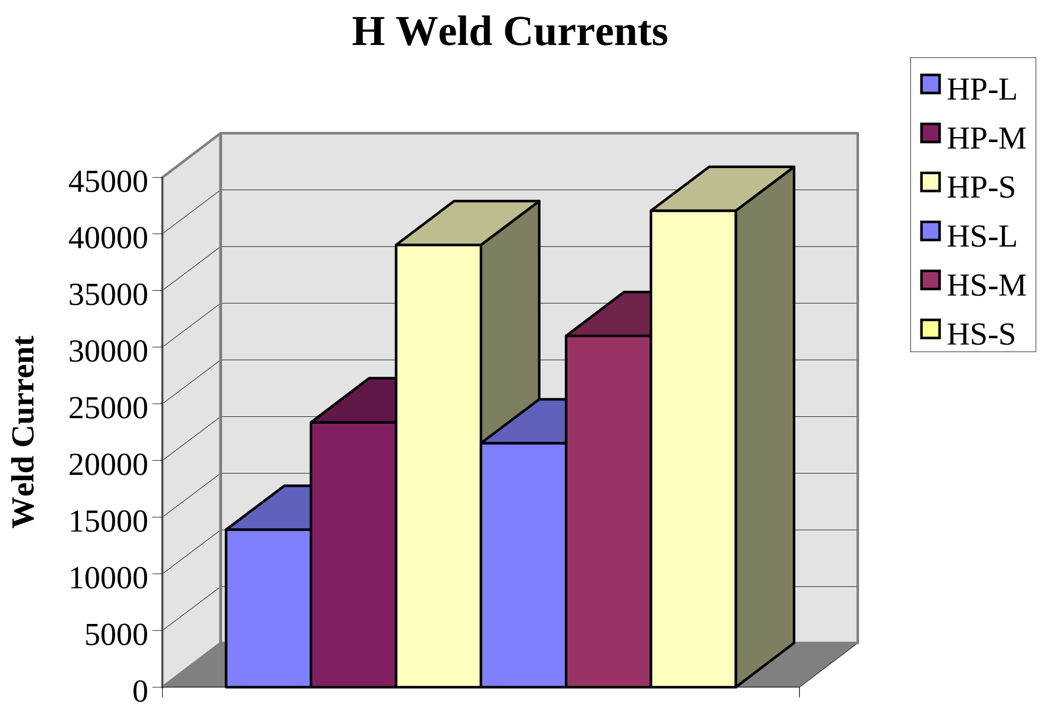

Figure 1. Weld Currents for H Transformer with Gun

Chart 5 and Figure 2 show the maximum tip to tip current of the R transformer.

Gun	RP-L	RP-M	RP-S	RS-L	RS-M	RS-S
Iweld	15043	24081	37351	20503	27576	34876

Chart 5. Weld Currents for R Transformer with Gun

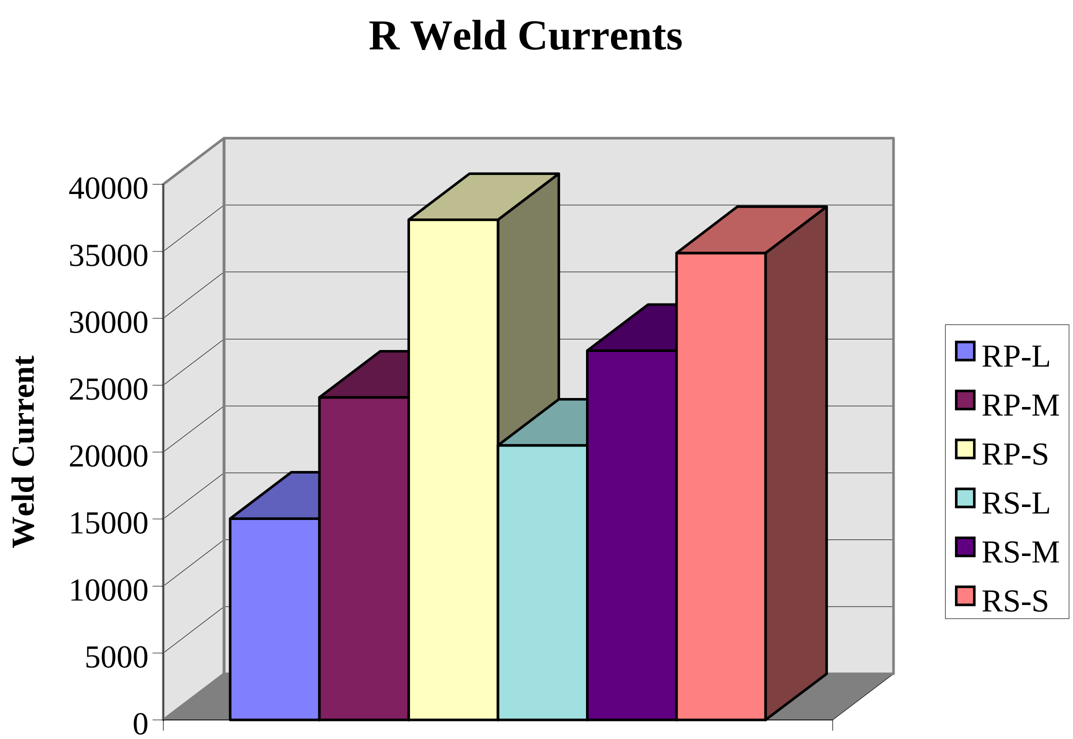

Figure 2. Weld Currents for R Transformer with Gun

A series secondary transformer has approximately four times the impedance as a parallel secondary transformer. Thus, as the weld gun impedance becomes less, the transformer impedance becomes a greater percentage of the total transgun assembly. With a low impedance gun, demonstrated by the small gun in this investigation, a condition can arise in which a transgun assembly using a parallel transformer can produce more weld current than a transgun assembly using a series transformer. This is the effect of impedance matching. Chart 5 demonstrates the condition of impedance matching.

PRODUCTION RATE

The production rate in this investigation is defined as the number of weld cycles per minute the transformer can produce at a given weld current. For clarity the data is presented in two different forms. In Figures 3 and 4, the data is shown in maximum allowable weld cycles per minute over a range of weld currents.

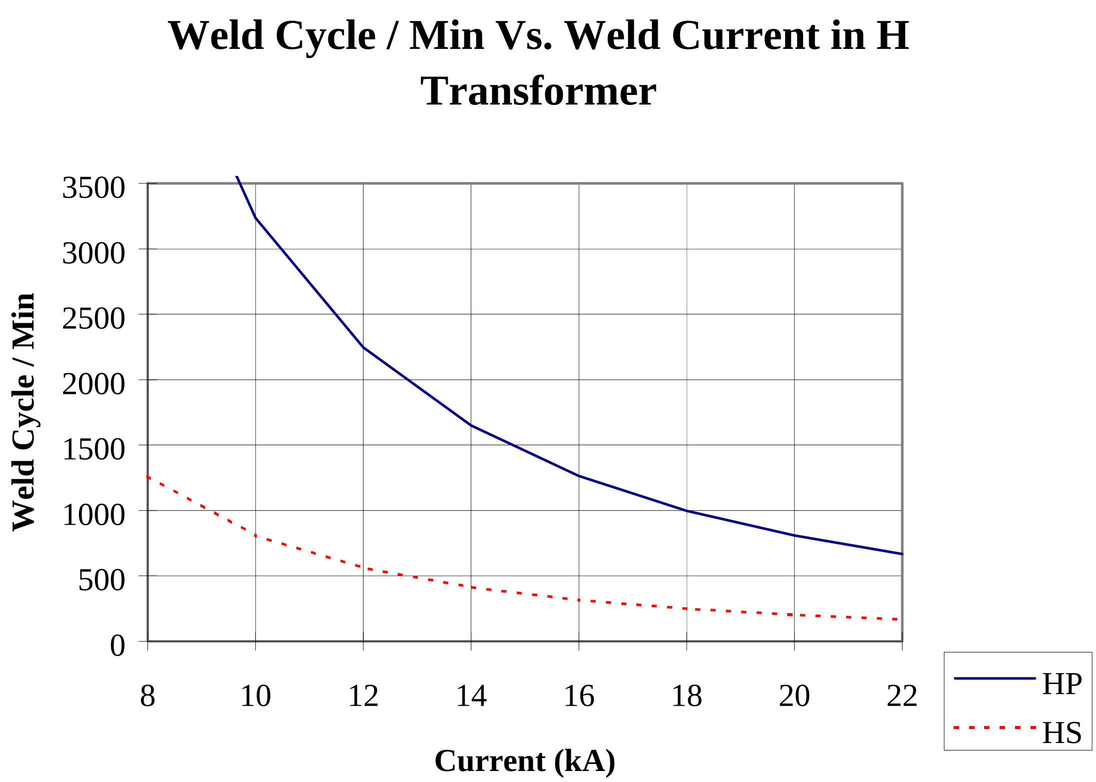

Figure 3. Weld Cycles Per Minute in H Transformer

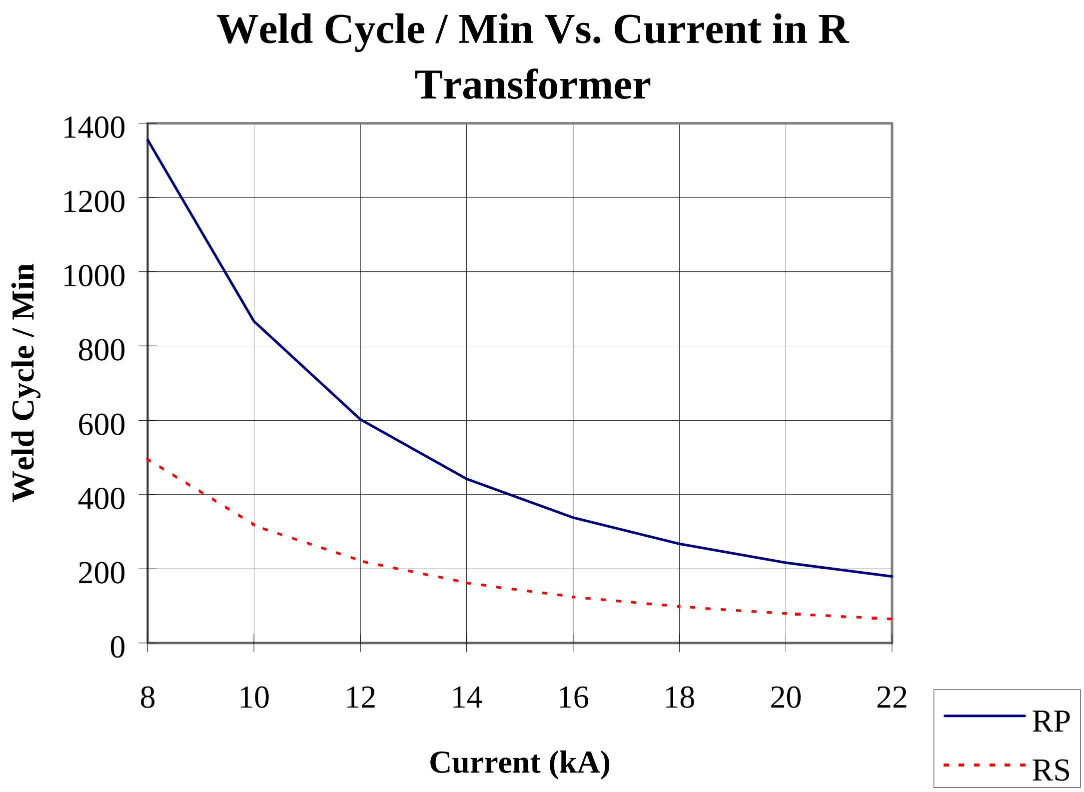

Figure 4. Weld Cycles Per Minute in R Transformer

The other method of data presentation is to assign typical weld times used in industry and determine the welds per minute. Figures 5 through 8 show the maximum welds per minute at 14 and 20 cycles of weld time over a range of weld current.

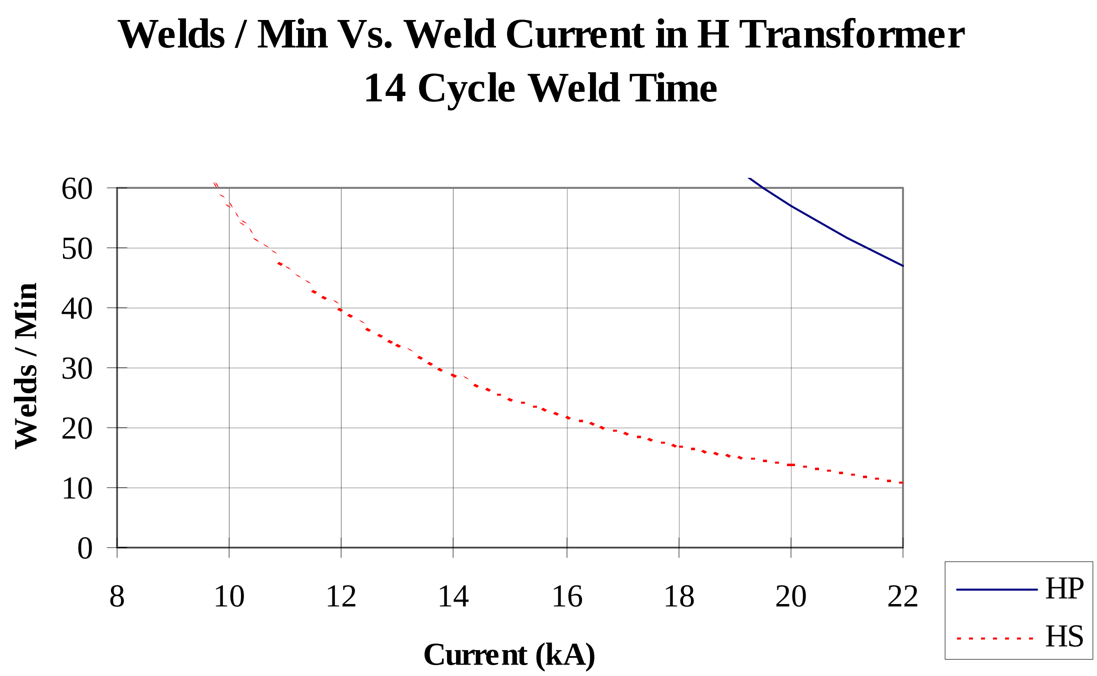

Figure 5. Welds per Minute with 14 Cycle Weld Time in H Transformer

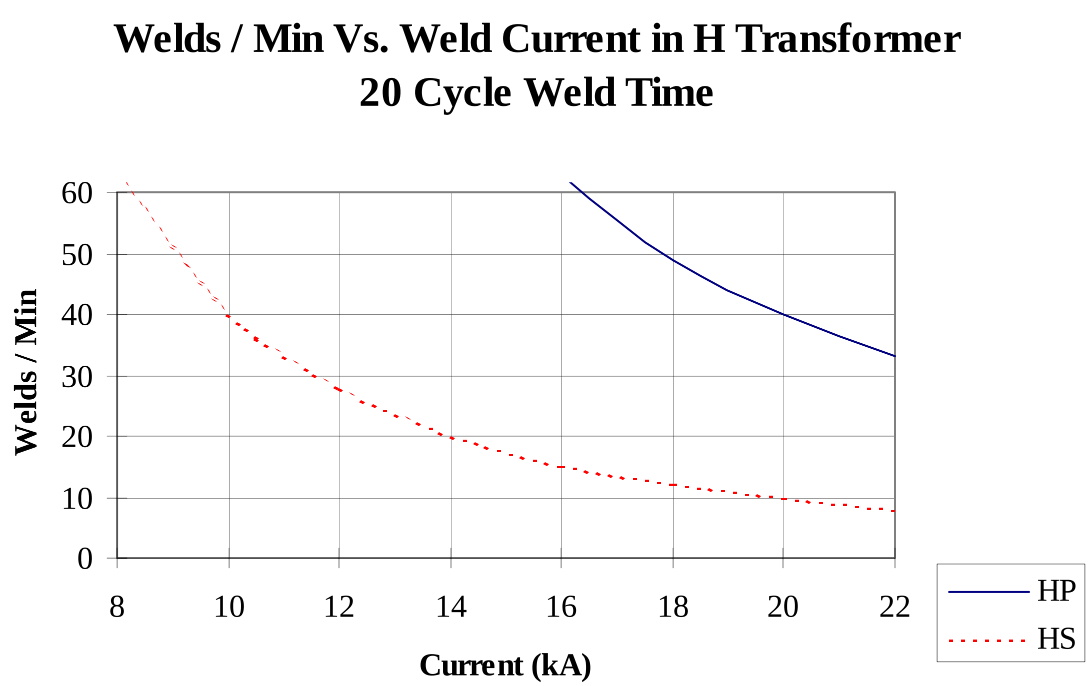

Figure 6. Welds per Minute with 20 Cycle Weld Time in H Transformer

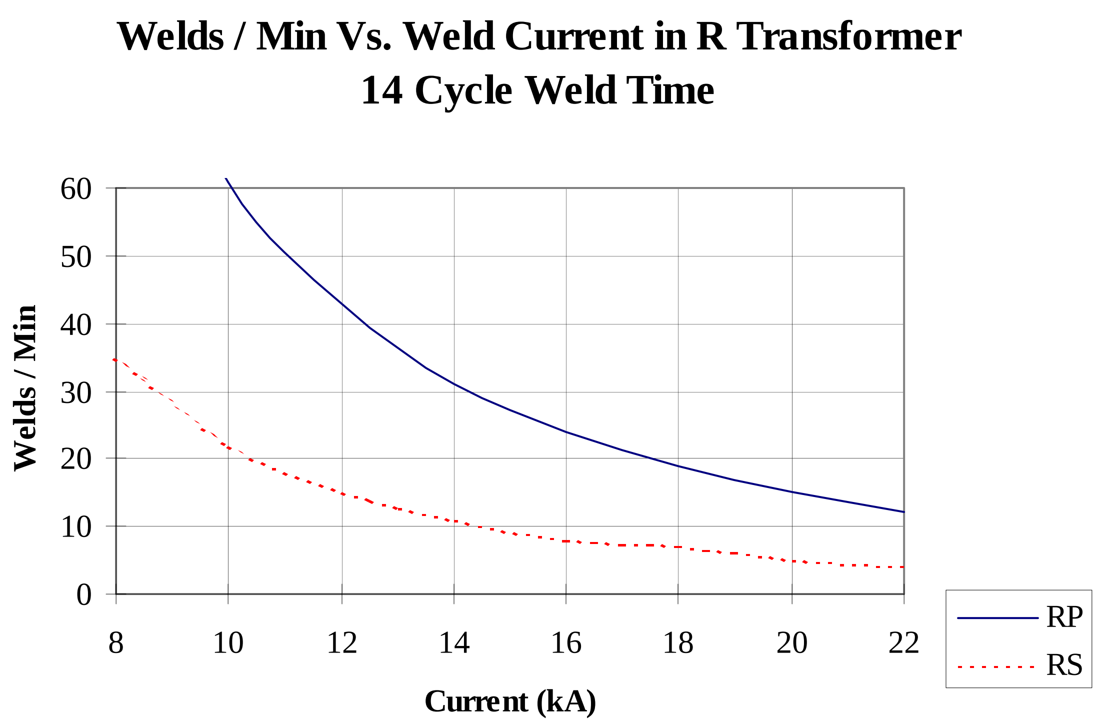

Figure 7. Welds per Minute with 14 Cycle Weld Time in R Transformer

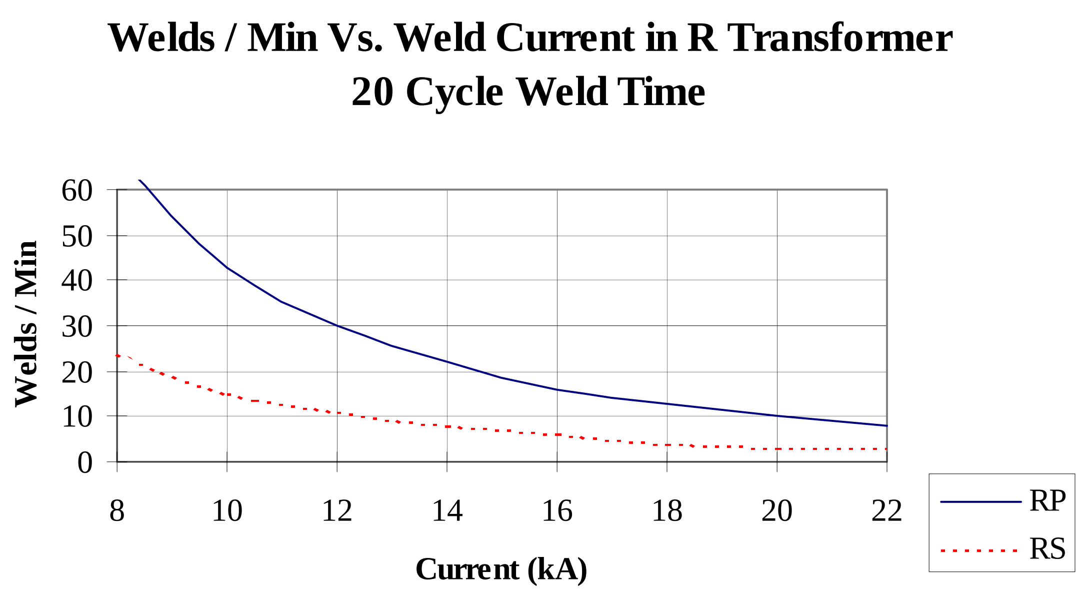

Figure 8. Welds per Minute with 20 Cycle Weld Time in R Transformer

The following equations were used to derive this data:

A manipulation of equation 3 can solve for either weld cycles per minute, or choose a weld time and solve for welds per minute. When reviewing the data shown in Figures 3 through 8, the observation can be made that the series transformer will have a lower production rate than the parallel transformer.

PRIMARY DEMAND CURRENTS

The primary current is related to the secondary current by the turns ratio of the transformer. The Appendix shows the turns ratios of the test transformers. In the H transformer, the series transformer turns ratio is one half as compared to the parallel transformer and twice the primary current for a given secondary current. Charts 6 and 7 show how the primary current relates to the secondary current for the H and R transformers. Note that the primary current, Ipri, for the R series transformer is not double that of the R parallel, as it is in the H transformer, due to the reduction of magnetic core.

Transformer	HP	HS
Iweld (A)	12,000	12,000
Ipri (A)	136	273

Chart 6. Primary Current in H Transformer

Transformer	RP	RS
Iweld (A)	12,000	12,000
Ipri (A)	158	279

Chart 7. Primary Current in R Transformer

SIZE AND WEIGHT

The size and weight of the transformer is an important variable when considering the type of transformer, parallel or series. The size and weight was held constant for the R transformer. Chart 5 and Figure 2 show that the series transformer will produce more current than the parallel transformer with the exception of a low impedance gun such as Gun S.

This report has compared equal size and weight transformers. Appendix B contains a chart showing the differences in series and parallel transformers holding the weld current constant.

CONCLUSION

The choice of transformer type utilized in a transgun assembly is determined by which criteria the user is optimizing or constrained by. These criteria include: impedance matching, size and weight, primary demand, and production rate.

In most cases, the series transformer will maximize weld current except when a low impedance gun is used. The series transformer has an advantage of reduced size and weight for a given weld current. The parallel transformer will minimize primary demand. The parallel transformer provides an advantage of higher production rates due to the lower KVA demand. Chart 8 summarizes the advantages of each transformer type.

Conclusion Chart

Series	Parallel
• Size and Weight	• Primary Demand
• Max. Weld Current	• Small Gun Impedance
	• Production Rate

Chart 8. Advantages of Each Transformer Type

APPENDIX A

TURNS RATIOS AND TRANSFORMER DRAWINGS

Chart #9 below is the list of the turns ratios for the H transformers studied in this report.

Transformer	HP	HS
Turns Ratio	88:1	44:1

Chart 9. Turns Ratios for the H Transformer

Chart #10 below is the list of the turns ratios for the R transformers studied in this report.

Transformer	RP	RS
Turns Ratio	76:1	43:1

Chart 10. Turns Ratios for the R Transformer

The drawings for the H and R transformers can be found on the following pages. Please note that the R series and the R parallel have the same physical dimensions were as the H series and H parallel dimensions differ.

APPENDIX B

COMPARISON OF SERIES AND PARALLEL TRANSFORMERS HOLDING WELD CURRENT CONSTANT

Transformer	Parallel	Series
Total Impedance with a Gun	290	337
Sec. Voltage	5.22	6.07
Rated KVA	70	40
Weld Current	18 kA	18 kA
Weld Time	20 Cycles	20 Cycles
Weight	100 #	65 #
Welds per Min	37	12

Chart 11. Comparison Holding Weld Current Constant.