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ELECTRICAL INDUCTION APPARATUS HAVING GRADED INSULATION

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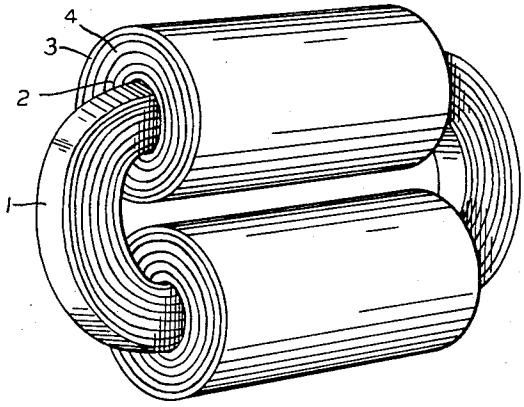


Fig. 1

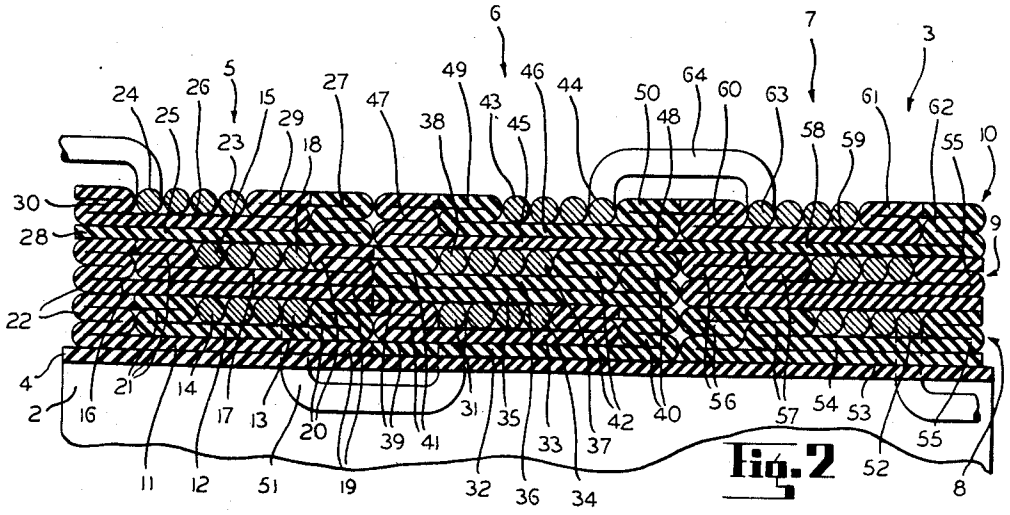


Fig. 2

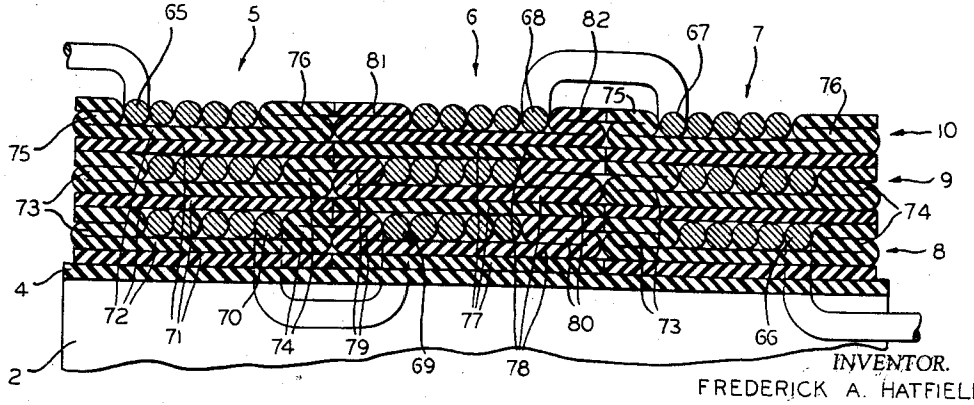


Fig. 3

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ELECTRICAL INDUCTION APPARATUS HAVING GRADED INSULATION

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This invention relates to electrical induction apparatus and particularly to high voltage coils or windings such as the primary winding in distribution transformers.

High voltage windings such as employed in distribution transformers are wound with a plurality of concentric layers of coil turns with the layers separated by electrical interlayer insulation. The coil turns and the coil layers may be series connected to add the voltage of the separate turns. In winding the coil, the coil layers are wound back and forth from a continuous conductor such that the voltage between the end turns of successive layers is alternately equal to zero and to the sum of the voltages of the individual coil turns in two layers. As the length of the coil increases, the voltage per coil layer also increases and the insulation required between layers, particularly immediately adjacent the end turns having the high potential difference, increases to such an extent that it is not always practical to provide adequate insulation.

A practical solution in high voltage coils is the use of "back-turn-sections" wherein the winding is axially divided into a plurality of individual coil sections which are connected in series. The adjacent coils are wound in opposite directions and alternately connected at the inner and outer coil layers to maintain positive voltage summation. The axial lengths of the coil sections are made sufficiently short to prevent a build up of large voltages per layer and thereby reduce the maximum voltage difference between adjacent layers. Therefore, the winding can be formed without the use of unwieldly thickness of interlayer insulation. However, in this method, potential differences will exist between the adjacent coil sections not only due to the summation of the voltages of the individual coil turns in the adjacent coil sections but also due to the distribution of irregular peaked voltage waves or surges to which the winding may be subjected because of lightning, switching, or the like. Normally, in the design of the coil sections, a maximum potential difference which is expected to occur between coil sections is determined or calculated. Sufficient intersection insulation having a constant axial thickness is provided between the coil sections to prevent flashover from one coil section, commonly by spacing the adjacent end coil turns in adjacent coil layers to provide the required insulating space and by crimping or folding the edge of the radially outermost piece of interlayer insulation upon itself to a thickness sufficient to mechanically lock the coil turns against axial movement. The voltage between coil sections is different at various radially spaced points corresponding generally to the different adjacent layers of adjacent coil sections. Equal insulation is inserted for the radial depth of the coil sections and consequently an excess intersection insulation exists at other than the position or points of maximum voltage difference.

In accordance with the present invention, the insulation disposed between adjacent coil sections is graded to more nearly conform to the actual voltage distribution therebetween. This provides a higher ratio of winding

space to insulation space and thus permits not only economy of insulation and the like but also more efficient use of the space within the core window. The intersection insulation is provided by radially folded extensions of all or part of the interlayer insulation. The intersection insulation is then simply and easily step-graded by either varying the width of the folds or by varying the number of folds or both.

The accompanying drawing illustrates the best mode presently contemplated by the inventor for carrying out the invention.

In the drawing:

Figure 1 is a perspective view of a distribution transformer;

Fig. 2 is an enlarged fragmentary view representative of the construction of the primary winding in a distribution transformer, taken on a plane through the axis of the winding; and

Fig. 3 is a view similar to Fig. 2 of another embodiment of the invention.

Referring to the drawing and particularly Fig. 1, a laminated core **1** of the wound strip type has a secondary winding **2** wound on each leg and a primary winding **3** superposed upon the secondary winding. Interwinding insulation **4** normally including a plurality of superposed layers of paper, fabric or the like is disposed between the windings **2** and **3**.

Transformers may be employed to deliver high voltage, low-current power to a load as low-voltage, high-current power. The primary winding is then the high voltage winding and is wound with a relatively large number of coil turns of small diameter wire which safely carries the relatively small current.

Referring to Fig. 2, a fragmentary portion of a transformer is shown with the secondary winding **2** partially shown, in outline only. The primary winding **3** is shown with cross sections of a relatively few coil turns, substantially enlarged for purposes of illustration. In actual construction, a much greater number of turns would be used.

The illustrated primary winding **3** comprises three individual coil sections **5**, **6** and **7** respectively. Each coil section is individually wound from an uninterrupted conductor into three concentric layers **8**, **9** and **10** of a plurality of individual coil turns.

Beginning with coil section **5**, the first coil layer **8** is wound upon two tubular sheets of interlayer insulation **11** and **12** of paper or other suitable fabric. The coil layer **8** is started with a first turn **13**, shown to the right of coil section **5** in Fig. 2, and is wound from right to left and is terminated in a final coil turn **14**, shown to the left in section **5** of Fig. 2. The coil turns in layer **8** of coil section **5** are assumed for purposes of illustration to be wound in a clockwise direction looking to the right in Fig. 2. The last turn **14** of layer **8** is integrally connected with a first coil turn **15** in the second coil layer **9**. The coil turn **15** is wound directly over the turn **14** and the second layer **9** is wound upon two sheets of interlayer insulation paper **16** and **17**. The second layer **9** is wound from left to right in Fig. 2 back over the first coil layer **8**. The second layer **9** terminates in a coil turn **18** which is axially aligned with the first turn **13** of the first coil layer **8**.

The corresponding interlayer insulation paper **11**, **12**, **16** and **17** for the first two coil layers **8** and **9** extends beyond the first and last turns and is similarly crimped or folded upon itself to provide axial intersection insulation adjacent the end coil turns. The right end of the interlayer insulation paper **11** and **16** for respective coil layers **8** and **9** projects beyond the coil turns **13** and **18**, as at **19**. The right end of the interlayer insulation paper **12** and **17** for the respective coil layers **8** and **9** is folded upon itself as at **20** to a sufficient portion of the

thickness of the coil layers 8 and 9 to mechanically lock the coil turns in an axial direction and to provide intersectional or axial insulation for the coil section 5. The length of the extensions 19 and the axial width of folds 20 are the same and are determined by the minimum potential difference which will arise between corresponding coil layers in adjacent coil sections. In coil section 5 of Fig. 2 a single width is provided to the right end of section 5 as this is a position of minimum potential as will more fully appear hereinafter.

The left end of the interlayer insulation 12 and 17 is folded upon itself adjacent the respective coil turns 14 and 15, as at 21 with the same axial width as folds 20 and mechanically locks the coil turns in an axial direction. The left end of the insulation paper 11 and 16 is extended beyond the folds 21 and is similarly folded as at 22 to provide a smooth outer end to the coil section 5. The left hand folds 22 of insulation 11 and 16 are made the same radial depth as the adjacent folds 21 by folding each sheet of insulation 11 and 16 upon itself an additional time.

The third coil layer 10 of coil section 5 is formed by a series of coil turns wound from right to left in Fig. 2 with the first turn 23 connected directly to the last turn 18 of the second coil layer 9. The third layer 10 of coil section 5 is wound back over a portion of the second layer 9 and terminates in a coil turn 24 which is extended outwardly of the coil section 5 to provide a connecting lead for the primary winding 3. Two sheets of interlayer insulation paper 25 and 26 separate the coil layers 9 and 10. The third layer 10 is shifted axially to the left in the drawing and away from the adjacent coil section 6 a distance equal to the width of one of the end folds in the interlayer insulation to provide increased axial spacing of the corresponding coil layers 10 in coil sections 5 and 6. The interlayer insulation paper 25 is folded upon itself as at 27 and the folded end is disposed in radial alignment with the right hand folds 20 in the first two layers 8 and 9. The left end of paper 25 projects beyond the last coil turn 24 as at 28 and terminates in alignment with the outer surface of the folds 22 in coil layers 8 and 9. The radially outer insulation paper 26 is folded at the right hand end as at 29 and fills the space between the first coil turn 23 of coil layer 10 and the folded end 27 of paper 25 which space is created by the shifting of the third layer with respect to the first two coil layers. The left hand end of the radially outer interlayer insulation 26 is folded as at 30 to provide insulation in alignment with the outer edge of the first two layers.

Coil section 6 of the primary winding 3 is wound in a reverse direction such that the first layer 8 of coil section 6 is a continuation of the first layer 8 of coil section 5. The first coil layer 8 of coil section 6 is wound, starting with a first coil turn 31, from left to right in Fig. 2 and in a counterclockwise direction looking to the right in Fig. 2. The first coil layer 8 is wound upon two superposed sheets of interlayer insulation paper 32 and 33 and terminates in an end coil turn 34, shown to the right in Fig. 2. The end coil turn 34 is extended to the second layer 9 and the second coil layer 9 is wound upon two superposed sheets of interlayer insulation paper 35 and 36.

The second coil layer starts with the coil turn 37 which is superposed upon the last coil turn 34 of coil layer 8 and is wound back over the first coil layer 8 with the final turn 38 disposed about the first turn 31 of the first coil layer 8.

The ends of interlayer insulation paper 32, 33, 35 and 36 of the first two coil layers 8 and 9 of coil section 6 are folded in the reverse direction of the corresponding insulation paper for coil section 5. The radially innermost interlayer insulation papers 32 and 35 project beyond the first and last coil turns 31 and 38, respectively, as at 39 into abutment with the similar projections 19 in coil section 5. The right hand end of insulation 32 and 35 is folded as at 40 and disposed in spaced relation to the coil turns 34 and 37 of the respective coil layers 8 and 9 a distance equal to the axial width of a single fold. The radially outermost interlayer insulation paper 33 and 36 is folded at both ends as at 41 and 42. The folds 42 fill the space between the coil turns 34 and 37 and the folds 40 of interlayer insulation paper 32 and 35. The left hand end folds 41 abut the corresponding end folds 20 in coil section 5 and provide insulation between the corresponding layers 8 and 9 of coil sections 5 and 6.

The third layer 10 of coil section 6 is axially offset away from the coil section 5, to the right in the Fig. 2, a distance equal to the width of a fold in the interlayer insulation paper. The third layer 10 begins with a coil turn 43 which is a continuation of the last turn 38 of the second layer 9 and is wound back over the second layer 9 to a final coil turn 44. Interlayer insulation paper 45 and 46 is disposed between layers 9 and 10. The radially innermost layer of insulation 45 is folded at the left end as at 47 in spaced relation to the initial coil turn 43. The opposite end of the insulation paper 45 projects beyond the final coil turn 44 as at 48. The radially outermost interlayer insulation paper 46 is folded at both ends as at 49 and 50 to mechanically lock the coil turns, thereby providing intersection insulation to each side of the third coil layer 10.

Thus four separate folds of insulating paper are provided between the third layers 10 in the adjacent winding sections 5 and 6 to provide maximum insulation therebetween. The adjacent first coil turns 13 and 31 of sections 5 and 6 are joined by a lead 51 to serially connect the winding sections 5 and 6. Therefore, the coil turns 13 and 31 are at the same potential and no axial or intersectional insulation is needed. While no intersectional insulation would actually be required at this point between the same layers, it is commonly accepted practice to provide the same amount as in succeeding layers. Because the winding sections 5 and 6 are relatively short, the voltage difference between the adjacent final coil turns 18 and 38 is still relatively small and the two abutting folds 20 and 41 provide adequate insulation.

The potential difference between the adjacent coil layers 10 of winding sections 5 and 6 is substantially greater than the first two layers because they lie at opposite ends of the winding sections which are serially connected and add their voltages.

Coil section 6 is wound in the same manner as coil section 5 except in a reverse direction.

The third coil section 7 is wound and arranged on core 1 exactly as is coil section 5 and thus is arranged in an opposite axial direction with respect to coil section 6. Coil section 7 starts at the right of the coil section 7 in Fig. 2 with the coil turn 52 in the first coil layer 8. The first and second layers 8 and 9 are each wound upon two interlayers of insulation 53 and 54 respectively with single folds of insulation 55 formed by folding the extended interlayer insulation 54 upon itself on the right end of coil section 7 and with double folds of insulation 56 and 57 formed by folding the extended interlayers 53 and 54 upon themselves to the left. The first layer of coil turns 8 is wound from right to left and the second layer 9 is wound from left to right as viewed in Fig. 2. The third layer 10 is wound upon two concentric interlayers of insulation 58 and 59 and is offset to the left in Fig. 2 as is the third layer of section 5. A single fold of insulation 60 is formed by folding the left end of extended interlayer 59 upon itself and a double fold of insulation 61 and 62 respectively, is formed by folding the right end of extended layers 58 and 59 upon themselves.

The last turn 63 in the layer 10 in the coil section 7 is connected to the last turn 44 of section 6 by a lead 64. As these coil turns are connected together, they are at

the same potential and a minimum insulation is required therebetween. However, between the first two coil layers 8 and 9 of section 7 and the first two coil layers 8 and 9 of section 6, there is a substantial potential difference due to the fact that the voltage at any coil turn within middle section 6 with respect to a coil turn of section 7 is equal to the sum of the individual coil turns in section 7 plus the individual coil turns in section 6 which connect the two turns under consideration. The voltages of the coil turns add and thus the voltage at the coil turns in section 6 is relatively high with respect to the initial coil turns in section 7.

Referring to Fig. 3, a second embodiment of the invention is illustrated which employs a single fold of varying axial width to provide the necessary radially graded insulation between adjacent coil sections. Corresponding elements in Fig. 1 and Fig. 2 are given corresponding numbers unless otherwise specifically described.

As in Fig. 2, the last coil turn 65 of coil section 5 in Fig. 3 is extended to provide connection to one side of a power source and likewise the first coil turn 66 of section 7 is also extended to provide connection to the corresponding primary winding 3 on the other leg of core 1. The end turn 67 in coil layer 10 of section 7 is connected to the end turn 68 in section 6 and the starting coil turn 69 of section 6 in coil layer 8 is connected to the starting coil turn 70 of section 5 in coil layer 8.

Sections 5 and 7 are similarly wound in Fig. 3. Two sheets or tubes of interlayer insulation 71 and 72 are disposed between the radially successive coil layers 8, 9 and 10. The first layer 71 is generally tubular in shape and terminates adjacent the axial end of the coil sections. The first layer 71 may be omitted from underneath the first coil layer 8 or may be wound as one piece for all sections 5, 6 and 7 as a part of the interwinding insulation of Figure 1. The second interlayer insulation 72 is also disposed between each layer and is crimped or folded at each end. The left hand projection and the right hand projection of the insulation 72 for sections 5 and 7 in the first and second coil layer 8 and 9 is similarly crimped, as at 73 and 74, respectively. The width of the folds 73 which lie to the left end of the coil sections in Fig. 3 is generally equal to the width of two individual folds employed in the embodiment of Fig. 2. The width of the folds 74 which lie to the right end of the coil sections 5 and 7 in Fig. 3 is generally equal to the width of one individual fold employed in the embodiment of Fig. 2. Thus, the folds 73 and 74 of Fig. 3 establish the same proportionate insulation value as the corresponding insulation folds 20, 21 and 22 and insulation folds 55, 56 and 57 of corresponding coil sections 5 and 7 in Fig. 2. In the third layer of coil sections 5 and 7 of Fig. 3, the left hand projection of insulation 72 is a single width fold as at 75 and the right hand projection is a double width fold as at 76. The width of the fold 75 and 76 is the same as the width of the individual folds 27, 29 and 30 in Fig. 2 and therefore provide corresponding insulation.

In coil section 6, two layers of interlayer insulation 77 and 78 are interposed between the successive coil layers 8, 9, and 10. The first layer 77 is tubular and extends past the end turns of each coil layer to the axial end of the coil section. This piece may also be omitted from underneath the first coil layer 8 or may be wound as one piece for all sections 5, 6 and 7 as a part of the interwinding insulation 4 of Figure 1. The second layer 78 is also tubular and extends past the end turns of each coil layer with the extended portion being folded upon itself to establish the intersectional electrical insulation. The left hand folds 79 for the layers 8 and 9 are the same width as the individual folds of Fig. 2, and therefore provide minimum insulation between coil sections 5 and 6 at the position of minimum potential difference. The right hand folds 80 of insulation in layers 8 and 9 are double-width folds and therefore provide maximum insulation between coil sections 6 and 7 at points of greatest potential difference. For the third layer 10 of coil sections 6 of Fig. 3, the left hand fold 81 is a double width fold and the right hand fold 82 is a single width fold. Maximum insulation is therefore provided between coil sections 5 and 6 in the third layer which is a position of maximum potential difference. Thus, in both Fig. 2 and Fig. 3, the same intersectional insulation distribution is obtained. The distribution in both constructions being generally in accordance with the actual potential existing between the existing coil sections.

In both illustrated embodiments, the insulation folds lie in a generally axial direction to establish insulation between coils sections in accordance with the radially varying axial potential established between the adjacent coil section. If desired, the insulation folds may lie in a radial direction with the width of the individual folds filling the radial space between successive layers and the number of folds varying in accordance with the desired insulating distribution.

The illustrated embodiments of the invention shows the same odd-number of coil layers in each coil section and an equal number of turns in each layer such that the connected turns of adjacent coils are immediately adjacent each other. In general practice this is seldom attained due to variations in the winding apparatus and the wire employed, particularly where many turns of fine wire are used. Thus, although the last turn of each section falls in the final layer, it often emerges from the center or opposite end of the coil section and is extended axially to the other coil section. Nevertheless, for practical purposes, the voltage between adjacent turns of the final layers does not appreciably vary regardless of where the final turn emerges. The designer normally assumes full maximum voltage occurs between the adjacent final or outer layers for purposes of design.

Although the illustrated winding employs three individual coil sections each having only three individual layers of coil turns, any other suitable number of coil sections and/or coil layers may be employed. The illustrated intersectional insulation is shown step-graded because it is a simple and practical form of construction. If desired, a smoothly progressively changing intersectional insulation may be employed.

In making the axial shift in the coil layers to change the insulating spacing of adjacent coil sections, a transitional layer may advisably be employed. The transitional layer would be axially shortened to dispose its initial turn in alignment with the preceding final turn and its final turn in axial alignment with the initial turn of the next succeeding layer. The transitional layer would provide a smooth shift at the change of insulation and would eliminate sharp bends and space between the coil turns.

The present invention provides a high voltage winding having a higher ratio of winding space to insulation space and permitting greater economy of insulating material and other cooperating components such as the core and housing. Further, varying the width or number of end folds of the interlayer insulation provides a simple construction for a radially step-graded insulation of adjacent coil sections.

Various modes of carrying out the invention are contemplated as being within the scope of the following claims particularly pointing out and distinctly claiming the subject matter which is regarded as the invention.

I claim:

1. In induction apparatus, a plurality of multilayer coil sections axially mounted in side by side relation and interconnected in an electrical circuit with a radially varying potential established between adjacent coil sections under operating conditions, and at least one layer of insulation between corresponding superimposed layers of the coil sections, certain of said insulation layers being individually reverse folded upon themselves immediately adjacent the ends of the coil layers to provide

radially-graded insulation material disposed between said sections generally in accordance with the radially varying axial potential difference established under operating conditions to prevent flashover between adjacent coil sections.

2. Electrical induction apparatus having a plurality of multilayer coil sections axially mounted in side by side relation and connected in a series circuit, which comprises interlayer insulation disposed between successive winding layers of said coils and axially extended beyond the end turns of the coils, the extended portion of the insulation being prefolded upon itself axially of the adjacent winding layer to provide electrical insulation between adjacent coil sections, and the total axial width of said folded insulation between each pair of coils varying in accordance with the potential between adjacent coil sections to provide a radially-graded insulation between adjacent coil sections and thereby increase the ratio of available winding space to insulation space.

3. Electrical induction apparatus, which comprises a magnetic core structure, a plurality of coil sections having an equal number of layers of continuous coil turns, said coil sections being axially aligned in side by side relation on said core structure and alternately having the initial turns and the final turns of adjacent coil sections connected together, alternate coil sections being reverse wound to establish a positive voltage summation of said coil sections, each coil section having certain of said layers axially offset to establish a spacing between layers of adjacent coil sections in proportion to the potential difference arising between aligned layers of adjacent coil sections, and electrical insulation disposed within the space between said adjacent coil sections to prevent flashover between adjacent coil sections said insulation characterized by being formed in layers disposed between the layers of the coil sections and having their ends folded radially and axially in a plurality of reverse bends adjacent the ends of the corresponding coil section layers and in alignment therewith.

4. A high voltage winding wound on a magnetic core structure, which comprises a plurality of coil sections each having a plurality of layers of continuous coil turns, the axial length of each of said layers being substantially the same, electrical insulating fabric disposed between successive layers and extended axially therefrom with the ends of said fabric being folded radially and axially in reverse bends to provide oppositely stepped-graded axial insulation on opposite ends of said coil, said coil layers being axially offset to maintain said coil section of a constant axial length, and a core structure having said coils arranged in axial alignment on the core structure with alternate coils axially reversed to dispose corresponding widths of axial insulation in abutting relation.

5. A high voltage winding, which comprises a core structure, a plurality of coil sections arranged in axial alignment on said core structure and each having a plurality of layers of series-connected coil turns beginning at the innermost layer and terminating in the outermost layer, alternate coil sections having the initial coil turns at corresponding axial ends and being reverse wound with respect to the adjacent coil sections to alternately dispose the initial turns adjacent each other, the axial length of each layer in said coil sections being substantially the same as all other layers, electrical insulation interposed between the layers and extended axially of the layers, the ends of said insulation being radially and axially folded in reverse bends adjacent and aligned with the corresponding coil section layers to axially lock the coil turns in the adjacent outer coil layer and to provide axial insulation, the axial width of folded insulation varying at opposite ends of each coil section in predetermined steps alternately from a minimum to a maximum and from a maximum to a minimum between the innermost layer and the outermost layer in accordance with the changing potential existing between adjacent coil sections, and said coil layers being axially offset in accordance with said varying insulation width to maintain a constant axial coil section length and to dispose corresponding widths of axial insulation in abutting relation.

6. Induction apparatus having a plurality of multilayer coil sections connected in series and disposed in side by side relation on a core and having certain coil sections reverse wound to provide an increasing voltage summation, which comprises at least one interlayer of insulation between successive winding layers of each coil section, and at least one of said interlayers of insulation being extended axially of the associated coil section and being folded radially and axially upon itself to establish at least one axially extended folded portion to provide electrical insulation between aligned coil layers of adjacent coil sections, the number of said extended folded portions varying and establishing axial insulation generally in accordance with the potential difference between the coil layer of the immediate coil section and an aligned coil layer of the adjacent coil section.

7. In a high voltage winding having a plurality of serially-connected multilayer coil sections disposed in side by side relation with the sections reverse wound with respect to the adjacent coil sections to alternately dispose initial turns, said coil sections having adjacent initial turns connected and final turns connected to provide increasing voltage summation and each coil section comprising a plurality of concentric layers of coil turns wound from a continuous conductor, a plurality of intervening layers of insulation interposed between and axially extended from said concentric layers of coil turns, one or more folded extensions of said insulation formed by radial and axial folds providing reverse bends disposed adjacent and in alignment with the axial ends of the corresponding coil turns, and the number of said folded extensions adjacent the ends of radially successive layers increasing from a minimum to a maximum in general proportion to the potential difference between the immediate layer of coil turns and the corresponding layer of coil turns of the immediately adjacent coil section.

8. A high voltage winding, which comprises a magnetic core structure, two or more multilayer coil sections disposed in side by side relation upon said core structure, said coil sections being alternately reverse wound from an inner start layer to a final layer, means to connect said coil sections in series by alternate connection of the inner layer ends and outer layer ends of adjacent coil sections to provide a positive voltage summation, two or more concentric layers of insulation interposed between layers of coil turns in each coil section, the ends of each of said intervening layers with a layer of coil turns wound thereon being radially folded immediately adjacent the axial end turns for the depth of the winding layer wound thereon to mechanically support the winding layer in an axial direction and to establish insulation between adjacent coil sections, the ends of certain other layers of said intervening layers extending beneath said folds and being radially folded immediately adjacent the first folds for the depth of the winding layer wound thereon and disposed in axially abutting relation with the first folds to increase the insulation between certain aligned layers of adjacent coil sections, and the corresponding coil layers wound on said last named intervening layers being axially offset to maintain a constant axial dimensioned coil section.

9. A coil section for a high voltage winding having a plurality of side by side and alternately reverse-wound coil sections connected in series by connection between end turns of adjacent coil sections, which comprises a plurality of concentric layers of continuous coil turns in each coil section, said concentric layers being disposed in general radial alignment and having relatively

high potential difference between certain of said aligned layers, and said layers having the higher potential difference being axially offset with respect to other of said concentric layers, two or more tubular interlayer insulators disposed between concentric layers to prevent electrical flashover between layers, the ends of the insulators being extended past the ends of the coil turns and each being radially outwardly folded upon itself to provide insulation adjacent the axial ends of the coil, the insulator upon which the corresponding layer of coil turns is immediately wound being folded adjacent the end coil turns in the layer, and the other insulators being folded in axially outwardly abutting relation to said first insulator and to each other to dispose the axial end of the coil section in a radial plane whereby greater axial insulation is provided between coils turns having an increased potential difference.

10. A high voltage winding, which comprises a plurality of individual multilayer coil sections disposed in axially abutting relation and each having a number of coil turn layers with a radially inner terminal at one axial end of the coil and a radially outer-terminal generally at the opposite axial end of the coil, means to join said adjacent coil terminals to connect the coil sections in series, the adjacent coils being wound in a reverse direction to dispose common potential terminals in generally side by side relation and to establish positive voltage summation of the individual coil sections, adjacent ends of the coil sections having a radially varying potential gradient therebetween which is the inverse of the potential gradient of the immediately adjacent coil sections, interlayer insulation disposed between the coil layers of each coil section and crimped at each end into a radially extended fold having an axial reverse bend immediately adjacent the end of the associated coil layer, the axial width of the successive folds being varied in predetermined steps in general accordance with the potential difference established between the aligned coil layers of adjacent coil sections, and the coil layers being axially shifted to permit radially inverse disposition of the insulation at the opposite axial ends of each coil.

11. A high voltage winding, which comprises a core structure, a plurality of similar coil sections each having a plurality of concentric layers having the same axial length and formed of continuous coil turns wound back and forth over the immediately preceding layer, said coil sections being arranged on said core structure in axial alignment and being alternately axially reversed to dispose initial starting coil turns adjacent each other, means to connect said adjacent initial coil turns and alternate final turns to serially connect said coil sections, a tubular electrical insulation of at least one layer of flexible material interposed between successive layers and axially extended past the axial end turns, the extended end of at least one layer of said insulation being folded radially and axially to provide a plurality of reverse bends and thereby build up axial insulation immediately adjacent the axial end turns and varying in axial length between different layers in accordance with the potential established between the coil sections, and said coil layers being axially offset to accommodate said varying widths with a constant axial coil section length.

12. Induction apparatus having a plurality of multilayer coil sections connected together and disposed in side by side relation on a core and having certain coil sections reverse wound to provide an increasing voltage summation, which comprises interlayer insulation disposed between successive layers of each coil section, said insulation being extended axially of the associated coil section and being folded in reverse bends upon itself to establish axially extended folded portions to provide electrical insulation between aligned coil layers of adjacent coil sections, and the number of said extended folded portions and the axial extent of said folded portions varying to establish axial insulation generally in accordance with the potential difference between the coil layer of the immediate coil section and the aligned coil layer of the adjacent coil section.

References Cited in the file of this patent

UNITED STATES PATENTS

1,450,362	Gilinson	Apr. 3, 1923
2,359,544	Camilli	Oct. 3, 1944