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T H E D E T R O I T - W I N D S O R T U N N E L

The Construction Story of the World's Only International Underwater Automobile Roadway

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The history of subaqueous tunnels goes back to the year 1818 when Marc Brunnel, a Frenchman, took out the first patent for the shield and cast-iron lining. About twelve years later, or in 1830, Sir Thomas Cochrane secured the first patent for compressed air. Between 1825 and 1843, Marc Brunnel built the first subaqueous tunnel under the Thames and, due to his genius, it was finished under the most difficult conditions without the use of compressed air. But this ambitious enterprise was a financial failure and checked all undertakings of a similar character for the next twenty-five years. It was not until James H. Greathead developed the circular one-piece shield, invented the grouting machine, made use of compressed air and cast-iron lining that subaqueous tunnels were economically built.

The first vehicular tunnel of magnitude and capacity was the Blackwall Tunnel under the Thames in London, opened for traffic in 1897. Others were the Glasgow Harbor Tunnel, England, the Elbe Tunnel in Germany and the Rotherhithe Tunnel in England, the last completed in 1908.

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All these tunnels were built previous to the advent of the automobile. As the automobile came into general use, the Holland Tunnel in New York, the Liberty Tunnel in Pittsburg, the George A. Posey Tube between the cities of Oakland and Alameda, California and the Detroit and Windsor Tunnel under the Detroit River were built.

We will take a quick trip through the Detroit-Windsor Tunnel:

Driving through the entrance on Woodbridge Street in Detroit, past the toll booths and circling to the right, going northbound down-grade, a spiral driveway is taking us underground, now heading South. We are driving on a granite block roadway in a brightly lighted, well ventilated white-tiled tunnel. For about five hundred feet we are on a five percent grade and then we are leveling out for the trip under the river. At our right is a railed-off sidewalk where guards are patrolling the length of the tunnel. Midway under the river is a dividing mark showing in colored tile the flag of the United States and Canada. It is known as the world's friendliest border. A little beyond this point the tunnel is at its lowest point, the roadway we are on is 75 feet under the surface of the river. Above us is the steel and concrete top of the tube, above that five feet of clay and above that 45 feet of water. Beyond the boundary line we start going up, the slope becomes steeper and we are now beyond the water's edge, climbing a five percent grade toward daylight in Windsor, Canada.

That was a trip through the Tunnel. Now we shall learn how it was built: There are three methods of building a subaqueous tunnel. Cut and Cover, Shield, and Trench and Tube. The Cut and Cover method is just what the name implies. Cut a trench into the ground, cover it over, and you have a tunnel. That is the way subways are built, and that is how the Detroit-Windsor Tunnel was built from the entrance points, on either side of the river, fifty feet under ground.

The Trench and Tube method was used in the river bed itself, we will come to that later. We will learn about the Shield method first. Picture a shaft in the ground, on the Detroit side of the river, about 450 feet back from the water's edge, 50 feet deep by about 40 feet square. It is a steel-lined shaft with elevators running up and down. At the bottom men are constructing the shield. This is not a new idea. Miners digging through sand and clay and muck must be protected from possible cave-ins and floodings. The shield gives them this protection. The Detroit-Windsor Tunnel shield was a hollow steel cylinder 32 feet and 8 inches in diameter and 15 feet long. This shield lies on its side and across the open front end steel platforms and vertical partitions are built and in the holes thus formed miners are at work digging at the earth. But how is the water kept out if the shield has an open front end? The answer is compressed air. To the rear of the shield, not a part of the shield itself, is an airtight bulkhead of steel. Built into this bulkhead are three chambers, these are called locks, two are for material and one for men. If you are coming from the shaft forward into the shield you have to go through the bulkhead.

You enter the man-lock by an air-tight door and find yourself in a long tube-like room with another door at the other end. There you will have to wait with doors closed while a roaring sound fills the lock. The noise comes from the compressed air shooting into the lock to raise the air pressure to a point equal to the pressure up ahead in the shield. When the air pressure is up you open the forward door and walk into the workings. The compressed air is protection against the water. When you are in the shield you are in an air-tight working tunnel, closed off at the rear by the bulkhead and at the front by the earth. The compressed air is an invisible force showing between the particles of dirt, forcing the water back; a marvelous force, pushing at the front end of the shield, holding back the water like a giant hand. When you are on the surface you are living under a pressure of 14 pounds per square inch, which is normal atmospheric pressure. Man can work safely under a pressure four times that much. Only 18 pounds of pressure was necessary to keep the water out of the Detroit-Windsor shield.

We will examine the Shield more closely now. We will go forward and climb a ladder to one of the miner's holes. The wall of the shield is of 2 and 3/4 inch steel. The front rim however is cast iron, tapered to a fine edge called the cutting edge. You watch a miner slicing out the clay in front of him with a draw knife. It is blue clay, easy to handle, and he tosses back long hunks of

it onto a conveyor that takes it back to the rear where it is transferred to small cars standing on a narrow-gauge track.

Midway of the shield, on a transverse girder, there is a device called an erector arm. It looks like the hand of a clock, about 16 feet long, working on a pivot at the exact center of the shield. This is the tool the engineer uses for erecting the pressed steel rings with which the tunnel is being lined as the shield moves forward. These rings come in segments and the erector arm swings them in place at the top, bottom or sides of the tunnel's circumference and holds them while workmen bolt them.

What force drives the shield through the earth? Around the circumference of the shield are 32 hydraulic jacks, each capable of exerting 100 tons pressure. The rear of each jack rests against the last placed steel ring. When it is time to shove the steel ring ahead these jacks go into action. The shield moves forward by 2 and 1/2 foot steps, just far enough to allow another steel ring to be put into place.

Here is a cross-sectional look of the shield in operation: Picture a hundred feet of tunnel. At the head of it is the shield with the men inside digging out the clay. The erector arm is at work installing the steel rings. Back of the shield is about 80 feet of completed tunnel, lined with pressed steel rings. At the rear of the tunnel is the air-tight bulkhead with its three locks, two for material and one for men. Running from the shield back through

the material locks is the narrow-gauge railroad. Running along the sides are cables and pipes to feed juice to the electric lights and water to the hydraulic jacks. In back of the bulkhead is the elevator shaft leading upward to daylight.

Now we have a picture of the shield with the men working safely inside, protected by compressed air. But as the shield burrows slowly through the earth it must be steered, it must change directions both laterally and horizontally, it needs a pilot just like a ship at sea steaming ahead through dense fog in the dead of night. The pilot rests on a small platform hanging from the top of the tunnel in back of the shield. With transit and level he sights on certain points in the shield itself. If he wants the shield to turn downward he orders the top hydraulic jacks into action, if he wants the shield to turn right he orders the left side jacks into action. And so the shield goes on, day after day, slowly steering for a predetermined point underneath the bank of the Detroit River. Out of the tunnel go the cars of blue clay, into the tunnel go steel, material and power. The shield must travel 466 feet, to a point 31 feet beyond the harbor line. Meanwhile, out on the river dredges are at work. They are big scows with clamshell buckets hanging from long derricks, buckets with two cubic yard capacity. The dredges have an exacting job. The trench must steer a diagonal course across the river. It must be 20 feet wide at the bottom and

about 90 feet wide at the top. The bottom of the trench must be 85 feet below the surface of the river. Since the water in mid-channel isn't much over 40 feet deep, that means at least 45 feet of excavation. (The War Department had specified that there must be 42 feet of draft over the tunnel after completion of the job.) These dredges are guided by sets of posts on shore. The proper depth is reached by marking the cable that holds the bucket.

While the gigantic trench takes shape in the river and the shield burrows its way toward one end of the trench, steel workers six miles downriver at Ojibway, Canada, were constructing the big tubes. There are nine sections of tube forming the underwater part of the tunnel. Each section is a steel cylinder 248 feet long with an outside diameter of 31 feet, constructed of 3/8-inch steel plate stiffened on the outside by octagonal diaphragms every 12 feet and stiffened inside by ring angles every 4 feet. There are bulkheads at each end of 10 x 10 timber supported by heavy steel trusses inside and covered by 1-inch sheeting and seven-ply waterproofing outside. All plates are welded and the rivets tested by air jets to guarantee water tightness of each section. These tube sections were built parallel to the river bank on skids and launched into the river. Each tube is towed into a slip and men enter the inside through manholes to cover the wall with its 18-inch layer of concrete and pour the roadway. Just before the tube was ready to be towed North concrete was poured into the form along the bottom of the tube, outside, to form a keel. Concrete can be

poured under water. The concrete is forced through a hose with a long pipe attached, it sets under water as well as it does in the air. It took four tugs to pull Section No. 1 upstream, two pulling and two pushing. At this stage the tube drew 23 and 1/2 feet of water but the top and sides were still to be concreted. This was done in the river, about 300 feet above the trench. The buoyant tube was moored to a row of heavy posts stuck in the river bottom and concrete was added until the point of buoyancy was reached and the tube sank lower and lower in the water until almost submerged. At this point four concrete cubes, each weighing 5 tons, were placed on one end of the tube, sinking it below water. That end sunk to the bottom, but when you remember that the tube is 35 feet in diameter after the concrete had been poured, and the river only 40 feet deep at this point, you realize that the tube didn't have far to sink. With one end under water, a floatation scow was run over that end and attached to the tube by means of cables. A diver hooked the cables from the floatation scow to each side of the submerged tube end, then concrete blocks were placed on the other end, a floatation scow ran over it and two more cables attached. Now we have a submerged tube weighing about 8,500 tons. Into the bottom of the trench 2 and 1/2 feet of sand had been dropped and graded level. Now tube Section 1 was ready to be placed into the trench on the American side of the river. When Section 2 was lowered into place two lugs (one on either side of the tube) overlapped similarly placed lugs on Section 1. A big steel pin, 5 inches in diameter, was

dropped through these two lugs and a diver guided it into place. Concrete was poured over the joint (a complete collar of it) and the divers had to slip the forms into place and guide the "tremie" pipe while the concrete was being poured. One of the most ticklish spots in the entire job was when the great section, 248 feet long and 35 feet in diameter, octagonal in shape, was dropped downstream 300 feet and swung broadside to the current over the trench. There is a two-mile current in the river and this tube, almost as deep as the river, will dam up considerable water when it is swung broadside. Four concrete anchors, each weighing 25 tons, were buried deep in the bottom of the river. Two of these anchors were placed off to one side, out on midstream, opposite the downstream end of the tube, the other two were placed straight upstream from the tube. Between the upstream anchors and the tube a "puller scow" - which is a big scow with engines powerful enough to pull against the buried anchors and haul the tube back if it should drop downstream too far - was interposed.

There are nine sections of tube in the Detroit-Windsor Tunnel with a total length of 2,200 feet. The first six sections slant downward, the last three slant upward to the Canadian shore. As each section was sunk it was lined up by means of tall masts on each end of the tube.

The last important step in the completion of the tunnel was the joining of the shield-driven and tube sections, in other words of land and river sections.

The landward end of the first section of the tube flares out with a bell-like rim. Toward this opening the shield is steering its way through the ground. But obviously the shield cannot force itself into the open water of the trench. Compressed air won't keep away a solid wall of water, so dredgers must cover the landward end of the tube with clay to a depth of at least 15 feet. Through this backfill the shield bores its way. As the shield leaves solid ground and begins to edge into the muck of the backfill the air pressure is increased to 21 pounds to keep out the water. As the shield entered the muck, workmen in the front end began to timber up the open end, and the shield was pushing blind through the muck, depending upon engineering science to hit exactly the bell opening of the tube. When contact was made at last there was less than an inch of error. The shield had traveled 466 feet, changing both direction and altitude and ended up only an inch off its course.

Now, underneath the backfill, 31 feet out beyond the harbor line, the shield was forced tight against tube Section 1. The skin of the shield was left there to become the wall of the tunnel. Now the bulkheads between each tube section were torn out. The 18 inch inner lining of concrete was poured at the joints. The sidewalk and granite-block pavement was laid, the walls were tiled, lighting and ventilation installed.

Ventilation is an important point. The tunnel can handle 1,200 cars an hour each way; but autos produce carbon monoxide gas. Engineers learned that man can live comfortable in a room that has four parts of carbon monoxide in ten thousand parts of air, but if the concentration were any greater he became fatigued. So the tunnel ventilation system does not permit a greater concentration than four parts to ten thousand. There is a tall ventilating tower on the Detroit side and another on the Windsor side. Each tower has twelve fans, six great blowers to force air into the tunnel and six exhausters to draw air out. The fans in each tower may be operated from a power supply from either side of the river. Fresh air goes into the tunnel through a duct alongside the roadway and is released through outlets every 15 feet; bad air is drawn out through ports in the roof also 15 feet apart. The tunnel ventilating system can supply 1,500,000 cubic feet of air a minute and completely change the air in the tunnel every 90 seconds.

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TUNNEL STATISTICS

Official Opening: November 3, 1930.

Length of tunnel from American to
Canadian portals: 5,135 feet.

Maximum depth of roadway below river surface: 75 feet.

Dirt excavated from river: 275,000 cubic yards.

Concrete poured: 80,000 cubic yards.

Width of roadway: 22 feet.

Capacity: 2,400 cars per hour.

Cost: \$23,000,000.

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