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A THEME CENTER FOR A WORLD'S FAIR

TWO SURFACES OF REVOLUTION

HYPERBOLOID OF REVOLUTION OF ONE SHEET—CIRCULAR OPEN RING TORUS
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Within the frame of an overall program for the Fair, the theme center building has been the particular subject of study. These brief notes summarize the main design limitations and assumptions.

PURPOSES

World's fairs have many purposes. Those can range from promoting politics to providing diversion. Curiously enough the two extremes used forming a circle which may include commercial, social, and cultural purposes. In attracting hundreds of thousands of visitors from all over, they may aid in establishing communication among peoples. Generally, however, based on what is observed at temporary exhibitions. Nevertheless since a great deal of energy, ingenuity, time, and money are involved, they could be planned on more permanent basis.

MAGNITUDES

The Magnitude—London 1851—Total area of the exhibition in one building (Crystal Palace) 500,000 square feet. International Exhibition—Paris 1867—Total area of the exhibition in one building 1,500,000 square feet.

International Exhibition—London 1862—Individualized from a main building (Great Exhibition of the Works of Industry of All Nations) 700,000 square feet (other buildings are not counted herein).

Projected attendance figures for the 1864-65 New York World's Fair give a total of 70,000,000 people in one year, with over 500,000 as the daily peak.

SITE

1200 acres of marsh land on the outskirts of N** City. The site has its own railroad station and good approach roads. The site is found to be lying between two rail lines, one running south, the other north. The Fair will be open for seven months from May 1st to November 1st. The design will be of a strictly temporary nature to be removed after the Fair closes. The site is well served by good access roads from all directions and the building to be used as an Arts and Science Center for the City of Chicago in addition as well as auxiliary displays. The temporary buildings are for the following exhibitions: city, standards, science, agriculture, art, industry, general services, administration, etc. The International Exhibition is located in the Theme Center.

MAIN REQUIREMENTS OF THE THEME CENTER BUILDING

The Theme Center will be visited by a mass of people, yet this mass is composed of individual human beings of different races, ages, interests, backgrounds, activities, creeds, etc., etc.

The Theme Center will accommodate different kinds of expositions and expositions from different countries with different styles and standards of living.

The Theme Center Building and a Plaza are the core of the Fair. The Plaza is the focal point of the entire building and building either walking or using low-speed vehicles such as tractor trains, electrically run, mules, etc. Service and trucks will have an underground connection.

Approximate distribution of areas: Exhibitions and public spaces 500,000 square feet. Public Service and vertical circulation, 200,000 square feet. Mechanical and building services, 200,000 square feet. Maximum occupancy of this building: 25,000 person.

Exhibitions and public spaces include: International Exhibition—1,500,000 square feet. Mississippi River, 400,000 square feet. Bars and Cakes for 1,000 people; Night Clubs for entertainment, dining, and other: 400 people; Lounges for 3,000 people; Observation decks.

Public Services include: Coat and rest rooms, kitchen, storage, administration, and information offices, travel, post offices, police, first aid, etc.

Additional requirements of the building: a) To predominant over the landscape, therefore, this is a factor in the distance; b) To define the Plaza; c) To provide spaces from which the Fair itself as well as the skyline of the City can be viewed; d) To offer a maximum unobstructed space free of column, stair, elevators, mechanical cores, for a maximum flexibility; e) To provide a simple, direct system of circulation; f) To comply with the regulations of the local Building Code.

DESIGN

The basic outline of the building was established based upon the factors of the site, the requirements of the Fair, the available facilities, and the desires of the community. The building will be of structural steel, reinforced concrete, and brick. The site will be well chosen, the site will have a fine view, the site will have an open space, and the site will be well connected to the rest of the building as a common element.

The accompanying drawings and models illustrate three schemes: VING, PAN, QUESO.
NOTES ON TWO SURFACES OF REVOLUTION

Torus
(1) The "classical" Torus is a continuous double-curved surface generated by revolving a circle or an ellipse around a co-planar axis which does not contain the center of the circle or ellipse.

CIRCULAR OPEN RING TORUS
(3) The surface considered in this paper belongs to the class of Surfaces of Revolution.

(5) A circular torus is determined by two radii (Fig. 1).
- Radial radius of the generating circle.
- Radius of rotation; that is, the distance from the center of the circle to the midline axis of rotation.

(6) Different sets of values of R and r determine a circular torus.

- Radial radius > 0: Open Ring Torus
- Radial radius > 0: Closed Torus

Other sets of values will determine respectively:
- Radial radius = 0: Sphere
- Radial radius > 0: Circle
- Radial radius = 0: Point

(4) Certain tori are special cases of the Dupin Cyclide surfaces. A circular open torus can also be generated as follows: A circular arc can be rotated about a straight line in the plane of the arc and away from the Locus of a Dupin Cylinder, and this cylinder must be rotated one plane (π) to generate a torus (Fig. 2).

(5) An open torus can also be generated as follows: a cylinder may be curved to meet itself in such a way that the central axis forms a circle. (Fig. 3)

(6) The surface of the torus is doubly curved with both positive and negative Gaussian curvature.

(7) The surface of the torus is the only surface which can be divided into seven mutually adjacent parts.

(8) The torus has two lines of constant curvature which are circles. These lines are also connective lines or canonical curves.

(9) Topologically, the torus, a two-sided surface, has a connectivity of +3 and can be deformed into a Klein bottle of co-surface.

(10) Surface area of circular torus:
\[ S = 4 \pi^2 R r \]

(11) Volume of circular torus:
\[ V = 2 \pi^2 R r^2 \]

(12) Equations of the surface of the torus for:
- Cartesian Coordinates:
  \[ (x - Y)^2 + (z - z_0)^2 = R^2 \]
- Cylindrical Coordinates:
  \[ x = r \cos \phi \quad y = r \sin \phi \quad z = z_0 \]

(13) Hyperboloid of one sheet:
(14) Hyperboloid of revolution:

The surface becomes a surface of revolution, all sections (XY) perpendicular to the (Z) axis of revolution being circles. The minimum circle at \( Z = 0 \) is called a hyperbola. (Fig. 39)

(15) It is also the locus described by a straight generatrix revolving around a non-planar non co-planar axis (Fig. 45). Furthermore, the projection of this line on a parallel plane in one of the asymptotes of the hyperbolic sections contained on the plane. Or, as Wren's Theorem states: The sections of a one-sheeted hyperboloid of revolution in a plane through the asymptote of a generating hyperbola perpendicular to the plane of this curve are two lines parallel to this asymptote.

(16) There are two generatrices that go through each point on the hyperboloid.

Notation (See Figs. 39, 40, 45, 66)

(17) The notation used below refers particularly to the generatrix drawn at equal intervals, or:

\[ X = Y = Z = N \]

(18) Straight generatrix or asymptote.

\[ X \]

(19) Circular sections parallel to XY plane.

\[ X \]

(20) Circular section or group circle when \( Z = 0 \) (level 0).

\[ X \]

(21) Circular sections at the intersection of a pair of generatrices at level 0.

\[ X \]

(22) Radius of circular sections at level 0.

\[ X \]

(23) Radius of group circles—Level 0.

\[ X \]

(24) A segment of generatrix between consecutive intersections.

\[ X \]

(25) Level or distance between group level and an intersection at level 0.

\[ X \]

(26) Chord of an arch of a circle between consecutive intersections at any level.

\[ X \]

(27) Distance between consecutive intersections levels.

\[ X \]

(28) Number of intersections levels from plane XY.

\[ X \]

(29) Horizontal projection of a segment of generatrix from group to an intersection at level 0.

\[ X \]

(30) Number of intersections at the same level.

\[ X \]

(31) Horizontal projection of the central angle between two consecutive intersections at the same level.

\[ X \]

(32) Angle between a generatrix and XY plane.

\[ X \]

(33) Called orientation angle.

\[ X \]

(34) Central angle of the common trace of a pair of generatrices at level 0.

\[ X \]

(35) Angle at the intersection of a pair of generatrices.
Algebraic Expressions

(See Figs. 39, 40 and 44, 45, 46)

(34) \( 2a = \frac{a}{2} \),
(35) \( 2a = \frac{2a}{2} = a \),
(36) \( 2a = 2a \),
(37) \( 2a = \frac{2a}{2} \),
(38) \( 2a = \frac{2a}{2} \),
(39) \( 2a = \frac{2a}{2} \),
(40) \( 2a = \frac{2a}{2} \),
(41) \( 2a = \frac{2a}{2} \),
(42) \( 2a = \frac{2a}{2} \).

CIRCULAR OPEN RING TORUS

PLATE I—GENERALIZATION—2. By rotation of a circle, 1. By rotation of a Dupin Cycloid, one phase, 2. By curvature of a Dupin Cycloid, one phase, 2.

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PLATE V—SCHEME VINO—MEMORIAL KOOP—Elevation and View of Approachingotorch.

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HYPERBOLOID OF REVOLUTION OF ONE SHEET

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PLATE XVIII—DIVISION OF SURFACE—D. DIAMOND AND TRIANGLES. Division determined by the intersection of straight generatrices, i.e., of generating curves in parallel and parallel sections at equal intervals. 51. DIAMOND AND TRIANGLES. Division determined by the intersection of hyperbolic generatrices, i.e., of generating curves in parallel and parallel sections at equal intervals.

PLATE XVIII—DIVISION OF SURFACE—63, 64, 65, 66. DIAMONDS AND TRIANGLES. Varieties of divisions illustrated on Fig. 51.
The roof is a variation of the membrane structures developed by the author and presented in the Studies Preliminary of the United States (Arch. 2, Fenes. 2, May 14, 1941). The type of membrane selected is determinately determined by a membrane-hanging from a circular perimeter. To minimize the flapping or vibrating effect caused by the wind and at the same time to avoid the costs of building a lightweight cylindrical form, a series of radial structural bands form a sphere, generating the form. The surface is composed of equal sectors. There are two characteristic vertical radial sections: a section through the lower vertex determines a circular component; the other section through the upper vertex determines a circular component of one horizontally curved line from the center to the perimeter. In this particular case, the membrane hangs from a central circular tower and forms a roof. The top sections, however, give other variations; that is, when the shape becomes a shell, the point of support being the top vertices. For practical reasons as can be noticed in the photographs, the model was built as a sail.

PLATE VI. WORLD'S FAIR—SCHEME PAN
12. Elevation.

SCHEME PAN Entire structure in reinforced concrete. The cover is a space frame dome. Twelve supporting poles create the vertical circulation. The space frame is a cage of metal bars. The roof and lower structure together form a reservoir of water and a subterranean exhibition space. Below each main floor there are secondary development with stages, roof rooms, offices, storage, mechanical machinery, etc. The other side of the structure forms a large mechanical exhibition space. The outside of a circular horizontal circular display, wells excited as the advantage of the central condition. Preliminary dimensions: Total height-100 feet. Diameter at ground floor level-75 feet. Diameter at balcony level (maximum diameter)-150 feet.

PLATE V. WORLD'S FAIR—SCHEME VINO—MEMBRANAL ROOF

BRUSSELS, THE EMBARK - Fragment of a Print
PLATE VII. WORLD'S FAIR—SCHEME PAM

PLATE X. WORLD'S FAIR—SCHEME PAN  18. View of entrance at Phase level

PLATE XII. WORLD'S FAIR—SCHEME QUESO 22. Elevation.

SCHEME QUESO Steel structure. The core is a double curvature surface derived from a dome. It has 18 box sections stabilized from the center with vertical struts. Open galleries at the top, and doors and windows for all levels. Seven main floors and a balcony containing the exhibition space. Below each main floor there are enclosures with lobbies, rest rooms, offices, storage, mechanical equipment, etc. Physical dimensions: total height over roof level—144 feet. Diameter at balcony level—160 feet. Diameter at roof level—300 feet.
PLATE I. TORUS GENERATION (isometric views) 1. By rotation of a circle. 2. By rotation of a Deltic Cylinder. one phase. 3. By carving a cylinder.

PLATE II. TORUS—PLANE SECTIONS 4. Horizontal projection of a torus indicating sections perpendicular to XY plane. These sections are called: Spire Lines of Perverts. 5. SECTION AA: Circular. 6. SECTION BB: Cylindrical Curve. 7. SECTION CC: (at a distance $R_2 = R_3$ from $X$-axis) Lemniscate of Bernoulli. 8. SECTION DD: Cylindrical Curve. 9. SECTION EE: (at a distance $R_2$ from $X$-axis) Ellipsoidal type. 10. SECTION FF: Ellipsoidal type.
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PLATE IV. TORUS—TRANSLATION AND ROTATION OF PLANE SECTIONS (Vertical and horizontal projections)
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35. Time exposure of a rotating circle. 36-37. Multiple exposure of a rotating circle. 38. Multiple exposure of a rotating sphere.

PLATE X, HYPERBOLOID OF REVOLUTION OF ONE SHEET—GENERATION—NOTATION
39. The locus described by a hyperbola revolving around its conjugate axis. 40. The locus described by a straight geodesic revolving around a non-parallel axis equal to axis.
PLATE XII. HYPERBOLOID—"PARALLEL." 44, 45, 46. ILLUSTRATE THE FOLLOWING PROPERTY: All the hyperboloids, with the same semi-axes of rotation at the same x level, have all the generators drawn at equal intervals. $\frac{Hx}{H} = \phi$. Intercepting at the same level: $h_1, h_2, h_3, \ldots, h_5$. 

PLATE XI. HYPERBOLOID—"DEFINING CONDITIONS" 41. $a = 0^\circ$: $e_2 > 0$ CYLINDER. 42. $a > 0^\circ$: $e_2 > 0$ HYPERBOLOID OF REVOLUTION. 43. $30^\circ > a > 0^\circ$: $e_2 > 0$ INVERTED COVER.
PLATE XVIII. HYPERBOLOID—DIVISION OF SURFACE

59. DIAMONDS AND TRIANGLES. Division determined by the intersection of pairs of straight generators, drawn at equal intervals. \( \frac{2\pi}{N} = \phi \) 60. DIAMONDS AND TRIANGLES. Division determined by the intersection of straight generators drawn at equal intervals. \( \frac{2\pi}{N} = \phi \) and circular sections at equal intervals.

61. DIAMONDS AND TRIANGLES. Division determined by the intersection of hyperbolic generators, drawn at equal intervals and circular sections at equal intervals.
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PLATE XX. HYPERBOLOID—ISOMETRIC VIEWS
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