CORRUGATED SHEET-LIKE YIELDABLE WALL ELEMENT

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CROUGRATED SHEET-LIKE YIELDABLE WALL ELEMENT

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This invention relates essentially to devices constituting each a sheet or plate element made from sheet-material stock or metal-plate stock and intended for constructing flexible or resiliently yielding walls or the like, and also to various applications of devices of this character in the construction of enclosure walls or the like.

In certain technical fields it is frequently desirable, in order to avoid any permanent set under normal service conditions, to use walls characterized by a substantial flexibility or permissible elastic deformation, notably under expansion or contraction strain caused by changes in temperature, these walls consisting for example of juxtaposed and assembled panels made of sheet or plate elements manufactured as a rule from sheet-metal stock in the commercially available sizes. These wall elements may comprise, in the manner already known per se a plurality of pleats, ribs or corrugations frequently of substantially cylindrical, prismatic or more generally polyhedral cross-sectional configuration, consisting of at least two series or groups of corrugations with secant generatrices respectively, the corrugations of a same series or group being preferably substantially parallel to each other and extending at right angles to those of the other series or group.

It is advantageous to use wall elements of this character in large-sized structures comprising for example a metal casing of which the temperature under normal service conditions deports considerably from the outside temperature, in that it is either higher or lower than this outside temperature. Such structures may constitute for instance containers for storing and transporting liquefied gas but heat exchangers, caissons of chemical or nuclear reactors, and other similar constructions are other examples of such containers. The corrugations formed in the wall of a structure of this type, in addition to the fact that they increase to a certain extent the rigidity imparted thereby to said wall in a direction substantially at right angles to the corrugations, facilitate the successive expansions and contractions of the casing at least in the corrugation portions extending between two adjacent crossings thereof during successive periods of operation and stoppage or holdup of the construction, so that these corrugations act somewhat like expansion joints. To this end these walls are made more particularly from sheet-metal stock of relatively reduced thickness in order to impart a certain flexibility thereto.

In a corrugation system or pattern based on two series or groups of respectively orthogonal corrugations, the elementary configuration consists of at least two secant corrugations extending at right angles to each other.

However, as a rule this arrangement is objectionable in that the zone in which two corrugations are interconnected or merge into each other in their intersecting or crossing portion cannot follow simultaneously the movements occurring in two perpendicular directions without producing a permanent set of the metal at these intersecting or crossing portions, and that each intersecting or crossing portion tends to become the center of a strain concentration and therefore a source of incipient fracture due to the fact that it is the seat of severe elongation or shrinking of the sheet material.

It is the essential object of this invention to reduce or avoid the inconveniences set forth hereinabove by providing a flexible wall element of relatively simple structure, which afford a relatively economical manufacture, and is capable of behaving efficiently and satisfactorily under severe conditions of temperature variations and heat strain, as well as in case of hydrodynamic stress.

The device according to this invention is remarkable notably in that the corrugations pertaining to one of said two series or groups are substantially continuous in their longitudinal directions while those pertaining to the other series or group are discontinuous longitudinally and consist of substantially aligned sections bounded by said continuous corrugations of the first series, and that said sheet element further comprises a third series or group of longitudinally discontinuous, preferably parallel corrugations, formed in the crests of the continuous corrugations of said first series or group. Thus, due to the interrupted form or sectional structure of the corrugations of said second series, the sheet-metal wall element can expand by undergoing a relatively free distortion in the direction parallel to the corrugations of the second series, i.e. at right angles to the discontinuous corrugations of the first series. Moreover, due to the provision of the aforesaid third series of corrugations the wall element can also be caused to undergo a certain relatively free deformation in directions parallel to the continuous corrugations of the first series, i.e. at right angles to the discontinuous corrugations of the second series, whereas if these third-series corrugations were not provided such deformation would involve detrimental elongations, notably in the crest or top surface of the continuous waves or corrugations of the first series. The aforesaid corrugations may be regular and disposed at spaced intervals or constitute a locally variable configuration, according to requirements.

It is a complementary feature of this invention to form the aforesaid corrugations with their convexity in relief, that is, projecting either from a single and same face of the aforesaid sheet element or alternatively on both faces of said elements.

Furthermore, in a sheet element of the type disclosed hereinabove and according to another feature characterizing this invention, said first and second series of corrugations form in said sheet element substantially plane rectangular surface portions.

Among the other objects of this invention is the provision of sheet wall elements of the type disclosed in the preceding paragraphs, wherein the discontinuous corrugations of the aforesaid third series are distributed by pairs with the corrugations of each pair disposed on either side of a discontinuous corrugation of the second series aforesaid and preferably parallel thereto.

According to another feature of this invention the discontinuous corrugations of the third series aforesaid constitute respectively impressions or cavities of which the depth is preferably inferior to the amplitude or height of the continuous corrugations of the first series aforesaid.

According to a typical feature characterizing this invention, the aforesaid corrugations are of substantially dihedral configuration with their connecting or intersecting crests and tops or solid angles formed preferably with rounded fillets.

Finally, this invention provides a sheet-metal wall element of the type set forth hereinabove wherein, in case the corrugations of said first and second series project from the same side of said wall element, the continuous corrugations of said first series have an amplitude or height preferably greater than those of the second series.
This invention is also concerned with the various possible applications of the sheet-metal wall elements broadly described hereinabove, notably in the form of panels or the like, in the construction of enclosure walls or the like, such as tanks, reservoirs, containers, hulls, cisterns, heat exchangers and apparatus and the like. It is particularly suitable for the construction of very large tanks or the like for transporting or storing low-boiling liquefied gas at very low temperature, such as methane.

It is known that liquefied gases at very low temperature can be transported or stored in tanks constructed according to the principle of so-called "integrated" containers wherein the cold liquid is retained within a capacity bounded by the flexible walls of a casing which bear on resistant or rigid supports. Tanks constructed according to the same principle may be used for obtaining the fluid-tightness necessary in the case of very high pressures in safety enclosures of nuclear plants or casings of nuclear reactors.

With the present invention it is possible to construct from relatively thin sheet stock a fluid-tight and flexible enclosure wall adapted to meet the requirements of the tank or casing construction contemplated this sheet stock consisting of a material having the properties consistent with the service conditions contemplated, such as corrosion-resisting properties, the mechanical characteristics to be preserved at the extreme values of service temperatures, etc. As a rule, materials suitable for this purpose are aluminum, light alloys, stainless steel or the like.

In constructions of this type the flexibility of the casing wall is an imperative requirement in order to permit the absorption, compensation or neutralization of the thermal effects and actions such as contraction or shrinking and expansion of the wall material on the one hand without involving a variation in the geometrical dimensions or on the contrary by causing dimensional variations according to a predetermined law, and on the other hand without producing appreciable strain in the wall material.

Other features and advantages of this invention will appear from the following description proceeds with reference to the accompanying drawings illustrating diagrammatically by way of example typical forms of embodiment thereof. In the drawings:

FIGURE 1 is a perspective view from above showing a first form of embodiment of a wall or panel element of a flexible casing according to this invention;

FIGURE 2 illustrates on a larger scale a view of a detail of the intersection zone of two corrugations;

FIGURE 3 is a section taken upon the line III—III of FIGURE 2;

FIGURE 4 is another section taken upon the line IV—IV of FIGURE 2, and

FIGURE 5 is a view from beneath of the wall element of FIGURE 2.

Referring to the form of embodiment illustrated in FIGURE 1 of the drawings, the flexible wall element designated by the reference numeral 1 and intended for constructing a tank casing or the like is manufactured or shaped from sheet-metal stock 2 preferably of relatively reduced thickness and in its initial form, that is, before the shaping or bending steps applied thereto, this sheet is preferably not too compulsorily plane and for instance of rectangular configuration. In order to impart the required flexibility to this metal panel or sheet a pattern of geometrical alterations or features, preferably in the form of corrugations, plates, ribs or the like, are formed therein, these alterations or features being preferably divided into at least three series or groups of corrugations having substantially rectilinear contours and being adapted each to impart the desired elasticity in a direction at right angles to their main or longitudinal axis.

These three series or groups of corrugations comprise: On the one hand, a first series of so-called "continuous," preferably parallel corrugation 3 having a constant or variable relative spacing or pitch between adjacent crests, and extending in a direction which may be parallel or not to one of the edges of the sheet-metal stock.

On the other hand, another series of parallel, so-called "discontinuous" corrugations 4 disposed between the corrugations of the first series and extending preferably in a direction substantially perpendicular to the corrugations of said first series, the relative spacing of the corrugations of said second series being likewise either constant or variable.

Finally, in order to provide the characteristic of elasticity in the longitudinal direction of the corrugations of the first series 3, a third series of substantially parallel, so-called "discontinuous" corrugations 5, for example in the form of impressions, cavities or channels of which the amplitude or corrugations 5 are generally inferior to that of the corrugations of the first series, these third-series corrugations being disposed preferably by pairs in the crests of the waves of the first series in a direction substantially at right angles thereto, so as to lie somewhat either side of one corrugation of the second series 4.

The depth of the corrugations 5 may extend to ¼ of the height of the first-series corrugations 3.

As a rule, these various corrugations 3, 4 and 5 have in cross section a substantially cylindrical or prismatic configuration and preferably a dihedral configuration as in the form of embodiment illustrated. To avoid or minimize stress concentrations it is advantageous to substitute rounded fillets of relatively small radius of curvature for the sharp connecting or intersection ridges, edges or angles, to prevent any localized cold-drawing of the metal.

The aforesaid corrugations may be disposed either on the same side as the initial plane or surface of the sheet-metal element, as in the example contemplated in FIGURE 1, or alternatively on either side of the sheet. The corrugated pattern will thus form a kind of chequerwork on the panel 1 and divide same into substantially rectangular surface portions or elements 6 bounded or surrounded by the first and second series of corrugations 3, 4 constituting the first or basic corrugations of the pattern.

This configuration providing substantially plane separate rectangular portions facilitates the fitting and fastening of the corrugated wall element on a rigid or resistant support which may be made of insulating material or consist of a metal wall with the interposition of expansion or like joints.

FIGURE 2 shows more in detail the zone of intersection or crossing of two corrugations 3 and 4 belonging to the first and second series set forth hereinabove, in case these corrugations project from the same side of the sheet 2. It will be seen that the height or amplitude of the continuous corrugations 3 are generally less than those of the discontinuous corrugations 4 which penetrate somewhat into the side faces or walls of the corrugations 3, as shown diagrammatically in FIGURES 3 and 4. As contrasted with FIGURE 2 showing what could be termed conventionally the right side of the sheet-metal stock 2, FIGURE 5 illustrates the back side thereof and it will be seen that each so-called "discontinuous" corrugation 4 is practically interrupted at its point of intersection with a so-called "continuous" corrugation 3 by the latter forming a space of penetration common to the two solid figures constituted by these two corrugations 3 and 4 at their point of crossing. The penetration of each corrugation section 4 through the side of a corrugation 3 produces a partial sinking of, or depression in the sides of this corrugation, so that the portion 7 of the "continuous" corrugation 3 which "clears" or "bridges" corrugation 4 is somewhat narrowed transversely or reduced in width.
and may cause a corresponding flattening of the crest as a consequence of the formation of a flat face 8 at its top. This flat face 8 occurs in the present instance as a substantially plane and rectilinear surface substantially parallel to the base plane of the sheet-metal element 2. On the other hand, as a rule the junction of two corrugations 3 and 4 in their intersection or crossing zone will form a top face either substantially plane and of square or rectangular configuration. If the height of the crest as illustrated, or substantially rounded or part-spherical or bulged, this surface merging into the corrugations preferably through geometrically developable surfaces.

It may be noted that each intersection or crossing zone such as shown in FIGURE 2 has two planes of symmetry substantially orthogonal to each other and respectively perpendicular to the base plane of the sheet-metal element 2, these planes extending along straight lines constituting the imaginary extensions of the crests of corrugations 3 and 4.

Theoretically, the thickness of the sheet-metal stock, and the design, spacing and direction of the corrugations are selected with a view to constitute the best possible approach to the sometimes contradictory characteristics that may be required in practice such as flexibility, mechanical resistance to pressure, possibility of fastening the elements on the rigid support, easy-clearing, etc.

However, it may be pointed out that any stress or movement in a direction at right angles to the waves or corrugations of the first series will involve a stress or a concomitant movement in the very direction of the corrugations of the first series due to the action exerted on the wave patterns of the second and third series, which are geometrically connected to the first-series pattern through impressed or projecting dihedrons or vice-versa.

As a result, when the first series of corrugations has been calculated geometrically with due consideration for these parameters (of which the value is determined as a function of the various criteria set forth hereinabove), the parameters of the second and third series of corrugations can be determined only by taking due account of the geometrical connections and relationships existing between these corrugations with a view to prevent considerable stress from developing in the metal as a consequence not anymore of the elastic deformation obtained with the substantially orthogonal configuration of the pattern, but of the elastic deformation caused by the mechanical properties of the metal proper, that is, of the stress thus tending not to alter the geometry of the wave pattern but to produce an elastic or plastic deformation of the metal.

From these basic principles it is possible to determine the geometric parameters of the second and the third wave patterns as a function of the parameters governing the first wave pattern and of the virtual or actual movements required by specific service conditions.

It is assumed, for example, in the case illustrated in FIGURE 2, that on either side of the zone of crossing of two substantially dihedral corrugations 3 and 4 belonging to the aforesaid first and second series of corrugations, respectively, each side 9 of the intermediate portion 7 of the continuous corrugation 3 of the first series which connects two adjacent discontinuous corrugations 5 of the third series, lies substantially in a plane approximately at right angles to the basic sheet surface 2, forming the aforesaid rectangular panel portions 6. It is assumed likewise, on the other hand, that the dihedral angle formed by the sides of the corrugation of the second series 4 is substantially a right angle. With this assumption it is possible to note that in order to obtain a same virtual or real displacement in either of the orthogonal directions of the first and second sets of corrugations, it is necessary that the depth of penetration of the crest of a discontinuous corrugation 4 of the second series, into a continuous corrugation 3 of the first series which depth is represented by the length of segment a as measured between said lateral face portion 9 and a plane passing through the concave fold line at the base of the continuous corrugation 3 and perpendicular to the basic plane 2, be substantially equal to the sum of the half-length c of the crest segment forming the top of said intermediate portion 7 (corresponding to the half-length of the above-defined rectangle 8) on the one hand, and of the height b (of the crest of corrugation 4) of the face 9 constituting the side of said intermediate portion 7 which is adjacent or contiguous to both re-entrant waves 5, on the other hand; in other words, the lengths of segments a, b, c as illustrated in FIGURE 2 should correspond at least approximately to the relationship a = b + c.

The above-described corrugations are formed preferably in commercially available sheet-metal stock, that is, consistent with the means and tools available for performing the shaping operation which will consist preferably of a folding operation. However, other manufacturing methods such as moulding, welding, stamping, pressing, etc. may be used. These sheet elements are subsequently assembled by welding, gluing, riveting, stapling or any other equivalent and suitable method adapted to provide a strict or relative fluid-tightness meeting the service conditions contemplated.

The sheet-metal elements according to this invention, when subjected to distortion stresses in any directions, with some of the stresses privileged or preponderant, operate or react as follows: any distortion resultant may be decomposed into at least two substantially orthogonal components respectively parallel to the directions of the corrugations constituting the aforesaid first and second series. Any deformation parallel to the direction of the discontinuous corrugations 4 of the second series may take place by transverse deformation of the continuous corrugations 3 of the first series of which the cross-sectional angular contour will thus tend to open or close more or less according as it is an expansion or a contraction that takes place, respectively. Any deformation parallel to the direction of the continuous corrugations 3 of the first series may take place, on the other hand, due to the distortion of the discontinuous corrugations 4 of the second series and on the other hand, due to the simultaneous deformation of the discontinuous corrugations 5 of the third series which permit a certain elongation or narrowing of the corrugations 3 in a direction parallel to their longitudinal axis.

Of course, this invention should not be construed as being limited by the specific form of embodiment described and illustrated herein which is given by way of example only.

What I claim is:

1. A sheet-like metal plate element at least a portion of which is formed with at least two sets of integral channel-like corrugations having their raised convex wave-like portions all projecting from a same side of said plate element, the corrugations of each set intersecting each one of the corrugations of the other set, thereby defining therebetween substantially smooth uncorrugated areas located in the initial sheet surface of said plate element, each corrugation having a substantially uniform cross-section throughout its length except in the intersecting regions, the convex dihedral angles of at least their ridge portions extending continuously across said plate element, whereas each corrugation of the other set is discontinuous and separated into substantially aligned wave sections by the continuous corrugations of said one set and raises to a wave height smaller than that of said continuous corrugations, with their ridges being disposed in a direction substantially at right angles with respect to the wave section of at least one of said corrugations, each one at least of some said continuous corrugations being formed, adjacent to each one of at least some of its intersections with said discontinuous corrugations and on either side of the latter, with one
depression in the shape of a substantially cylindrical recess impressed into and extending transversely of at least the crest portion of said continuous corrugation, in substantially parallel relation to said discontinuous corrugation, each depression forming a transverse rib across and inside the trough-like concave portion of said continuous corrugation and protruding by its outer sidewise in opposite directions, from said continuous corrugation, thereby forming a lateral bulge therein, two successive depressions adjacent to two successive intersections, respectively, on a same continuous corrugation, being connected by a continuous section of continuous corrugation extending between said intersections, so that the length of any adjacent uncorrugated area in a direction parallel to said continuous corrugation is longer than that of any one of said depressions.

2. A plate element according to claim 1, wherein the corrugations of each set extend in substantially parallel spaced relationship and are of substantially cylindrical configuration.

3. A plate element according to claim 2, wherein the depth of each depression is less than the wave height of the associated continuous corrugation and either of said depression and any one raised wave-like portion of corrugation has a substantially angular cross-sectional contour defining a pair of spread apart lateral faces meeting along a substantially rounded fillet corresponding to a folding edge, the crest folding edge line of a continuous corrugation ending adjacent one depression by dividing into two diverging convex fold lines joining the sidewise projecting opposite ends of the concave folding edge line of said depression, respectively, thereby defining triangular lateral faces for the latter, the lateral faces of each corrugation being connected at their base to said uncorrugated areas by rounded fillets corresponding to theoretical concave fold lines.

4. A plate element according to claim 3, wherein each end of the concave folding edge line of each depression is connected by a convex fold line to the meeting point of the two concave fold lines bounding a same corrugated area along the bases of two intersecting corrugations, said meeting point being also connected by two concave fold lines to the crest folding edge lines of said two corrugations respectively.

5. A plate element according to claim 3, wherein each depression has substantially the shape of a fragmentary re-entrant dihedron.

6. A plate element according to claim 5, wherein each raised wave-like portion of each corrugation has substantially the shape of a dihedron.

7. A plate element according to claim 6, wherein said initial sheet surface and said smooth uncorrugated areas are substantially plane, whereas said corrugations of each set are substantially straight and intersect at right angles the corrugations of the other set.

8. A plate element according to claim 7, wherein each dihedral corrugation is substantially symmetrical with respect to a plane passing through its crest edge line and extending at right angles to said initial plane sheet surface and each discontinuous corrugation has a substantially right dihedral angle and extends at least with its crest portion into the sides of each continuous corrugation at each intersection thereof, by such a distance that those lateral face portions of the continuous corrugation, which are comprised between two associated depressions and overlap said discontinuous corrugation to form a top hump at said intersection, are substantially perpendicular to said initial plane sheet surface, whereas the depth of penetration of the crest edge line of said discontinuous corrugation into the side of a continuous corrugation, as measured by the length of said crest edge line between that lateral face portion of continuous corrugation which joins said crest edge line and a plane passing through the concave fold line at the base of said continuous corrugation and perpendicular to said initial plane sheet surface, is equal to the sum of the half-length of said top hump measured parallel to the crest of said continuous corrugation, on the one hand, and of the height of said lateral face portion above the crest of said discontinuous corrugation on the other hand, said height being at least equal to the difference between the wave heights of said continuous and discontinuous corrugations, respectively.

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