Jan. 8, 1963 E. SCHWARZ ET AL 3,072,826

PLURAL DISCHARGE LAMP CIRCUIT AND LAMINATED CORE TRANSFORMER THEREFOR AND METHOD OF MAKING SAID TRANSFORMER

Filed Feb. 2, 1961 2 Sheets-Sheet 1

Fig. 1.

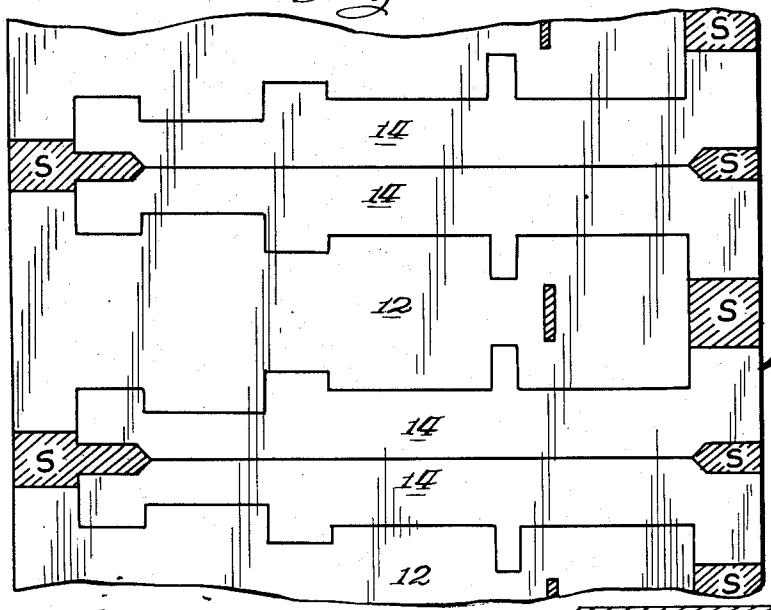


Fig. 2.

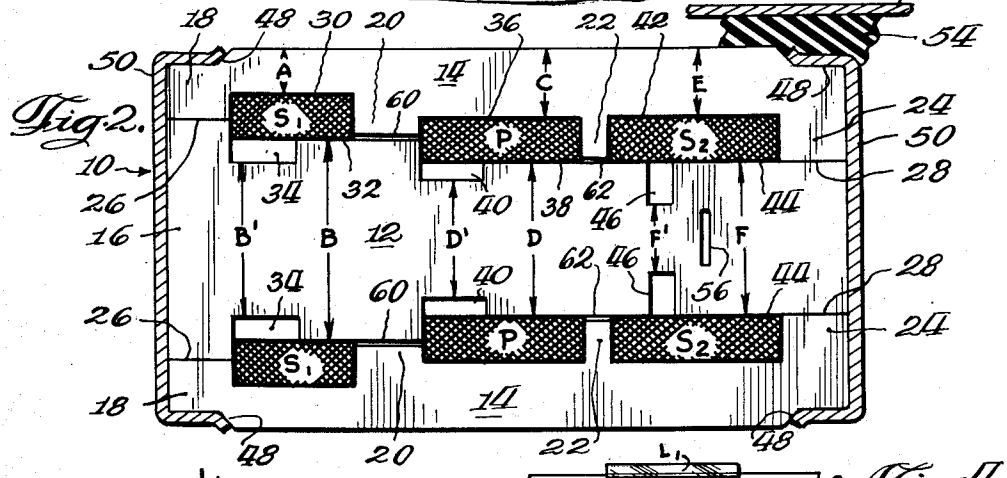


Fig. 3.

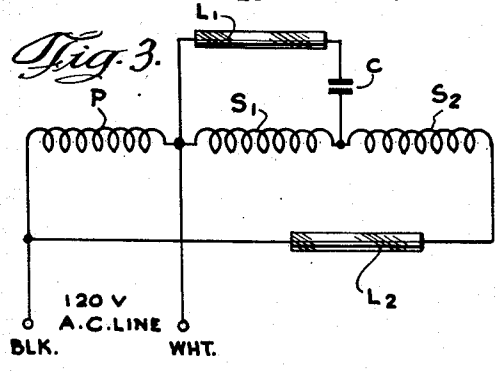
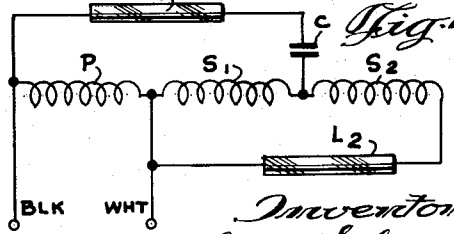


Fig. 4.



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Fig. 5.

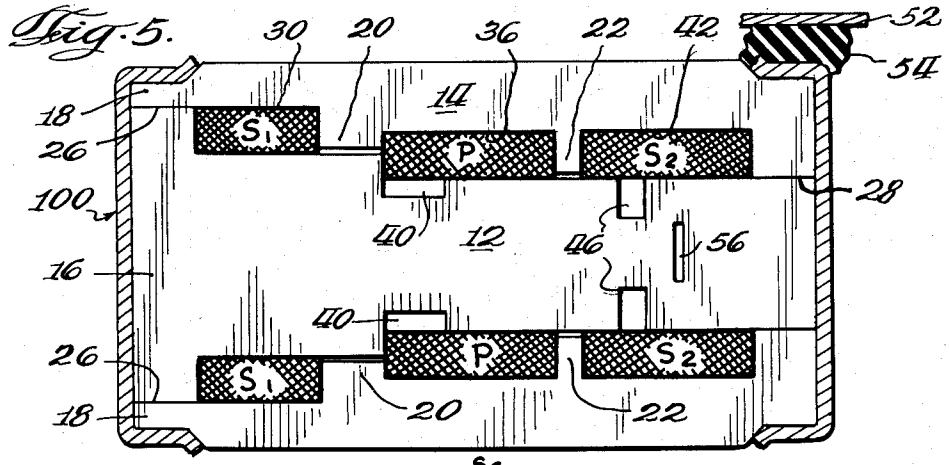


Fig. 6

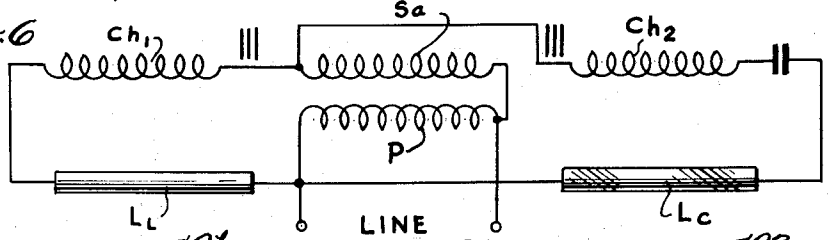


Fig. 8.

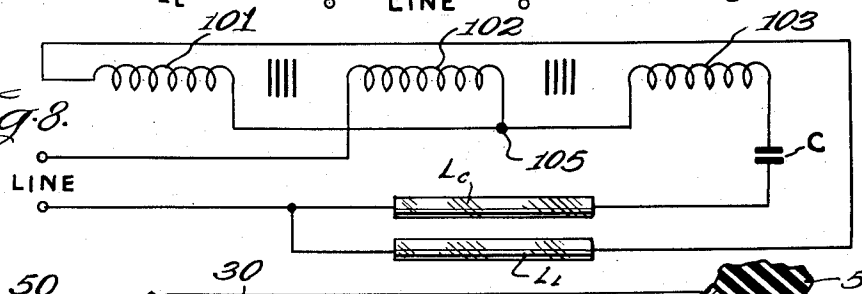
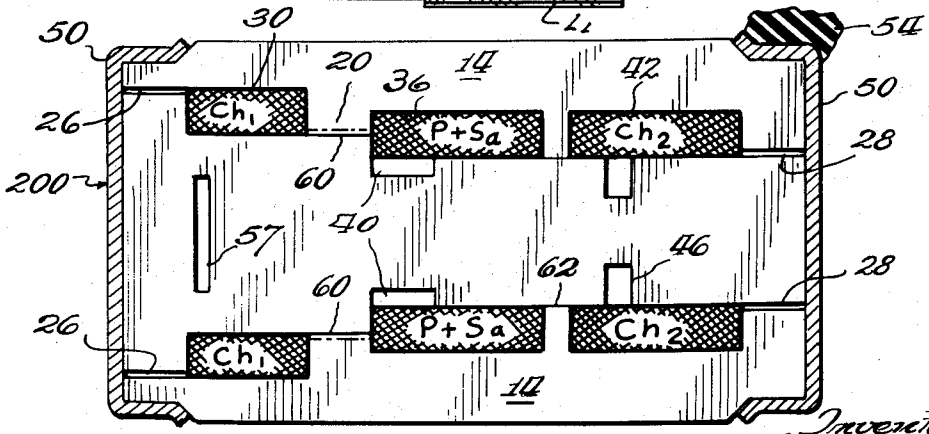


Fig. 7.



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PLURAL DISCHARGE LAMP CIRCUIT AND LAMINATED CORE TRANSFORMER THEREFOR AND METHOD OF MAKING SAID TRANSFORMER

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Filed Feb. 2, 1961, Ser. No. 86,751
18 Claims. (Cl. 315—278)

This invention relates generally to the construction of ballasts for gaseous discharge devices and more specifically is concerned with a method of manufacture and a construction of an iron core ballast in which the core is made up of laminations of the so-called scrapless variety.

In U.S. Patent No. 2,892,249 there is disclosed a method of making a ballast transformer structure in which the core is formed of three stacks of laminations, the center or winding leg being formed of a stack of laminations of generally T-shaped configuration and each of the outer or side legs being formed of a stack of laminations of generally F-shaped configuration. Ballast transformers assembled using this core structure have provided inwardly extending center projections of the F's which, when cooperating with the center winding leg, provide a high reluctance shunt between windings separated thereby in order to achieve a high leakage reactance.

Because of such method and structure it has been possible to achieve substantially scrapless formation of the laminations since the F- and T-shaped parts are punched from a continuous strip of electrical steel in groupings of three pieces with the two F-shaped parts nested on opposite edges of the T-shaped parts. In assembling the ballasts, the laminations are arranged into suitable stacks, and translated longitudinally of their mating dispositions in the center winding leg as the result of the removal of material to form the shunt projections occurring ordinarily beneath a winding where they will have no deleterious effect.

In still another co-pending application Ser. No. 63,076 filed October 17, 1960, by Paul Berger and assigned to the same assignee as the above referred to patent and the application herein, the improvements taught by said patent were applied to the construction of a ballast transformer core in which the notches were used as a reduced cross section in the secondary winding of a rapid start ballast transformer in order to achieve certain beneficial results. It will be recalled that the secondary winding of a rapid start ballast transformer carries leading current. This is also true of sequence-start circuits.

For the most part the structures utilizing the so-called F-shaped laminations have been limited to ballast transformers which are constructed using two coils, or ballast transformers constructed using three or more coils but in which all but two of the coils are arranged relatively closely coupled so that no shunt is required between them. Reference is intended to coils each formed into a single assemblage.

Many problems have prevented the utilization of the principles of the F lamination structure in ballast transformers having at least three coils or windings where a shunt is required between each pair of coils or windings. These problems have included the mounting of the windings, the adjustment of leakage, undesirable reduction of the cross section of certain members, proper adjustment of the magnetizing current, etc.

Probably the most desirable use for lamination structures of this kind would be in the construction of ballasts in accordance with Feinberg Patent 2,558,293. In these so-called series-sequence ballasts, three windings or winding assemblages are mounted end to end on an elongated iron core, comprising a primary winding, a first secondary

winding of a large number of turns of fine wire used for starting the first of two gaseous discharge lamps, and a second secondary winding whose function is primarily for providing the operating voltages for the lamps, although also useful in starting the second lamp. In such structures, the primary winding assemblage is mounted in the center of the core and each of the secondary assemblages is mounted on opposite sides thereof, with the first secondary winding having a substantially looser coupling relative the primary than the second secondary winding, and hence, being separated from the primary by a much wider shunt than is the second secondary.

Modifications of these structures have included one or more additional windings in the three formed assemblages, and such structures are included in this invention. Some structures built in accordance with Feinberg Patent 2,558,293 have utilized substantially no shunts between the second secondary and the primary windings, thereby requiring only a single shunt between the first secondary winding and the primary. In such structures, however, bridged air gaps in the vicinity of the second secondary winding have been needed, but when used without magnetic shunts, these have given rise to noise and do not always give the most desirable wave shapes. Bridged gaps have also been used under the first secondary winding, but this has been found to increase the primary magnetizing current somewhat more than desirable.

If an F lamination structure were used with a ballast transformer of this kind, the notch produced under the primary winding assemblage by providing a very large shunt between the primary and first secondary winding would cause a great increase in the magnetizing current because of the substantial decrease in the winding leg cross section beneath the primary winding.

It has been found, according to this invention, that by a suitable design of the laminations and method of forming same, they can be punched from a continuous strip of electrical sheet metal mated, and after separation they may be moved longitudinally and provide the necessary pair of shunts for three assemblage ballast transformers. In this case the first secondary winding is disposed at the end of the core having the cross-head of the T thereat instead of disposing the second secondary adjacent said cross-head.

Accordingly it is the principal object of the invention to achieve all the benefits of the substantially scrapless lamination structure and method of manufacturing the same but eliminating the disadvantages which have been attendant upon the use of such method and structure with three coil or winding assemblages.

The invention has as additional objects the privision of a method and means for forming a substantially scrapless ballast core construction especially intended for use with series sequence circuits, providing a relatively wide shunt between the first secondary and the primary winding and a relatively smaller shunt between the second secondary winding and the primary winding.

Still a further object of the invention is to provide the benefits of the scrapless lamination method which produces two shunts suitably located along the length of the core for use with lead-lag ballast transformers of the structure requiring two shunts.

The foregoing objects are merely illustrative of those which will occur to artisans skilled in this art as the description of the invention proceeds in connection with which preferred embodiments have been illustrated and described in considerable detail. It is obvious that many variations may be made without departing from the spirit of the invention.

In the drawings:

FIG. 1 is a plan view of a strip of electrical steel pass-

ing through an automatic punch press, for example, and showing the manner in which the laminations are made in accordance with the invention and the resulting articles.

FIG. 2 is a sectional view through a ballast transformer constructed in accordance with the invention and using the laminations formed by the method of the invention.

FIG. 3 is a circuit diagram of one form of series sequence circuits which is adapted for use with the transformer core shown in FIG. 2.

FIG. 4 is a variation of the circuit of FIG. 3, also capable of being used with the core of FIG. 2.

FIG. 5 is a sectional view similar to that of FIG. 2 but illustrating a modified construction.

FIG. 6 is a circuit diagram showing a lead-lag circuit, adapted to be incorporated into a ballast constructed in accordance with the invention.

FIG. 7 is a sectional view through a ballast transformer using the circuit of FIG. 6.

FIG. 8 is a circuit diagram of another lead-lag circuit adapted to be incorporated into a ballast constructed in accordance with the invention.

The invention is based upon the recognition that under certain circumstances and in certain ballasting structures, reduction in the cross-sectional area of certain portions of ballast transformer cores will not be detrimental to the operation and functioning of the ballasts, and in some cases will be beneficial. The invention is further based upon recognition of the discovery that the cross-sectional area of the outer legs of the transformer core may be reduced under certain circumstances with the achievement of favorable results.

Attention is first invited to FIG. 2 which illustrates a ballast transformer core having the windings of a series-sequence circuit, such as shown in FIGS. 3 and 4, mounted thereon. The ballast transformer **10** has an iron core which is formed of laminations of electrical steel, the method of formation of which shortly will be described. There is a center winding leg **12** and two outer legs **14**, each of the latter of which is abutted against edges of the center winding leg, as shown.

The center winding leg **12** may be considered a T-shaped section in accordance with conventional understanding although its configuration departs quite substantially from a T. Nevertheless, at the left-hand end there is illustrated what may be termed a transverse portion **16** which has a width (measured up and down) that is substantially greater than any other dimension of the center winding leg **12** except its length. The outer legs **14** each have four inwardly extending projections **18**, **20**, **22** and **24**, the end projections **18** and **24** adapted to abut the respective left and right end lateral edges of the center winding leg **12** at **26** and **28** respectively. In the particular structure shown, the junctions **26** and **28** are not intended to have any air gaps, although in one structure to be described at least one of these junctions will be provided with an air gap.

Between the projections **18** and **20** there is provided a recess or notch **30**, the notch being produced during punching of the laminations by the removal of the material eventually forming a lateral projection **32** on the center winding leg **12**. In cooperation with the center winding leg **12**, the notch **30** forms a winding window within which there is adapted to be disposed what may be termed a winding assemblage comprising the first secondary winding S_1 of either of the circuits of FIGS. 3 and 4. In the center winding leg **12**, beneath the winding S_1, it will be seen that there is a relatively narrow notch **34** which is formed due to the removal of the material of the lateral extension **18** of the outer legs **14** during punching of the laminations. In Patent 2,892,249 the method disclosed teaches providing the cross-head of the T at the opposite end of a series-sequence ballast.

A second notch **36** is formed in the side legs **14** due to the removal of the material therefrom by the formation of the lateral projection **38** of the central winding leg during punching of the laminations. This notch **36** cooperates with the central winding leg **12** to form a winding window within which is disposed the winding assemblage comprising the primary winding P of the circuits of FIGS. 3 and 4. There is a notch **40** formed in the side edges of the central winding leg **12** due to the removal of material by the formation of the inward projections **20** of the side legs **14**.

A third notch **42** is formed in the side legs **14** due to the removal of material therefrom by the formation of that portion of the central winding leg designated **44**, at the right-hand end thereof. A relatively narrow notch **46** is formed in each side edge of the central winding leg **12** beneath the winding S_2 caused by the removal of the material in the formation of the lateral projections **22**.

The notch **42** cooperates with the side edges of the central winding leg **12** to form a winding window within which is disposed the said second secondary winding S_2 of the circuits of FIGS. 3 and 4. This notch **46** in each side edge of the central winding leg **12** provides a reduced cross-sectional area which is advantageously located to prevent saturation of the core beneath the S_2 winding. This improves wave shape of the current through the lamps served by winding S_2.

The windings which are referred to here are produced by winding suitable size wire upon tubular paper forms, the bore of the form being of the same size and configuration as that portion of the central winding leg **12** upon which the form is adapted to engage. For the most part, a single winding is mounted upon a single length of tubing, forming a unitary assemblage which is mounted in a single window. Under certain circumstances, however, more than one electrical winding is included upon a single tubular form in one assemblage, and the entire assemblage is physically handled during assembly as one member. For example, by taps, or by winding more than one winding of wire on the form and bringing separate leads out, two or more electrical windings will be provided to be connected into the circuit.

It will be noted that according to this invention the tubular form for the winding S_1 will be substantially larger in bore than those used for mounting the other windings.

In the discussion which follows, reference will not always be made to assemblages, since this is not a term commonly used in this art. It will be left to the sense of the discussion and the reference to the figures to enable those familiar with this field to understand what is intended. In all cases involving the circuits of FIGS. 3 and 4 each winding is mounted by itself in a window. In the case of FIG. 5, the primary winding and its autotransformer secondary winding are both assembled on a single form and together disposed in the center window. In the case of variations of the circuits where there are split primaries, additional secondaries, compensating windings, etc., the invention is intended to include those cases where more than one winding is mounted in a single assemblage and disposed in a single window. This should be borne in mind in reading the claims, and in reading the specification wherein reference is made to a "winding" being disposed in a window.

The core of the ballast transformer **10** of FIG. 2 is held in assembled relationship by virtue of corner notches **48** formed in opposite ends of the side legs **14** engaged by suitable clamping members designated generally **50**. The transformer core and windings as well as the condenser C of either of the circuits of FIGS. 3 and 4 and certain other components are potted in a suitable canister such as indicated symbolically at **52**, in potting compound **54**, as customary. A bridged air gap **56** beneath the second secondary winding S_2 is shown for purposes of preventing saturation in the vicinity of the second sec-

ondary winding S_2 and to maintain good wave shape in the gaseous discharge lamps L_1 and L_2.

In examining the structure of FIG. 2 it will become obvious that the central winding leg **12** and the side legs **14** would mate or nest if the side legs **14** were moved longitudinally to the right relative the central winding leg **12** and then moved laterally inward thereof. This relative configuration is that which obtains while the laminations forming the central winding leg and side legs are being punched.

In FIG. 1 there is illustrated a strip of electrical steel **56** as it is passing through a high-speed automatic punching machine, for example. The layout of the mating laminations from which the core of the ballast **10** is formed is illustrated on the strip **56**. The lateral carrying strips which are usually used to support the pieces as they pass through the multistage dies are not shown, but it may be assumed these will be present in most cases. The individual laminations are designated **12** and **14** in accordance with their eventual use as parts of center winding legs or side legs. It will be seen that the side legs are punched back to back with a single center leg between a pair of side legs. The portions which are shaded and marked S are scrap, and it will be noted that there is a minimum of such scrap. The various notches and projections formed during the punching process will be recognized through a comparison of FIG. 1 with FIG. 2 without the need for repeating the reference characters. The assembled arrangement of one center lamination **12**, and two side laminations **14** may be punched from strip moving either crosswise of the laminations or lengthwise.

Attention is now invited to the relative dimensions of the central winding leg **12** and the side legs **14**.

The accepted cross-sectional area of the center winding leg in transformers for ballasts of this general type has been twice the cross-sectional area of each of the outer legs. In considering area, it will be recalled that the height of the stack is everywhere equal and the normal direction of flux is along the length of the respective legs. Thus, the measurements and discussion concerning cross-sectional area may be related to the transverse length measured on the plan view of the laminations as viewed in FIG. 2.

It has been found, however, that there can be a reduction to some extent of the outer legs, that is, by making them less than half the area of the center winding leg, without deleterious effects. The degree of reduction permissible depends upon the nature of the contiguous winding. Thus, in the core of ballast transformer **10**, the dimension A alongside the first secondary winding S_1 is substantially less than half of either the dimension B or B'. In an actual example constructed and successfully tested, these dimensions were A=.32 inch, B=1.15 inch, and B'=1.55 inch. Thus, the total outer leg area of .64 inch was only 48.5% of the average area of the central winding leg beneath the first secondary winding leg. This dimension A was even less than half the dimension D of the main flux carrying path.

The reason that this departure from the ordinary construction is believed feasible in this circuit is that the winding S_1 is primarily active only during the starting of the lamps L_1 and L_2 and hence the possibilities of saturation in the outer legs at that point would have little if any effect upon starting. During operation, where the reduced cross-section might in other cases contribute to distortion of wave shape because of saturation, the winding S_1 carries very little current and the high flux density in the outer legs is not detrimental.

The width C adjacent the primary winding P is of importance because its two halves carry the main flux returned to the primary winding P at all times. Furthermore, the width D beneath the primary winding P is of importance since, if the flux density rises, the magnetizing current will be increased and the ballast will be hot and inefficient. The increased dimension B means that the inwardly directed extent of the projections **20** beyond the dimension C is very little, and hence the dimension D' is as large as possible. Making the dimension D' equal to the dimension F' would so decrease the flux carrying capacity of the center winding leg beneath the primary winding P as to render the ballast inefficient. The manufacture of the resulting transformer core by the scrapless lamination methods would be the economizing in manufacture at the expense of proper operation.

The increased dimension B, that is, its increase over the dimensions D and F which are taken as proper, enables the dimension D' to be .91 inch, a reduction of only about 20% from D in the practical structure referred to above. This results in the requirement that the portion **18** be in the form of a small projection, and result in the notches **34** under the winding S_1. There is no effect upon the ballast because of this.

The width (measured horizontally in FIG. 2) of the shunt formed by the projections **20** is quite substantial compared to that of the projections **22**, so that the decrease in the iron beneath primary winding P because of the notches **40** would be prohibitive if the dimensions B and D were the same. With the structure of the invention the small notches **40** increase the primary magnetizing current much less than the use of bridged air gaps in the core beneath the secondary windings as required when using the F-shaped laminations previously used.

The bridged air gap may under certain circumstances be desirable at **56** beneath the winding S_2. This winding carries leading current during operation and the constricted sections provided by notches **46** and gap **56** result in good wave shape and decrease the possibility of saturation which occurs where the iron carries leading flux. Gap **56** may not be needed in many instances.

The dimension of E and C is approximately 45% of the dimension of D and F so that there is a reduction of not more than about 10% in the total outer legs **14** relative to the cross-sectional area of the center winding leg **12** in the vicinity of the primary and second secondary windings. In the practical structure, the central winding leg dimensions D and F were both 1.15 inches and the outer leg at C and E was .52 inch.

The gaps **60** and **62** of the shunts, which may be designated **20** and **22** corresponding to the inwardly directed projections thereat, are dimensioned in accordance with the depth of the respective notches **40** and **46**. In the practical example, these were both .030 inch gaps.

It should be recognized that the advantages of the invention have been achieved in great part by placing the S_1 winding at the end of the core having the transverse part **16**, having the increased dimension B for the center winding leg beneath the first secondary S_1 and adjusting the configuration of the core members accordingly. This may be more generalized by referring to the transformer as one in which there is a central winding assemblage in the form of a primary or other winding or windings which cannot afford to have the cross-section of iron in the center winding leg beneath it decreased substantially, but in which the benefits of the scrapless method of punching laminations are achieved by increasing the area of the cross-section of the center winding leg of the adjacent portion and thus mounting the winding of said adjacent portion on an enlarged portion of the center winding leg. Obviously in forming the assemblage coil for the adjacent portion, the form upon which the winding is taking place will have to be larger than the forms upon which the other windings are mounted.

In FIGS. 3 and 4 are illustrated the circuitry of two examples of series-sequence ballasts each connected with a pair of gaseous discharge lamps. The iron cores are not shown, but these can be either of the cores of FIGS. 2 or 5. The primary winding P in each case is con-

nected across a suitable line, such as illustrated—a 120 volt A.C. line of 60 cycles. The first lamp to light is at L_1 and the second at L_2. In FIG. 3, the voltage of the first secondary winding S_1 on energization of the primary winding is sufficient to ignite the first lamp L_1. The open circuit instantaneous voltage of S_1 bucks that of the primary winding P and the second secondary winding S_2 in said FIG. 3.

As soon as the lamp L_1 ignites and current flows through the condenser C and the winding S_1, in FIG. 3, there is a voltage generated in S_1 which has a component out of phase with the normal open circuit phase of S_1, and this component adds to the voltages of P and S_2 and causes ignition of lamp L_2. Thereafter, with the leakage reactance caused by S_1 being very high, due to the large shunt **20**, current prefers to flow through the lamps, condenser and S_2 in series to the practical exclusion of S_1. Shunt **22** provides operating leakage reactance for secondary S_2.

In the case of the circuit of FIG. 4, the windings P and S_1 are additive, with S_2 bucking S_1 on open circuit. The first lamp L_1 starts by virtue of the voltages of P and S_1 adding, after which flow of current through the condenser C and S_1 again causes a phase reversal and provides a component of voltage which adds to the voltage of S_2 to ignite the second lamp L_2. On operation, current again flows through the lamps and condenser in series with the winding S_2 to the practical exclusion of the winding S_1.

The above explanation is given merely to illustrate the requirements of the transformer core—to emphasize the problems which are solved by the invention herein. The core requires high leakage reactance between the primary and each of the secondary windings, with the leakage reactance between P and S_1 much greater than between P and S_2.

The mehod of the invention can be used to provide cores of varying constructions. In FIG. 5, for example, there is illustrated a ballast transformer **100** which differs from the ballast **10** only in the respect that the junction **26** at the left hand end of the ballast is formed by means of a straight portion **18** and the transverse portion **16** without the need for a notch **34** similar to that of ballast **10**.

In FIG. 7 there is illustrated a ballast core structure **200** in which the same type of core structure is used for a three winding ballast which requires that there be an ungapped shunt between windings. The circuit which is involved is shown in FIG. 6 and comprises a lead-lag circuit in which there is at least a primary winding and a pair of windings such as provided by chokes connected in parallel. The primary winding P in this case has an auto-transformer secondary winding Sa closely coupled therewith. There are two choke windings Ch_1 and Ch_2 connected in series with lamps L_L and L_C respectively and together therewith in parallel across the primary and secondary windings. Ch_2 is a leading choke since it has a condenser C in series therewith, and the gaseous discharge lamp L_C therefore has a leading current flowing therein during operation. The winding Ch_1 is a lagging choke since it is in a circuit which has no capacitive reactor and causes flow of lagging current through the lamp L_L which it serves.

Since the windings Ch_1 and Ch_2 are chokes, there is no need for a common magnetic circuit between them and the primary winding. The core **200** therefore has no gaps at **60** and **62** but provides close abutting junctures thereat. Since the winding windows **30** and **42** now house choke windings, they require gaps in their magnetic circuits. This can be provided at those locations which, in the ballest core of FIG. 2 are normally abutting junctions. Thus, there can be gaps at **26** and **38**, whose locations enable the maintenance of independent magnetic circuits for the chokes and autotransformer P—S_a. In addition, or as an alternative, there may be a bridged gap at **57** in the lagging portion of the ballast. The gaps **26** and **28** will normally have filler in the form of paper or cement so that the clamps **50** will not close the same.

If desired the shunt **20** could be provided with a gap at **60** as indicated by the broken line to make the winding Ch_1 actually a lag secondary in the magnetic circuit of the auto-transformer P—S_a while the winding Ch_2 remains a lead choke winding. This is a convenient and advantageous core for use with a popular circuit for lead-lag ballasts, in which the lag side is actually a secondary, while the lead side is a choke with an air gap. Notches **40** in ballast **200** will not have bad effects. In this latter case, there will be no gaps at **26** and no slot **57**.

Obviously, the core structure of FIG. 5 and even FIG. 2 is suitable for use with the more conventional lead-lag circuit in which the inner winding window **36** holds the primary winding or a primary and auto-transformer secondary winding, while each of the outer winding windows holds one of the secondaries.

The practical structure described in FIG. 2 above was constructed for igniting and operating a pair of 40 watt instant start gaseous discharge lamps. The physical constants of the apparatus were as follows:

Overall length of the core	5.35 inches.
Width of core	2.89 inches.
Stack height	.8 inch.
Primary P—600 turns	#25 wire.
Secondary S_1—2800 turns	#34 wire.
Secondary S_2—1360 turns	#28 wire.
Condenser C	3.25 mfd.

The resulting characteristics were as follows:

Lamp current L_1	amp.	.430
Lamp current L_2	amp.	.420
Primary current I_p	amp.	.680
Line current I_{line}	amp.	.835
Lamp watts 39 and 41:		
Power factor	percent	100
Condenser	volts	340

The open circuit voltages generated were of the order of 480 volts, sufficient to ignite the gaseous discharge devices. Obviously the open circuit voltage of the lamp L_2 is determined only with the lamp L_1 in place. The voltages across the secondaries during operation were V_{S1}—360 volts, V_{S2}—275 volts. The flux densities in the various parts of the ballast during operation were, in the primary part—13 kilogauss, in the first secondary part 6.3 kilogauss and in the second secondary part 13.3 kilogauss.

The circuit of the ballast was that of FIG. 3. The circuit of FIG. 4 is as practicable, and constants therefor are readily determined. The choice is merely one of design, choosing the best conditions of lamp balance, etc.

In FIG. 8, there is illustrated a novel ballast primarily for use with pre-heat start lamps that is a form of lead-lag circuit disclosed and claimed in application Serial No. 20,412, filed April 6, 1960, and assigned to the same assignee as this application, now Patent 3,050,659. This circuit uses three windings **101**, **102** and **103** all joined at a common terminal **105** which extends to one side of the line. Winding **101** is connected in series with lamp L_L and winding **103** is connected in series with condenser C and lamp L_C. Both lamps connect to the second side of the line. The winding **102** is arranged to buck the other two. The circuit is for use in connection with high voltage lines which have more than enough voltage to ignite the lamps.

Although this is a lead-lag structure, it will be seen that the line is not connected across any windings alone, but that each lamp is in series with two windings across the line, but with one winding common to both lamp circuits.

It was found that this circuit operated with great efficiency when the windings were mounted on a core with winding **102** in the center, winding **101** at one end sepa-

rated from winding **102** by a large shunt, and winding **103** was at the opposite end, separated from winding **102** by a smaller shunt. Winding **102** had a relatively large bridged gap in its iron. It will be seen that the cores of FIGS. 2 and 5 meet all the requirements with winding **101** in window **30**, **102** in window **36**, and **103** in window **42**. If notches **46** are insufficient for good results, a bridged gap **56** can be added.

It is believed that the invention has been sufficiently described to enable those skilled in this art to understand the same and construct ballasts in accordance with the principles thereof and to practice the method thereof. It is again pointed out that many variations of minor character can be made without departing from the spirit or scope of the invention. The advantages which are mentioned either directly or indirectly are not intended to be limiting, but rather exemplary of the benefits which flow from the invention. The theories of operation which have been mentioned are not intended to limit the invention, but merely to aid in an understanding thereof, irrespective of whether correct or not.

What it is desired to secure by Letters Patent of the United States is:

1. A method for producing a shell type transformer core which is comprised of individual laminations of electrical steel stacked and arranged together in a unitary core structure and in which the individual laminations consist only of elongate T-shaped members and elongate side members having lateral projections perpendicular thereto along one edge thereof including one of said projections at least at one end of each side member, said T-shaped members are stacked to form the central winding leg of the core and said side members are stacked and arranged with respect to the stack of T-shaped members to form the side parts of the core, the length of the side parts are equal, and the sum of the width of the long leg of the T-shaped lamination at the end opposite the cross-head of the T plus twice the maximum length of the said end projection of the side lamination is equal to the maximum length of the cross-head of the T-shaped lamination plus twice the width of the side lamination at the second end of each side part, and there are two of said lateral projections integral with each said side part between the ends thereof, and said T-shaped member has its elongate portion adjacent the cross-head substantially wider than the remainder thereof; said method comprising stamping said T- shaped and side part laminations in a continuous process from a strip of electrical steel moving through a stamping machine, albeit in a predetermined geometrical arrangement of said individual laminations along the direction of movement of said sheet which defines groups of said laminations, each group including a pair of side laminations and one of said T-shaped laminations all nested together with the said lateral projections between the ends engaged in notches in the elongate portion of the T-shaped lamination and the lateral end projections of said side laminations facing one another with their short dimensions common with the narrow end of the said T-shaped lamination, whereby said stamping results in a substantial reduction in waste, forming said projection at the same time of stamping, and thereafter stacking and assembling the said laminations to form said core.

2. A method as claimed in claim 1 in which the stamping of laminations occurs along said strip in a direction transverse of the said members and the groups are arranged with the side members back to back.

3. A ballast structure having a multiple winding electromagnetic device mounted on an iron core, said core being formed of three parts comprising a central winding leg and two abutting side legs, windings mounted each in one of a plurality of pairs of windows formed between the side and center legs on opposite sides of the center leg, said side legs having projections shunt-forming extending toward the central winding leg, said side legs having a facing configuration equivalent to a nested configuration of the opposite side edges of the central winding leg with the side legs being laterally spaced a predetermined distance outward from and shifted longitudinally relative to said central winding leg, the spaces between projections cooperating with said side edges of said central winding leg to form said windows, said central winding leg having notched portions corresponding to the nested location of said shunt-forming projections, said central winding leg being substantially wider beneath one pair of said windows and the adjacent shunt-forming projections than it is beneath the next pair of windows and the shunt-forming projections following same whereby the depth of the notched portions in said central winding leg corresponding to the nested locations of said adjacent shunt-forming projections beneath said next pair of windows is less than the said predetermined distance, such as to provide a minimum of adverse magnetic effect upon the winding mounted in said next pair of windows.

4. A ballast structure as claimed in claim 3 in which said central winding leg is of substantially T-shaped formation and each side leg has two shunt-forming projections, and a third projection at the end opposite the cross-head of the T, with the two shunt-forming projections located between the ends of each said side leg.

5. A ballast structure as claimed in claim 3 in which said central winding leg is of substantially T-shaped configuration, and the wider portion thereof is immediately adjacent the cross-head of the T.

6. A ballast structure as claimed in claim 3 in which said central winding leg is of substantially T-shaped configuration with the wider portion thereof immediately adjacent the cross-head of the T, and in which each side leg has a projection at the end opposite the cross-head of the T with each end projection extending toward one another and sandwiching the smaller end of the T between them.

7. A ballast structure as claimed in claim 3 in which the central winding leg is of substantially T-shaped configuration with the wider portion immediately adjacent the T, and two of the said shunt-forming projections of each side leg are located between the ends thereof, and in which there is a third projection on each side leg at the end opposite the cross-head of the T with the end projections of the side legs sandwiching the smaller end of the central winding leg therebetween.

8. A ballast structure as claimed in claim 3 in which the central winding leg is of substantially T-shaped configuration with the wider portion immediately adjacent the T, and two of the said shunt-forming projections of each side leg are located between the ends thereof, and in which there is a third projection on each side leg at the end opposite the cross-head of the T with the end projections of the side legs sandwiching the smaller end of the central winding leg therebetween, one of said two shunt-forming projections of each side leg being substantially wider than the other and disposed opposite said wider portion of the central winding leg while the other of said projections is disposed opposite the narrower portion of the central winding leg.

9. A ballast structure as claimed in claim 3 in which there are two of said shunt-forming projections integral with each of said side legs, a relatively long third projection at one end, a relatively short fourth projection at the opposite end, and two shunt-forming projections being disposed between the ends, and in which the central winding leg is of generally T-shaped configuration with the wider portion adjacent the cross-head of the T, the side legs being assembled to the center winding leg with the shorter end projections opposite the cross-head of the T and the longer end projections opposite the narrower end of the center winding leg, there being notched portions formed in each side edge of said central winding leg from three of said projections, each opposing a pair of notched portions being located under the resulting windows.

10. A ballast structure comprising a core formed of a central winding leg of generally elongate T-shaped configuration, a pair of side legs each having an inwardly extending lug at one end thereof facing opposite one another with the narrow end of the central winding leg sandwiched therebetween and side legs each having a relatively narrower second end engaged each upon opposite ends of the cross-head of the T, and said side legs each having two inwardly projecting lugs between the ends thereof cooperating with the side edges of the central winding leg to form shunts, each side leg having three recesses formed therein, one being formed between the center projections and the other two being formed respectively between each of the center projections and the opposite ends of the said side legs, said recesses forming pairs of windows adapted to have windings disposed therein, the side legs and the central winding leg have a configuration such that if each side leg is moved longitudinally relative the central winding leg by a distance equal to the thickness of the cross-head and then moved inward such that the recesses are closed completely, each of the two center projections will nest in notched portions provided in the central winding leg such that in assembled condition there will be a notched portion beneath each of the two windings disposed in pairs of windows closest adjacent the inwardly extending lugs at the ends of the side legs.

11. A structure as claimed in claim 10 in which the central winding leg is substantially wider adjacent the cross-head of the T than the remainder thereof such that each pair of windows formed adjacent thereto is laterally separated by a greater distance than the windows of said other pairs.

12. A structure as claimed in claim 10 in which said ballast structure includes means for connecting said windings to ignite and operate gaseous discharge devices, and in which said windings include a primary winding in the central pair of windows and secondary windings in the other two pairs of windows and in which the central winding leg is substantially wider adjacent its cross-head than the remainder thereof, such that the notched portions formed beneath the primary winding by the projection between it and the cross-head is substantially shallower than the notched portions formed in the central winding leg beneath the winding adjacent the end lugs.

13. A ballast structure for igniting and operating at least a pair of gaseous discharge devices adapted to be connected to a source of alternating current voltage, said ballast structure having at least three windings, an elongate iron core comprising a pair of side legs and a central winding leg, three pairs of windows disposed along the iron core each for receiving therein one of said windings, said central winding being spaced from one end winding a greater distance than from the other end winding, and there being shunts between windings, said central winding leg having a generally T-shaped configuration and having the said first end winding immediately adjacent the cross-head of the T, that portion of the central winding leg immediately adjacent the cross-head of the T having a substantially wider dimension than the remainder of the central winding leg, a pair of inward shunt-forming projections on each side leg, said side legs having a third inward projection at the end thereof adjacent the narrow end of the T, the configuration of side legs and central winding leg being such that the parts would nest if moved longitudinally and towards one another, and there being notched portions formed thereby beneath the central winding and that end winding adjacent said third inward projection.

14. A ballast structure as claimed in claim 13 in which the central winding is a primary and the winding separated therefrom by the narrower shunt is adapted to carry a leading current whereby the notched portions beneath the center winding are shallow compared with those beneath the winding carrying the leading current.

15. A ballast structure as claimed in claim 14 in which there is a bridged gap beneath said winding carrying the leading current.

16. A ballast structure adapted to ignite and operate a pair of gaseous discharge devices in a lead-lag circuit and in which there is a primary winding adapted to be connected across an A.C. line, a pair of secondary windings each adapted to have one of the gaseous discharge devices connected in series therewith and connected in auto-transformer relation with the primary winding but with a condenser in series with one of said secondary windings to constitute same a leading secondary winding, a core structure for mounting the said windings, said core structure comprising a central winding leg of generally T-shaped configuration and having a wider portion adjacent the cross-head of the T, a pair of abutting side legs provided with inwardly directed projections adapted to cooperate with the side edges of the T-shaped central winding leg to form shunts between the three windings, and each of the side legs having an end projection adapted to engage against the side edges of the central winding leg opposite the cross-head of the T, the central winding leg having notched portions corresponding to the nested configuration of the side legs therein, but the side legs being assembled to the central winding leg spaced from and moved longitudinally relative thereto and forming thereby opposed windows between the side legs and center winding leg along the length thereof, the lagging winding being mounted in the opposed windows adjacent the wider portion of the central winding leg, the primary winding being mounted in the central opposed windows and the leading secondary winding being mounted in the opposed windows at the end adjacent the narrow portion of the center winding leg and having the notched portion corresponding to the shunt between it and the primary winding disposed beneath said leading secondary winding whereby to improve operation of said ballast structure thereby.

17. A ballast structure as claimed in claim 13 in which the center winding is adapted to be connected with said source, each of the other windings comprises a choke winding, the shunts have no gaps therein, there are gaps provided in the magnetic circuit of each choke winding adjacent the ends of the iron core, and each choke is connected in series with a lamp and with the center winding.

18. A ballast structure as claimed in claim 17 in which the center winding is a primary.

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