

April 19, 1938.

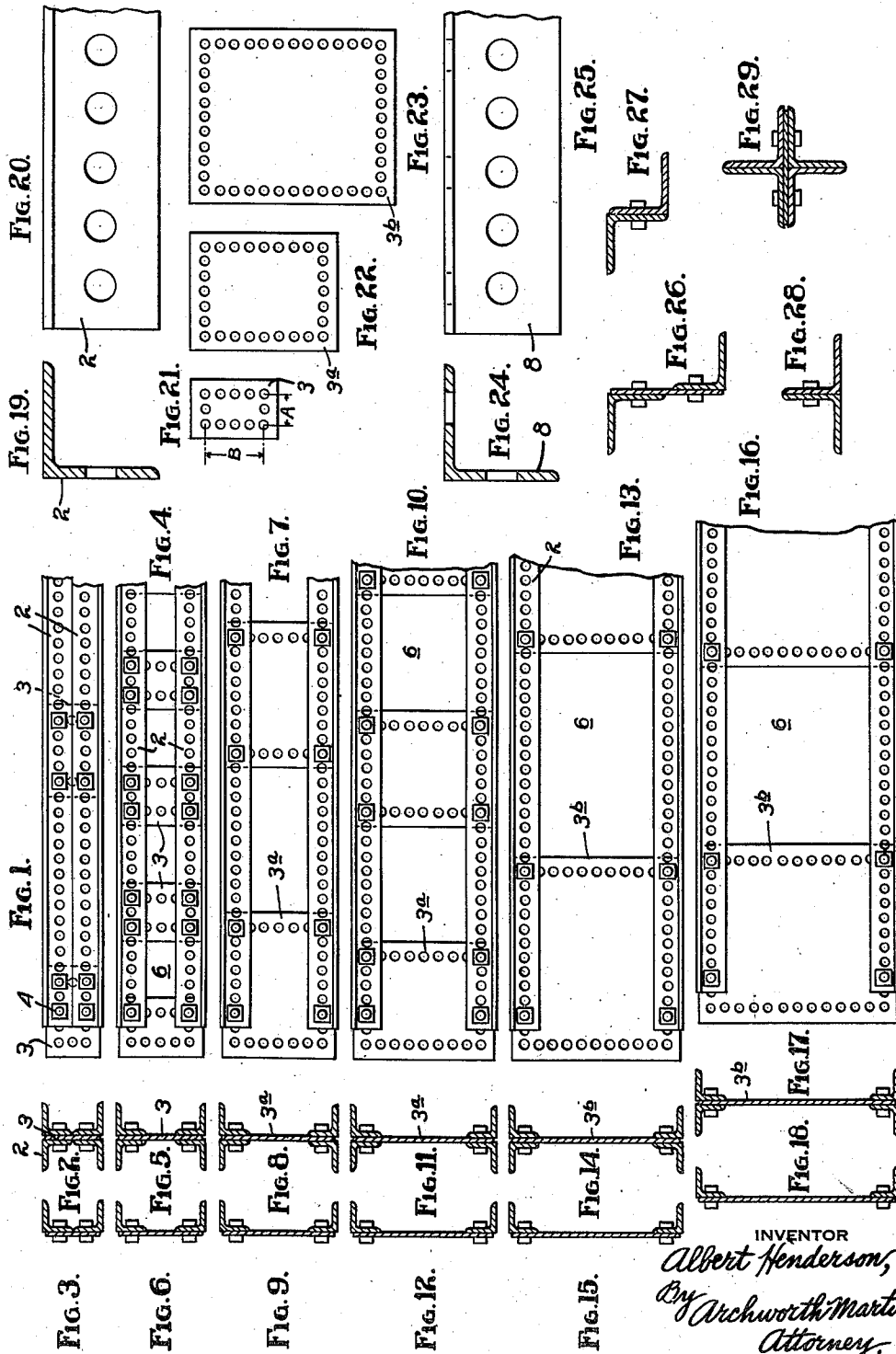
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2,114,901

STRUCTURAL STEEL SYSTEM

Filed March 6, 1934

7 Sheets-Sheet 1



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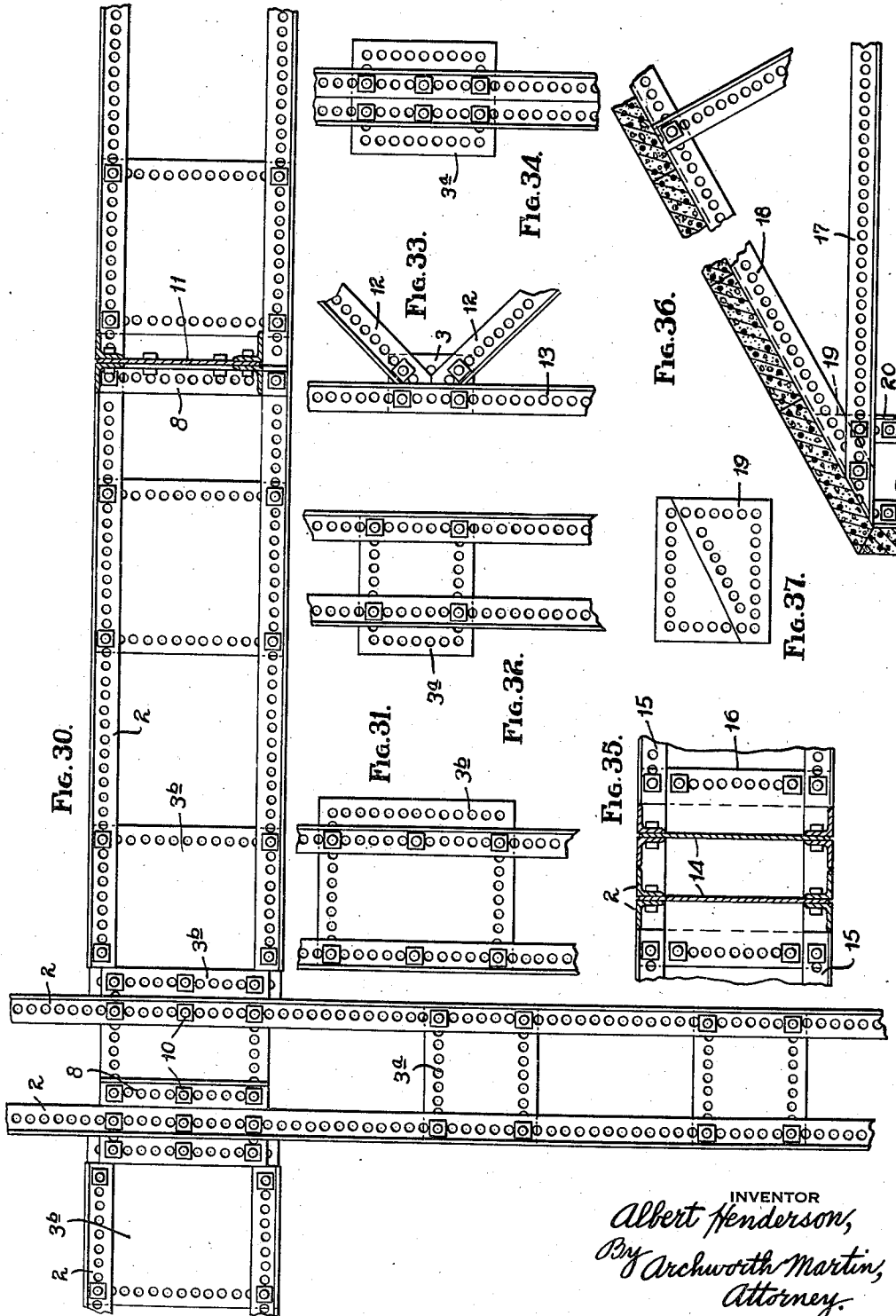
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STRUCTURAL STEEL SYSTEM

Filed March 6, 1934

7 Sheets-Sheet 2



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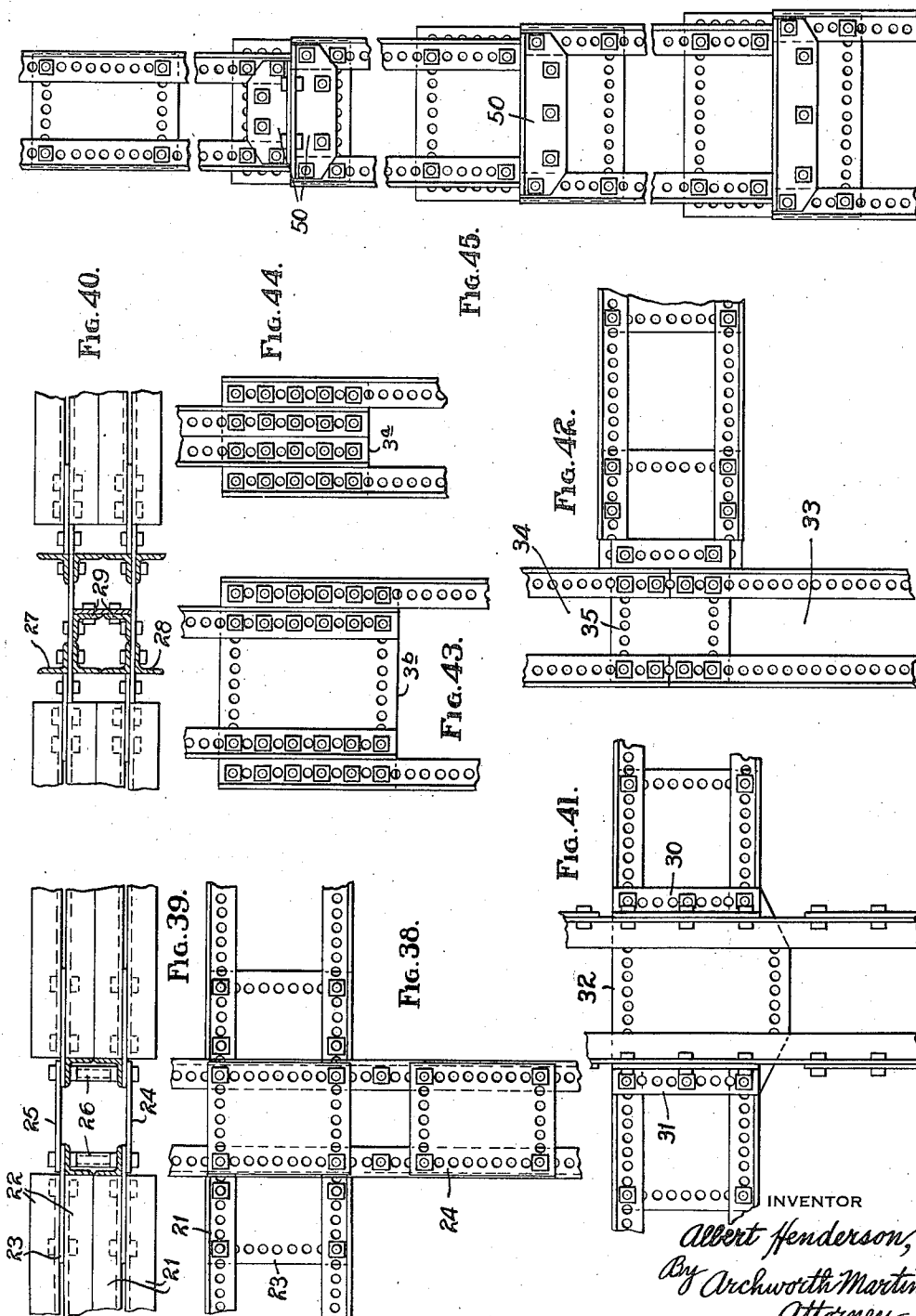
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STRUCTURAL STEEL SYSTEM

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7 Sheets-Sheet 3



April 19, 1938.

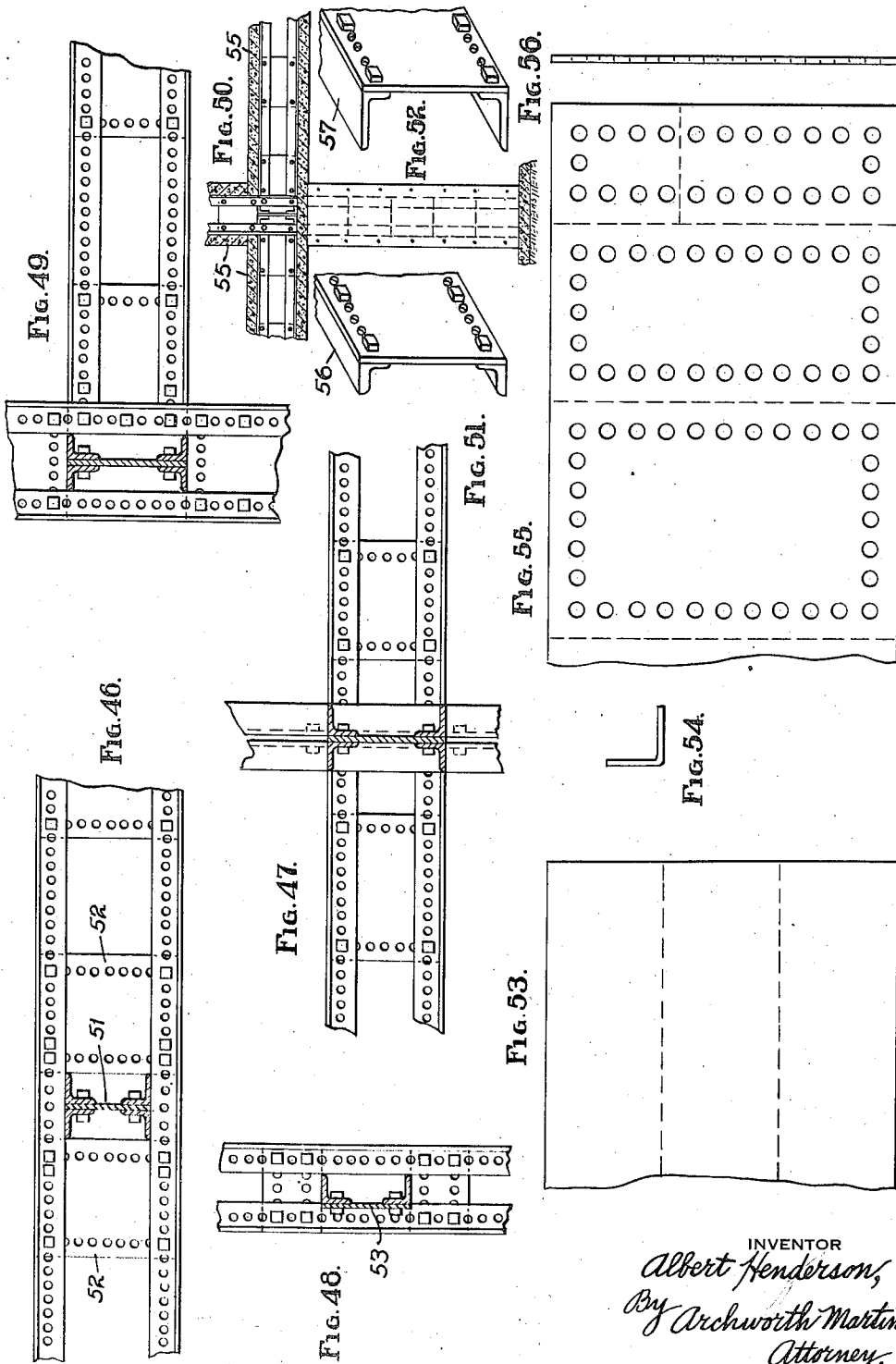
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STRUCTURAL STEEL SYSTEM

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7 Sheets-Sheet 4



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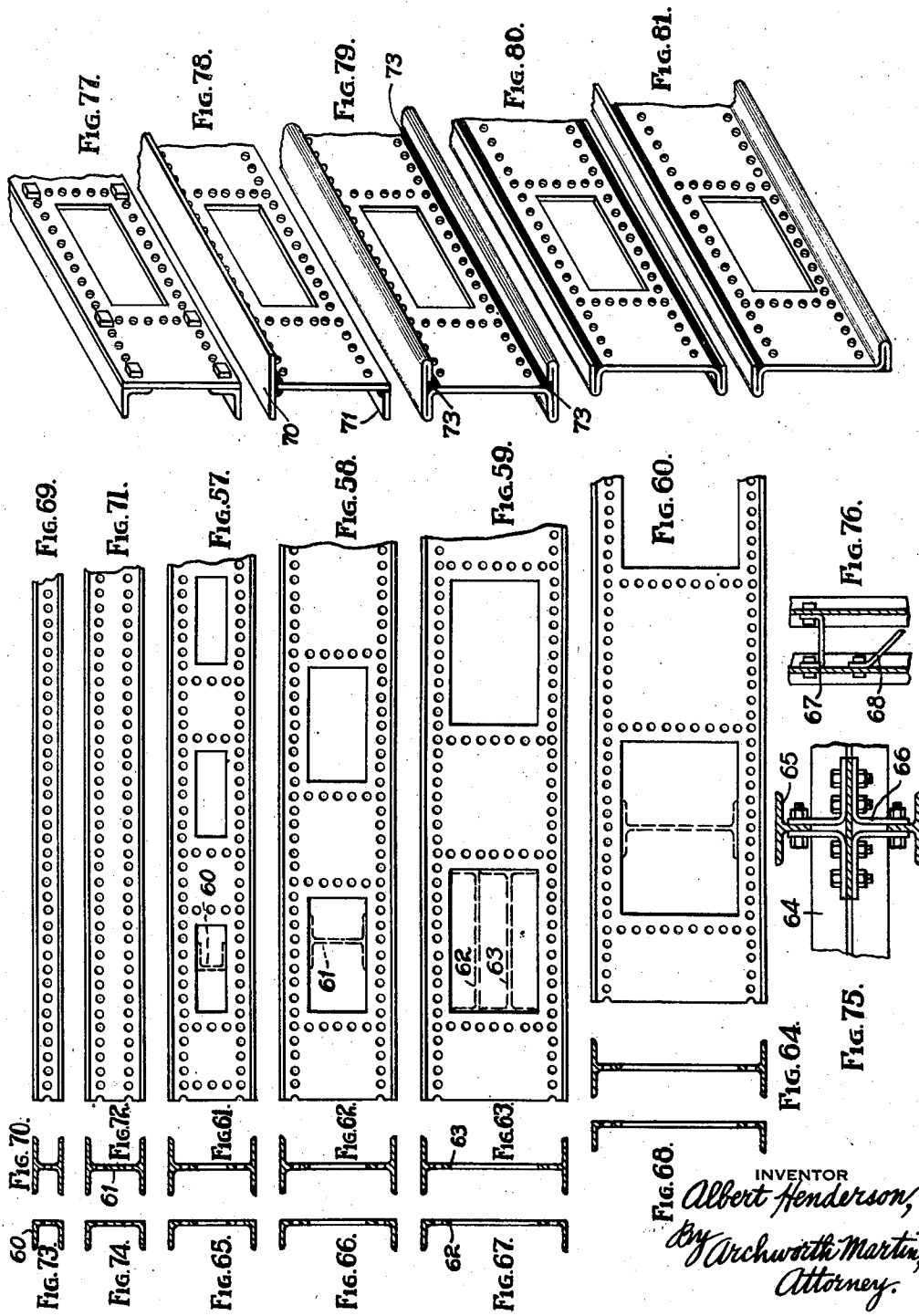
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STRUCTURAL STEEL SYSTEM

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7 Sheets-Sheet 5



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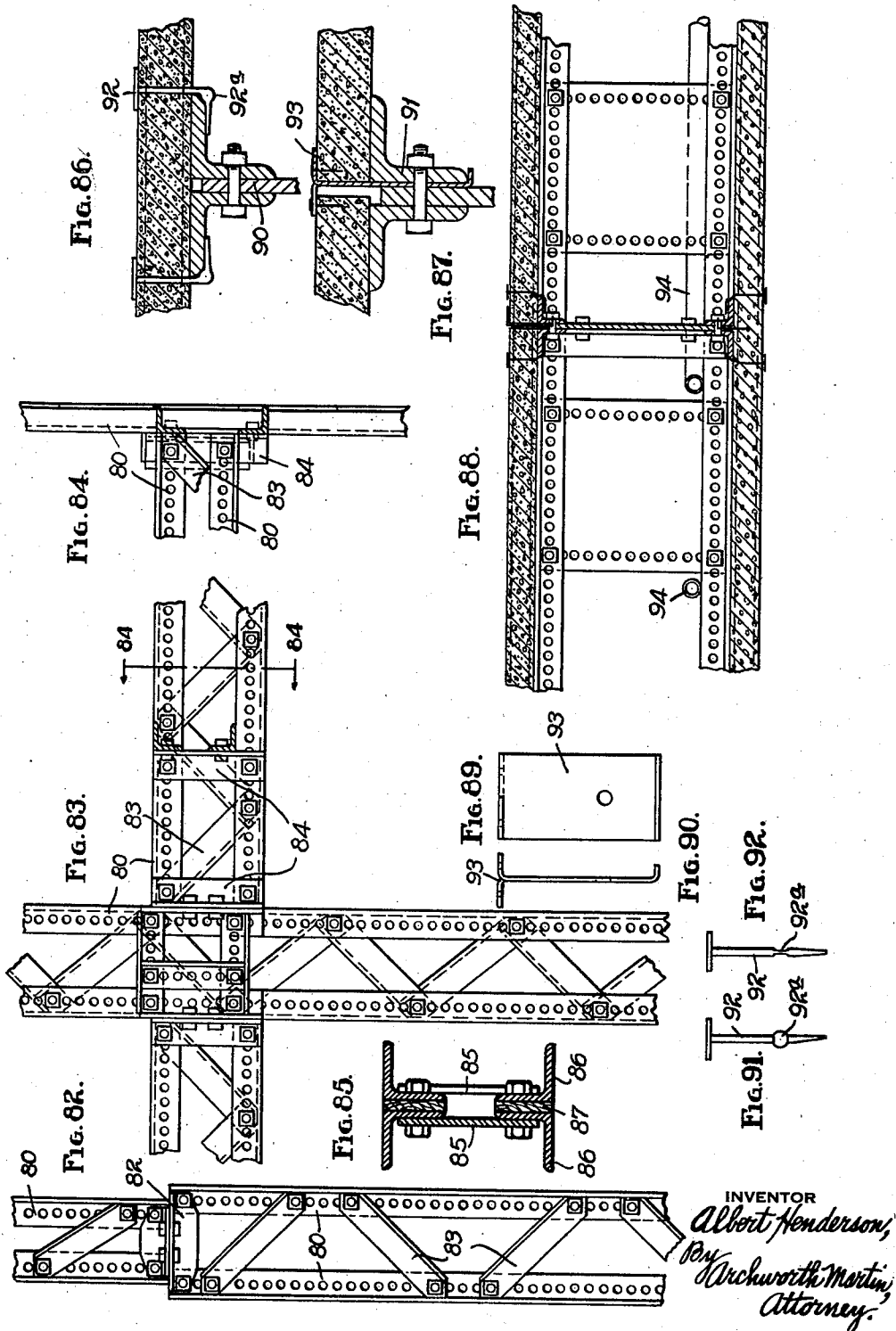
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STRUCTURAL STEEL SYSTEM

Filed March 6, 1934

7 Sheets-Sheet 6



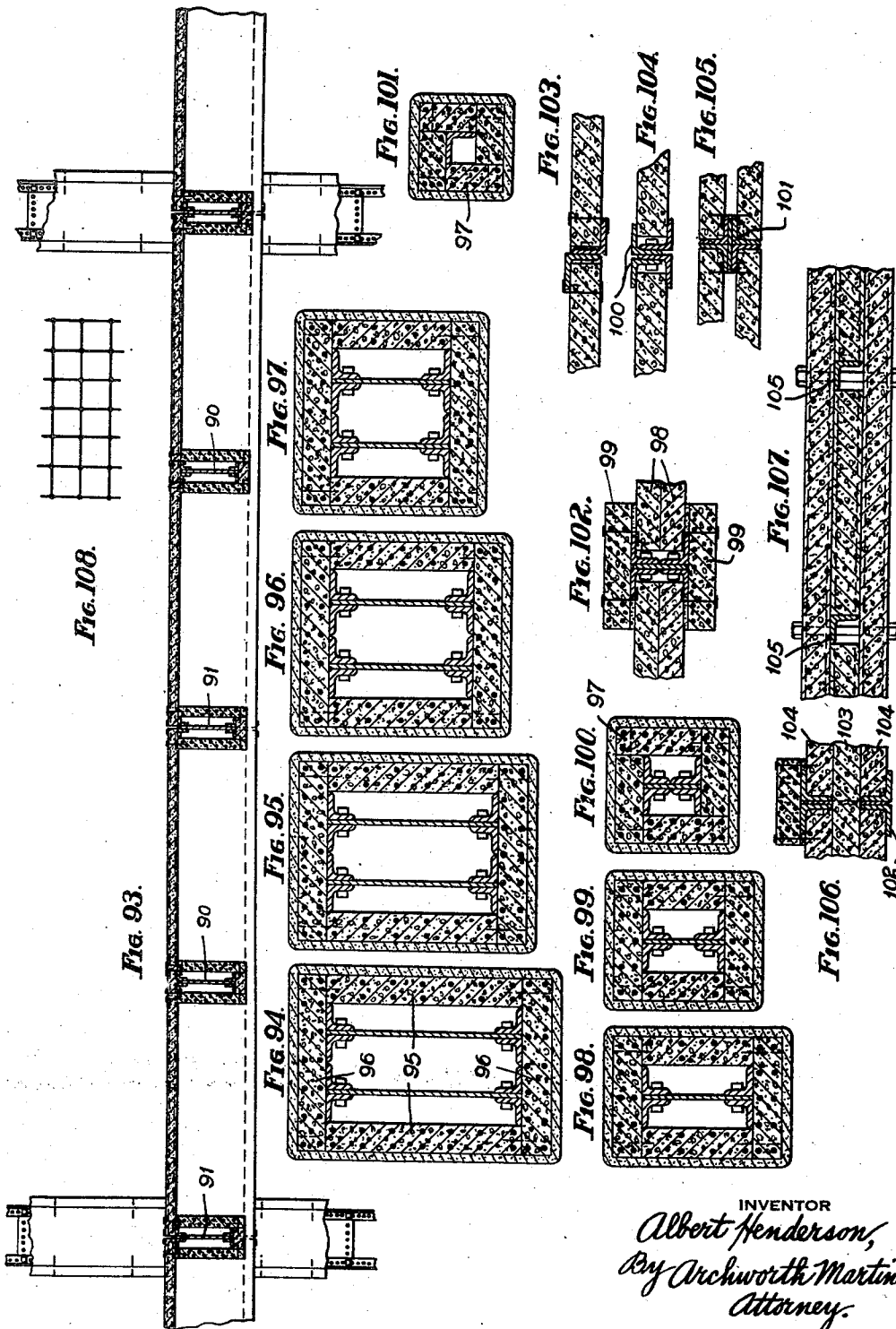
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STRUCTURAL STEEL SYSTEM

2,114,901

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7 Sheets-Sheet 7



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UNITED STATES PATENT OFFICE

2,114,901

STRUCTURAL STEEL SYSTEM

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15 Claims. (Cl. 189—37)

My invention relates to the building art, and more particularly to the use of an improved system of structural steel, with covers or protecting material of fire-proofing or the like therefor.

One object of my invention is to provide, particularly for use in connection with smaller buildings, an improved arrangement of structural elements which can be supplied and erected at lower cost than in the case of various well-known types of buildings, and a system of elements composing the advantages of simplicity, light weight, elasticity, detachability and adjustability.

Another object of this invention is to provide structural metal manufacturers with an increased market for light-weight shapes, and to enable said metal shapes to be economically employed instead of wood.

Another object of my invention is to provide structural steel manufacturers with an outlet for waste granulated slag and cinders, which combined with water and cement and metallic reinforcement, and made into planks or slabs, can be utilized as fireproof covers for the structural steel.

A further object of this invention is to provide structures which may be kept in permanent use and having little or no depreciation, but which if dismantled will have greater salvage value than various types of buildings heretofore constructed.

As stated generally, the foregoing objects are obtained as follows:—

The structural metal members are composed primarily of chord members such as angles and web plates, the angles being of a given size and, in most instances, each having spaced holes along only one flange or leg thereof and the plates being of rectangular form, and of such sizes that the widths thereof are multiples of the angle widths, and having spaced holes along their edges which match with spaced holes in the angles. By this means, I am enabled to form a variety of useful structural shapes of different sizes. The angles and plates also have other definite relative features to facilitate the various combinations as hereinafter described in detail.

The plates and the angles may be purchased by the builder from his dealer, and by the use of a hand book provided for that purpose, the builder can readily assemble the angles and plates at the place of installation, to produce buildings of various designs. Some of the shapes could, of course, be assembled by the dealer for shipment to the builder. Short scrap pieces cut from the angles having one leg punched can be punched also along the other leg to conform to the punching in the plates and punched legs, and used as con-

necting angles, and for lattice bars. When used as connecting angles, they will afford a convenient manner of floor spacing at various heights and beam spacing, to within fractions of an inch.

The metal members will preferably have protective coatings applied thereto at the factory, before shipment to the place of installation, so that they can be assembled, without the necessity of the builder painting same. These protective coatings may be of tar, paint, galvanizing, or the like. This procedure greatly reduces the cost, as compared to present practice, in the way of design, shop fabrication, and field painting.

By employing the conveniently assemblable metal elements, as above-explained, they will, in many cases, replace wood, and therefore open a vast market, which has as yet been practically untouched by structural steel makers. The majority of buildings are of the smaller sizes requiring only a few tons of steel, but the cost of drawings, fabrication, etc., has heretofore rendered the cost of such steel per ton very high, as practically every building has different sizes and shapes of members entering into its construction, and the structural steel elements heretofore provided have not been of such form as to render them extensively useful in an economic manner when constructing buildings of the smaller sizes.

As to the non-metallic planks of fire-proof lumber, for use in connection with the steel frame of the buildings, they may conveniently and economically be manufactured at the steel plants by employing by-products or waste material such as granulated slag and cinders which combined with cement and water and metallic reinforcement, where necessary, constitute excellent fire-proof covers for the metal structure, and can also be utilized for outside walls, roofs, ceilings, floors, and partitions.

Granulated slag is an excellent building material, and when formed into concrete-like bodies has great strength and is of approximately only one-half the weight of ordinary sand and gravel concrete, and can be interiorly expanded by suitable gas-forming agents, in ways well-known in the art, in which case it will have but one-third the weight of ordinary concrete.

These planks can be made of two inch thickness, and will hold nails, and will not warp, or shrink. Also, due to their cellular structure, they are good thermal insulators, are sound-proof, sound-absorbing, and can be sawed like wood, as well as nailed together, or nailed to the steel framework.

The entire shell of the building can be built of

the metal shapes, and reinforced slag planks, all of them being products of the structural steel makers.

The reinforced slag planks can be retailed to dealers or sold direct, and handled like ordinary lumber. The market for the slag lumber will provide the steel makers with a profit instead of a loss on the slag, which has heretofore been discarded at considerable expense, and will, at the same time, provide better and cheaper buildings, such as houses, schools, etc. The planks are made in widths to match the depths of the angle and plate members. For example, where the angles have legs of 2 inch widths, planks of 2 inch thickness will be employed. The planks may be of various sizes and widths, such as 2" x 4", 2" x 6", 2" x 8", 2" x 10", 2" x 12", and may be cored to reduce their weight, without much loss of strength. Their lengths may correspond to the lengths of wood floors in lumber practice.

Most of the buildings in the United States are less than four stories, and have light live loads on their floors, and most of them use lumber, such as wood framing, studs and joists, and wood flooring, as well as wood walls in many cases. The buildings are, of course, subject to fire losses, and when dismantled have little salvage value. The use of light structural steel with fire-proof covering is an excellent and economical substitute for the wooden structures.

The sizes of the structural metal members are similar to lumber sizes, thus the channel-like members employed may be 2" x 4", 2" x 6", 2" x 8", 2" x 10", 2" x 12", 2" x 14", etc., and the sizes of the I-beam members may be 4" x 4", 4" x 6", 4" x 8", 4" x 10", 4" x 12", 4" x 14". The sizes of the reinforced fireproof planks may be of dimensions corresponding to the channel-like members, and the I-beam-like members.

Since the builder is accustomed to certain standard sizes of lumber for studding and joists, and my metal members can be readily assembled to like sizes, he will have no difficulty in assembling and erecting framing from these metal members, and the metal is of such greater strength that wider spacing can be had between the various members, such as girders, beams, and studding, than in the case of the usual practice in wooden buildings. A hand book would serve as a convenient guide to the builder in the matter of spacing and sizes of metallic members required. The reinforced slag planks 2 inches thick have sufficient strength to bridge over several feet of floor span.

An important advantage of the invention is the fact that there is a linear relation between the depth of the structural members made in accordance therewith, and their load carrying capacities. It thus becomes possible to calculate the capacity of a member of any depth, knowing the capacity of only one similar member. For example, if the capacity of a 12" I-beam for a given span is considered 100%, it is found that the capacity of an 11" beam is 90%, that of a 10" beam 80% and so on. The advantage of this feature to builders accustomed to handling lumber and not familiar with the extensive tables and complex formulas ordinarily encountered in steel construction is readily evident.

The small number of sizes and shapes required for the structural steel members would permit complete stock to be carried by dealers throughout the country, at a small investment, and permit the builders to promptly obtain the necessary

structural metal framing, and could from the same source procure reinforced fire-proof planks. The angles shipped in long lengths are easily sheared to lengths as required, and any slight extra punching needed could be done by the dealer or builder.

While I hereinafter describe and refer to the bolting of the metal members together, I contemplate that they may be riveted or welded, and that they may be made of either steel, iron, aluminum, or other materials, and contemplate also the use of web plates of various lengths and widths, including lengths having spaced holes punched along their longitudinal edges, and of sufficient length to permit them to be sheared into suitable smaller lengths.

Also, I contemplate the use of angles having legs of different widths, and the punching of holes of different sizes and relative spacing than those hereinafter described.

Some of the forms which my invention may take are shown in the accompanying drawings wherein Figure 1 is a side view of a structural member constructed according to my invention; Fig. 2 is a cross-sectional view thereof; Fig. 3 shows a modification of the structure of Fig. 2; Fig. 4 is a face view of a structural member similar to that of Fig. 2, but wherein the web plates are turned to upright position, to give the beam increased depth; Fig. 5 is a cross-sectional view thereof; Fig. 6 is a modification of the structure of Fig. 5; Fig. 7 is a side view of a structural member having web plates of dimensions different than the plates of Figs. 1 and 4; Fig. 8 is a cross-sectional view of said member; Fig. 9 shows a modification thereof; Fig. 10 is a side view of a structural member having the web plates as in Fig. 7 turned to a different position; Fig. 11 is a cross-sectional view thereof; Fig. 12 shows a modification of the structure of Fig. 11; Fig. 13 is a side view of the structural member having web plates of different dimensions than those of the above-named figures; Fig. 14 is a cross-sectional view thereof; Fig. 15 shows another modification.

Fig. 16 is a side view of a structural member using web plates as in Fig. 13, in a different position; Fig. 17 is a cross-sectional view thereof; Fig. 18 is a modification; Fig. 19 is an enlarged cross-sectional view of one of the angles employed in the structures heretofore referred to; Fig. 20 is a face view of said angle; Fig. 21, 22 and 23 show various of the web plates employed in Figs. 1 to 18; Figs. 24 and 25 are sectional and side views, respectively, of angles similar to those shown in Figs. 19 and 20, but having both flanges thereof punched or drilled; Figs. 26, 27, 28 and 29 show various modified forms of structural elements which may be formed from the angles and plates of Figs. 19 to 23.

Fig. 30 is an elevational view of a portion of a column and girder structure built from the elements of Figs. 1 to 25; Figs. 31 to 35 show various other structures embodying various elements of my invention; Fig. 36 shows a roof truss; Fig. 37 shows one of the structural elements embodied in the arrangement of Fig. 36; Figs. 38 and 39 show side and plan views of a column and girder structure; Fig. 40 is a sectional plan view of a modified form of column and girder structure; Figs. 41 and 42 are elevational views of still other forms of column and girder structures; Figs. 43 and 44 are side elevational views of other types of connections for column structures; Fig. 45 is a fragmentary elevational view

showing the assembly of a column composed of superimposed members of various widths.

Fig. 46 is an elevational view of a girder and floor joist, with the floor joist shown in section; Figs. 47 and 48 are elevational and cross-sectional views showing a column with a beam projecting therethrough, the beam being shown in section in Fig. 48; Fig. 49 is a side elevational view showing a column with a beam and a girder connected thereto, the beam being shown in section; Fig. 50 is a view of the structure of Fig. 49 with fire proof covering material applied thereto; Figs. 51 and 52 show structures employing modified forms of angles; Fig. 53 is a fragmentary face view of a plate which may be employed for forming the angles and the web plates; Fig. 54 shows one of the angles which may be formed by slitting and bending the plate of Fig. 53; Figs. 55 and 56 are face and edge views, respectively, showing the manner in which the plate of Fig. 53 may be punched and divided to form the web plates.

Figs. 57 to 60 are face views of column or girder members formed of rolled sections having openings in their webs for receiving beams and joists or other transverse structural members; Figs. 61 to 64 are cross-sectional views thereof; Figs. 65 to 68 show similar members, but of channel form instead of I-beam form; Figs. 69 and 70 are face and sectional views, respectively, of a transverse member which may extend through the openings of the webs in Figs. 57 to 60; Figs. 71 and 72 are face and sectional views, respectively, of still another form of transverse member which may be so employed; Figs. 73 and 74 are sectional views showing modifications of Figs. 70 and 72; Fig. 75 is a sectional plan view of a structure embodying various of the elements heretofore shown; Fig. 76 shows a manner in which column elements may be connected; Figs. 77 to 81 show modifications of the structures of Figs. 57 to 60.

Fig. 82 is a fragmentary view of a lattice column composed entirely of angles; Fig. 83 shows a column and girder composed entirely of angles; Fig. 84 is a view taken on the line 84—84 of Fig. 83; Fig. 85 shows a modification of the structures of Figs. 4 and 5, with nailing strips between the angles; Figs. 86, 87 and 88 show various ways in which fire-resisting covers or planks may be applied to the structural members; Figs. 89 and 90 are face and edge views, respectively, of one of the fastening members for the planks; Figs. 91 and 92 are face and edge views of a nail-like fastening element for the said planks.

Fig. 93 is a fragmentary sectional view of a completed structure with the fire-resisting covering in place; Figs. 94 to 97 show cross-sectional views of a completed column of diminishing width toward its top, taken at various elevations; Figs. 98, 99, 100 and 101 are views similar to Figs. 94 to 97, but showing modified forms of structural members encased in the fire-resisting covering; Figs. 102 to 107 show various arrangements of the structural members, with the fire-resisting covers connected thereto, and Fig. 108 shows the reinforcing mesh which is employed in the fire-resisting planks.

Referring first to Figs. 1 and 2, I show an I-beam built up of angles 2 and web plates 3; these figures showing the longer dimension of the plate 3, as extending parallel to the angles, and the angles secured to the web plates by means of suitable bolts 4. For beams of different depth,

the web plates 3 would be turned to a vertical position, as shown in Figs. 4 and 5, in which case the bolts 4 would, of course, be fastened through the holes near the ends of the plates 3. The web plates in both Figs. 1 and 4 can be placed in edge-to-edge abutting relation or spaced apart as shown in said figures.

When spaced apart as shown in Fig. 4 with the upper angles 2 in vertically-spaced relation to the lower angles, the spaces or openings as indicated at 6 can be utilized for receiving conduits or the like, as shown in Fig. 88, or for beams, girders and the like, as shown in Figs. 46, 48 and 49. The bolt holes in the plates may be $\frac{1}{2}$ inch in diameter, for example, and spaced $\frac{1}{2}$ inch apart so that the spacing will be 1 inch from center-to-center, and the holes in the angles 2 will be similarly formed and spaced. Employing $\frac{1}{2}$ inch holes in angles whose legs are 2 inches in width, the holes will be located midway in said legs, that is from the center of the hole to each edge of the leg, will be 1 inch, it being necessary to punch only one leg of each angle. The centers of the holes in the plates 3 are 1 inch from the adjacent edge of the plate, less $\frac{1}{8}$ "', which is one-half the thickness of the plate.

It will, of course, be understood that the holes can be of any desired size, but it is important that the spacing of the holes in the plates and their positions with respect to the edges of the plate correspond to the spacing of the holes in the angle legs, and the position of said holes with respect to the edges of the legs. This arrangement permits the plates to be readily assembled with the beams in either lengthwise or upright position, as shown in Figs. 1 and 4, with assurance that the holes in the plate will match with the holes in the angles, and that the edges of the plates will not project outwardly from the edges of the angles.

The center-to-center distances between the parallel rows of bolt holes in the plate 3, as indicated at A—B of Fig. 21, are multiples of the distances between the center of a hole and an edge of the angle 2, so that windows or openings formed in the beams of Figs. 7, 10 or 13, will be of such size as to receive and have proper fitting engagement with a smaller beam. For example, the beam of Fig. 1 could be slid into the windows or openings of Fig. 7, as indicated in Fig. 46, for example. Similarly, the beam of Fig. 4 could be slid into the windows or openings of Fig. 10, etc.

By this arrangement, the beam of Fig. 1, for example, if extended through a plurality of beams of Fig. 7, would have the advantages of continuous beam action. This arrangement results, of course, in simplified connections, and saving in material. The adjustability of the plates 3, lengthwise of the angles, permits the windows or openings to be made of any desired width, with closer engagement with the sides of a girder or similar member, as shown in Figs. 46 and 48, to thereby more firmly support the girder.

Another advantage of employing the plate which may be adjusted longitudinally of the beam permits of their being positioned at points where greatest stresses ordinarily occur, and also permits of economy, in that only a required number of plates need be employed with the angles. Furthermore, the use of the sliding adjustable plates is very advantageous in alterations and repairs, where it is desired to change the conduit lines or add other framing. Also, upon tear-

ing down of the building, the material can be fully salvaged.

The slidable plate has an advantage also when the beam is employed as a column for convenience in locating the floor levels at various desired heights. Also, the spacing of floor joists with respect to the supporting beams of Figs. 14 and 16, for example, can be readily varied either while constructing the building, or to effect changes after completion of the building.

The structures of Figs. 3, 6, 9, 12, 15 and 18 can be employed in substantially the same manner as the structures of the other figures, in cases where channel sections are sufficient.

The width of the plate 3a may be twice the width of the plate 3, and similarly the width of the plate 3b may be three times the width of the plate 3, it being understood, of course, that plates of various widths and lengths and also thickness, may be employed in accordance with the different depths of beams desired, but it is desirable, however, that the spacing of the holes in the plates be such as to match the holes in the beams within the angles with which they are to be employed, and that the spacing and number of holes bear a proper relation to the dimensions of the plates.

It will also be understood that the thickness of the metal employed in the angles may vary for greater loading-carrying capacity. That is, while I show angles 2 x 2 x 1/8 inches, and 1/8 inch plates, other thicknesses of plates and angles may be employed with the angles having the same width. This permits the continuation of built up members of different depths and load-carrying capacities and of equal depths, but different load-carrying capacities, to have the same width of flanges throughout. When thicker angles are used the plates may be drawn closer together or thicker plates used.

The web plate 3a of Fig. 22 is shown as incorporated in its two positions in the beams of Figs. 7 and 10, while the plate 3b of Fig. 23 is shown as incorporated in the beams of 13 and 16.

In the case of all of these web plates, the lengths and widths thereof are proportioned to the width or depth of the legs of the angles with which they are to be employed, the angles being of uniform size. In other words, the dimensions of each size of plates are multiples of the widths of the perforated angle legs with which they are to be employed.

Assuming that the plates 3, 3a and 3b are respectively 4 x 6 inches, 8 x 10 inches, and 12 x 14 inches (disregarding the 1/8 inch scant cutting thereof above-referred to), the shorter parallel rows of holes in each plate will be spaced apart (center-to-center) 4 inches, 8 inches and 12 inches, respectively, while the longer parallel rows of holes will be spaced apart 2 inches, 6 inches and 10 inches, in the respective plates. Therefore, the difference in length as between the short rows of holes and the long rows of holes in each case will be 2 inches, which is the width of the perforated legs of the angles. The difference in length between the shorter rows of holes of plates 3 and 3a, is 4 inches, which is twice the width of the perforated legs of the angles, and the same is true with respect to the plates 3a and 3b. Similarly, the difference in length between the longer rows of holes in plates 3 and 3a is equal to twice the width of the perforated legs of the angles, namely 4 inches. The same relation exists between the longer rows of holes in plates 3a and 3b.

This relation may be expressed mathematically by the equation:

$$d = \frac{2w}{n_2 - n_1}$$

where d is the center-to-center distance between adjacent holes, w is the width of the perforated angle flange, and n_1 and n_2 are the numbers of holes along corresponding edges of successive sizes of plates.

I may also make the plates of other sizes, such as 4" x 5", 6" x 7", etc., to produce beams of other depths, and such plates may be employed with the angles 2. One advantage of using the same size angles in building up the channels as are employed in building up the I-beams is that the channels and beams are frequently both employed in a building structure, and the beams and channels can match up in coordinate relation because they have angle legs of the same dimensions.

Calculations of the capacities of the structural members of my invention show that for a given span, the capacity of either type of member (i. e., either channel or I-beam) varies linearly with the depth. An I-beam 11" deep is found to have 90% of the capacity of a 12" beam while beams 10, 9 and 8" deep are found to have capacities 80, 70 and 60% of that of a 12" beam. By reason of this relation, it is very easy to arrive at the proper depth of beam for a given load, knowing the capacity of only one depth of beam. This means that it will only be necessary to furnish builders with a table of the capacity of, say, a 12" beam for various spans, since the capacities of beams of lesser depth can readily be calculated therefrom. The invention thus makes it possible for the first time in steel construction to avoid the use of complex formulas and extensive and abstruse tables in choosing the members for a particular structure.

The angle of Figs. 24 and 25 may conveniently be formed of scrap lengths of the angles 2, with the other leg of such angle perforated, to suit desired spacing. The angles 3 can be used as connecting members, as shown for example in Fig. 30.

Figs. 26, 27, 28 and 29 show standard shapes which may be fabricated by the use of angles 2 and plates 3.

Figs. 30 and 31 show a column and girder construction which may be formed of angles 2 and plates 3a and 3b. It will be seen that the girders and the column, individually, are constructed substantially as shown in Figs. 16 and 10. The column is formed of the angles 2 and plates 3a, but at the points of connection with the girders, a plate 3b is employed, and its vertical rows of holes extend beyond each side of the column, so that it may be connected to the ends of the plates 3b of the beams. Since in Fig. 30, the vertical angles 2 will ordinarily each have connection through only two holes of the plate 3b, I may punch additional holes for the reception of bolts 10 to give additional strength at such point, if required. The angle 8, with holes punched in both legs, is secured to the plate 3b, so that there may be connected thereto a beam extending at right angles to the girder.

A suitable number of cross beams or floor joists extending at right angles to the girder may be connected to the girder as indicated at 11, through holes in the angles corresponding to the angles 8.

Figs. 31 and 32 show a means whereby single

girders or beams may be connected to columns, through the medium of plates 3a and 3b.

Fig. 33 shows the manner in which angle brace members 12, which correspond to angles 2 are connected to a vertical angle 13, which may also be of the same form as the angle 2. The connecting plate of these angles may be the same as the plate 3.

Fig. 34 shows a column composed of angles such as the angles 2, placed closely together and combined with plate 3a in such manner as to permit of the connection of two beams or girders thereto, as in Fig. 30. The relationship between the hole spacing in the plate 3a and the angle width permits abutting engagement between the angles, which results in increased rigidity for the column.

Fig. 35 shows a beam and girder construction wherein the beam and girders are of the same vertical depth. The girder 14 may be composed of plates 3b and angles 2, and the girders 15 may similarly be formed, the connections between the ends of the girders and the beam being effected by a plate 16 which may be formed somewhat after the manner of 3a or 3b. The plate 16 is of such vertical dimension that it will lie between the angles that enter into the construction of the beam and the girders.

Fig. 36 shows a roof truss structure with horizontal members 17 and diagonal members 18 which may be composed of angles similar to the angle 2, and are connected by a gusset plate 19 to a vertical column 20. The plate 19 may be formed from a plate such as 3a, by cutting the same along a diagonal line, as indicated in Fig. 37, and additional holes punched therein through which certain of the attaching bolts extend.

Figs. 38 and 39 show plan and elevational views of column and girder construction, the girder being composed of pairs of angles 21 and 22 and plates 23, the two beams of each girder being constructed as shown in Figs. 10 and 11, for example. The column is composed of two structural elements 24 and 25, each being made according to Fig. 9. The column elements 24 and 25 are secured together by suitable bolts passing through pipe spacers 26, the bolts extending through the projecting web plates 23 at the points of girder connection.

In Fig. 40, I have shown a structure wherein a modified arrangement of column is employed for supporting girders such as the girders of Fig. 39. In this arrangement, the column is composed of structural elements 27 and 28, as shown in Fig. 8, for example, and secured together by short angles 29 which may correspond to the angle 3, the angles in turn being connected together by a plate, such as the plate 3.

Fig. 41 shows a modified form of girder and column connection employing connecting angles 30 and 31, corresponding to the angles 8. The legs of these angles are respectively connected to the column angles and the girder plates. A plate 32 which may be similar to the plate 3b is connected at its vertical edges to the girders, and therefore serves also to tie the column angles together.

Fig. 42 shows the manner in which two superimposed column members 33 and 34 are connected, such connection being effected by a plate 35 which may correspond to plate 3a.

Figs. 43 and 44 show connections between column sections of reduced width. Obviously, as the top of the building is approached, the columns need not be of so great dimension as at lower

levels. Therefore, upper sections of the column can be reduced in width, by positioning the angles of the upper column section between the angles of the lower column section, and joining them as by plates 3b and 3a, it being desirable in some cases, of course, to punch additional holes for the bolts that pass through the intermediate angles.

The spacing of the holes in the plates is equal to one-half the width of the angles, as above-explained is important, for the further reason that it will insure abutting engagement between lower angles and an associated upper angle, thus adding rigidity to the structure. Further, in Fig. 44, the advantages and importance of having the distance between the parallel rows of holes of the plate 3a a multiple of the dimensions of the angle legs is emphasized because it permits the upper angles to have abutting engagement with one another, as well as abutting engagement with the other angles.

In Fig. 45, I show a modification of the structure of Figs. 43 and 44, in that the reduction in width between the superimposed column sections is not so great. For example, if the difference between each lower and the adjacent upper section of Figs. 43 and 44 is 4 inches, the difference in width between the adjacent upper and lower sections of Fig. 45 is 2 inches.

In Fig. 45, the upper vertical angles can therefore not lie between the adjacent ends of lower vertical angles. For this reason, I provide angle bars 50 which correspond to the angle bars 8, to afford additional vertical support for the sections.

Figs. 46, 47, 48 and 49 show a girder and beam arrangement that may be constructed from the elements such as shown in Figs. 1 to 17, and which are for the purpose of showing some of the advantages of having the web plates adjustable longitudinally of their angles, and also show the necessity for the definite dimensional relationship between the depth of the beams and the heights of the openings in the web which results from the hole spacing in the plates and the angle width.

For example in Fig. 46, the beam 51 is shown as closely embraced by the web plates 52 and the upper and lower angles, the plates 52, of course, being adjustable longitudinally of the girder. Similarly in Fig. 48, the beam 53 is in abutting engagement with the web plates and angles.

Fig. 50 shows a steel framing as heretofore described covered by reinforced fireproof planks 55, the details of which will be hereinafter explained. The columns are covered by the planks which extend from the floor to the ceiling, one on each of the four sides of the column, and are nailed together.

In Fig. 51, I show a structure employing angles 56, which may be of the same leg length as the angle 2, but having one of the legs thickened, and the thin leg perforated for the attaching bolt. The thickening of one leg gives the angle greater strength to compensate for the weakness caused by the holes in the thin leg thereof.

In Fig. 52, the angles 57 each have one of their legs of greater width than the other—such as a 2" x 4" angle. The wider leg gives the angle greater strength, and will in some cases permit the use of a single angle instead of two angles, thereby compensating for the weakness caused by two rows of holes on two angles.

Figs. 53 to 56 show the manner in which plates and angles may be conveniently formed from metal sheets, certain of the sheets being perforated, as desired. The manufacturer could supply the plates in long lengths and 12 inches wide

and having the spaced holes along both the longitudinal edges, and the dealer could then shear the strip or plate to the desired measurement to suit the depth of members. In many cases, the addition of transversely-extending rows of holes will not be necessary. This would make all plates of one length and only two holes would be available in each angle for connection purposes. This is sufficient in the majority of cases.

Figs. 57 to 74 show standard rolled shapes, certain ones of which have punched windows or openings in their webs which openings may correspond to the openings formed by the spacing of the web plates, which correspond to the widths and depths of the other members of the series. For example, the windows or openings in Fig. 57 are adapted to receive the structural member 60, as of the shape shown in Fig. 70.

In Fig. 58, the openings may be provided for receiving a shape such as the element 61, as in Fig. 72, for example. Fig. 59 can receive elements 62 and 63, as shown in Figs. 63 and 67, for example.

In Fig. 75, I show a column and beam structure wherein the beam 64 may be constructed as in Fig. 59, for example, and is connected to column members 65, by means of angles 66. The inner legs of the angles 66 are bolted to the web of the beam and the outer legs thereof are bolted to the column webs.

Fig. 76 shows the manner in which brace members 67 and 68 may be connected to latticed column elements. The column elements may suitably consist of two structural elements such as in Fig. 59.

The structure in Fig. 77 is somewhat similar to that of Fig. 6 or 9, but shows a continuous web plate, instead of the series of web plates, the continuous web plate having window openings cut therethrough, similar to the openings in the web of Fig. 57.

Fig. 78 is a modification of Fig. 77, but showing welded flanges 70 and 71.

Figs. 79, 80 and 81 show various ways in which the flanges may be formed on plates by bending the edges thereof and welding the horizontal edges to the web, as indicated at 73, for example, adjacent to their fillets. This also provides a bond to the middle of the flange.

Figs. 82, 83 and 84 show structures composed of angle bars such as the angle 2. For example, up-rights 80, connecting angles 82 and lattice bars 83 may all be formed substantially as shown in Figs. 19 and 20, they being, of course, cut to suitable lengths and bolted together. The beams and joists can be connected to the columns by angle bars 84, which correspond to the bars 8.

Fig. 85 shows a beam constructed of the plates 85 and angles 86, which correspond to the angles 2 and the plates 3a, for example, the plates 85 at opposite sides of the angles being offset relative to one another in directions longitudinally of the beam, so as to permit the insertion of a continuous nailing strip 87 of wood, or other suitable material, the plates 85 being placed at both sides of the beam so as to give the structure a better balanced strength.

Figs. 86 and 87 show the manner in which the covering plank may be secured to the structural work. These planks are of nailable material, such as concrete-like slag or cinder compositions. Fig. 86 shows the manner in which the planks are secured to an intermediate joist 90, where the planks are long enough to bridge several joists, as in Fig. 93, and Fig. 87 shows the manner in

which the ends of the planks are secured to beams 91, as shown also in Fig. 93. The planks are shown as secured to the beam 90 by means of nails 92 which are deformed near their inner ends, as shown more clearly in Figs. 91 and 92. The widened portion 92a of the nail has a fulcrum-like engagement with the corner of the beam so that when the inner end of the nail is bent, the head of the nail will be drawn more firmly against the exposed face of the plank.

In Fig. 87, the planks are held in place by a metal clip 93 formed as shown in Figs. 89 and 90, said clip being clamped between the angle bars and having its upper ends turned over to receive the ends of the plank, nails being driven through said ends to hold them snugly against the planks.

In Fig. 88, I show a floor joist and a girder constructed substantially as shown in Fig. 35, but with the fire-proof plank applied thereto, and conduits 94 extending into the windows or openings in the webs of the floor joists and the girder. These conduits can be extended up the columns between the fire-proof plank and the structural work. In this Fig. 88, I have shown a continuous flat ceiling, because the depths of the girder and the depths of the floor joists are the same. The vertically-extending abutting planks can therefore be moved to any point along the floor and ceiling without cutting. The arrangement shown in Fig. 88 also permits the location of the conduits as described, eliminating the present practice of disposing of the conduits in a concrete fill disposed on top of the floor. The vertically-extending planks with their edges abutting when used as partitions could be secured at their ends to the ceiling and the floor.

As shown in Figs. 94 to 101, which represent the cross-sectional views of columns and their fire-proof plank coverings, I illustrate the manner in which the thicknesses and widths of the planks are proportioned to the dimensions of the structural members. For example, in Fig. 94, the wider planks 95 are of a width substantially equal to the width of the column, while the planks 96 are equal to the width of the column in the other direction, plus the thickness of the planks 95. In the case of Figs. 100 and 101, the planks 97 are each equal to a width of the beam, plus the thickness of one of the other planks.

Figs. 102 to 106 show arrangements illustrating the thicknesses of the planks relative to the dimensions of the angles, thus in Fig. 102, which shows a structural column composed of two pairs of angles each intermediate plank 98 is of a thickness corresponding to the depth of the angle, as in Figs. 1 and 2. A fire-proof covering plank 99 is secured by nails to the column. Fig. 103 shows the relation of the fire-proof plank to a post such as in Fig. 27, while Fig. 104 shows two pair of angles assembled to form channels 100, for receiving the ends of the fire-proof planks.

Fig. 105 shows the planks assembled with a post 101 constructed as in Fig. 29. In Fig. 106, I show a column 102 constructed as in Fig. 5, provided with openings as shown at 6 in Fig. 4, through which openings intermediate planks 103 may pass, certain portions of said planks being cut away at the web plates 3, and other planks extending full length through the openings. Facing planks 104 are supported by the angles of the column 102.

In Fig. 107, I show angle posts 105 formed of angles 2, with fire-proof planks positioned between and against the sides thereof. Here again

is shown the necessity of having the planks of proper thickness relative to the dimensions of the structural members. For example, the intermediate plank is of a thickness equal to the depth or width of the angle post, so that the facing planks can lie against the intermediate planks, as well as against the angles.

The planks of Fig. 107 are reinforced by wire fabric such as that shown in Fig. 108, the fabric being incorporated in the plank in such position that openings through the mesh will be in alignment with the bolt holes of the angle posts. The mesh, whether employed in connection with the planks of Fig. 107, or with the planks of other figures is so positioned in the plank that the mesh openings will be at such predetermined locations in the plank as to permit of the insertion of the various attaching bolts.

I claim as my invention:—

1. A structural system comprising metal framing having interconnected members of different widths, each embodying spaced angles having perforated legs connected by web plates which have rows of holes adjacent to their edges, matching the holes in adjacent angle legs which are of uniform width, the center-to-center spacing of the holes being equal to twice the width of the perforated angle legs, divided by the difference between the number of holes in a row of holes in the plates of a wider member and the number of holes in a corresponding row of holes in the plates of a narrower member.

2. A series of structural metal members of different depths comprising spaced flange angles and rectangular web plates, a leg of each angle having spaced holes matching parallel rows of spaced holes adjacent the edges of said web plates, the width of the free legs of the angles, the distance from the center lines of the holes in the angles to the corners of said angles; the distance from the center lines of the rows of holes on the plates to the edges of the plates, and the difference in the depth of the members, all being substantially integral multiples of the center-to-center spacing of said holes.

3. A series of structural members each including spaced chord members connected by spaced rectangular web plates, the chord members including angles with holes spaced uniformly along one flange thereof, said plates having similarly spaced holes along all their edges matching those in the angles, the web plates being disposed with their short dimension perpendicular to the chord members in one structural member and with their long dimension perpendicular to the chord members in another, to provide a series of structural members of different depths.

4. A structural member comprising a pair of spaced angles both having one flange in a common plane, said flanges having holes spaced uniformly therealong, and rectangular web plates with holes similarly spaced along all their edges, extending between the angles, the holes in the edges of the plates which lap the flanges being aligned with the holes in the flanges, and fasteners extending through said aligned holes, whereby members of different depths may be provided with the same web plates depending on whether they are positioned with their longer or shorter dimension perpendicular to the length of the member.

5. A series of structural members each comprising spaced chord members connected by spaced web plates, the chord members and the edges of the plates having uniformly spaced

holes, the spacing of the holes, d , being obtained from the formula:

$$d = \frac{2w}{n_2 - n_1}$$

wherein w is the dimension of a chord member perpendicular to its length and parallel to the web plates, and n_1 and n_2 are the numbers of holes along corresponding edges of successive sizes of web plates.

6. The series defined by claim 3, characterized by the spacing between the centers of adjacent holes in said plates and angles being substantially equal to the distance from the center of a hole in an angle flange to the edge of the flange:

7. The series defined by claim 3, characterized by the spacing between the centers of adjacent holes in said plates and angles being an integral factor of the distance between the center of a hole in an angle flange and the vertex of the angle.

8. A metal structural member comprising a pair of spaced angles forming chord members, rectangular web plates connecting said angles, the plate edges lapping a leg of each angle, the leg of each angle lapped by the plates having holes spaced therealong, all of the edges of the plates having holes so spaced therealong that the holes in any edge of the plates align with holes in the angle legs when that edge laps an angle leg whereby the plates and angles may be bolted together, the distance between the center lines of the rows of holes adjacent a pair of opposite edges of said plates and the distance between the center lines of the rows of holes adjacent the other pair of opposite edges of said plates being integral multiples of the center-to-center distance between adjacent holes in the angle legs.

9. A metal structural member comprising a pair of spaced angles forming chord members, rectangular web plates connecting said angles, the plate edges lapping a leg of each angle, the leg of each angle lapped by the plates having holes spaced therealong, all the edges of the plates having similarly spaced holes therealong whereby the plates and angles may be bolted together, the width of each of said legs of said angles being an integral multiple of the distance between adjacent holes.

10. A metal structural member comprising a pair of spaced angles forming chord members, rectangular web plates connecting said angles, the plate edges lapping a leg of each angle, the leg of each angle lapped by the plates having holes spaced therealong, the edges of the plates having similarly spaced holes therealong whereby the plates and angles may be bolted together, the center lines of the holes in the plate and the holes in said angle legs being spaced inwardly of the edges thereof by a distance substantially equal to that between center lines of adjacent holes.

11. A structural system including angle units and plate units, the angle units comprising angle bars having holes in one leg spaced apart uniformly on a common center line along the entire length thereof, the plate units comprising rectangular pieces of flat stock having holes on center lines adjacent each edge, said last-mentioned holes being spaced apart by the same distance as the holes in the angle units, the center lines adjacent both pairs of opposite edges of said plates being spaced apart by integral multiples of the center-to-center spacing between adjacent holes in the angle units, said angle units and plate units being adapted to be assembled with

their holes in alinement for receiving fasteners to provide different types and sizes of structural members.

12. A structural steel system comprising angle units and plate units, the angle units having a leg which is generally imperforate, and a perforated leg having a series of holes therein, which holes are equally spaced from center-to-center, the plate units being generally rectangular and having a series of holes therein along the sides and ends thereof and substantially parallel thereto, which holes are equally spaced from center-to-center, the spacing of the last-mentioned holes being the same as the spacing of the holes in the angle units, the angle units and the plate units being adapted to be secured to one another by fastening members extending through aligned holes in different units, in such fashion that the generally imperforate legs of the angle units form flanges for a structural member and the perforated legs and the plate units form a web therefor, the center line of the holes in the perforated legs of the angle units being so spaced from the vertices of said units and the width of the imperforate legs of the angle units being such that the cross-sectional dimensions of the assembled structural member correspond approximately to a standard lumber size.

13. A structural system comprising flange members adapted to be disposed in spaced parallel relation, and web plates spaced apart along said members and secured thereto to connect them, holes spaced uniformly along all edges of said plates, holes similarly spaced along said members whereby fasteners may be inserted

through aligned holes in the plates and members, the center lines of all the edge rows of holes in said plates being spaced apart by distances which are integral multiples of the center-to-center spacing of the holes in said members.

14. A structural system comprising flange members adapted to be disposed in spaced parallel relation, and web plates of different sizes, the plates of each size being adapted to be spaced apart along said members and secured thereto to connect them, holes spaced uniformly along all edges of said plates, holes similarly spaced along said members whereby fasteners may be inserted through aligned holes in the plates and members, the spacing between center lines of corresponding edge rows of holes in the different sized plates differing by an integral multiple of the center-to-center spacing between adjacent holes in said members.

15. A series of composite structural members, each including spaced flange units and web plates secured thereto in spaced relation along said members, the flange units having holes spaced uniformly therealong, the web plates being substantially rectangular and having similarly spaced holes along all edges thereof, whereby said members may be readily assembled to form composite members of different depths, the flange units of different members being substantially identical, the web plates having different depths, and the safe load-carrying capacity of the several members for a given span varying substantially linearly with the depth of the member.

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