

March 27, 1973

G. G. FUSS

3,723,237

PACKING MATERIAL AND METHOD

Filed Feb. 16, 1971

3 Sheets-Sheet 1

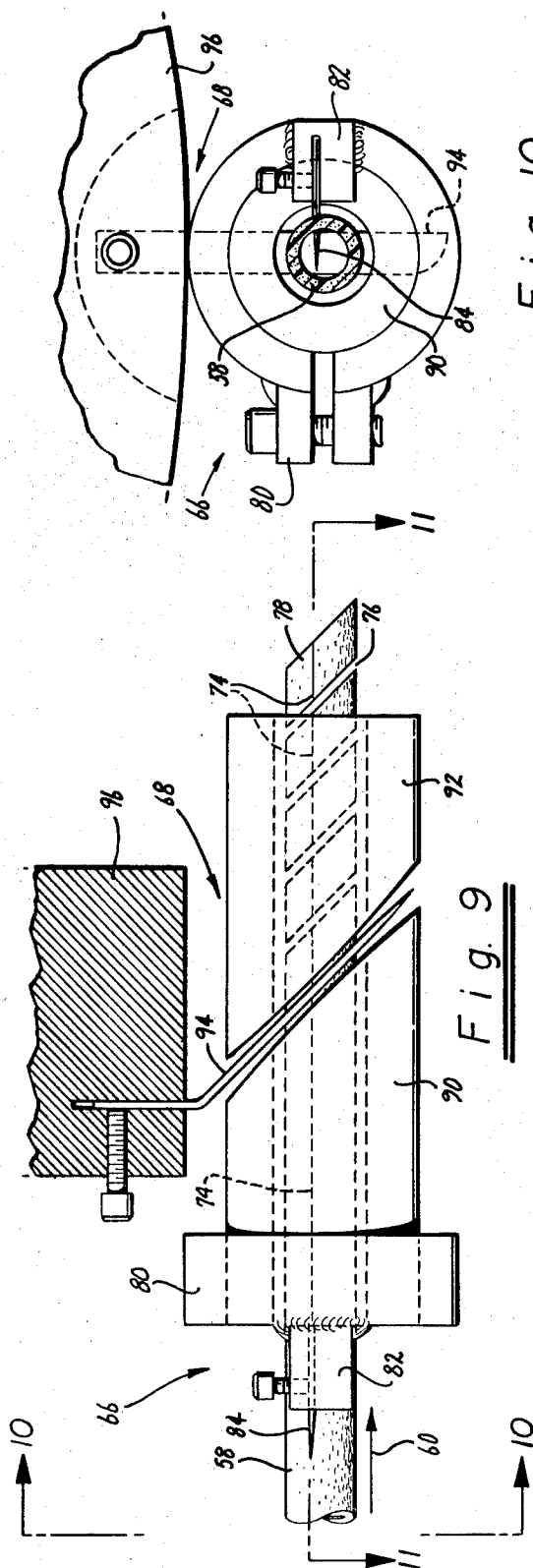


Fig. 10

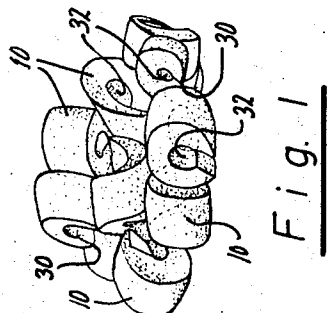


Fig. 1

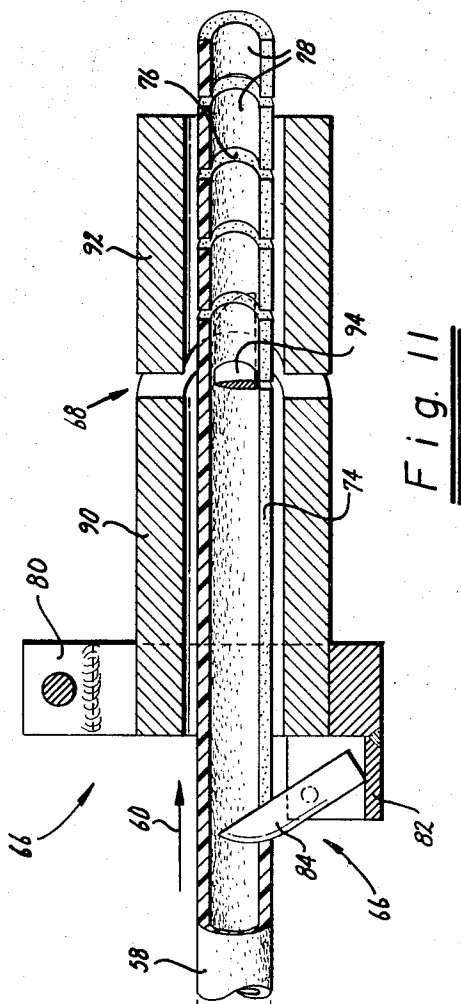


Fig. 11

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3 Sheets-Sheet 2

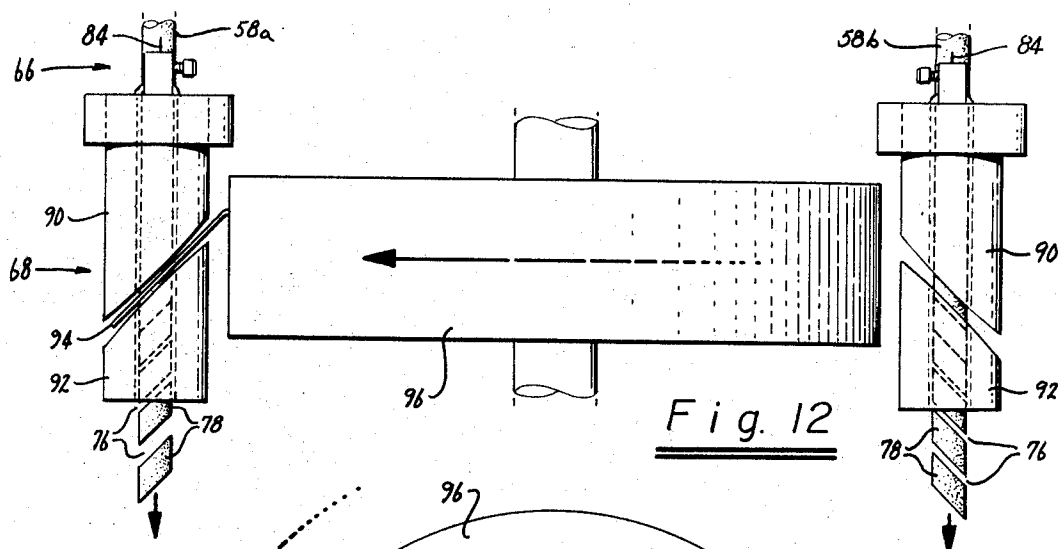


Fig. 12

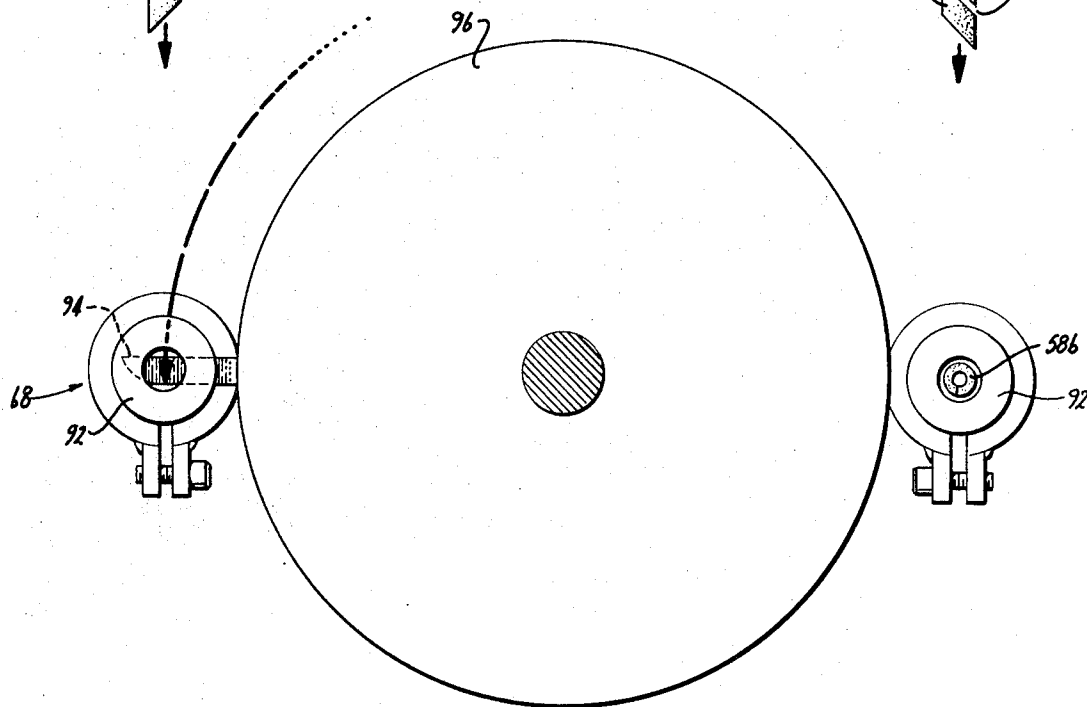


Fig. 13

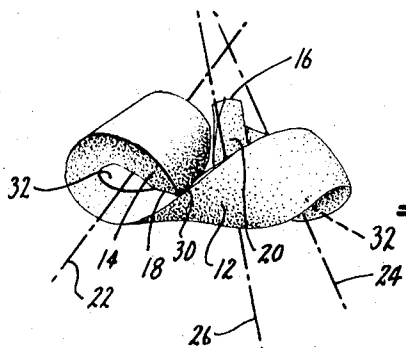


Fig. 2

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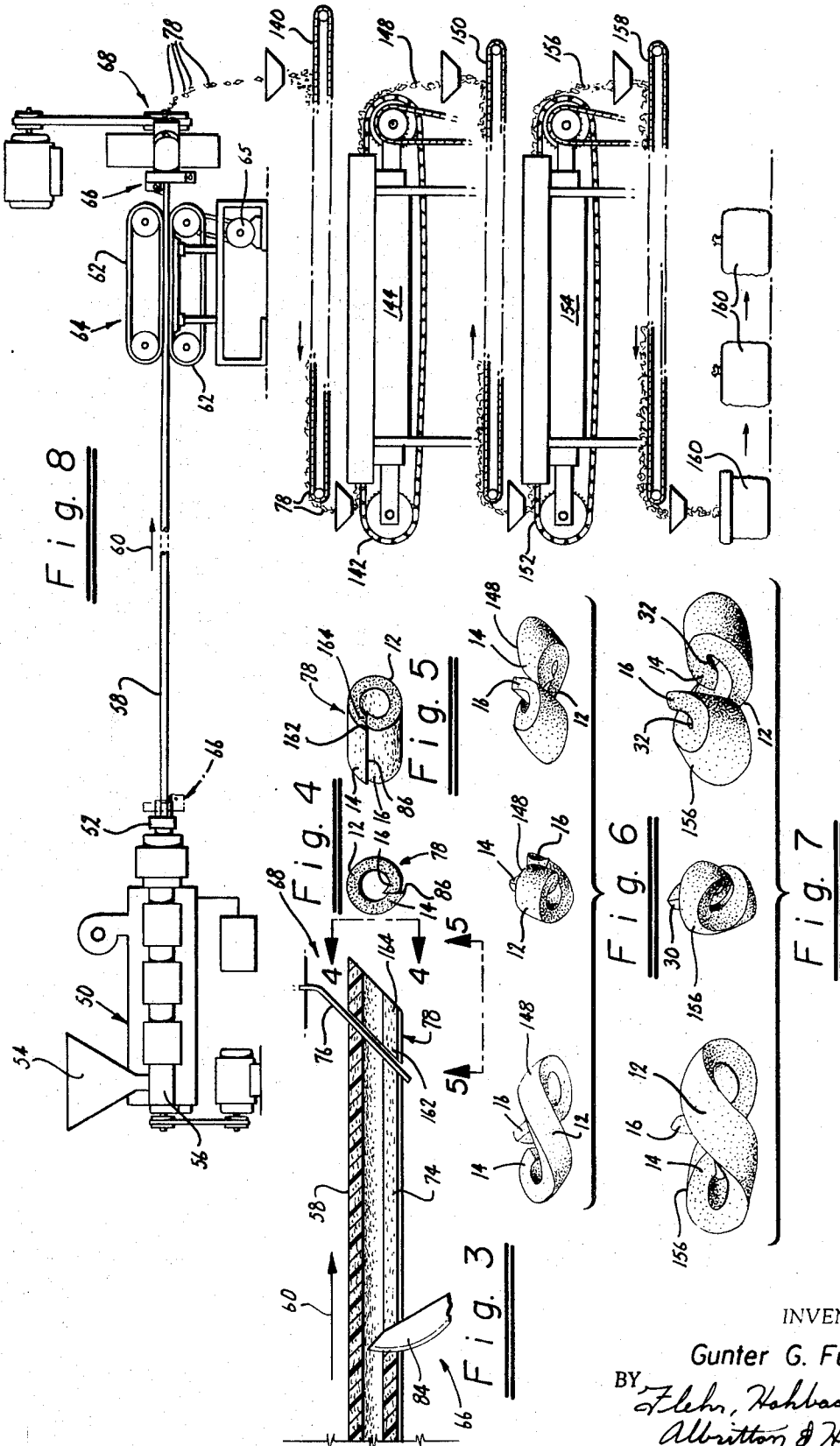
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PACKING MATERIAL AND METHOD

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3 Sheets-Sheet 3



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3,723,237

PACKING MATERIAL AND METHOD
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Filed Feb. 16, 1971, Ser. No. 115,527
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U.S. Cl. 161—168

10 Claims

ABSTRACT OF THE DISCLOSURE

An improved free flow packing material particularly characterized by its ability to isolate packed items and to absorb the energy of potentially destructive shocks and impacts, together with a method and means for its manufacture. The individual units of the packing material are structurally in the form of relatively elongate thick continuous strips wherein each strip is formed with a gradually twisting spiral configuration, having curling central and end portions. The individual units are of a size and shape to provide a desired free-flowing characteristic, and are formed of a foamed expanded crushable plastic material which inherently possesses a shock absorbing characteristic.

BACKGROUND OF INVENTION

This invention relates generally to free flow, loose fill packaging materials and to methods and means for their production, and more specifically to a particular improved form of such packaging materials.

The present invention improves on the packaging materials, and the methods and means for producing packaging materials, as disclosed in Graham and Stanley Pat. 3,481,455, copending application Ser. No. 43,527, filed June 4, 1970, by Alexander G. Makowski, now U.S. Pat. No. 3,632,705, and copending application Ser. No. 82,697, filed Oct. 21, 1970 by Arthur Graham, Alexander G. Makowski and Gunter G. Fuss.

SUMMARY OF INVENTION AND OBJECTS

Generally stated, the present invention is directed to an improved free flow, interlocking, foamed expanded plastic packaging material wherein the individual units are in the form of gradually twisting, elongate spirals, each having a central portion and at least two end portions of a generally curving or spiral configuration. The end portions are closely adjacent and disposed at a substantial angle with respect to one another so as to provide individual packing units (and a packing mass composed of such units) with a multi-directional resistance to collapse and/or deformation in the presence of an external force, such as shock or impact. The present invention is also directed to a method and means for the continuous manufacture of free flow interlocking packing units of the type described. The method generally comprises the successive steps of heating an expandable plastic material to a plastic or heat softened stage, continuously extruding the heat softened plastic material to form an elongate hollow tube, continuously slicing through a wall of the elongate tube to form a longitudinal cut substantially parallel to the axis of the tube, and then slicing through the wall of the tube at a substantial angle (20 to 70° with respect to the axis of the tube) to form relatively short lengths of specially shaped and sliced tube. The severed lengths are heat expanded to effect a gradual twisting of the tube walls on either side of the longitudinal cut to achieve a desired final configuration (generally resembling a twisted version of the numeral 8, or a ram's horns).

It is an object of the present invention, therefore, to provide a free flow, interlocking packing material in a particular desired form, such form providing enhanced energy or shocks absorbing characteristics to individual

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packing units and to the material from which the packing units are formed.

Another object of the invention is to provide a method and means for the continuous manufacture of improved packing materials of the type described.

Another object of the invention is to provide a novel procedure for extruding, slicing and severing foamed expanded plastic materials to continuously form improved packing units of the character described.

A particular object of the invention is to provide a novel procedure for forming foamed expanded units of the character described wherein the foamed structure is initially stretched and sliced in a longitudinal direction and then sliced and severed by angular cuts in such fashion as to facilitate subsequent formation of a desired packing unit shape.

Still another object of the invention is to provide a method and means for making foamed expanded packing units of the character described which is readily adapted to machine-type, production line techniques.

Additional objects and advantages of the present invention will appear from the following description in which preferred embodiments have been set forth in detail in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a view in perspective of a quantity of packing material embodying the present invention.

FIG. 2 is an enlarged view of a unit of packing material according to the present invention, illustrating particular features thereof.

FIG. 3 is a schematic representation of slicing and severing operations useful in producing the packing units as illustrated in FIGS. 1 and 2.

FIG. 4 is a view in elevation of a packing unit as produced in FIG. 3, along the line 4—4 of FIG. 3.

FIG. 5 is a like view along the line 5—5 of FIG. 3.

FIGS. 6 and 7 are similar views, illustrating further stages of the formation of the packing units.

FIG. 8 is a reduced schematic representation of a system of apparatus for carrying out the method of the present invention.

FIG. 9 is an enlarged detail view in top plan of slicing and severing means useful in the apparatus of FIG. 8.

FIG. 10 is a view in section and elevation along the line 10—10 of FIG. 9.

FIG. 11 is a like view along the line 11—11 of FIG. 9.

FIG. 12 is a view in top plan, somewhat reduced in scale, additionally illustrating the slicing and severing means.

FIG. 13 is a view in end elevation of the apparatus of FIG. 12.

DESCRIPTION OF PREFERRED EMBODIMENT

FIG. 1 illustrates the improved packing material of the present invention wherein the individual units of packing material are designated by the reference numeral 10. As more particularly illustrated in FIGS. 2 and 7, each packing unit 10 is formed as a relatively elongate thick continuous strip having a central portion 12 and end portions 14 and 16. As respects the central portion 12, the end portions 14 and 16 follow opposite, gradually twisting spiral paths so that edge portions thereof, represented at 18 and 20 respectively, are disposed at a substantial angle to each other (e.g. of the order of 90°). As will be more fully explained hereinafter, the described construction provides each packing unit with a curling resistance to collapse about the non-parallel axes 22 and 24 of the end portions and the axis 26 of the central portion. The end portions 14, 16, and the central portion 12, also have an enhanced resistance to crushing or permanent deformation in directions generally parallel of the axes 22, 24,

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and 26. As respects each individual packing unit 10, the described characteristics provide a substantially three dimensional resistance to collapse and deformation in the presence of vibration, impacts and other destructive forces normally encountered in shipment and handling of packaged items.

As best seen in FIGS. 1 and 2, the described construction of the packing units 10 also provides a plurality of generally wedge-shaped projections 30 and openings 32. As will hereinafter be explained, these wedge-shaped projections and openings promote a relatively high degree of interlocking between adjacent packing units in a packing mass to thereby not only provide a relatively firm cushioning support but also an unusual degree of resistance to migration of a packed item through the packing mass. On the other hand, the wedge-shaped projections and openings are not such as to prevent or interfere with a desired "flowability" of the packing mass. This latter characteristic permits the units of the packing mass to be poured into recesses and openings of oddly shaped items, and within the confines of a shipping carton, to isolate the packed item from the sides of the carton. In commercial practice, pouring or filling operations of the type described can be performed rapidly and efficiently with automatic machinery, or by means of unskilled hand labor.

In accordance with the present invention, the individual packing units 10 are formed of a foamed expanded plastic of sufficient internal strength to be essentially shape-retaining during normal handling, but capable of crushing or permanent deformation in response to potentially damaging shocks, or continued vibration. In preferred embodiments, the foam is characterized by an essentially cellular structure (unicellular or interconnecting) having a volume of cells or void spaces ranging from about 25% to as much as 85% of the total volume of the units. When an appropriate resin is selected to make the expanded plastic foam, the described highly porous foam structure possesses both a desired initial stiffness and resilience and an essential characteristic of crushability provided by the void spaces within the expanded foam, which imparts a latent crushability or shock absorbing characteristic to interior portions of the plastic material itself. This characteristic of internal crushability supplements the special characteristics imparted to the packing units 10 by their unique structure or shape. Thus, as noted, the individual packing units 10 possess an unusual three dimensional resistance to collapse, or to deformation through crushing, except in the presence of potentially damaging forces or shocks.

Expanded plastic foams particularly suited for use in the present invention include both thermoplastic and thermosetting resinous materials. Because they are more easily processed into the desired shapes, thermoplastic resins are generally to be preferred and include specifically the alkenyl, aromatic polymers as disclosed in U.S. Pat. 3,066,382, and the aliphatic olefin polymers as disclosed in U.S. Pat. 3,251,728. These thermoplastic materials (in either modified or unmodified form) are customarily employed in conjunction with suitable foaming and nucleating agents. Thermosetting resins adapted for use in the present invention include foamed polyester resins such as the polyurethane foams (i.e., derived from isocyanate resins) and specifically the more rigid polyurethane foams made from relatively highly branched resins. Blowing or foaming agents can be advantageously used with the thermosetting resins, as more specifically disclosed in the copending Makowski application, Ser. No. 43,527.

Regardless of the particular plastic material employed, it is essential in carrying out the present invention that the packing units, in their foamed expanded state, possess the desired cellular structure and the desired proportion of void spaces with respect to the total volume. Thus, the formulation of the plastic materials should be very carefully controlled to provide foamed expanded plastics of desired essential characteristics, for example: desired cell

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sizes (i.e., ranging from 0.001 to 0.1 inch), a desired proportion of void spaces to the total volume (i.e., ranging from at least 25 percent to not more than 85 percent), a desired foam density (i.e., ranging from about 0.3 to about 4.5 pounds per cubic foot), and other essential characteristics as hereinafter specified.

In one procedure adapted to the present invention, elongated plastic tubes are extruded through an extrusion device which effects an initial chemical expansion of an expandable thermoplastic extrusion mass. Such an extrusion device is schematically illustrated at 50 in FIG. 8, wherein the extruder head is represented at 52. In general, the extrusion apparatus including the extruder head 52 is employed in conjunction with conventional auxiliary equipment including a hopper 54 and feed chamber 56 which are adapted to cooperate with an extruder screw or other pressure device (not shown) which forces a liquid or heat-softened plastic mixture through an annular passage or extrusion outlet as a substantially hollow elongated plastic tube. One particularly satisfactory method and apparatus for producing elongated hollow plastic tubes in this fashion is specifically disclosed in the aforementioned copending application, Ser. No. 43,527 filed June 4, 1970, in the name of Alexander G. Makowski. As therein disclosed, elongate hollow tubes of foamed expanded plastic are continuously extruded from the extrusion apparatus, as represented by the elongate tube 58 in FIG. 8. In the ambient atmosphere, the heat-softened plastic material quickly cools to a set stage, thereby facilitating frictional engagement of the tube 58 to pull it away from the extrusion apparatus (arrow 60). In a preferred operation of the apparatus, the tube 58 is pulled away from the extrusion apparatus at a rate appreciably faster than the heat-softened plastic material is extruded from the extrusion apparatus. The effect is to longitudinally stretch the heat-softened material to hereby longitudinally orient gas pockets and void spaces (cells) formed within the walls of the tube. Such longitudinal orientation of the cells provides an expansion capability to severed sections of the tube 58 so that upon subsequent heating of the thermoplastic material, the expansion is substantially greater in a radial direction than along the axes of the severed units.

As particularly illustrated in FIG. 8, the elongate tube 58 is frictionally engaged by endless belts or other friction devices 62 forming part of a pulling mechanism 64. The variable drive 65 for the belts causes the extruded tube 58 to be continuously pulled from the extrusion apparatus at a rate ranging from 5 to 58 times the normal extrusion rate, to cause the described cell elongation. The pulling action of the belts also causes the tube 58 to be continuously pulled into the zone of operation of slicing and severing means, generally represented at 66 and 68.

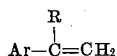
FIG. 3 illustrates the sequential operations of the slicing and severing means 66 and 68, to first make a continuous slicing cut 74 along the axis of the tube 58 and thereafter to make a series of severing cuts 76, at an appreciable angle to the axis of the tube. These cooperative functions produce short severed lengths of sliced tube, as represented at 78 (FIGS. 3-5). In one form of suitable apparatus, the longitudinal slicing means 66 is mounted immediately adjacent and between the pulling mechanism 64 and the severing means 68. Alternatively, however, the longitudinal slicing cut may be made by slicing means 66 positioned in the path of the freshly extruded tube, as illustrated by the dotted line position of FIG. 8. In either event, suitable means such as the ring clamp 80 and knife support 82 are provided to properly position the slicing knife 84. As best seen in FIGS. 9 and 10, the longitudinal slicing cut 74 may be parallel but slightly offset from the longitudinal axis of the extruded tube 58. The effect of this slight offset is to initiate a transverse wedging, along the line of cut represented at 86 in FIGS. 4 and 5, tending to slide adjacent portions of the tube in opposite directions. As hereinafter explained, this wedging assists in obtaining a desired spiral configuration of the tube on subsequent expansion.

FIGS. 12 and 13 illustrate a particular embodiment of the severing means 68 by which more than one extrusion line can be simultaneously processed. Thus, as schematically represented in FIG. 12, freshly extruded tubes 58a and 58b are simultaneously fed to cooperating tube guides 90, 92 mounted on either side of a rotor for the angularly disposed severing knife 94. As will be apparent from FIG. 12, the knife 94 makes successive angular severing cuts 76 in the tubes 58a and 58b, at each rotation of the rotor 96. Preferably the included angle between the knife 94 and the axis of the tube 58 should be at least 20° but not greater than about 70° (optimum about 45°). As noted above, the severing knife 94 cooperates with the slicing knife 84 to sever short sliced, angularly cut sections of extruded tube 78, which have the desired pre-expansion characteristics.

Packing units of final desired shape or configuration (see FIGS. 1, 2 and 7) are obtained by a progressive expansion of the sliced and severed units 78, in the presence of heat. The desired progressive expansion occurs normally with the resins, nucleating and expanding agents customarily employed in the practice of the present invention, as hereinafter disclosed.

In carrying out the manufacturing procedures of the present invention, it is possible to employ various foamable, thermoplastic polymers, including any of the resinous alkenyl aromatic polymers or aliphatic olefin polymers disclosed in U.S. Pats. 3,066,382 or 3,251,728, or resins of similar characteristics. As noted these resins are customarily employed in conjunction with volatile organic foaming or expanding agents which are uniformly distributed throughout the polymers. To achieve a desired foam structure characterised by an essentially cellular structure (unicellular or interconnecting) it is also desirable that the polymer incorporate or be intermixed with a suitable nucleating agent. Although the proportion of foaming and nucleating agents will vary somewhat with the particular resinous material employed, the proportions should be such that the plastic in a foamed expanded state will possess a desired cellular structure having a desired proportion of void spaces with respect to total volume. Specifically, the formulation of the thermoplastic materials should be very carefully controlled to provide foamed expanded plastics having desired essential characteristics after the initial extrusion and expansion, for example cell sizes within the range from about 0.001 to 0.1 inch, void spaces ranging from at least 25% to no more than 85% of the total extruded volume and an initial foam density within the range from about 1 to no more than 12 pounds per cubic foot. When cooled to ambient temperatures, the extruded foam should also possess sufficient internal strength to retain the characteristics of a rigid foam during normal handling, but be capable of expansion upon being heated to achieve foam densities preferably below about 1 pound per cubic foot and within the range from about 0.3 to 1.5 pounds per cubic foot. As is hereinafter noted, the ability of the plastic foams processed in accordance with the present invention to achieve the desired foam structures and densities is dependent upon the ability of the foam structures to accommodate the longitudinal stretching and orientation of the cells within the foams during the initial or extrusion stage of formation of the foams.

Alkenyl aromatic polymers useful as the thermoplastic resins herein generally comprise, in chemically combined form, at least about 70 percent by weight of at least one alkenyl aromatic compound having the general formula:



wherein "Ar" represents an aromatic hydrocarbon of the benzene series, and "R" is hydrogen or the methyl radical. Examples of such alkenyl aromatic polymers are homo-

polymers of styrene, alphanemethyl styrene, ortho-, meta- and para-methyl styrene, ar-ethylstyrene, and ar-chloro-styrene; the copolymers of two or more of such alkenyl aromatic compounds with one another; and copolymers of one or more of such alkenyl aromatic compounds with minor amounts of other readily polymerizable olefinic compounds such as divinylbenzene, methylmethacrylate, or acrylonitrile, etc.

With thermoplastic resins of the above type (e.g., foamable and expandable polystyrene), the usual practice is to incorporate a foaming agent as a uniform dispersion distributed throughout the resin. Typical foaming agents which may be employed for this purpose are known in the art, for example, as disclosed in U.S. Pats. 2,941,964, 2,983,692, and 3,344,215 and also in H. R. Lasman, "Foaming Agents," Modern Plastics Encyclopedia 381 (1968-1969). Suitable foaming agents include low boiling aliphatic hydrocarbons such as pentane, hexane, heptane, and butanes; low boiling halo-hydrocarbons, e.g. fluorinated hydrocarbons sold under the trademark "Freon" by E. I. du Pont de Nemours, Wilmington, Del., carbon tetrachloride, chloromethanes, -ethanes, -propanes and -butanes; low boiling petroleum ethers; inert gases such as carbon dioxide, and other gases hereinafter noted; and mixture of the above. These foaming agents are incorporated within the thermoplastic polymer of resinous material.

Foam structures according to the present invention should have a thermoplastic cellular character capable of being heated and expanded to achieve a desired low foam density and in the cooled rigid state should possess a desired characteristic of crushability. To insure the obtaining of foam structures of desired characteristics, nucleating agents are preferably employed. In the case of the alkenyl aromatic polymers (e.g., polystyrene) many conventional nucleating agents are known as disclosed, for example, in U.S. Pat. 3,344,215 and in Naturman, L. I., "How to Select Blowing Agents for Thermoplastics," Plastics Technology 43 (October 1969). Such nucleating agents include combinations of an acid, suitably organic acids such as malonic, citric, phthalic, and fumaric acid, with carbon dioxide-liberating compounds such as sodium and potassium bicarbonate. Combinations such as sodium citrate and sodium bicarbonate are also suitable for use. Other suitable nucleation agents functioning like "boiling chips" include finely divided resin, barium sulfate lithopane, clay, talc, diatomaceous earth and pigments as disclosed in the Naturman article. Still further nucleating agents which may be used are combinations of nitrogen liberating compounds with finely divided solids as disclosed in Pat. 3,344,215. The aforementioned nucleating agents are incorporated with the extrusion material in a desired proportion, for example by gravity feed into the hopper for the extrusion apparatus, or by tumbling with beads or pellets of solid polymer feed. The nucleating agents generally perform the function of insuring a uniform distribution of cells during the initial extrusion processing to produce a foamed plastic.

In general the foaming and nucleating agents are present in amounts sufficient to provide a cellular foam which will be rigid on cooling to the set stage but which will have a desired characteristic of crushability. In practice the proportion of these agents will vary somewhat with the particular resin employed. In the case of a polystyrene resin employing a dispersed pentane or dichlorodifluoromethane expanding agent, the expanding agent may range from about 5 to 15% by weight of the extrusion mixture. The proportion of citric acid and sodium bicarbonate as nucleating agents may range from 0.3% to about 2% of the extrusion mixture. A typical proportion is 0.4% citric acid and 0.5% sodium bicarbonate for a total of 0.9% of the nucleating agent to the total extrusion mixture. Other agents may also be employed to obtain a uniform dispersion of these agents. For example, a small

amount of a cooking oil may be used as a wetting agent to achieve a uniform coating of plastic pellets with sodium bicarbonate.

When aliphatic olefin polymers are used in making the free-flow packing units of the present invention, such polymers are normally solid polymers. Satisfactory polymers may be obtained by polymerizing at least one alpha-mono-olefinic aliphatic hydrocarbon containing from 2 to 8 carbon atoms, such as ethylene, propylene, butene-1, pentene-1, 3-methylbutene-1, 4-methylpentene-1, 4-methylhexene-1, or 5-methylhexene-1, alone, with one another, or with various other polymerizable compounds. Foamed expanded polymers of ethylene or propylene alone are highly satisfactory and produce desired foam structures which are chemically inert. Polymerizable organic compounds which can be polymerized with ethylene or propylene include vinyl acetate, C₁-C₄ alkyl acrylates such as ethyl acrylate, styrene, lower alkyl esters or methacrylic acid such as methyl methacrylate, tetrafluoro-ethylene and acrylonitrile.

The expanding or foaming agents employed with the aliphatic olefin polymers may be selected from a wide group of normally gaseous or volatile liquids. Indicated expanding and foaming agents include nitrogen, argon, neon, helium, acetylene, ammonia, butadiene, carbon dioxide, cyclopropane, dimethylamine, 2,2-dimethylpropane, ethane, ethylamine, ethylene, isobutane, isobutylene, monomethylamine, propane, pentane, propylene, and trimethylamine, certain of the halogen derivatives of methane and ethane, such as chlorodifluoromethane, dichlorodifluoromethane, dichlorofluoromethane, trichlorofluoromethane, difluorotetrafluoroethane, difluorochloroethane, 1,1-difluoroethane, trichlorofluoromethane, and particularly 1,1-dichlorotetrafluoroethane and 1,2-dichlorotetrafluoroethane.

The dichlorotetrafluoroethanes have been found to be particularly effective as foaming agents for making foamed bodies from normally solid aliphatic olefin polymers when employed in accordance with the present invention in amounts to about 0.2 to 1.0% by weight of the aliphatic olefin polymers. Again the precise amount of expanding or foaming agent employed will depend in large measure on the particular aliphatic olefin polymer used in the extrusion process. In general, among the aliphatic olefin polymers, foamed expanded polyethylene and polypropylene resins based on initial resins of molecular weight 250 to 400,000 are to be preferred.

As schematically illustrated in FIG. 8, the tube 58 extruded from the extrusion apparatus 50 is pulled and forced through the slicing and severing means 66 and 68 by the endless belts 62 or the pulling mechanism 64. Individual packing units sliced and severed by the devices 66 and 68 fall onto a first set of conveyers 140 where they are subjected to continued cooling and aging, during which gas pressures and temperatures within the cellular structure of the foam are equalized with that of the ambient atmosphere. In a typical operation, the severed units 78 are held for approximately four hours on the belt conveyers 140 (or in bins), following which they are passed to the conveyor 142 of a first expansion unit 144, wherein they are subjected to the action of atmospheric steam at about 210° F., for a period of the order of 60 seconds. The product 148 issuing from this first expansion unit (see FIG. 6) is then fed continuously to a second set of holding conveyers 150, and again subjected to aging or holding at atmospheric conditions for a period of approximately four hours (again to permit the outside air to penetrate the cells and to relieve the partial vacuum created by the cooling). Thereafter, the cooled equalized units at 152 are fed to a second stage expansion unit 154 where they are again subjected to atmospheric steam at about 210° F. for an additional 60 seconds. The twice expanded product issuing at 156 is generally represented by the form of the packing units illustrated in FIG. 7. If desired the twice expanded products may be subjected to

accelerated aging in a heated hopper (not shown) to achieve the desired equalized conditions. Such accelerated aging avoids undesired expansion during storage or shipments involving use of the twice expanded product. Finished product discharged from the conveyor 158 can be suitably packaged for shipment to the customer, in polyethylene bags or other packaging, as represented schematically at 160 in FIG. 8.

Multiple expansion of the packing units, with particular reference to the type of packing unit illustrated in FIG. 1, is schematically represented in FIGS. 3 through 7. Thus, FIGS. 3, 4, and 5 represent sliced severed packing units as delivered directly from the severing device 68. The packing units 78 shown in FIGS. 3, 4, and 5 illustrate a normal degree of expansion which might be achieved without deliberate heat expansion of the units. FIG. 6 illustrates the product as obtained from the first stage expansion unit 144, as discharged to the cooling and aging conveyers 150. In like fashion, FIG. 7 illustrates the product obtained from the second stage expansion unit 154, as discharged to the conveyers 158.

As noted previously, expansion of the longitudinally sliced, angularly severed, units 78 unexpectedly longitudinally sliced, angularly severed, unit 78 unexpectedly produces packing units which have optimum characteristics for use as a free flow packing mass. More specifically, the shape of the units 78 is such that subsequent expansion creates unequal expansion forces within the body which cause a warping or twisting of adjacent body portions of the units to achieve an ideal packing unit shape. Thus, referring initially to the shape of the units 78, as illustrated in FIGS. 3 through 5, each unit has roughly parallel angular faces, as obtained by the sequential slicing cuts 76, and a line of cleavage at the slicing cut 74. Upon first stage expansion as illustrated in FIG. 6, internal forces generated within the expanding bodies cause the end portions 14 and 16 to gradually rotate in opposite directions, adjacent the slicing cut 74, to establish an initial configuration which is generally retained throughout the subsequent expansion processing. This initial configuration is generally illustrated (from three separate vantage points) in FIG. 6. FIG. 7 represents the packing units 156, viewed from the same vantage points following a second stage expansion in the expander unit 154. As shown in FIGS. 6 and 7 the general relationship of the body components 12, 14 and 16 of the packing units is substantially the same although the units are substantially larger in size due to the further expansion. In final configurations of the units 10, the adjacent free edges 18 and 20 of the end portions 14 and 16, respectively, are disposed at a substantial angle to each other, generally of the order of 60 to 120° (optimum about 90°).

While the nature of the internal forces generated in the packing units during expansion is not clearly understood, such forces are clearly a product of the particular steps involved in producing the units 78, including the extrusion of the hollow tubes 58 and the slicing to form the longitudinal cut 74 and the angular severing cuts 76. Also involved is the effect of longitudinally stretching the heat-softened plastic material, as it is continuously extruded and pulled to form the tube 58. In general, the effect of such stretching is to cause the void spaces and gas pockets within the walls of the tube (hereinafter referred to as "cells") to be longitudinally oriented, with the result that the foamed plastic material tends to expand more rapidly in a radial than in a longitudinal direction. At the points of intersection of the longitudinal and angular slicing cuts 74, 76, this differential expansion apparently imparts an opposite rotational twist to the adjacent ends 14 and 16 of the packing units. Thus, by way of possible explanation, it is believed that the radial expansion potential at the point of greatest angularity of intersection, represented at 162 in FIGS. 3 and 5, is greater than at the points of least angularity, represented at points 164 in FIGS. 3 and 5. The resulting uneven expansion forces, coupled

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with behavior of the central and end portions of the units 12, 14, 16 as an elongate thick ribbon, apparently causes the gradual twisting or curling of the end portions 14 and 16 in opposite directions. In any event, regardless of cause, expansion of the units 78, as generally represented in FIG. 3, produces a resultant configuration as generally represented in FIG. 3, produces a resultant configuration as generally represented in FIGS. 1, 2 and 7.

It has been further determined that the packing units of the present invention are characterized by a greater degree of resistance to permanent deformation or crushing in a direction along the axis of the extruded tube 58, than traverse to such axis. Thus, a cylindrical packing unit cut from the tube 58 would be more easily crushed by exertion of force transverse to the axis of the tube than lengthwise along the axis of the tube. A particular advantage of this characteristic is taken in the packing unit configurations of the present invention. Thus, referring to the packing unit 10 illustrated in FIG. 2, the gradual twisting of the ends 14 and 16 of the unit, during the expansion, causes a rotation from the original extrusion axis as represented by the inclination of the axes 22 and 24 with respect to the axis 26 of the central portion 12 of the packing unit. It follows that the packing units 10 present no specific direction of weakness to an external force sufficient to crush the unit, principally because of twisted orientation of the two end portions 14 and 16. Also, such twisted orientation of the end portions provides the packing units 10 with a rolling resistance to collapse, generally about the separate axes represented at 22, 24 and 26. It will be appreciated, because of the gradual twisting during expansion, that these axes will necessarily be nonparallel. The net effect is to impart a substantially three dimensional resistance to collapse of the packing units 10, in the presence of an external force.

In a mass of the packing units 10, the described characteristics provide a cumulative effect in protecting a packed item from damage or breakage. Individually, each of the units 10 is characterized by a generally three dimensional resistance to crushing or deformation schematically represented by the separate axes 22, 24 and 26, coupled with a rolling resistance to collapse about the same axes. Collectively, a mass of the units 10 produces a multiplication of these characteristics in virtually all directions. Accordingly, the packing units 10 come close to providing the ideal configuration for a packing unit which is designed to be essentially shape-retaining yet crushable, both as structural shape and as a material. The packing units 10 also provide a series of outwardly facing wedge-shaped projections and openings, represented at 30 and 32, which particularly adapt the individual units to interlocking contacts with other like units in a packing mass. Accordingly, a mass of the packing units 10 not only serves to immovably position a packed item within a shipping carton, but also to achieve a maximum resistance to migration or movement of the packed item due to multiple impacts or vibration during shipment or handling operations. These characteristics, coupled with an essential flowability of the individual units, provide a highly utilitarian material for a wide variety of packaging operations.

From the foregoing, it will be evident that the present invention makes possible the production of highly effective, efficient packing materials particularly adapted to the packing of various fragile items and components such as electronic and optical equipment, lenses, radio tubes, glassware, art objects, etc., as well as various other items. The improved packing material has proved particularly effective in the packing of items of delicate nature, which can be rendered useless because of changed position, alignment or adjustment of the parts. Such changes may frequently occur in normal shipment due to constant vibration of the item against the wall of the container, without any visible breakage occurring. In particular, the multidirectional of shock absorbing characteristics of the pack-

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ing materials of the present invention provide an unusually high degree of energy absorption through permanent deformation in the presence of abnormal or potentially destructive forces or impacts, which serve to efficiently cushion and protect the packed item.

To those skilled in the art to which this invention relates, many variations in its application and in the specific procedures described therein will be readily apparent. For example, the successive angle cuts to slice and sever the units can easily be combined with more than one longitudinal slicing cut, to provide modified packing units having highly desired characteristics. While the products of such processing would differ from the preferred embodiment herein disclosed, they would still have useful properties for packing operations. The described and like variations in the processing are clearly within the scope of the present invention. It should be understood therefore that the disclosures herein are intended to be purely illustrative and not in any way limiting.

I claim:

1. A free flow interlocking packing material of low bulk density comprising a plurality of individual packing units formed of a foamed semi-rigid expanded plastic material possessing sufficient internal strength to be self-sustaining under normal handling but capable of permanent shock absorbing deformation in response to substantial external force, each of said units being relatively elongated and formed with a central portion and at least two end portions of twisted spiral configuration, the axes of said end portions and central portion being nonparallel so as to provide a substantially three dimensional resistance to collapse in the presence of an external force, each of said end portions being additionally provided with at least one free edge disposed at a substantial angle to the free edge of an adjacent end portion.

2. A packing material as in claim 1 wherein said foamed expanded plastic is selected from the group of polymers consisting of alkenyl aromatic polymers, aliphatic olefin polymers and polyurethane polymers.

3. A packing material as in claim 1 wherein said foamed expanded plastic material has a density of the order of 0.3 to 4.5 pounds per cubic foot.

4. A free flow interlocking packing material of low bulk density comprising a plurality of individual packing units formed of a foamed semi-rigid expanded plastic material possessing sufficient internal strength to retain the semi-rigid foamed expanded characteristic during normal handling but capable of permanent shock absorbing deformation in response to an abnormal external force, each of said units being formed as a relatively thick elongate continuous strip having at least two twisting and curling end portions, said end portions resembling a twisted spiral in configuration and having at least one free edge, the axes of said end portions being nonparallel so as to provide a substantially three dimensional resistance to collapse in the presence of abnormal force, the edges of said two end portions being closely adjacent and disposed at a substantial angle with respect to each other.

5. A packing material as in claim 4 wherein said curling end portions of the packing unit lie within surfaces generated by a pair of spaced apart topographically parallel line segments moving along a generally spiral gradually rotating path.

6. A packing material as in claim 4 wherein each of said individual packing units is characterized by a curling resistance to collapse about at least three intersecting non-colinear axes.

7. A packing material as in claim 4 wherein each of said individual packing units is characterized by an enhanced resistance to permanent deformation along at least three intersecting non-colinear axes.

8. A packing material as in claim 7 wherein the foamed expanded plastic material of said packing units possesses a greater resistance to deformation in a direction trans-

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verse to the elongate dimension of said units and generally parallel to the axes of curl of the end portions thereof.

9. A packing material as in claim 4 wherein said foamed expanded plastic material is characterized by the presence of oblong, transversely oriented gas cells which provide said packing units with an enhanced resistance to permanent deformation in a direction transverse to the elongate dimension of said packing units.

10. A free flow interlocking packing material of low bulk density comprising a plurality of individual packing units formed of a foamed semi-rigid plastic material possessing sufficient internal strength to be self-sustaining under normal handling but capable of permanent shock absorbing deformation in response to an abnormal external force, each of said units being formed as a relatively elongate thick continuous strip having a gradually twisting spiral along its length, said gradually twisting spiral configuration providing two curling end portions to the units, each having an edge closely adjacent and at a substantial angle to the edge of the other of said end portions, said

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configuration of the packing units providing a curling resistance to collapse about a plurality of nonparallel axes and a cooperating enhanced resistance to permanent deformation generally in the direction of said nonparallel axes.

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