640.00 **Tension and Compression**

640.01 One cannot patent geometry per se nor any separately differentiated out, pure principle of nature's operative processes. One can patent, however, the surprise complex behaviors of associated principles where the behavior of the whole is unpredicted by the behavior of the parts, i.e., synergetic phenomena. This is known as invention, a complex arrangement not found in, but permitted by, nature, though it is sometimes superficially akin to a priori natural systems, formulations, and processes. Though superficially similar in patternings to radiolaria and flies' eyes, geodesic structuring is true invention. Radiolaria collapse when taken out of water. Flies' eyes do not provide human- dwelling precedent or man-occupiable, environment-valving structures.

640.02 Until the introduction of geodesic structures, structural analysis and engineering-design strategies regarding clear-span structural enclosures in general, and domical structures in particular, were predicated upon the stress analysis of individual beams, columns, and cantilevers as separate components and thereafter as a solid compressional shell with no one local part receiving much, if any, aid from other parts. Their primarily compressional totality was aided here and there by tensional sinews, but tension was a discontinuous local aid and subordinate. As academically constituted in the middle of this 20th-century, engineering could in no way predict, let alone rely upon, the synergetic behaviors of geodesics in which any one, several, or many of the components could be interchangeably removed without in any way jeopardizing the structural-integrity cohering of the remaining structure. Engineering was, therefore, and as yet is, utterly unable to analyze effectively and correctly tensegrity geodesic structural spheres in which none of the compression members ever touch one another and only the tension is continuous.

640.03 It appeared and as yet appears to follow, in conventional, state-licensed structural engineering, that if tension is secondary and local in all men's structural projections, that tension must also be secondary in man's philosophic reasoning. As a consequence, the popular conception of airplane flight was, at first and for a long time, erroneously explained as a compressional push-up force operating under the plane's wing. It "apparently" progressively compressed the air below it, as a ski compresses the snow into a grooved track of icy slidability. The scientific fact remains, as wind-tunnel experiments proved, that three-quarters of the airplane's weight support is furnished by the negative lift of the partial vacuum created atop the airfoil. This is simply because, as Bernoulli showed, it is longer for the air to go around the top of the foil than under the foil, and so the same amount of air in the same amount of time had to be stretched thinner, ergo vacuously, over the top. This stretching thinner of the air, and its concomitant greater effectiveness of interpositioning of bodies (that is, the airplane in respect to Earth), is our same friend, the astro- and nucleic-tensional integrity of dynamic interpatterning causality.

640.10 **Slenderness Ratio:** Compression members have a limit ratio of length to section: we call it the slenderness ratio. The compression member may very readily break if it is too long. But there is no limit of cross section to length in a tension member; there is no inherent ratio.

640.11 The Greeks, who built entirely in compression, discovered that a stone column's slenderness ratio was approximately 18 to 1, length to diameter. Modern structural-steel columns, with an integral tensional fibering unpossessed by these stone columns, have a limit slenderness ratio of approximately 33 to 1. If we have better metallurgical alloys, we can make longer and longer tension members with less and less section—apparently ad infinitum. But we cannot make longer compression columns ad infinitum.

640.12 If we try to load a slender column axially—for instance, a 36-inch-long by l/8-inch-diameter steel rod—it tends to bend in any direction away from its neutral axis. If, however, we take a six-inch-diameter bundle of 36-inch-long by 1/8-inch-diameter rods compacted parallel to one another into a closest-packed, hexagonally cross-sectioned bundle, bind them tensionally with circumferential straps in planes at 90 degrees to the axis of the rods, around the bundle's six-inch girth, and then cap both ends of the tightly compacted, hexagonally cross-sectioned bundle with tightly fitting, forged-steel, hexagonal caps, we will have a bundle that will act together as a column. If we now load this 36-inch-high column axially under an hydraulic press, we discover that because each rod could by itself be easily bent, but they cannot bend toward one another because closest packed, they therefore bend away from one another as well as twisting circumferentially into an ever-fattening, twisting cigar that ultimately bursts its girth-tensed bonds. So we discover that our purposeful compressing axially of the bundle column is resulting in tension being created at 90 degrees to our purposeful compressing.

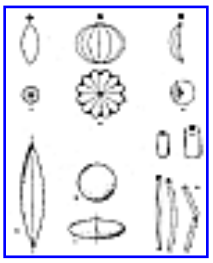

Fig. 640.20

640.20 Sphere: An Island of Compression: Aiming of the compressional loading of a short column into the neutral or central-most axis of the column provides the greatest columnar resistance to the compressing because, being the neutral axis, it brings in the most mass coherence to oppose the force. To make a local and symmetrical island of compression from a short column that axial loading has progressively twisted and expanded at girth into a cigar shape, you have to load it additionally along its neutral axis until the ever-fattening cigar shape squashes into a sphere. In the spherical condition, for the first and only time, any axis of the structure is neutral—or in its most effective resistant-to-compression attitude. It is everywhere at highest compression and tension- resisting capability to withstand any forces acting upon it.

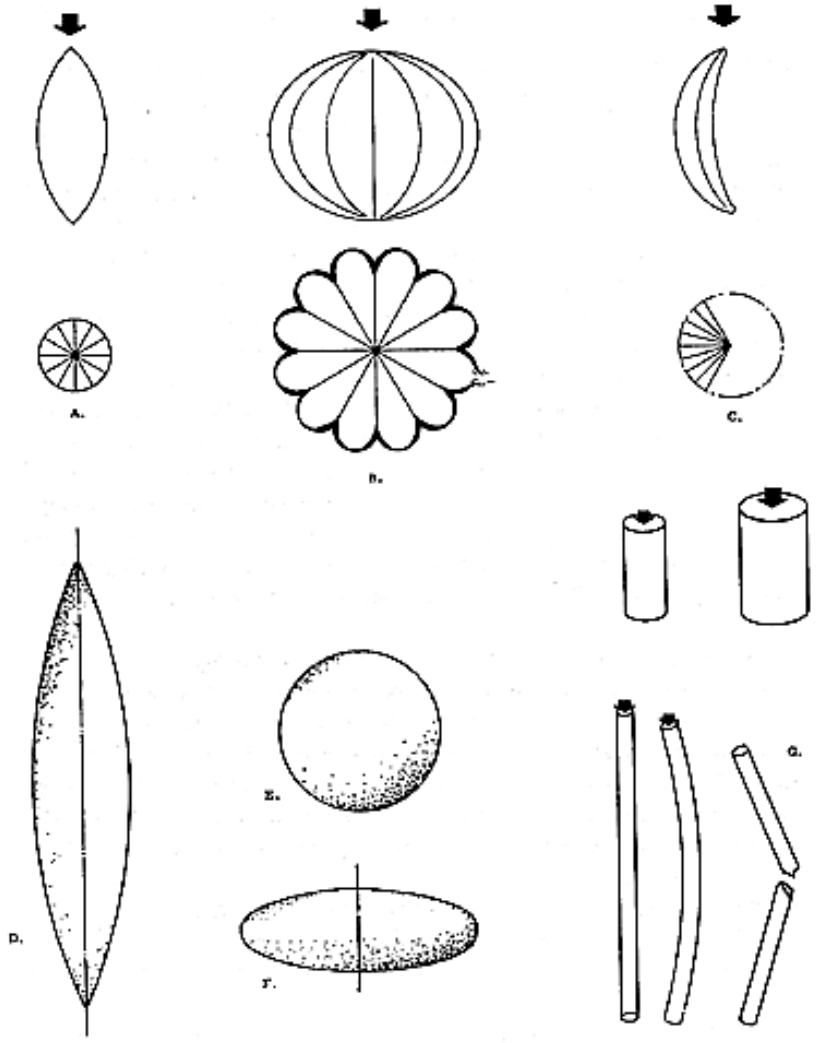

Fig. 640.20 Compression Members Under Stress: A cigar shape (A) (with radials short and compact) under pressure in its long axes goes to squash shape (B) (radials long and separating) or to banana shape (C) (radials longer and collecting). Note that on the squash the stretching edge gets thinner and breaks. The cigar (D) has only one neutral axis: axial or polar exaggerated asymmetry. The sphere (E) has an infinity of equi-neutral axes: symmetry. The disc (F) has only one neutral axis: equatorially exaggerated asymmetry. Compression columns (G) tend toward axes of ever lesser radius. As columns become longer in respect to their cross section (slenderness ratio) they tend to flex and break into two shorter columns in an attempt to restore a desirable slenderness ratio.

640.21 It is not surprising, in view of these properties, that ball bearings prove to be the most efficient compression members known to and ever designedly produced by man. Nor are we surprised to find all the planets and stars to be approximately spherical mass aggregations, as also are the atoms, all of which spherical islands of the macrocosmic and microcosmic aspects of scenario Universe provide the comprehensive, invisible, tensional, gravitational, electromagnetic, and amorphous integrity of Universe with complementarily balancing internality of compressionally most effective, locally and temporarily visible, islanded compressional entities. It is also not surprising, therefore, that Universe islands its spherical compression aggregates and coheres the whole exclusively with tension; discontinuous compression and continuous tension: I call this tensional integrity of Universe *tensegrity.*

640.30 **Precession and Critical Proximity:** Compressions are always local and, when axially increased beyond the column-into-cigar-into-sphere stage of optimum compression-resisting effectiveness, they tend toward edge-sinused, lozenge shapes, then into edge-fractionated discs, and thereafter into a plurality of separately and visibly identifiable entities separating inwardly in a plane at 90 degrees to the compressional forces as the previously neighboring atoms became precessionally separated from one another beyond the critical threshold between the falling-inward, massive integrity coherence proclivities of islanded "matter"—beyond that proclivity threshold of critical proximity, now to yield precessionally at 90 degrees to participate in the remotely orbiting patterns characterizing 99.99 percent of all the celestially accountable time-distance void of known Universe.

640.40 **Wire Wheel:** In the high- and low-tide cooperative precessional functionings of tension versus compression, I saw that there are times when each are at half tide, or equally prominent in their system relationships. I saw that the exterior of the equatorial compressional island rim-atoll of the wire wheel must be cross-sectionally in tension as also must be its hub-island's girth. I also saw that all these tension-vs- compression patterning relationships are completely reversible, and are entirely reversed, as when we consider the compressively spoked artillery wheel vs. the tensionally spoked wire wheel. I followed through with the consideration of these differentiable, yet complementarily reversible, functions of structural systems as possibly disclosing the minimum or fundamental set of differentiability of nonredundant, precessionally regenerative structural systems. (See Sec. 537.04.)

Fig. 640.41a

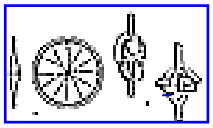

Fig. 640.41b

640.41 As I considered the 12 unique vectors of freedom constantly and nonredundantly operative between the two poles of the wire wheel—its islanded hub and its islanded equatorial rim-atoll, in effect a Milky Way-like ring of a myriad of star islands encircling the hub in a plane perpendicular to the hub axis—I discerned that this most economic arrangement of forces might also be that minimum possible system of nature capable of displaying a stable constellar compressional discontinuity and tensional continuity. A one-island system of compression would be an inherently continuous compression system, with tension playing only a redundant and secondary part. Therefore, a one-island system may be considered only as an optically illusory "unitary" system, for, of course, at the invisible level of atomic structuring, the coherence of the myriad atomic archipelagos of the "single" pebble's compression-island's mass is sum-totally and only provided by comprehensively continuous tension. This fact was invisible to, and unthought of by, historical man up to yesterday. Before the discovery of this fact in mid-20th- century, there was naught to disturb, challenge, or dissolve his "solid-rock" and other "solid-things" thinking. "Solid thinking" is as yet comprehensively popular and is even dominant over the practical considerations of scientists in general, and even over the everyday logic of many otherwise elegantly self-disciplined nuclear physicists.

640.42 As I wondered whether it was now possible for man to inaugurate an era of thinking and conscious designing in terms of comprehensive tension and discontinuous compression, I saw that his structural conceptioning of the wire wheel documented his intellectual designing breakthrough into such thinking and structuring. The compressional hub of the wire wheel is clearly islanded or isolated from the compressional "atoll" comprising the rim of the wheel. The compressional islands are interpositioned in structural stability only by the tensional spokes. This is clearly a tensional integrity, where tension is primary and comprehensive and compression is secondary and local. This reverses the historical structural strategy of man. His first wire wheel had many and varied numbers of spokes. From mathematical probing of generalized principles and experimentally proven knowledge governing the tensional integrity of the wire wheel, we discover that 12 is the minimum number of spokes necessary for wire wheel stability. (See Sec. 537, Twelve Universal Degrees of Freedom.)

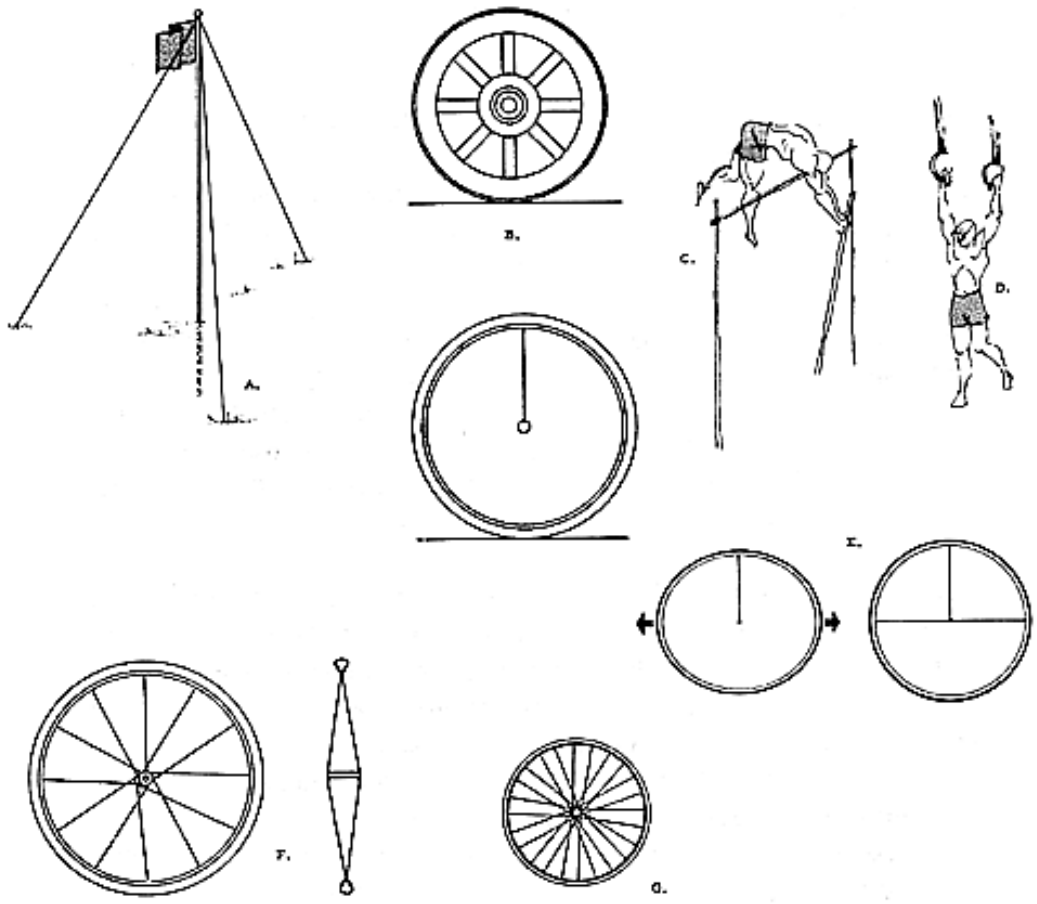

Fig. 640.41A Stabilization of tension: Minimum of 12 Spokes:

A. A solid mast without stays stands erect by itself in "solid" earth. Tension stays may be added at end of the lever arm helping against hurricane "uprooting." Men have until now employed a compression continuity as the primary load-carrying structural system with tension employed secondarily to stabilize angular relationships.
B. The old artillery wheel provides a series of vaulting poles.
C. Pole vaulting along, a "pushing-up" load.
D. Hanging in tension like the wire wheel.
E. The wire wheel provides a series of tension clings. The axle load of the wire wheel is hung from the top of the wheel, which tries to belly out, so spokes as additional tension members are added horizontally to keep it from bellying.
F. It takes a minimum of 12 spokes to fix the hub position in relation to the rim: six positive diaphragm and six negative diaphragm, of which respectively three each are positively and negatively opposed turbining torque members.
G. Many spokes keep rim from bending outwardly any further while load is suspended by central vertical spokes successively leading from top of wheel to hub and its load.

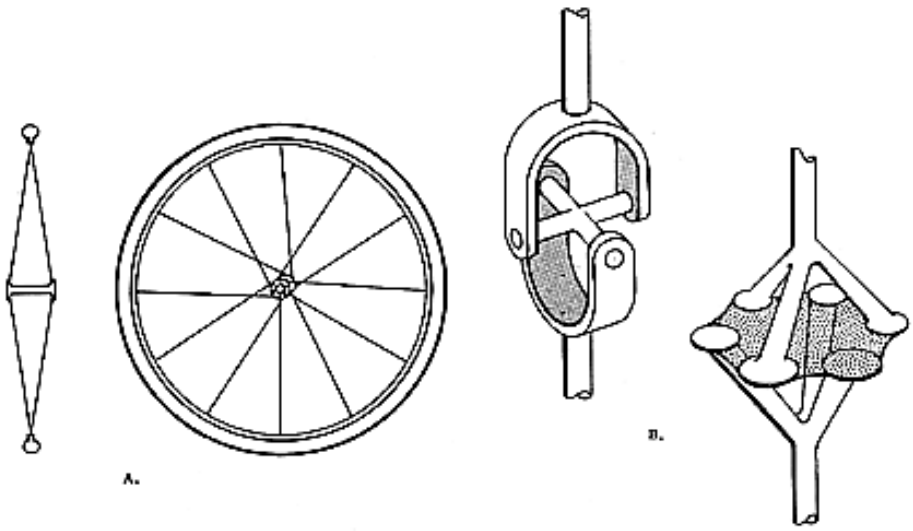

Fig. 640.41B Minimum of Twelve Spokes Oppose Torque: Universal Joint:

A. It takes a minimum of 12 spokes to overcome the turbining evident with the minimum four vectors of restraint. This is demonstrated with the 12-spoke wire wheel with its six positive diaphragm and six negative diaphragm of which respectively three each are positively and negatively opposed turbining or torque members.
B. Two-axis and three-axis "universal joints," analogous to the wire wheel as a basic system relying on the differentiation of tension and compression for its effectiveness. These all may be considered basic tensegrity systems.

640.50 **Mast in the Earth:** In his primary regard for compressional structuring, man inserts a solid mast into a hole in the "solid" Earth and rams it in as a solid continuity of the unitary solid Earth. In order to keep the wind from getting hold of the top of the mast and breaking it when the hurricane rages, he puts tension members in the directions of the various winds acting at the ends of the levers to keep it from being pulled over. The set of tension stays is triangulated from the top of the masthead to the ground, thus taking hold of the extreme ends of the potential mast-lever at the point of highest advantage against motion. (See illustration 640.41A.) In this way, tension becomes the helper. But these tensions are secondary structuring actions. They are also secondary adjuncts in man's solidly built, compressional-continuity ships. He puts in a solid mast and then adds tension helpers as shrouds. To man, building, Earth, and ship seemed alike, compressionally continuous. Tension has been secondary in all man's building and compression has been primary, for he has always thought of compression as solid. Compression is that "realistic hard core" that men love to refer to, and its reality was universal, ergo comprehensive. Man must now break out of that habit and learn to play at nature's game where tension is primary and where tension explains the coherence of the whole. Compression is convenient, very convenient, but always secondary and discontinuous.

640.60 **Tensed Rope:** There is a unique difference in the behaviors of tension and compression. When we take a coil of rope of twisted hemp and pull its ends away from one another, it both uncoils along its whole length and untwists locally in its body. This is to say that a tensed rope or tensed object tends to open its arcs of local curvation into arcs of ever greater radius. But we find that the rope never attains complete straightness either of its whole length or of its separate local fibers or threads. Ropes are complexes of spirals. Tensed mediums tend to a decreasing plurality of arcs, each of the remainder continually tending to greater radius but never attaining absolute straightness, being always affected in their overall length by other forces operating upon them. We see that tension members keep doing bigger and bigger arc tasks. The big patterns of Universe are large-radius patterns, and the small patterns are small-radius patterns. Compressed columns tend to spiral-arc complexes of ever-increasing radius. So we find the compression complexes tend to do the small local structural tasks in Universe, and the tension complexes tend to do the large structural tasks in Universe. As tension accounts for the large patternings and pattern integrities, compression trends into locally small pattern integrities.

Next Section: 641.00