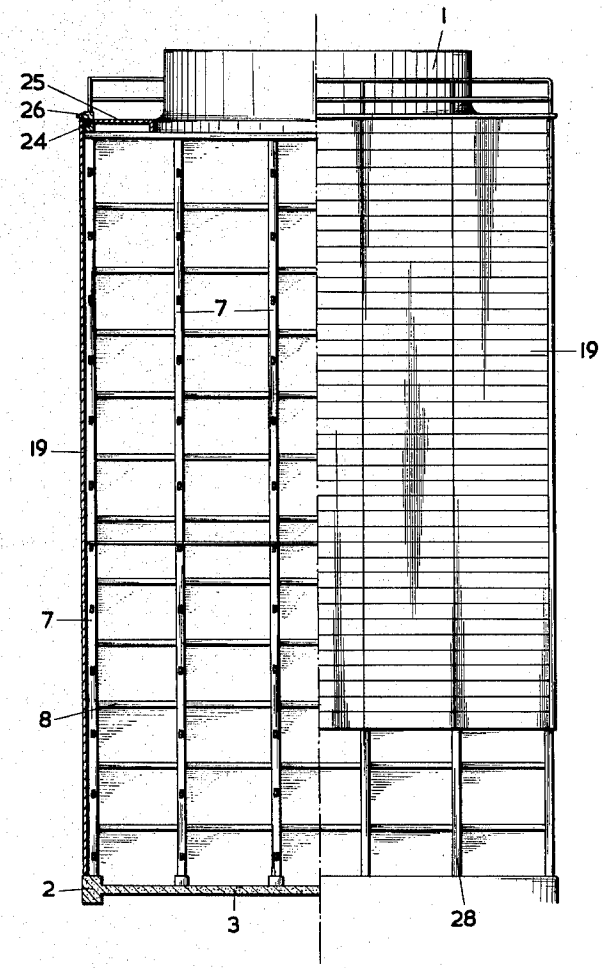
Jan. 4, 1966 K. BURCHARDT ETAL 3,226,894

CONCRETE COOLING TOWER

Filed Aug. 27, 1963 6 Sheets-Sheet 1

Fig. 1



INVENTORS
KURT BURCHARDT AND
WILHELM KAUFMANN
BY Irvin S. Thompson
ATTORNEY

Jan. 4, 1966 K. BURCHARDT ETAL 3,226,894

CONCRETE COOLING TOWER

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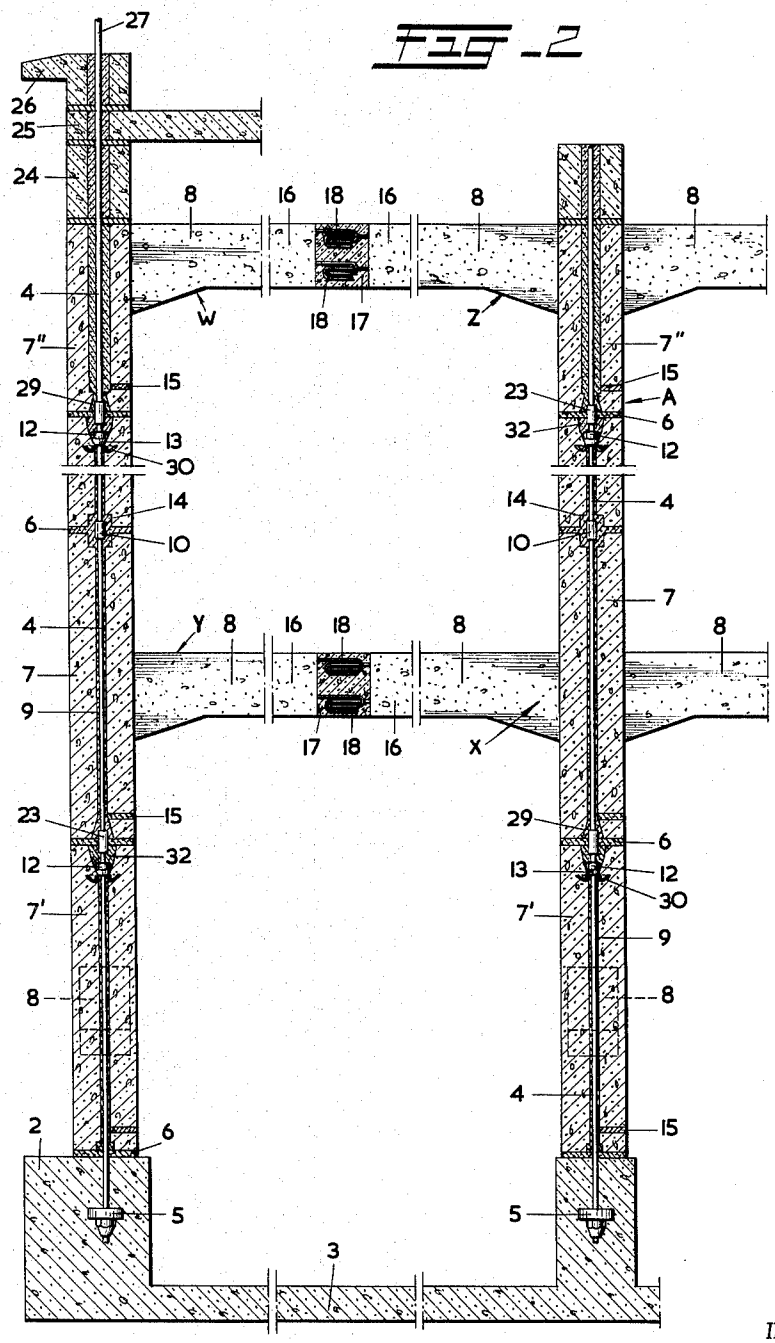
Fig. 2



INVENTORS

KURT BURCHARDT AND

WILHELM KAUFMANN

BY Irvin S. Thompson

ATTORNEY

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CONCRETE COOLING TOWER

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Fig - 3

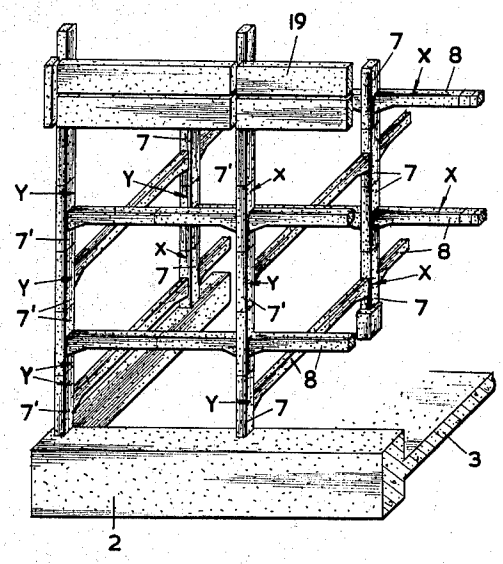
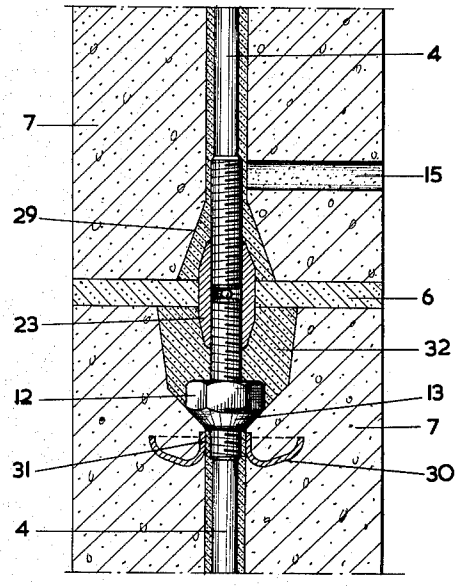


Fig - 4



INVENTORS

KURT BURCHARDT AND

WILHELM KAUFMANN

BY Irvin S. Thompson

ATTORNEY

Jan. 4, 1966 K. BURCHARDT ETAL 3,226,894

CONCRETE COOLING TOWER

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Fig - 5a

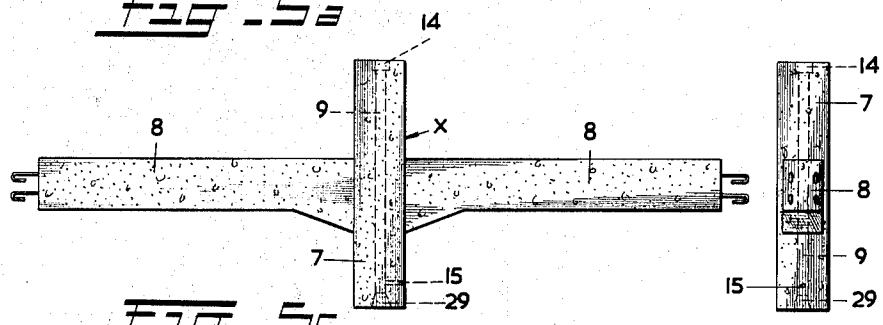


Fig - 5b

Fig - 5c

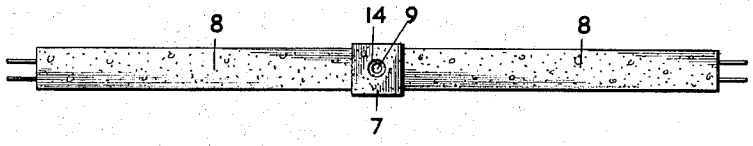


Fig - 6c

Fig - 6a

Fig - 6b

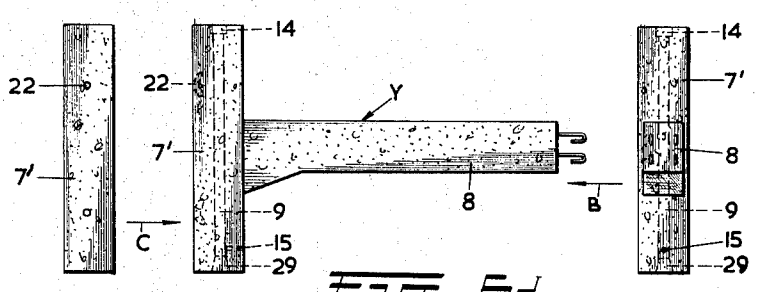
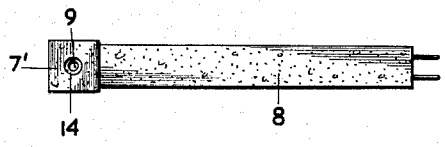


Fig - 6d



INVENTORS

KURT BURCHARDT AND

WILHELM KAUFMANN

BY Irvin S. Thompson

ATTORNEY

Jan. 4, 1966 K. BURCHARDT ETAL 3,226,894

CONCRETE COOLING TOWER

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FIG - 7a

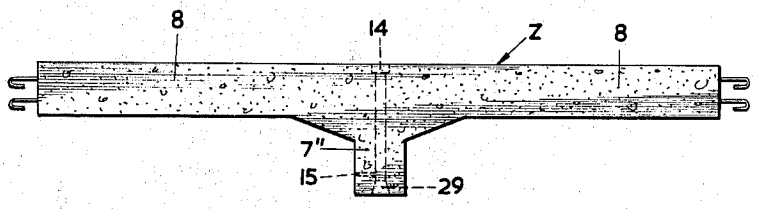


FIG - 7b

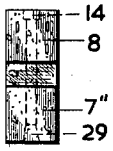


FIG - 7c

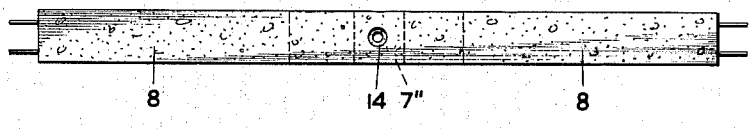


FIG - 8a

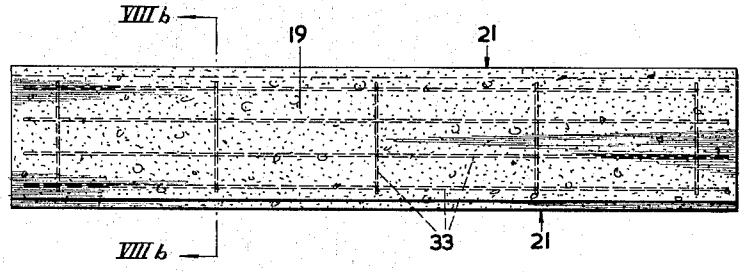
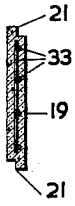


FIG - 8b



INVENTORS

KURT BURCHARDT AND

WILHELM KAUFMANN

BY Irvin S. Thompson

ATTORNEY

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CONCRETE COOLING TOWER

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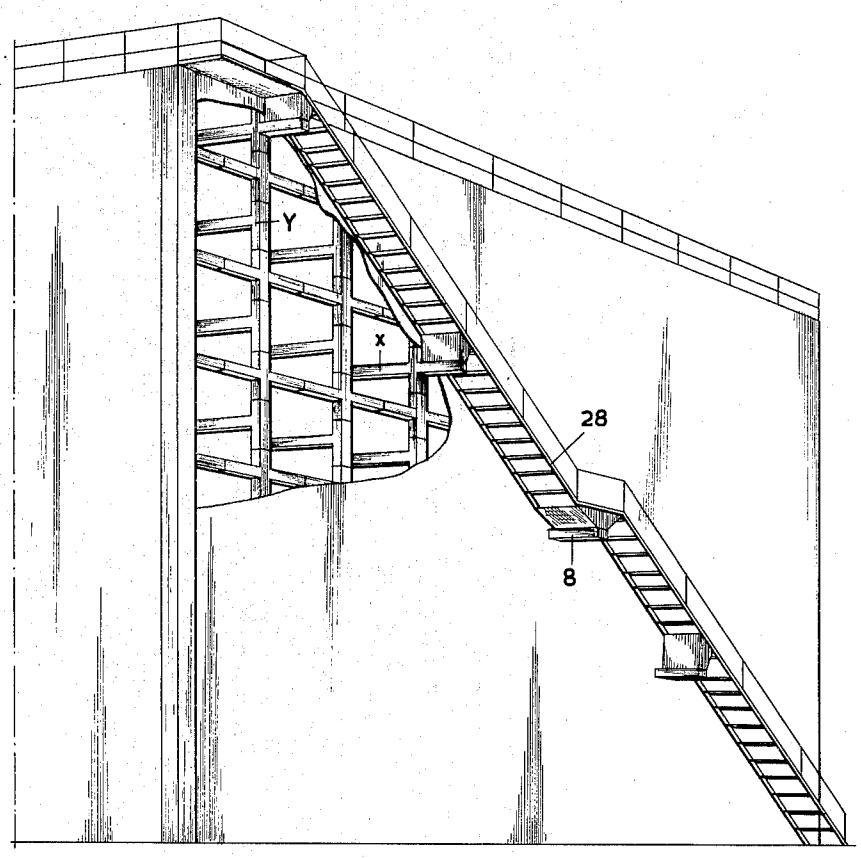
Fig - 9



INVENTORS
KURT BURCHARDT AND
WILHELM KAUFMANN
BY Irvin S. Thompson
ATTORNEY

United States Patent Office

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3,226,894

CONCRETE COOLING TOWER

Kurt Burchardt, Hamburg-Othmarschen, and Wilhelm Kaufmann, Hamburg-Blankenese, Germany, assignors to Ernst Kirchner, Hamburg-Blankenese, Germany, a firm

Filed Aug. 27, 1963, Ser. No. 305,003
7 Claims. (Cl. 52—223)

This is a continuation-in-part of application Serial No. 648,070, filed March 25, 1957, and now abandoned.

This invention relates to cooling towers, and relates more particularly to cooling tower structures of concrete made of prefabricated building elements.

While cooling towers have heretofore been made of concrete, usually cast on site, with attendant great height and heavy construction, in most of these instances substantially all of the load carrying has been assigned to the outer walls.

In contrast hereto, it is among the principal objects of the present invention to provide a cooling tower structure made of prefabricated concrete standard parts which enables a nearly equal distribution of wind and static load throughout the entire cooling tower area. The columns composed of superposed building elements are stressed after emplacement by highgrade steel stressing rods, after which the hollow spaces, into which the stressing rods are placed, are filled with a binder material.

The construction of the cooling tower with prefabricated parts has the advantage that the individual elements can be manufactured economically on a production line in a factory to precise specifications by procedures including vibration of the concrete. The high quality vibrated parts of small cross section enable a lightweight concrete structure contrary to heavy columns and beams when cast in situ. Furthermore the building elements can be of comparatively small sizes and weight to enable an easy handling. The erection can be carried out in repetitive series of simple steps.

The instant construction avoids any exposed steel parts. The outer and inner walls are manufactured also of easily exchangeable elements, for instance they are made of asbestos cement, and fastened to the concrete structure. The concrete structure supports also the tower filling, for instance grid decks, water distribution system, drift eliminators, etc., thereby rendering unnecessary any additional construction.

The grid decks may serve as scaffolding during erection of the tower. The load carrying construction parts support the grid decks, thereby rendering any additional construction unnecessary.

With the above and other objects of the invention in view, the present invention consists in the novel construction, arrangement and combination of various devices, elements and parts, as set forth in the claims hereof, one embodiment of the same being illustrated in the accompanying drawings and described in the specification.

In the accompanying drawings,

FIG. 1 is an elevational view, partly in vertical section, of a cooling tower structure assembly, in accordance with the invention;

FIG. 2 is a fragmentary large scale sectional view of parts of the assembled cooling tower frame structure;

FIG. 3 is a fragmentary schematic perspective view of parts of the cooling tower structure, with the outer wall plates removed in part;

FIG. 4 is a large scale fragmentary sectional detail view of a building element embodiment, showing a detail "A" of FIG. 2;

FIG. 5*a* is a front elevational view of a building element embodiment;

FIG. 5*b* is an end elevational view thereof;

FIG. 5*c* is a plan view thereof;

FIG. 6*a* is a front elevational view similar to FIG. 5*a*, but of an embodiment of a different building element;

FIG. 6*b* is an end elevational view of FIG. 6*a* seen in the direction of the arrow B;

FIG. 6*c* is an end elevational view of the element of FIG. 6*a*, but seen in the direction of the arrow C;

FIG. 6*d* is a plan view thereof;

FIG. 7*a* is a front elevational view of an embodiment of still another building element;

FIG. 7*b* is an end view thereof;

FIG. 7*c* is a plan view thereof;

FIG. 8*a* is an elevational view of a wall plate element;

FIG. 8*b* is a sectional view taken on line VIII*b*—VIII*b* of FIG. 8*a*.

FIG. 9 is a perspective view of part of the cooling tower showing the arrangement of a staircase.

In carrying the invention into effect in one of the embodiments which has been selected for illustration in the accompanying drawings and for description in this specification, and referring now particularly to FIG. 1, there is provided a cooling tower with a number of layers formed by the grid decks and supported by the horizontally extending parts of the building elements. At the top, the tower carries a top plate **1**.

As best shown in FIGS. 1 and 2, there is provided a foundation which includes a bottom **3** and upright parts including a rim or flange **2**. The foundation serves at the same time as a water basin. The foundation is composed of concrete and anchors, by means of plates **5**, the lowermost of the stressing elements **4**. Each of the stressing elements **4** includes a rod of high-grade steel, over which the building elements are inserted. Between the various building elements of each column, there is a joint or layer of cement **6** (FIGS. 2 and 4).

The frame construction of the cooling tower has been erected from building elements selected from a small group of building elements.

There are essentially four types of concrete prefabricated building elements used, three types of which designated X, Y, Z are shown in FIGS. 5*a* to 7*c* and the fourth type element W is shown in FIG. 2. Each type of building element, may appear in two different forms or embodiments, as explained below. Each of the building elements has a vertical portion **7**, **7'**, **7''** that defines on its interior a vertical passage or bore **9** in which there is disposed a stressing rod **4**, but the rod does not completely fill out the volume of the passage or bore **9**, so that there remains after the insertion of the rod **4** an annular space between the surfaces of the passage **9** and of the rod **4**.

The building element X has a long vertical portion **7** which carries about midway of its height two oppositely disposed horizontal arms **8**. The building elements X are used throughout the tower structure, except for the corner columns and for some of the external columns and for the top part of the tower. In FIGS. 5*a*, 5*b* and 5*c* there is shown one form or embodiment of the building element X. The vertical portion **7** of this embodiment has at its lowermost end a tapered recess **29** (FIG. 5*a*) of the passage **9**, to receive a bushing **23** (FIG. 4) for interconnecting two superposed rods **4**. The passage **9** in vertical portion **7** of this embodiment, furthermore, has its upper end enlarged to provide a cylindrical recess **14** (FIG. 5*a*) to receive a hollow sleeve **10** (FIG. 2) through which the rod **4** passes. The length of the stressing rods is twice the length of the vertical portion **7** of the elements and the sleeve **10** is located at the level of the layer **6** between the ends of two elements interconnected by one stressing

rod. The upper element of said two elements forms the second embodiment of the element X having a similar cylindrical recess at the bottom of the passage **9** of the vertical portion **7** for receiving the sleeve **10** which operates as a seal. Said second embodiment has an annular dish-shaped member **30** (FIG. 4) which is embedded near the top in the vertical portion **7**. The member **30** is disposed substantially horizontally, and may be of steel sheet or the like. The vertical portion **7** has immediately above the member **30** a conical recess **32** for engagement of a taper **13** of a nut **12** and for supporting a stress generating means (not shown) for stressing of the stress rods **4**.

The building element Y has a long vertical portion **7'** similar to that of the element X with, however, but a single horizontal arm extending on only one side about midway of the height of the vertical portion **7'**. These building elements Y are used to form the corner columns and some of the other external columns of the tower structure (FIG. 3), except for the top part of the tower, with the arms **8** projecting at one side. For some of the elements forming the external columns, however, there may be chosen elements X positioned to have the second arm **8** extending beyond the confines of the tower wall surface in order to attach thereto a staircase (FIG. 9). The building element Y, similar to the building element X, comes in two forms or embodiments one, which is shown in FIGS. 6*a–d*, having a tapered recess **29** at the bottom and a cylindrical recess **14** at the top of the vertical portion **7'** and the other embodiment having a cylindrical recess at the bottom and a tapered recess **32** near the top of the vertical portion **7'** above an embedded annular member **30**.

The building element Z is used for the topmost part of the tower (see FIG. 2), and has a vertical portion **7''** which is shorter than that of the elements X or Y, and carries two opposite horizontal arms **8**, the upper surface of which is flush with the upper surface of the vertical portion **7''**. The building element Z also comes in two forms or embodiments: one, that is shown in FIGS. 7*a–c*, and which has a tapered recess **29** at the bottom and a cylindrical recess **14** at the top of the vertical portion **7''**; and the other embodiment has a cylindrical recess at the bottom, and a tapered recess **32** near the top of the vertical portion **7''** above an embedded annular member **30**.

The fourth type building element W is shown at the top left side of FIG. 2. It is like the element Z but has only one arm **8** formed on a short vertical portion **7''**. It forms the top elements for the corner columns and for some of the other external columns otherwise built up of elements Y. Similar to the other building elements, the building element W may also appear in two different forms or embodiments.

The arms **8** of the elements X and Z are of equal length while the length of the single arms **8** of the elements Y and W is equal to the length of the arms **8** of the said elements X and Z. This not only greatly facilitates the construction because the workman can operate according to very simple prescriptions but also has the great advantage that the distribution of the bending moments resulting from the wind load, which is the greatest load occurring at the cooling tower, has its zero value there, where the ends of the arms are connected with each other, the maximum value of the moment lying at the spot where the horizontal arms **8** emerge from the vertical portion. Due to the fact that the horizontal portions of the elements in one layer extend perpendicularly to the horizontal portions of the elements in the adjacent layers, the cooling tower structure is able to take up the wind forces from all directions. The load resulting from the wind forces on the horizontal arms is much greater than the moments resulting from the static load because said static load mainly results from the grid decks.

Further, the vertical portions **7** and **7'** have a length corresponding to the distance between corresponding regions of the horizontal portions of vertically adjacent layers. This means that the triangular momentlines of the columns which are the result of the horizontal wind load have their maximum values at the junctions of vertical and horizontal parts of two adjacent layers, having the horizontal parts extending in the same direction, while the minimum value or zero point is at the junction of the vertical and horizontal parts of the elements of the layer extending in between the two mentioned layers. This means that at the points where the vertical portions are interconnected, there is a small load but this load can be neglected, especially when the elements are pressed upon each other by the stressing rods.

The individual building elements may be formed with the aid of cores and forms. Due to the fact that the elements with two horizontal arms have said arms extending ing the same plane, the forms remain simple whilst transportation costs can be kept low.

In the process of erection, there is first put a layer of cement **6** onto the upright parts of the foundation, and then building elements X and Y are inserted over the lowermost stress rods **4** and rest on the cement **6**, forming the lowermost series or layer of building elements. Another layer of cement **6** is added to the top of the lowermost building elements, and the next series or layer of building elements X and Y is then superposed on the building elements of the lowermost series, but with their arms **8** at right angles to the direction of the arms **8** of the lowermost series. The vertical portions **7** and **7'** of the building element layers are superposed in such a manner that the passages or bores **9** are in vertical alignment and the rods **4** are provided with the hollow sleeves **10** at the level of the layer **6** between the superposed vertical portions.

After one or several layers of these building elements have been emplaced, the rods **4** will be stressed. For this purpose, there is mounted at the free upper end of a rod **4** the said hexagonal nut **12** which has a downward taper **13** (FIG. 4). In the upper region on the interior of the vertical portions **7**, **7'** of some of the building element embodiments, as previously described, there is embedded an annular substantially horizontal dish-shaped member **30**, against which the taper portion **13** of the nut **12** bears. The purpose of the member **30** is to distribute the vertical stress forces of the rod **4** as well as the transverse forces occurring in the concrete owing to the stress exerted on the end by the rod **4**. After the stressing of the rod **4**, the stress force is permanently fixed by threading down the nut **12**, after which the apparatus secured to the upper end of the rod **4** for stressing it is removed. Subsequently, a binder, such as cement paste, will be injected into the passages **9** through an injection opening **15**. The passages **9**, in order to permit the complete filling by the binder, are provided with ventilating apertures (not shown).

Each of the stressing rods **4** preferably protrudes through two or more superposed building elements of the type X, Y, Z and W, and each rod is provided with threads at its opposite ends and may be prolongated by the threaded bushings **23** (FIG. 4) which are disposed at the point of abutment of two building elements.

The arms **8** of the elements of two laterally adjoining columns are so dimensioned relative to the space between two adjoining columns that they define between their free end surfaces a gap **17** which has a length of approximately 4 inches. Into this gap **17** there protrude the bent ends **18** of the reinforcing wires of the arms **8**. The reinforcing wire ends **18** will then be interconnected, for instance, by welding, and thereafter the gap **17** will be filled up with a cement that is quick-hardening and subject to but little shrinking. The surfaces of the free end portions **16** of the arms **8** are preferably rough or roughened, in order to promote a good adhesion of the filling cement.

Subsequently, there will be mounted the outer wall plates **19** (FIGS. 3 and 8*a* and 8*b*). Each plate **19** has a height of about one-half of the height of the vertical portion **7** (FIGS. 5*a* and 5*b*) and is of rectangular shape and has a length corresponding to the space between two adjoining columns formed of superposed building elements. The plates have, however, off-set horizontal end surfaces **21**, each forming a shoulder for proper overlapping of vertically adjoining plates **19**.

The grid decks (not shown) may be placed during the erection of the tower and if made, for instance, of wood may serve as a scaffold for the further build-up of the frame structure.

Following the erection of two layers of building elements, the worker will first prolongate the rods **4** by means of the threaded bushings **23**. Thereafter, the operations of the first two layers will be repeated for the next two layers.

In the top layer, the vertical portions **7''** of the elements Z and W reach only to the height of the upper surfaces of the arms **8**. The rods **4** of the external building columns, which protrude beyond the top of the building elements, will serve to hold a flange beam **24** which encircles the tower and, furthermore, to hold the ends of roof plates **25** as well as of molding beams **26** that are placed over the roof plates **25**. Still furthermore, the rods **4** of the exterior building columns may serve either directly as railing parts or as supports for a railing that may encircle the top of the tower. Moreover, a suspension rod (not shown) may be threaded onto the thread of a rod **4** to serve as a rearward anchor for an outrigger (not shown) which may be erected on the roof of the tower, for use for instance for the exchange of machinery forming part of the blower system.

FIG. 9 shows that a staircase **28** can be easily secured to the outwardly extending horizontal arms **8** of the building elements X which are positioned at suitable locations in the outer columns for supporting the staircase.

We wish it to be understood that we do not desire to be limited to the exact details of construction shown and described, for obvious modifications will occur to a person skilled in the art.

Having thus described the invention, what we claim as new and desire to be secured by Letters Patent is as follows:

1. A cooling tower comprising a frame structure formed of a plurality of horizontally spaced vertical columns of prefabricated concrete elements stacked in layers, each of the concrete elements being monolithic and having a vertical column-forming portion with at least one horizontal beam extending at right angles to the column-forming portion and within the same plane as the column-forming portion, the horizontal beam being of a length substantially equal to one half the distance between adjacent horizontally spaced vertical columns and having its end connected to the end of a horizontal beam of an adjacent said vertical column, the elements in one layer of one column being at the same level as corresponding elements at the corresponding layer in other columns and having their horizontal portions parallel to the horizontal portions of elements in the same layer in other columns, all the horizontal beam parts of the elements in one layer extending in a direction perpendicular to the direction in which all of the horizontal beam parts of the concrete elements in layers just above and just below said one layer extend, the vertical column-forming portions of said elements being of a length about equal to the distance between corresponding regions of the horizontal portions of vertically adjacent layers.

2. A cooling tower as claimed in claim **1**, each column-forming portion having a passage extending longitudinally therethrough from end to end and a stressing member extending through said passage and engaging at least the lower and upper column-forming portion of the column through which the stressing member extends to prestress the column.

3. A cooling tower as claimed in claim **1**, each column-forming portion having a passage extending longitudinally therethrough from end to end and a stressing member extending through said passage and connected to the stressing member passing through the concrete element immediately below and engaging the column-forming portion through which the stressing member extends to prestress the column.

4. A cooling tower as claimed in claim **1**, said horizontal beam being located about midway of the height of the column-forming portion.

5. A cooling tower as claimed in claim **2**, the horizontal beam being located about midway of the height of the column-forming portion.

6. A cooling tower as claimed in claim **3**, the horizontal beam being located about midway of the height of the column-forming portion.

7. A cooling tower as claimed in claim **6**, the column-forming portions of the concrete elements of the uppermost layer in each column having a shorter length and terminating at a level corresponding to that of the horizontal beams of said uppermost layer of the frame structure.

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RICHARD W. COOKE, JR., *Primary Examiner.*

JACOB L. NACKENOFF, *Examiner.*