June 30, 1970 R. WARSHAW 3,517,515

TUNNEL CONSTRUCTION SLIDING ASSEMBLY

Filed July 17, 1968 4 Sheets-Sheet 1

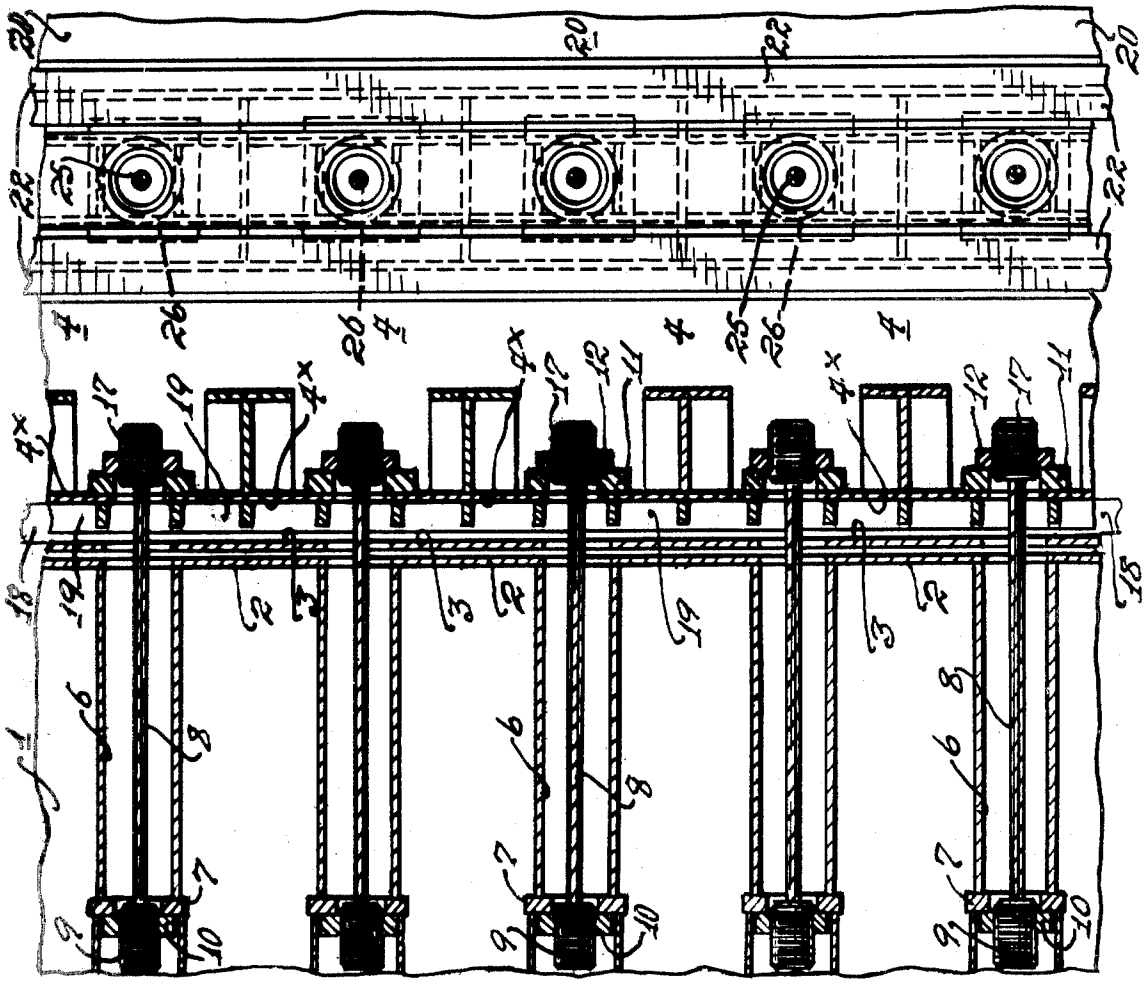


FIG. 7.

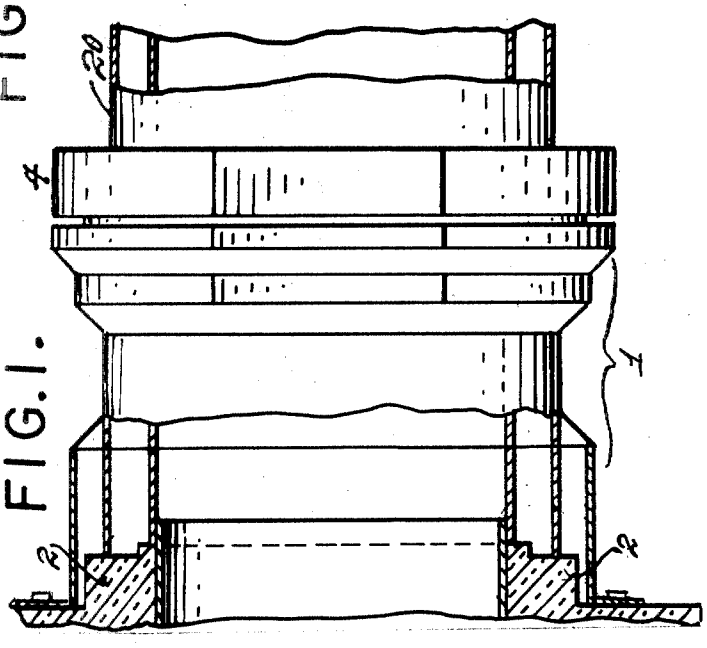


FIG. 1.

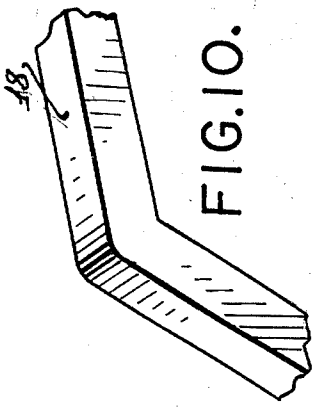


FIG. 10.

BY

INVENTOR.
Robert Warshaw
By H. Lee Helms
Attorney

June 30, 1970 R. WARSHAW 3,517,515

TUNNEL CONSTRUCTION SLIDING ASSEMBLY

Filed July 17, 1968 4 Sheets-Sheet 2

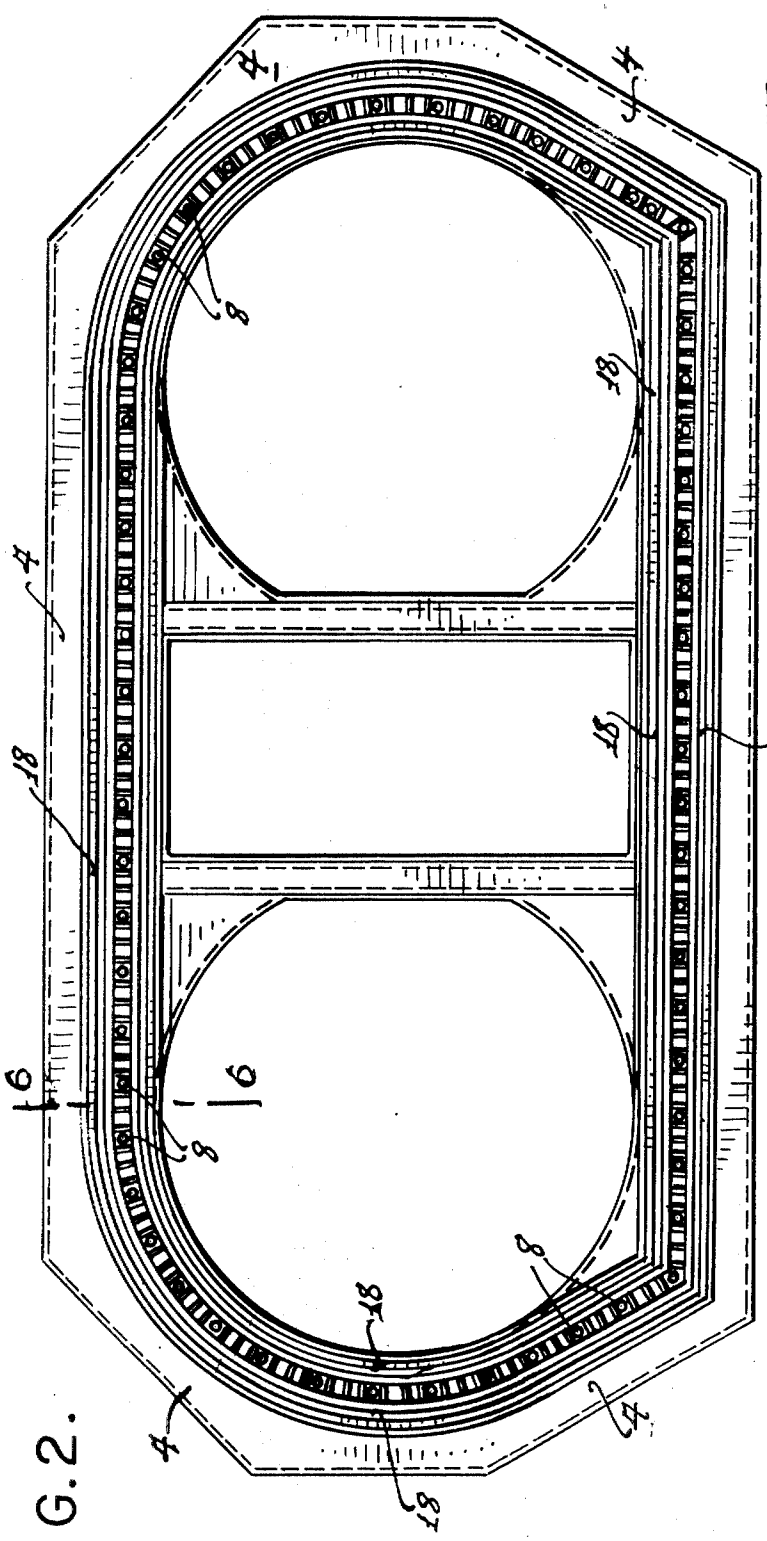


FIG. 2.

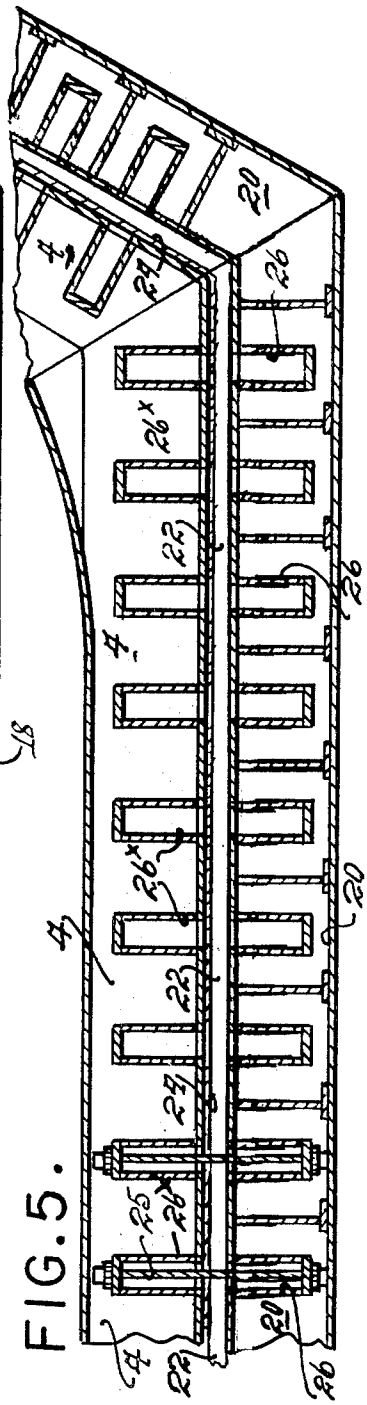


FIG. 5.

INVENTOR.
Robert WARSHAW
By W. Lee Nelms
Attorney

June 30, 1970 R. WARSHAW 3,517,515

TUNNEL CONSTRUCTION SLIDING ASSEMBLY

Filed July 17, 1968 4 Sheets-Sheet 3

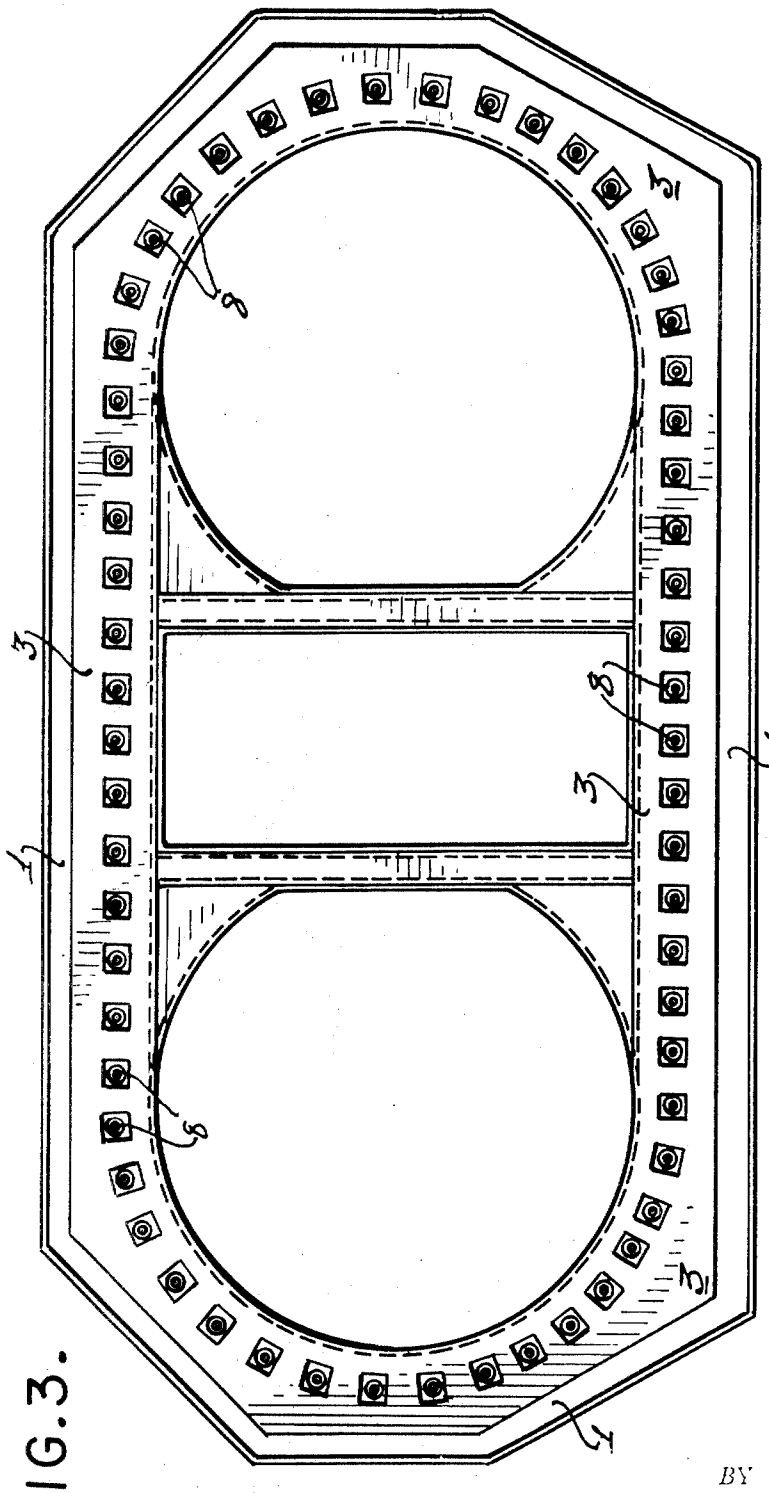


FIG. 3.

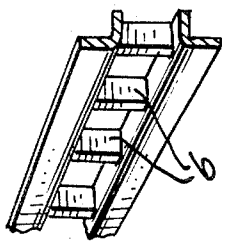


FIG. 11.

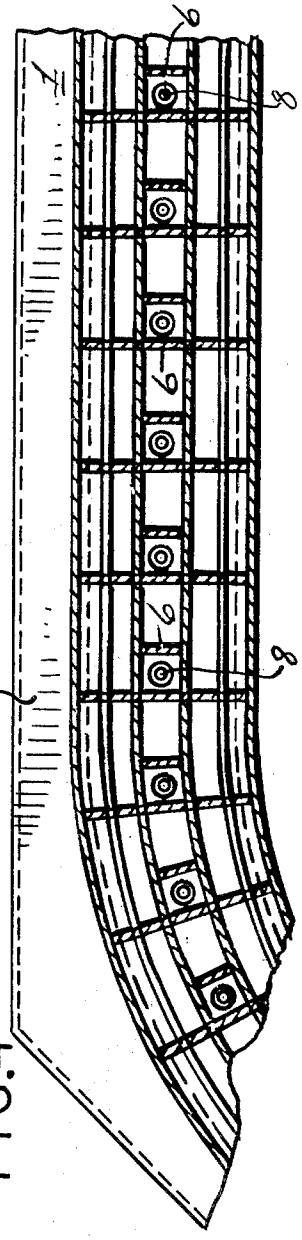


FIG. 4

BY

INVENTOR.
Robert WARSHAW.
By H. Lee Helms
Attorney

June 30, 1970 R. WARSHAW 3,517,515

TUNNEL CONSTRUCTION SLIDING ASSEMBLY

Filed July 17, 1968 4 Sheets-Sheet 4

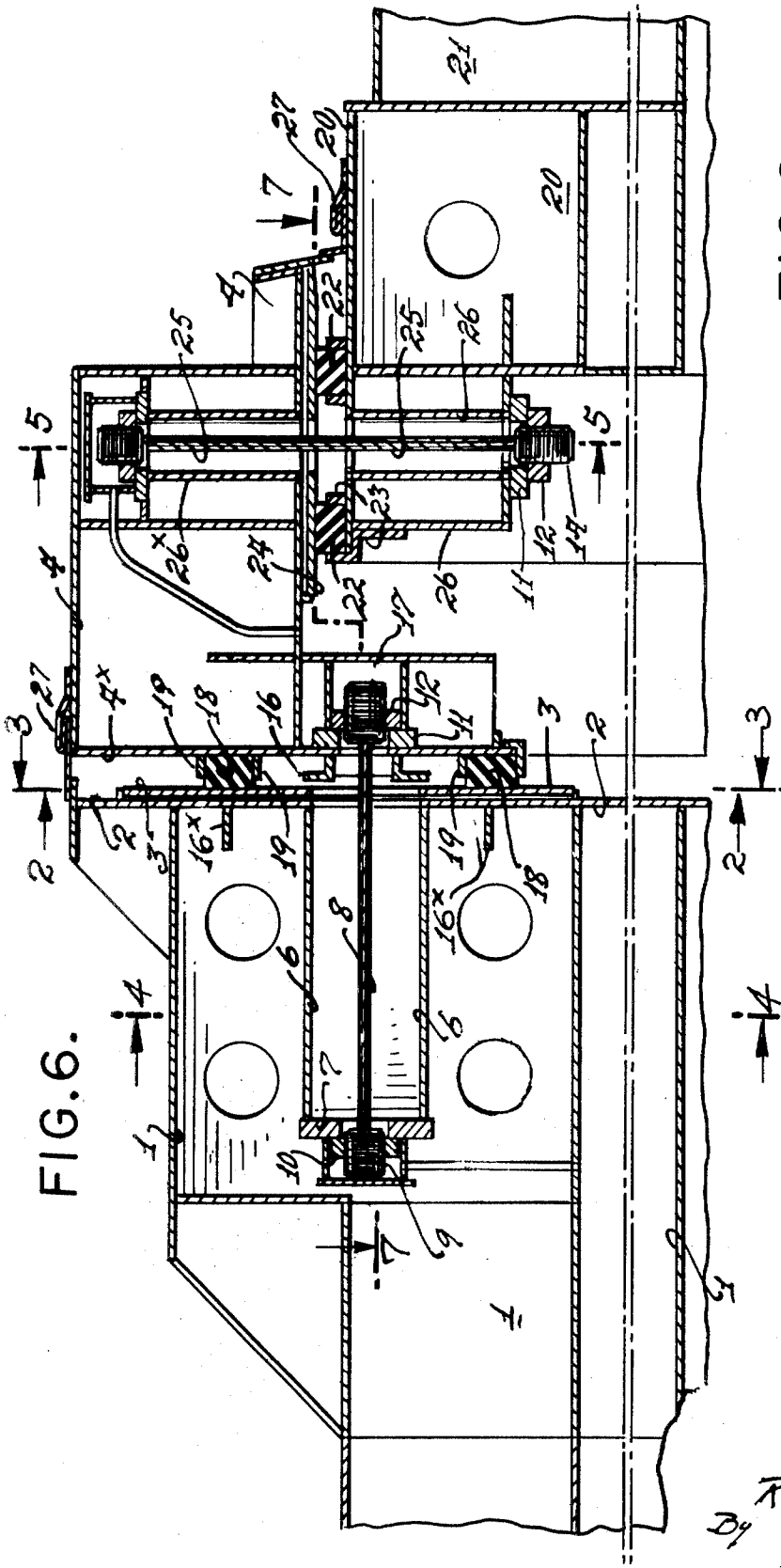


FIG. 6.

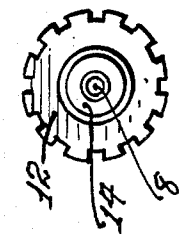


FIG. 9.

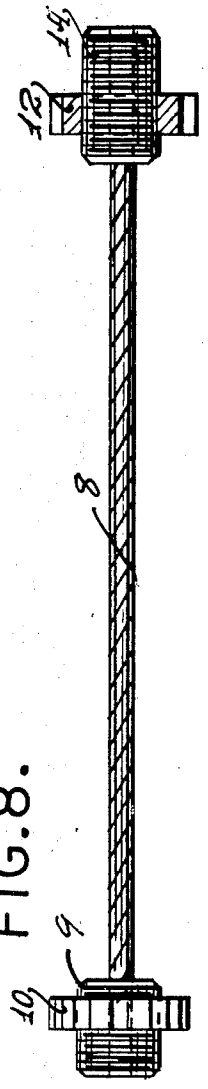


FIG. 8.

INVENTOR.
Robert WARSHAW
By H. Lee Helms
Attorney

United States Patent Office 3,517,515 Patented June 30, 1970

3,517,515

TUNNEL CONSTRUCTION SLIDING ASSEMBLY

Robert Warshaw, East Meadow, N.Y., assignor to Parsons, Brinckerhoff, Quade & Douglas, Inc., New York, N.Y., a corporation

Filed July 17, 1968, Ser. No. 745,463
Int. Cl. E01g 5/06
U.S. Cl. 61—42 10 Claims

ABSTRACT OF THE DISCLOSURE

The invention controls disturbance by earthquake or other forces upon tunnel tube sections leading to a caisson or building to which they are connected. The embodiment shown and described relates to a major parallel tunnel construction for vehicular passage, which provides a fixed caisson or building and watertight sliding joint between the caisson and the initial connected tube sections of the tunnel. Also, the invention is applicable to a single tunnel and as a joint between tunnel sections. It controls said dangerous disturbing forces by enabling vertical, transverse, and longitudinal, sliding and coordinate, movements at said joint, whilst maintaining watertight connection, the invention being specially applicable to caisson-tunnel or building-tunnel tube constructions under water.

The invention will be described with reference to the accompanying drawings, in which:

FIG. 1 is a view in side elevation, partly broken away, showing the projecting end of a caisson or building, one of the tunnel tubes, and the exterior of the joint between them.

FIG. 2 is a view in elevation, showing the outer face of the joint-ring which is connected to the tunnel tubes and has sliding relation to the joint-ring of FIG. 3.

FIG. 3 is a view, in elevation, of the joint-ring which si joined to the fixed caisson, and which has facing-relation to the FIG. 2 joint-ring and to the tunnel tubes.

FIG. 4 is a vertical section taken on the line 4—4, FIG. 6.

FIG. 5 is a vertical section taken on the line 5—5, FIG. 6.

FIG. 6 is a vertical section on the line 6—6, FIG. 2.

FIG. 7 is a horizontal section taken on the line 7—7, FIG. 6.

FIG. 8 is a longitudinal view of one of the cables with its end screw heads and nuts.

FIG. 9 is a face view of one of the nuts on FIG. 8.

FIG. 10 is a fragmentary corner view of one of the gaskets used in multiple at the sliding surfaces of the joint.

FIG. 11 is a fragmentary detail view of a stiffener arrangement, particularly adapted for the ring of FIG. 3.

In FIG. 1 of the drawings is shown the form of the ring **1** which forms a rigid projecting connection of the caisson and thus may be considered a primary element thereof. In FIG. 1 said ring **1** is shown as carried by the steel and concrete structure **2** which normally will be the lower part of a building into and out of which the traffic passes to and from the tunnels. Since the embodiment illustrated is for a major, parallel double-tube tunnel, the ring **1** encompasses two tube passageways with an intermediate or central passageway for general uses. It is now expedient to describe the internal and face construction of ring **1**, and this description will be with reference to a section thereof shown in FIG. 6 and taken on the line **6—6**, FIG. 3. The construction will be the same at any other like section throughout the ring **1**, at a peripheral margin.

Referring to FIG. 6, the outer face of ring **1**, indicated at **2**, has fixed thereto a plate **3** outwardly faced with "Teflon" or other suitable slide-augmenting or friction reducing surfacing material. Opposite plate **3** is the face shown in FIG. 2, of ring **4** which directly carries the initial tunnel tubes, but with controlled sliding connection.

Ring **4**, best shown in cross sectional margin in FIG. 6 (on the line **6—6**, FIG. 2) may be considered as the major joint member, because it is adapted to transverse movements on ring **1**, in either direction, also for vertical movements up and down or a twisting movement which is a combination of vertical and transverse movements; and it so mounts the initial tunnel tubes to permit controlled longitudinal and other movement of those tubes under applied force as by earthquakes or other forces.

Referring to FIG. 6, it will be seen that the ring **1**, which is a projection of the caisson, and fixed, is shown with one of the box stress-resisting members **6** carried by ring **1**, in multiple, inwardly of its front face-plate **2**. Box **6** has a heavy end plate **7** with an aperture greater than the diameter of a cable **8** which passes through the box. At its rear end the cable threaded head **9** receives a nut **10** which bears against heavy box-plate **7**. The opposite end of the cable passes through enlarged openings in plates **2** and **3** and iinto an enlarged opening in ring **4** which is inwardly faced by a heavy bearing plate **11** abutted by nut **12**, which is toothed to allow for adjustments on the threaded head **14** of the cable assembly. The bearing plate **11** directly engages wall 4^x of ring **4**. Any suitable stiffeners, such as indicated at **16**, and **17**, FIG. 6, may be employed.

Ring **4** carries two heavy gaskets, each of which is extended entirely around ring **4**, as indicated in FIG. 2 at **18**. Referring to FIG. 6 it will be seen that each gasket is held between spaced metallic strips which will be welded to plate 4^x of ring **4**, and as indicated at **19** in FIGS. 6 and 7, the latter figure showing only the top of one strip **19**. The gaskets **18** bear upon plate **3** and have sliding relation thereto under certain applied forces.

Ring **4** in one of its functions serves as a piston-receiving cylinder, the piston being a ring shaped member **20** rigidly connected to the two spaced tunnel tubes and shaped to conform with the general contour of the rings **1** and **4**, but of lesser area so as to be received within ring **4**. Thus the two spaced tunnel tubes are held connected by piston ring **20**. The outer face of piston-ring **20** at the area thereof extending within ring **4** carries two spaced gaskets which preferably, of continuous length, extend each as a unitary member around said piston-ring. The said gaskets are shown at **22**, FIG. 6, and each kasket is held between metallic strips **23**, carried by said ring. The gaskets **22** bear upon a plate **24** carried by and internally of ring **4** and preferably surfaced with "Teflon" or other suitable anti-friction material.

The gaskets are pressed against plate **24** by spaced cables extending along the contour of the inwardly projecting area of piston ring **20**, extending through the marginal area of the latter, and thence outwardly at points of connection with ring **4**, as shown in FIGS. 6 and 5. By reference with FIG. 6, showing one of the cables, **25**, the cable is adjustably anchored at its inner end by the screw head thereof and nut **12** bearing upon the same type of heavy bearing plate **11** previously mentioned, the latter engaging the lower end of a box element of ring **20**, indicated at **26**, and through which the cable **25** extends. The cable then extends outwardly through wide openings, including one in plate **24**, thence through box 26^x of ring **4**, the outer ring end of the cable carrying a threaded head which receives a nut such as **10** or **12** of FIG. 8, which bears upon the outer closing plate of box 26^x.

A protective sleeve **27** best shown in FIG. **6** is placed around the periphery of rings **1** and **4** to keep solid material from the space between plates **3** and **4x** and plates **2** and **4x**. The sleeve in this instance is a neoprene belt, reinforced with nylon cord and folded to allow the joint to move as required. Protective sleeve **27x** around the entire periphery of rings **4** and **20** keeps solid material from the space between plate **24** and the outer plate of ring **20**. Sleeve **27x** is the same material as sleeve **27**.

While in the embodiment illustrated, the ring **4** which holds the "piston" members **20** for the two tunnel tubes, is unitary and thus for two tunnel tubes, it will be understood that the invention may be used for a single equivalent ring for a single tunnel tube, or individual rings for each of a plurality of tunnel tubes.

When, as in the embodiment shown, the tunnel tubes are in the order each of 16 feet in diameter, it may be considered that the joint ring **4** may be 27 feet in height and 53 feet in breadth, with a weight, including the piston-like "collar" **20** of 113 tons. As hereinbefore set forth the slide permitting connections between ring **4** and the fixed projecting end of the caisson comprise in said embodinmet a plurality of cables which impose pressure on the sets of heavy sealing gaskets **18**. The cables, which are best shown in FIGS. 8 and 9, with their end members for adjustment of tension by hydraulic or mechanical jacks carry toothed nuts on their threaded end-heads, so that the nuts may be engaged for adjustment.

With the size and weight of ring 4 indicated above, both horizontal cables and the vertical cables may each be of 1⅜" in cross section and 47⅛" in length (including the threaded heads thereof) and the pressure of the gaskets may be 100 lbs. p.s.i. or calculated as about twice the outside water pressure when the structure is submerged.

In the example indicated above, the ultimate strength of the wire cables may be specified as about 192 kips, the embodiment illustrated showing 62 cables leading from ring **4** to the caisson projection. or fixed ring **1**, and in practice there may be somewhat less in number extending vertically in connection with the ring **4** and its cylinder formation and the piston-like ends of the initial tunnel tubes. In such example, the gaskets may each be of 5½ x 2 11/16" in cross section when compressed or as required by proper ratio of stress-load—gasket size.

The fixed caisson may be part of a ventillation building, or other type of building leading to the tunnel tubes, and the criteria for movement relatively between the building and the connecting tunnel tubes, by way of the joint of this invention, may provide for a maximum vertical differential movement between the building and ring **4** of +4", plus a 2" allowance for settlement of the structure. The maximum lateral motion may be set as +2", and the maximum motion along the axis of the joint as +1½". However, the invention is such that provision is made for +6" vertical motion; +6" lateral motion; and +3" along the tube axis, thus providing for the accumulative effects of several earthquakes or equivalent disturbing force applications. Adjustment of the wire cables may be made after an earthquake or explosive force, for example, to realign the cables horizontally or vertically should the residual differential be large. Thus it will be seen that the wire cables are flexible enough to move with the joint components and still maintain a uniform compression in the rubber or equivalent gaskets and make the joints watertight and the contacting faces slide under substantial disturbing forces such as earthquakes as one example.

It will be understood that various modifications may be made in the form and arrangement of the elements illustrated and described in the embodiment shown, without departure from the spirit of the invention. Thus rigid bars may be used instead of the cables, and with swivel ends. The swivel ends would permit lateral movement of the bars when there is relative movement between the caisson or building and the joint assembly. A major utility of the invention is that it provides a moveable joint connecting tunnel sections and allowing for the differential displacements between tunnel sections under disturbing forces, earthquakes being an example.

Having described my invention, which I claim and desire to secure by Letters Patent, is as follows:

1. A tunnel construction sliding joint assembly, in combination with a fixed caisson-like member having at least one tunnel passageway and a face margin, of a ring-like structure having at least one tunnel passageway and having a face opposite the face of the caisson-like member, said ring-like structure being adapted for connection with at least one tunnel tube assembly, means for connecting the ring-like structure along its said face to the face margin of the caisson-like member, said means comprising a plurality of spaced tension members, said tension members extending longitudinally of the caisson-like member and adapted to move said ring-like structure toward the caisson-like member to bring the face thereof into juxtaposition relative to the face of the caisson-like member, at least one of the last named faces being adapted to hold gasket means, and said tension members being adjustable to the point of permitting relative lateral movements of the caisson-like member and the ring-like structure upon imposition on either or both of major forces, exemplified by earthquakes.

2. In a tunnel construction sliding joint assembly, constructed in accordance with claim **1**, at least one gasket following the contour of the ring-like structure at its face-margin and facing and adapted to engage the face of the caisson-like member, and means for supporting said gasket in normally vertical position as to its surfaces contacting the faces of the caisson-like member and the ring-like structure.

3. A tunnel construction sliding joint assembly, constructed in accordance with claim **1**, in which at least two gaskets are positioned between the ring-like structure and the caisson face, the tension members being positioned between two of the gaskets and being provided with exposed adjustment members adapted to increase or decrease the pressure of the gaskets upon the caisson face.

4. A tunnel construction sliding joint assembly, in accordance with claim **1**, in which the tension members are wire cables projecting through enlarged apertures in the ring-like structure for relative lateral movement of the latter and the caisson-like member, a plurality of the tension members being wire cables with a threaded head at an end thereof, and a nut on said head and adapted to receive a power tool for rotation.

5. A tunnel construction sliding joint assembly, in accordance with claim **1** in which an anti-friction surfaced plate is interposed between the faces of the caisson-like member and ring-like structure, a gasket contacting said plate, and adjustment means applied to the tension members adapted to move the ring-like structure toward the face of the caisson-like member with compression of the gasket, or to relieve compression of the gasket by reverse resulting movement of the ring-like structure.

6. A tunnel construction sliding joint assembly, in accordance with claim **1**, in which the ring-like structure is formed with a cylinder-like reception chamber forming a collar, in combination with a tunnel-tube connecting member operative within said collar for limited movement as a piston, and a plurality of spaced tension members surrounding an interior wall of the ring-like structure and an outer wall of said collar, said tension members having an exposed tension-adjusting member on each of them.

7. A tunnel construction sliding joint assembly, in accordance with claim **1**, in which the ring-like structure is formed with a cylinder-like reception chamber, in combination with a tunnel-tube connecting member operative within said chamber for limited movement as a piston, in combination with at least one gasket intermediate and conforming with the surface of said reception chamber and the opposed face of the tunnel tube connecting mem-

ber and adapted to receive compression forces from tension members, and tension members connected to said tunnel-tube connecting member and to said chamber and adapted to impose compression forces on said gasket means herein specified; said gasket means surrounding an outer wall area of said tunnel-tube connecting member.

8. A tunnel construction sliding joint assembly, in accordance with claim 7 in which the tension members surrounding an interior wall of the ring-like structure and an outer wall of the collar are wire rope cables extending in a general plane normally vertical, the cables connecting the ring-like structure and the caisson being normally horizontal, and the cables intermediate their ends being relatively free from engagement with structural elements except for end-attachment thereto.

9. A tunnel construction sliding joint assembly, in accordance with claim 6, in which gaskets at opposite sides of the tension members are disposed between the interior wall of the ring-like structure and the outer wall of the collar, at least one end of each tension member being exposed and having applied thereto an adjusting element for varying compression of the gaskets.

10. A tunnel construction sliding joint assembly, in accordance with claim 2, in which the gasket is of rubber-like characteristics, block-like in cross section, and follows the contour of ring-like structure margin in integral form.

References Cited

UNITED STATES PATENTS

439,841	11/1890	Hobart	61—43
907,357	12/1908	Hoff	61—43
1,076,738	10/1913	Berry	285—224
1,291,376	1/1919	Berry	285—223 X
2,211,589	8/1940	Widner	61—42
2,217,664	10/1940	Berger	285—224

FOREIGN PATENTS

960,139	6/1964	Great Britain.

DENNIS L. TAYLOR, Primary Examiner

U.S. Cl. X.R.

61—84; 285—223