Oct. 25, 1955 E. O. WILLIAMS 2,721,630

BUILDING CONSTRUCTION

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Fig. 1.

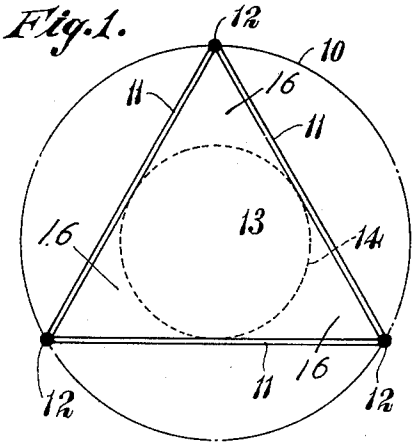


Fig. 3.

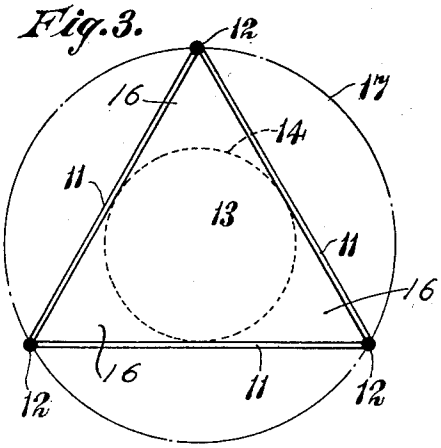


Fig. 2.

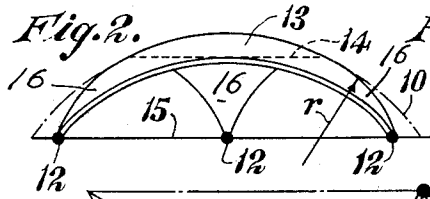


Fig. 4.

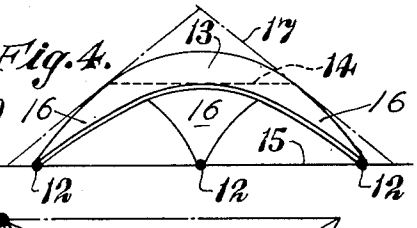


Fig. 5.

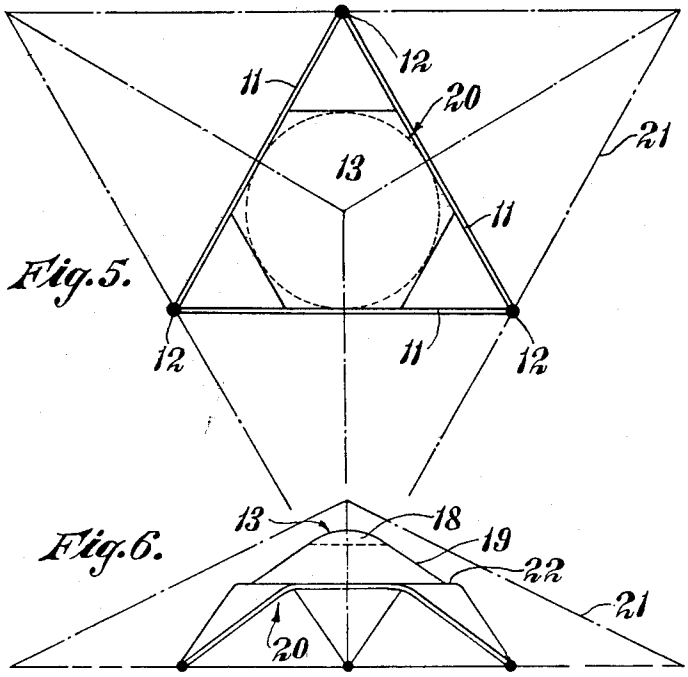


Fig. 6.

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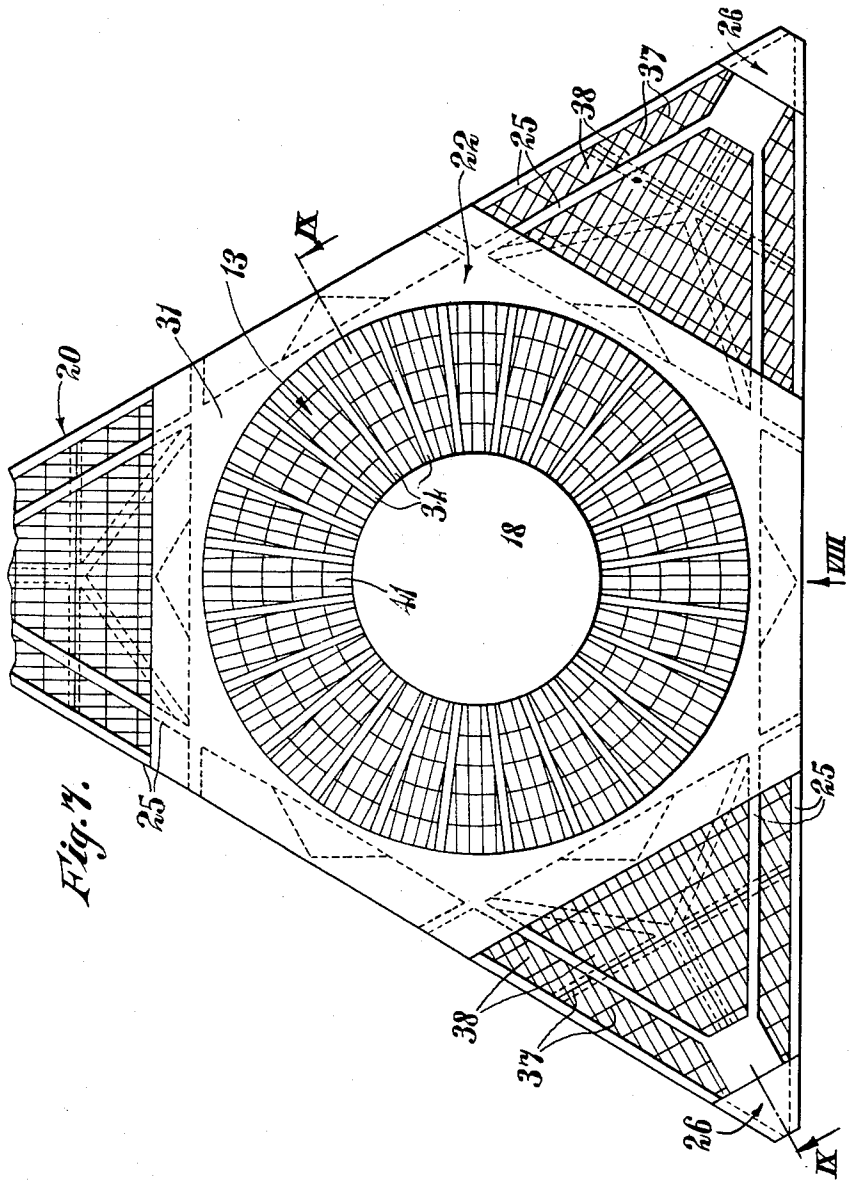


Fig. 7.

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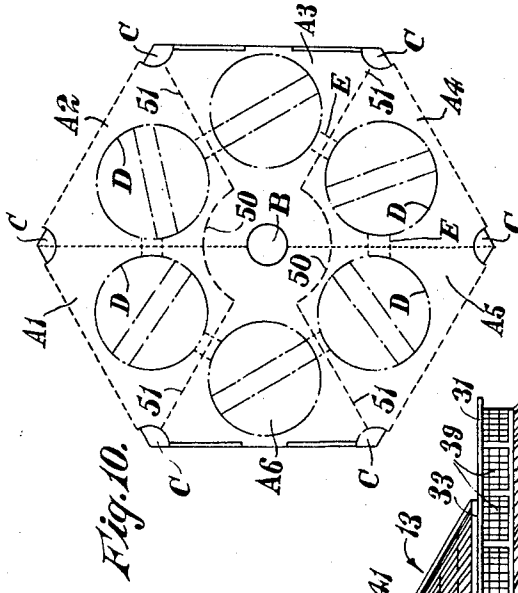


Fig. 10.

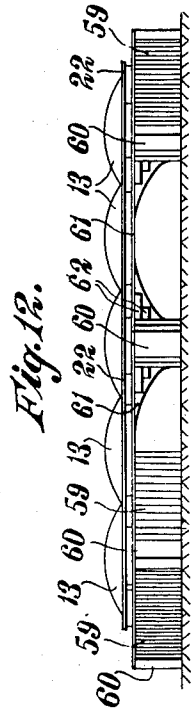


Fig. 12.

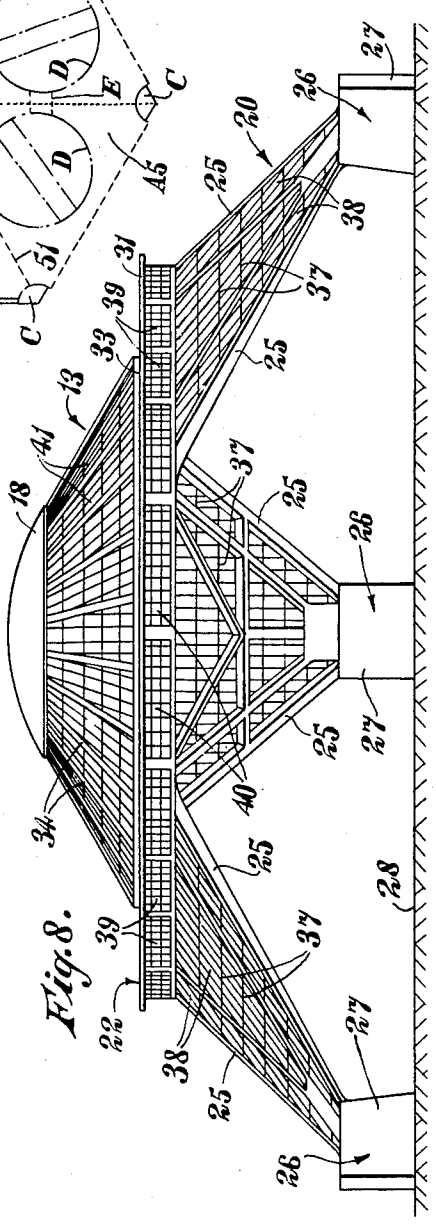


Fig. 8.

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Fig. 9.

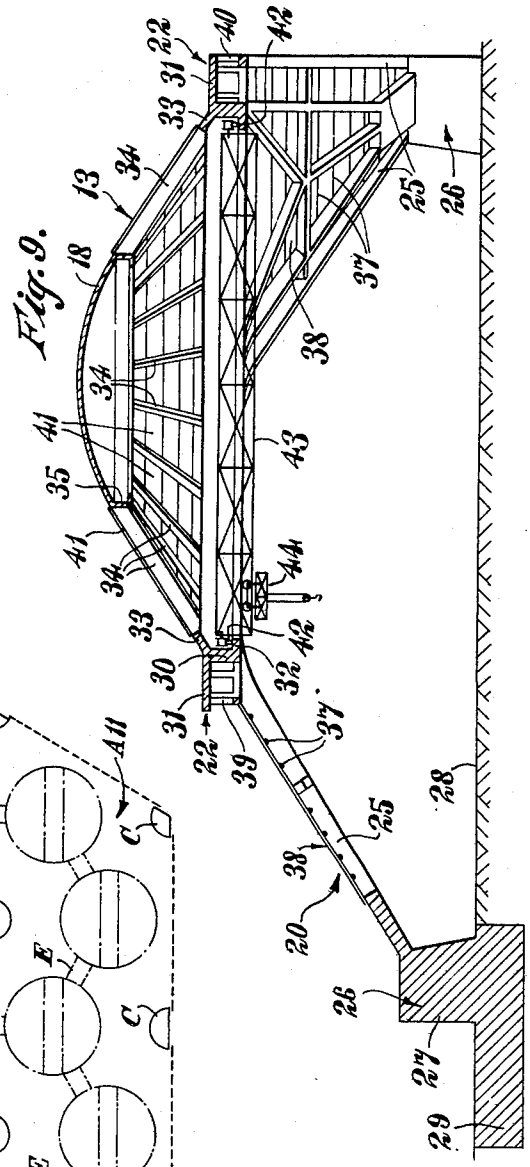
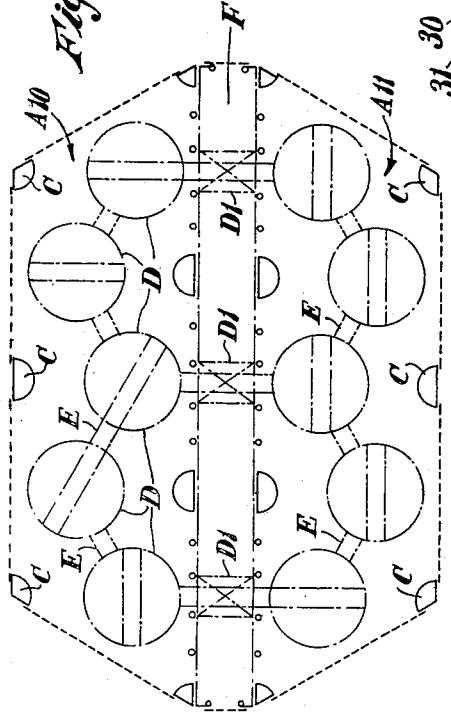


Fig. 11.



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Fig. 13.

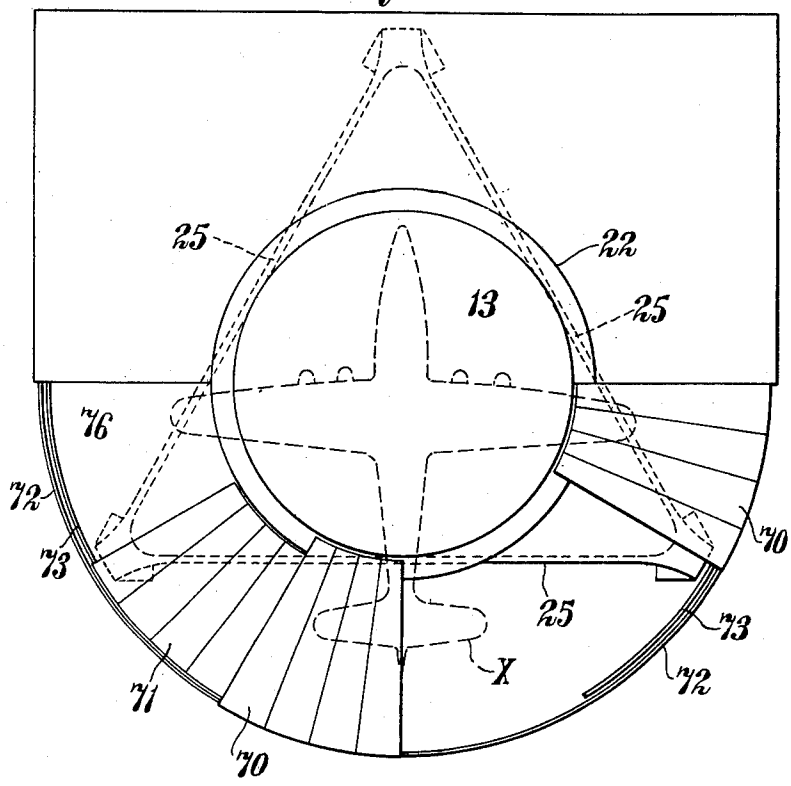
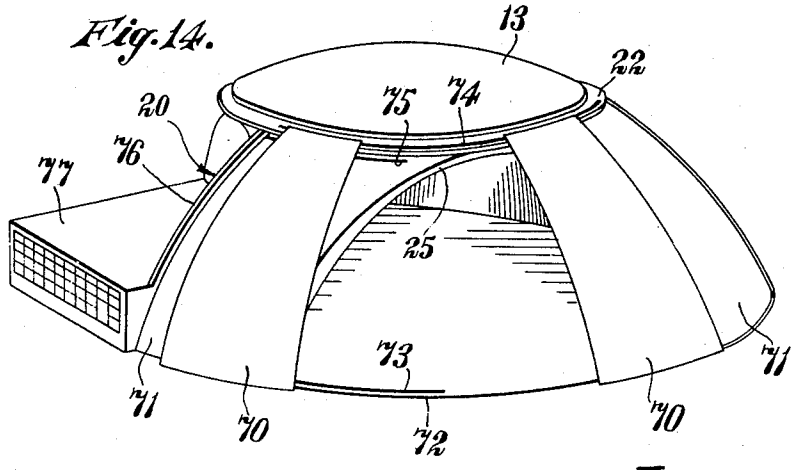


Fig. 14.



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United States Patent Office 2,721,630 Patented Oct. 25, 1955

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BUILDING CONSTRUCTION

Evan Owen Williams, London, England

Application October 14, 1949, Serial No. 121,266

Claims priority, application Great Britain October 25, 1948

3 Claims. (Cl. 189—1.5)

This invention relates to the construction of airplane hangars, assembly sheds and other like buildings of extensive and unobstructed floor area and volume.

The conventional form of construction of such buildings, i. e. rectangular in plan and rectangular in cross-section, while reasonably satisfactory in the smaller sizes becomes increasingly uneconomical as the size and volume is increased. In connection with airplane hangars, for example, the progressive increase in both width and height necessary to accommodate the enhanced size of modern aircraft has imposed problems of increasing difficulty regarding inherent strength and stability while the cost has become comparable with and may even exceed that of the aircraft themselves.

Hitherto some attempt has been made in the larger type of hangar to provide the headroom which is required only at the centre by the use of arched roofs but always retaining the rectangular plan. A study of the shape, in plan, of aircraft indicates that a rectangule is not necessarily the most suitable figure for economically covering the craft many of which have an enveloping plan resembling that of a triangle with one side, that of the forward end of the craft, rounded out; other crafts having an enveloping plan which more nearly resembles that of a rhombus. Much of the covered space in a building of rectangular plan is therefore, in such a hangar application, wasted for its primary purpose of covering the craft. Furthermore in a building of rectangular plan and the resultant provision of at least four spaced points of ground anchorage and support, the problem of the stresses set up by unpredictable loading due to uneven ground settlement becomes increasingly acute and difficult of economical solution as the size is increased.

The object of this invention is to provide a more economical construction for buildings of the types referred to and, in the case of airplane hangars, better suited to the shape in plan and in elevation of modern aircraft.

In accordance with the broadest aspect of the invention a building or a unit portion thereof has the form of a dome-shaped upper shell whose lower peripheral edge is supported upon a structure of arches springing from three spaced ground anchorage points. In a preferred form the three ground anchorage points form the corners of an equilateral triangle whereby, if desired, a building of extended floor area may be formed by arranging a plurality of similar units in nested location each with its own domed upper shell.

The dome-shaped shell may be formed as a part-hemisphere or, particularly where glazing thereof is required, as a shallow truncated three-sided pyramid completed at its apical region by a part-hemisphere forming a smooth upward continuation of the pyramid.

The lower arched structure for the upper dome is, of course, covered in between the arched supporting members and the resultant outward form may be that of a segment of a hemisphere from which portions have been removed by cuts upon three vertical planes forming between them a triangle, or alternatively the outward form may resemble a cone frustum from which portions have similarly been removed by cuts on three vertical planes. In a further modification, particularly adapted to the provision of glazing over part of the wall area of such arched structure, the outward form is one of a triangular pyramid from which portions have been removed in vertical planes lying at right angles to the lines joining the corners and the centre of the base area of the pyramid.

The construction of the domed-shaped upper shell and the lower arched structure may be carried out in any suitable materials, for example, in steel framing with sheet metal or sheet asbestos covering but more preferably the construction according to the invention is carried out in reinforced concrete. The arched supporting members of the lower arched structure constitute the major strength providing elements of the building, the upper dome-shaped shell and any areas between the arched supporting members being designed more with a view to providing the requisite coverage than of providing strength to the structure.

In order that the various features of the invention may be more readily understood a number of examples will now be described with reference to the accompanying drawings, in which,

Figs. 1 and 2 are purely diagrammatic plan and elevational views respectively illustrating the basic features of one embodiment of the invention.

Figs. 3 and 4 are further diagrammatic views, similar to Figs. 1 and 2, illustrating another embodiment of the invention.

Figs. 5 and 6 are still further diagrammatic views, again similar to Figs. 1 and 2, illustrating a further embodiment.

Fig. 7 is a plan view, partly in section, showing one practical application of the invention to the construction of an airplane hangar.

Fig. 8 is a side elevation looking in the direction of the arrow VIII of Fig. 7.

Fig. 9 is a vertical sectional view taken on the line IX—IX of Fig. 7.

Fig. 10 is a plan view showing one simple arrangement of a multiplicity of units according to the invention for the construction of a building of extended area.

Figs. 11 and 12 are plan and elevational views respectively of an extended building, for instance, a hanger of very large area and accompanying workshops utilising a plurality of units according to the invention, while

Fig. 13 is a plan view and Fig. 14 is a perspective view of another application of the invention to an airplane hangar construction.

Referring first to Figs. 1 and 2, the form of structure there shown consists of a part-hemisphere **10** of radius *r* from which three portions have been cut in vertical planes along the lines **11** which jointly form an equilateral triangle between the three points **12** spaced around the periphery of the base area of the original part-hemisphere **10**. The height of the part-hemisphere is conveniently of the order of one quarter of its base diameter.

By virtue of the removal of these three portions there remains an unmutilated dome-shaped shell portion **13** whose periphery is indicated by the dotted line **14** and this is supported at an elevated position above the level of the base plane **15** of the part-hemisphere **10** by the lower arched structure **16** which is characterised by the three arched supporting members, shown in double lines, formed at the cutting planes of the lines **11**.

The points **12**, hereinafter referred to as "ground anchorage points," lying at the corners of the triangle constitute the sole supporting and connection points be-

tween the structure and the ground and in consequence thereof there will be no unpredictable stresses on the arched supporting members on the upper shell should settlement of one corner be greater than that of another. The arched supporting members **11** are inherently strong and constitute the principal weight supporting elements while the inherent strength of the domed shell formation is highly suited to the resisting of loads such as may occur with snow or wind at one side more than on another.

Figs. 3 and 4 show a similar but alternative arrangement in which the upper dome-shaped shell **13** of part-hemispherical form its retained but is supported at elevated position upon a lower arched structure **16** which, instead of being generated from a part-hemispherical shell as in Figs. 1 and 2, is derived from a part-conical shell **17**. This arched structure **16** is generated from a cone frustum lying between the planes **14** and **15** and from which three portions have been removed by cuts in vertical planes along the lines **11** again to provide an equilateral triangle shape in plan between the three ground anchorage points **12**.

The dimension and inclination of the cone frustum **17** is such, with relation to the domed shell **13** completing the coverage thereof, that there is a smooth continuation from one to the other at the junction region in the plane **14**. In this instance the lower arched structure **16** is again characterised by three arched supporting members defining the apertures in the cutting planes **11** and as shown in double lines.

In the further embodiment illustrated in Figures 5 and 6 the upper domed-shaped shell **13** is not truly a part-hemisphere but is a combination of an upper part-hemispherical section **18** merging smoothly into a cone frustum **19**. This domed shell **13** is supported at its elevated position upon a lower arched structure **20** which is derived from a triangular pyramid **21** whose initial shape is shown in chain-dotted lines and from which portions have been cut in the three vertical planes corresponding to the lines **11** which each lie at right-angles to the lines joining the original base corners of the pyramid to the centre of its base area. The latter is coincidental with the vertical axis through the centre of the upper dome-shaped shell **13**. The resultant form of the lower supporting structure **20** is shown in full lines and again comprises the three main arched supporting members **11** extending between the three equi-spaced ground anchorage points **12** which lie at the corners of an equilateral triangle. Such supporting structure presents at the regions between the downwardly convergent arched supporting members **11**, areas which are of planar form eminently suitable for the application of glazing as a means of effecting both coverage and light transmission to the interior.

In this last embodiment, by virtue of the hexagonal perimeter of the upper terminating surface of the lower structure **20** and the circular perimeter of the lower edge of the upper dome-shaped shell **13**, there is necessarily provided a platform disposed in a horizontal plane at the junction region **14** in order to combine the two upper and lower structure portions **13** and **20**. This platform is not disadvantageous and has, in fact, been found most advantageous in that it may be formed as a ring hereinafter termed a "shoulder slab" **22** which can be given a high mechanical strength and which, by virtue of its association with the bottom edge of the upper dome-shaped shell **13** can be used to enhance the strength of the latter in its ability to resist any displacement or spreading forces due to unequal loading such as may be caused by wind pressure on one side or the deposition of snow of unequal depth at various points thereof. In this way the dome-shaped shell **13** itself may be made of much lighter construction with consequent saving of weight of materials and cost.

The provision of such shoulder slab **22**, which is a feature of the present invention, may also advantageously be made in the previous embodiments of Figs. 1 and 2 and Figs. 3 and 4 where its application merely involves the provision thereof at the junction plane **14** between the upper shell **13** and the lower arched structure. Such provision may be accompanied by a difference of diameter between the bottom periphery of the upper domed-shaped shell **13** and the periphery of the circular or other shaped upper plane of the arched structure.

In order to illustrate in greater detail how the basic conception already outlined in connection with the previous Figs. 1 to 6 may be put to practical application in the construction of, for instance, an airplane hangar, one practical form of such hangar will now be described in some detail with reference to Figs. 7, 8 and 9.

Referring to these figures the building consists essentially of a lower arched structure **20**, which is of the form derived from a triangular pyramid in the manner already referred to in connection with Figs. 5 and 6, and an upper part-conical/part-spherical dome-shaped shell **13** which is supported at the elevated level determined by the upper edge of the lower arched structure **20**, the interconnection of the upper and lower parts being effected through the intermediary of a shoulder slab **22**.

The lower arched structure **20** consists essentially of three main arched supporting members **25** of reinforced ferro-concrete girder construction arranged along the sides of an equilateral triangle and having their lower ends united with and supported at the ground anchorage points by the anchor blocks **26**. These anchor blocks **26** (Fig. 9) have an upper part **27** projecting above the ground level **28** and a lower foundation **29** which is buried in the usual manner in the supporting ground. The lower ends of the arched supporting members **25** connect with said anchor blocks **26** near their uppermost end so as to provide the maximum effective headroom even at the three lower corners of the lower structure **20**.

The central regions of each of the main arched supporting members **25** combine with the shoulder slab **22** which takes the form of an unbroken ring having a vertical circular rib **30** and a horizontal web **31** projecting outwardly therefrom. The rib **30** of the ring is provided with an inwardly directed flange **32** around its lower edge while at its upper end it is combined with an upwardly and inwardly inclined flange **33** which forms a support for the lower ends of a plurality of pre-cast concrete beams **34** of V-section which, at their upper ends, rest upon and are secured to a dependent circular flange **35** formed at the lower circular periphery of the dome-shaped shell portion **18** which is of thin reinforced concrete construction.

The areas between the pair of arched supporting members **25** converging on to the anchor blocks **26** are of planar form and carry transverse horizontal bearers **37** at suitably spaced intervals between which are arranged suitable glazing panels **38** in any convenient and known constructional manner. The upper limit of these glazing panels is conveniently made substantially coincidental with the plane of the bottom level of the vertical rib **30** of the shoulder slab **22** and the vertical space between such termination level and the underside of the projecting horizontal platform portion **31** is again filled with suitable glazing **39**. The platform **31** is arranged slightly to overhang such vertical glazing **39**. The vertical glazing **39**, which constitute three of the six sides of the hexagonal shape of the upper limit of the lower arched structure **20** are repeated by further similar vertical glazed portions **40** overlying the centre of the three arched openings.

The spaces between the plurality of converging concrete beams **34** of the upper domed-shaped shell are again filled in with glazing **41** supported in any convenient and known manner in between said beams. If, as is usually the case, flat glazing is employed then the lower portion of this upper domed-shaped shell **13** becomes more correctly a part of a multi-sided pyramid instead of a cone frustum but such shape is intended to be included in the

general frusto-conical form which it closely resembles. The relative dimensions of the glazed and unglazed portions of the upper domed-shaped shell are conveniently between 1:1 and 2:2, the relative expense and weight being roughly equal for any ratio between these two limits, while the light transmission is similarly substantially unaffected due to the permissible decrease in width and number of the beams **34** with the smaller glazing dimension.

The inwardly directed flange **32** at the lower end of the vertical circular rib **30** of the shoulder slab **22** forms a convenient support for a circular track rail **42** carrying thereon a rotatable crane gantry **43** on which is mounted the usual traversable hoisting mechanism **44**. By virtue of the rotatability of this gantry and the traversability of the hoisting mechanism **44**, anywhere within the projected area of the shoulder slab ring **30** is accessible for cranage.

The construction of the building is, as previously noted, conveniently carried out in reinforced concrete and the configuration and design of the various parts described may be made in accordance with the established practice of the art. The ground anchorage blocks **26** are necessarily of massive construction and conveniently have their buried foundation portions **29** extended considerably away from the building so as to provide a platform which can be loaded during the constructional period in order to provide for proper take-up of the weight by gradual removal of such loading as the shuttering used in the reinforced concrete construction of the building itself is being struck.

A building such as that described generally in connection with Figs. 1 to 6 or more particularly in connection with Figs. 7 to 9 may conveniently form a unitary part of a larger building constituted by a plurality of interested units. Fig. 10 illustrates an elementary form of such inter-nested arrangement where six units **A1, A2, A3, A4, A5** and **A6** each similar to any of those described are arranged symmetrically in hexagonal form. The central ground anchorage point B for the arched supporting members of each of the units is formed as a single element while the adjacent anchorages C at the six equi-distance points around the perimeter are also combined. Preferably, but not essentially, the arches defining the adjacent side planes of the nested units are combined in the form of a single arch of appropriate strength.

In the arrangement shown in Fig. 10, four of the six units i. e. those of units **A1, A2, A4** and **A5** are proposed for use as hanger space and the remaining two units **A3** and **A6**, lying diametrically opposed to the one another are suggested for use as workshops or the like. By the erection of a suitable low wall **50** the centre areas of the units **A1, A2, A4** and **A5**, which are of lesser headroom may be combined with the workshop area, which may be divided off by ordinary walls **51**.

The circular crane tracks D, one in each unit as shown are interconnected by transfer junction tracks E, such tracks forming a continuation of the diametral tracks D provided on the crane gantries for traversing the hoisting mechanism whereby the latter may be moved from one crane gentry to the next and so on around the complete closed circuit thereby permitting easy transfer of any load between the workshop units and any of the hangar units. These transfer or junction tracks E are conveniently provided by suitable rails suspended from the underside of the shoulder slabs of the supporting structures of the units.

Figs. 11 and 12 show a more ambitious arrangement of inter-nested units wherein two sections **A10, A11** each composed of five alternately disposed units as previously described are disposed on each side of a central and rectangular workshop building F of relatively low elevation, such building F being formed between the oppositely facing and aligned rows of arches formed by the alternately arranged units according to the invention. As in the arrangement of Fig. 10 the circular crane tracks D are interconnected by transfer tracks E which pass also to the workship building which includes a further gantry or gantries **D1** movable longitudinally therealong, such gantries **D1** serving if necessary as a continuation track for any desired hoisting gear to travel from the hangar units on one side of the workshop to those on the other.

In each of the arrangements so far described the arches defined by the three main arched supporting members may be either permanently closed by a vertical wall of suitable material such as brick or sheet metal or glazing although for aircraft hangar use at least one will, of course, be provided with some form of movable door, conveniently a door of the multiple section folding type. This door may be arranged in the manner shown more clearly in Fig. 12 where the doors **59** are shown as supported between end pillars **60** which carry a top horizontal guide **61** lying parallel with and conveniently made integral with the top of the adjacent arched supporting member and the adjoining portion of the shoulder slab.

The embodiment shown in Figs. 11 and 12 also illustrates by way of example an alternative manner of providing glazing over part of the coverage area between the converging and descending arches of the lower structure by means of the clerestory windows **62**. In this embodiment for the sake of illustration of possible alternatives the upper dome-shaped shells **13** are shown as unglazed and each made as a single thin section reinforced concrete shell extending downwards and with its lower perimeter connected to the related circular shoulder slab **22**.

A further construction embodying the invention is shown in Figs. 13 and 14. This embodiment, which is more particularly suited for the construction of a single unit building particularly for a single large sized aircraft follows closely upon the lines already described and is in closer accord with the spherical form fundamentally illustrated in Figs. 1 and 2.

This modification comprises a dome-shaped upper shell **13** supported at its lower periphery upon a circular shoulder slab **22** which is structurally combined with the upper edge of the lower arched structure **20** which is generally in the form of a truncated part-hemisphere cut upon vertical planes in the manner already described. The upper and lower spherical surfaces of the structure are conveniently of substantially similar radius to form a smooth and almost unbroken continuation one of the other.

In this embodiment the main opening of the building constituted by one of the arches **25** is closed by a series of cupola doors **70, 71** which follow the spherical contour of the lower arched structure and are carried upon lower inwardly coned circular track rails **72, 73** and upper outwardly coned circular track rails **74, 75** mounted on the lower supporting structure near to or on the shoulder slab **22**. These cupola doors **70, 71** are conveniently made in four sections, two to each side and with one **70** overlapping the other **71** in the manner shown whereby they may be transferred, in the open position of the door, to positions overlapping one another and covering the winged extensions **76** of the lower spherical supporting structure so as to leave the doorway completely unobstructed. The provision of these winged extensions **76** is conveniently combined with an ordinary rectangular building structure **77** of low elevation disposed at the rear of the arched lower supporting structure so as to form convenient workshops or other buildings.

With this last mentioned construction advantage is taken of the increased coverage area afforded by the cupola type doors which virtually extend the coverage area out to that of a semi-circle from the vertical axis of the building; such extended coverage is of considerable advantage with many forms of modern aircraft where the overall outline as shown in chain dotted lines at X has an enveloping plan which is substantially rhomoidal in form. The extended coverage area provided beneath

the winged extensions 76 is also of advantage in accommodating the wing tips of the aircraft. Furthermore the spherical form of the cupola doors provides for greatly decreased wind resistance whether open or closed while the appearance of the building is enhanced in that they virtually form a continuation of the otherwise part-spherical form thereof.

In this embodiment and in those previously described the doors are preferably and in most cases essentially arranged for power operation.

By the construction of this invention in its application to airplane hangars the requisite enclosure and protection may be made with a building which is only half the floor area and a third of the volume of a rectangular building of comparable size to deal with any given aircraft while at the same time the construction is of a form which reduces the effects of and may readily be given adequate strength to withstand wind pressures, unpredictable loadings and so forth.

As will be apparent to those skilled in the art many modifications are possible without departing from the scope of the invention. For instance, a wide variety of inter-nesting arrangements are possible such as that of four units of equilateral triangular plan as described, placed one centrally and the other three adjacent one to each side of such central unit. Such a disposition while giving a covered area four times that of a single unit, needs ground supporting points located only along the outer sides. A wide variety of movable door constructions are also possible such as for instance, the use of part-cylindrical doors running upon circular tracks and terminating in a horizontal plane at a convenient height above ground level but appreciably less than the centre height of the arched openings. The remainder of the opening above doors may then be closed by a fixed canopy or porch constituted by a downward continuation of the outer spherical or conical shell contour from the shoulder slab. If aircraft having a tall tail fin or fins have to be accommodated this canopy may be provided with one or more vertical slots closed by a rolling shutter. Similarly the crane gantry or equivalent member could be suspended or partly suspended from a central pivot instead of entirely operating upon a circular track.

The shaping of structures according to the invention, largely devoid of extensive plane areas disposed perpendicular to the ground level, coupled with the use of reinforced concrete instead of lattice girders results in a material reduction of the reflection coefficient or response given thereby to radar exploring pulses with consequential reduction of ground "clutter" caused thereby to the ground or aircraft radar equipment operating in the vicinity.

The invention is clearly not restricted to use only in the construction of airplane hangars. It is clearly of ready application to the construction of any large covered-in building such as workshops, assembly halls, exhibition halls, covered car parks and so forth where large floor area with the minimum of obstruction is required. By suitable addition of inter-nested units in the manner already referred to a building of almost limitless proportions may be provided.

I claim:

1. A building such as an aeroplane hangar comprising three ground anchor blocks disposed at the vertices of an equilateral triangle, three arched supporting members springing upwardly from and supported at their lowermost ends by different pairs of said ground anchor blocks, a horizontal ring-shaped shoulder slab supported by the three uppermost points of said arched supporting members, said shoulder slab comprising a vertical circular web, a horizontal hexagonal web projecting outwardly from said circular web at the upper end thereof, an inwardly directed flange projecting from said circular web at the lower end thereof and an upwardly and inwardly inclined flange projecting from the annulus of junction of said circular web and said horizontal web, and a dome-shaped shell supported by said upwardly and inwardly inclined flange of said shoulder slab.

2. A building such as an aeroplane hangar comprising three reinforced concrete ground anchor blocks disposed at the vertices of an equilateral triangle, three arched supporting members of reinforced ferroconcrete construction springing respectively from and supported at their lowermost ends by said ground anchor blocks, the projection of said three arched supporting members on to a horizontal plane at the level of said three ground anchor blocks forming said equilateral triangle, each of said arched supporting members comprising a plurality of girders carrying spaced transverse horizontal bearers having glazing panels therebetween, a ring-shaped shoulder slab supported by the three uppermost points of said arched supporting members, a plurality of V-section concrete beams upwardly and inwardly inclined from and supported by said shoulder slab and carrying further spaced transverse horizontal bearers having glazing panels therebetween and a dome-shaped shell supported by the upper ends of said V-section beams.

3. A building such as an aeroplane hangar comprising three ground anchor blocks disposed at the vertices of an equilateral triangle, three arched supporting members springing respectively from and supported at their lowermost ends by said ground anchor blocks, a ring-shaped shoulder slab supported by said arched supporting members at the three uppermost points of said arched supporting members, a plurality of V-section concrete beams upwardly and inwardly inclined from and supported by said ring-shaped shoulder slab carrying spaced transverse horizontal bearers having glazing panels therebetween and a thin reinforced concrete part-spherical dome-shaped shell having a dependent circular peripheral flange, said dome-shaped shell being united with the upper ends of said V-section beams by way of said dependent flange.

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