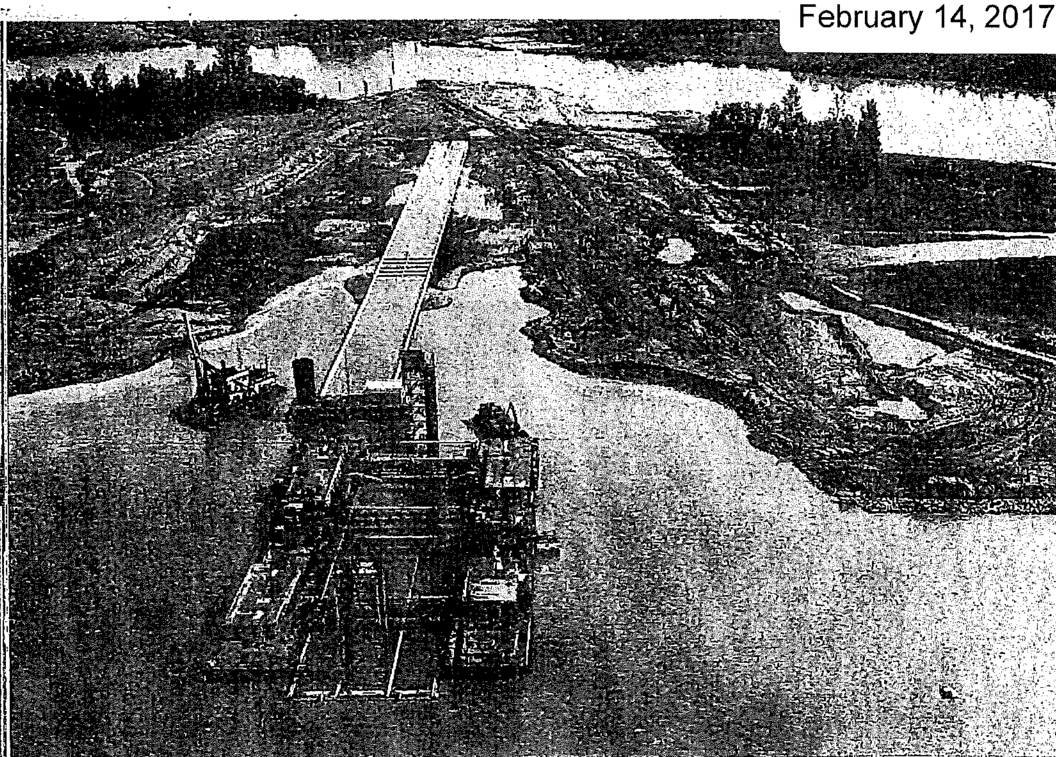
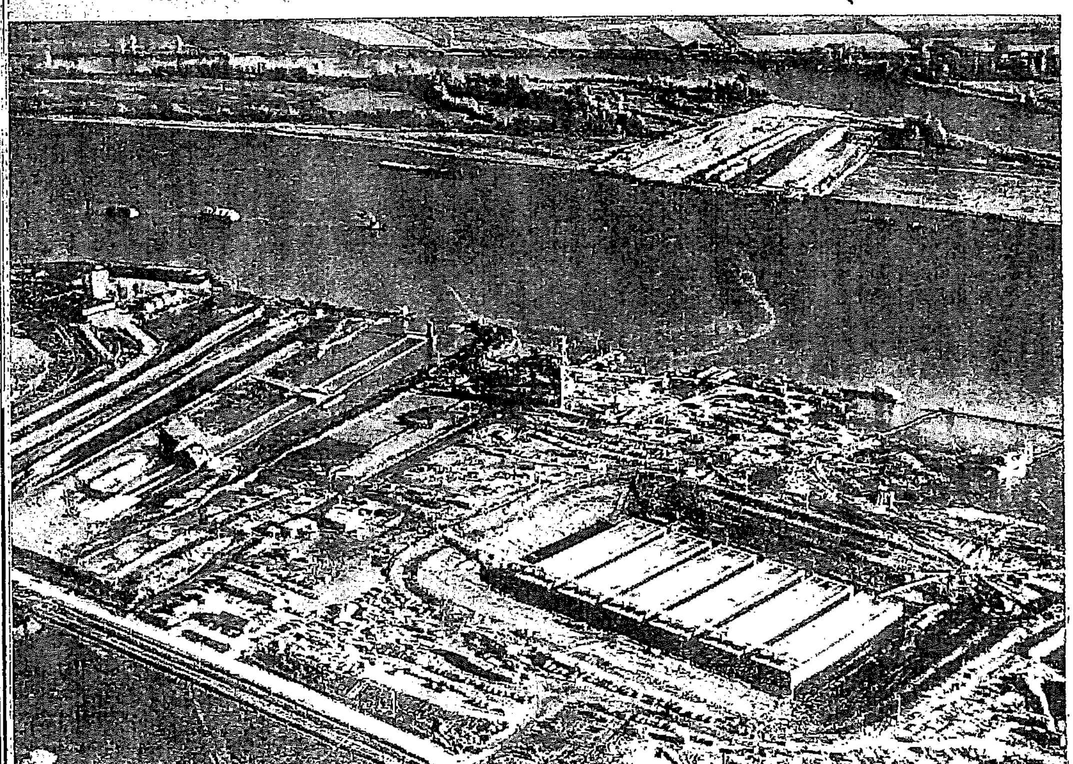
Schedule 1 to the Minutes of the Regular meeting of Richmond City Council held on Tuesday, February 14, 2017.

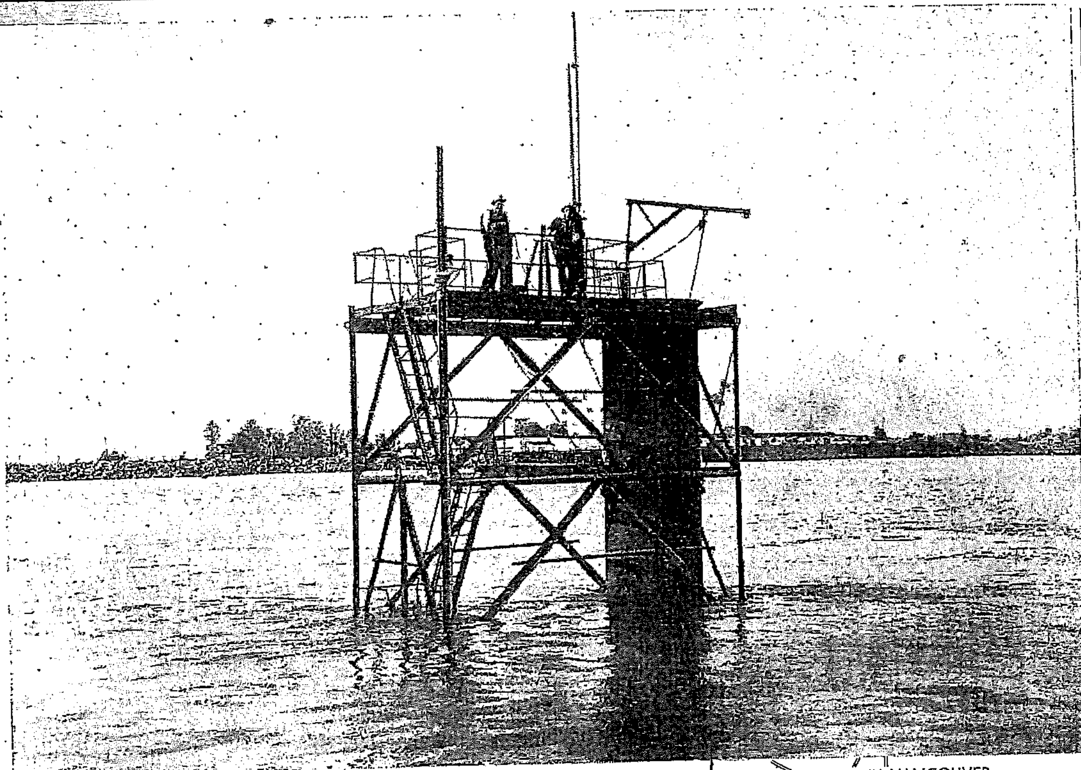


Four steel scows ease a prefab section of the tunnel into position for sinking—six inches per second

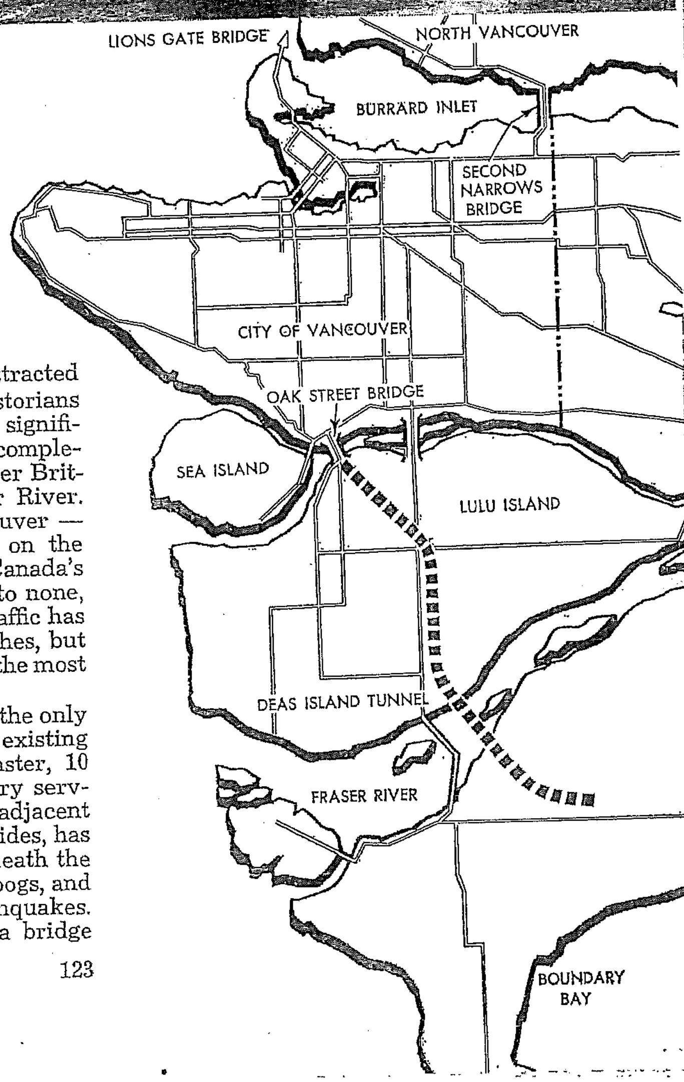
A Prefab Tunnel Conquers a Tough River

Six sections of tunnel (lower right) were prefabricated in 40-foot drydock; then floated to positions





Shafts 70 feet high were fitted to the sections before sinking. Right, dotted lines show main traffic route via tunnel

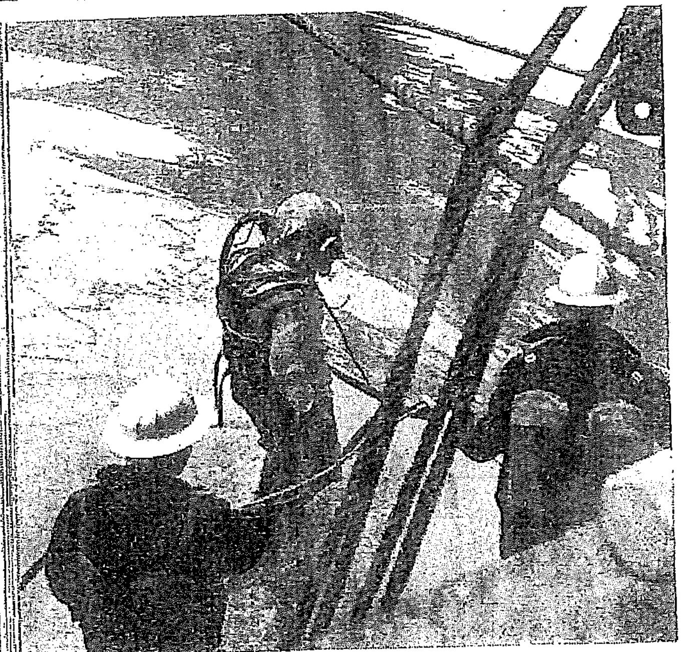


By Carson Kerr

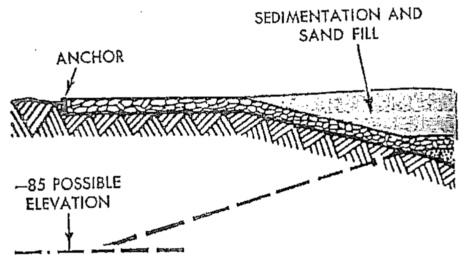
THE BIG RIPPLE ROCK blast attracted more attention, but future historians will probably attach much more significance to the comparatively quiet completion of the Deas Island Tunnel under British Columbia's treacherous Fraser River. The scenic surroundings of Vancouver — mountains north and east, ocean on the west and river to the south—give Canada's third largest city a setting second to none, but also complicate access to it. Traffic has demanded more southerly approaches, but the scenic features have presented the most problems.

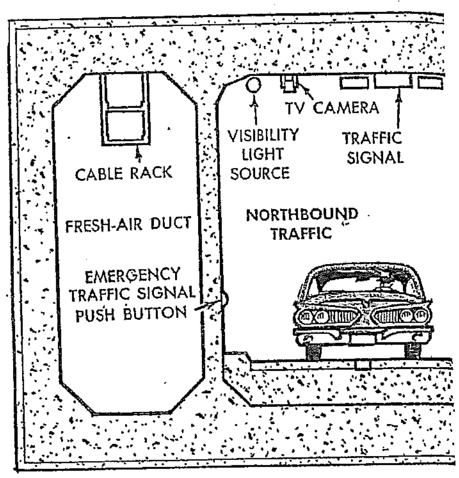
For years, experts have felt that the only possible supplement to the one existing highway bridge at New Westminster, 10 miles up-river, was additional ferry service. At any feasible crossing point adjacent to the city the Fraser is subject to tides, has constantly shifting sand dunes beneath the surface, is bordered by large peat bogs, and frequently feels the force of earthquakes.

After decades of deliberation, a bridge



Divers played important part in helping position the sections



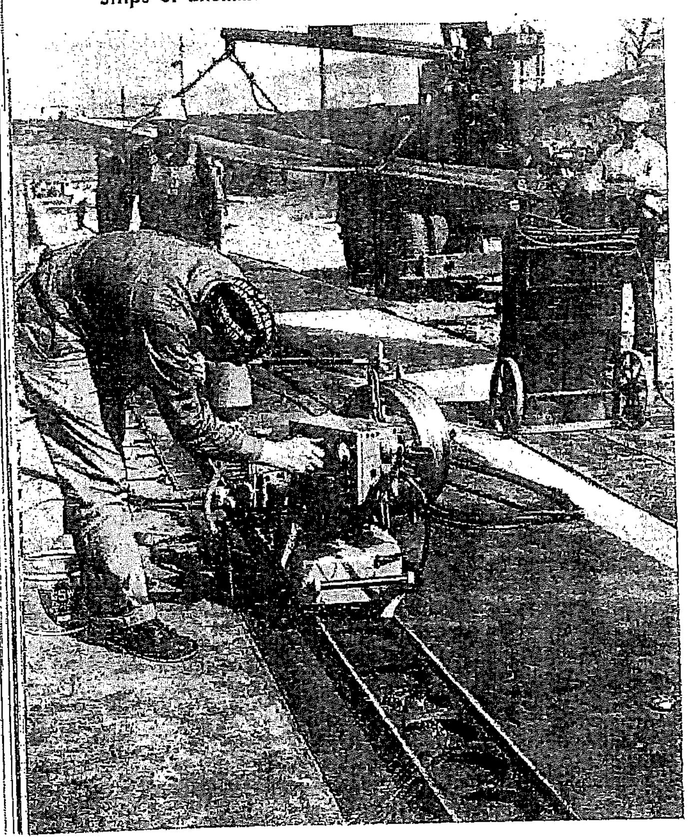


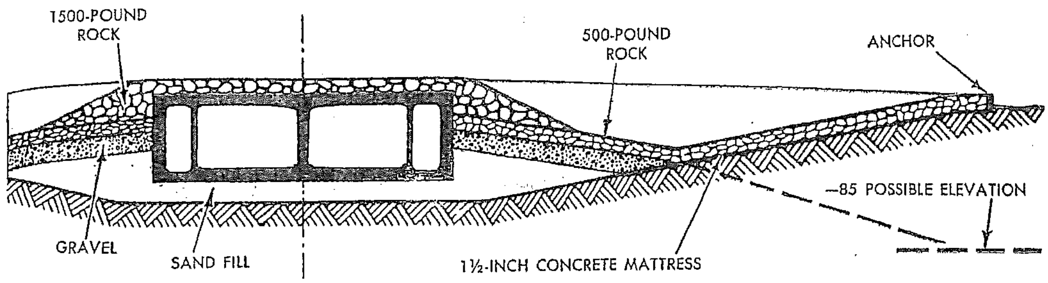
had been ruled out, for two reasons: It was almost impossible to find firm foundation for one lofty enough to provide clearance for the ocean-going freighters that frequent the river route; also, a high bridge would create a hazard to aircraft using Vancouver Airport on nearby Sea Island. A solution to the problems was finally found in going under, instead of over, the river. But it was by no means a simple one. History was made last year with a unique prefabricated tunnel, first of its kind in North America and second in the world, and the mighty Fraser met its match in the combined engineering and construction skills of man.

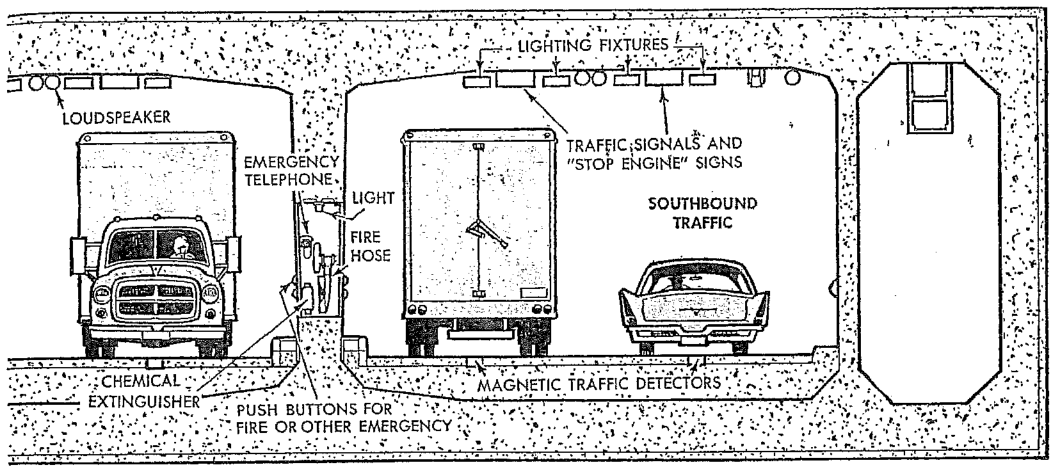
The tunnel was one of the most complex construction jobs ever undertaken, according to project manager Ole H. Bentzen. A Danish engineer, Bentzen represents the Foundation of Canada Engineering Corporation, which shared credit for the project with Christiani & Neilsen of Canada, designers of the famous Maas Tunnel under Rotterdam Harbor.

"The Fraser River is under the double influence of tides and mountain freshets," Ole observes. "The flow varies from 12 feet per second to almost-still water. Work had to be done at extreme low tide and when velocity dropped below two feet per second. We were limited to a period from the beginning of winter to mid-April, because at any other time the river was unmanageable. Most of the critical work was done 'blind,' in heavy rain, high winds or dense fog. The river was so muddy that contractors had to rely on instru-

Strips of bituminous material are sealed for waterproof cover





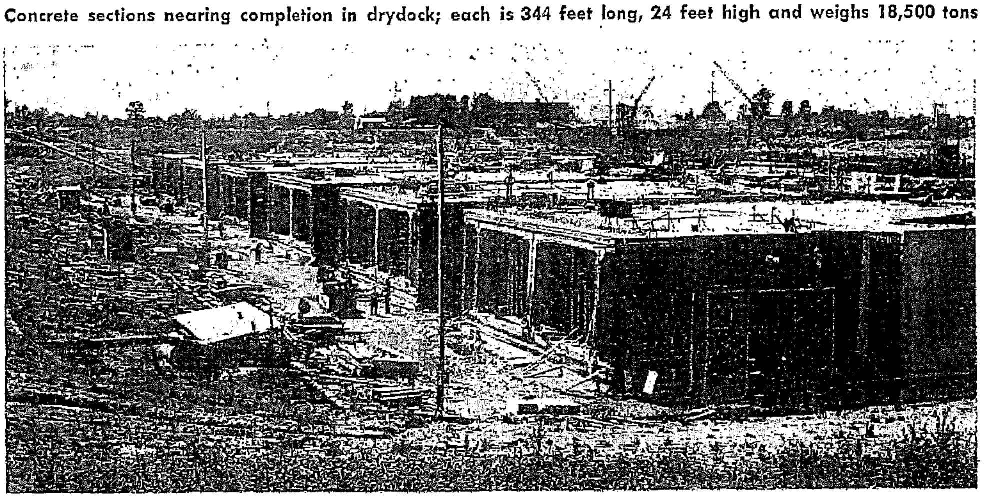


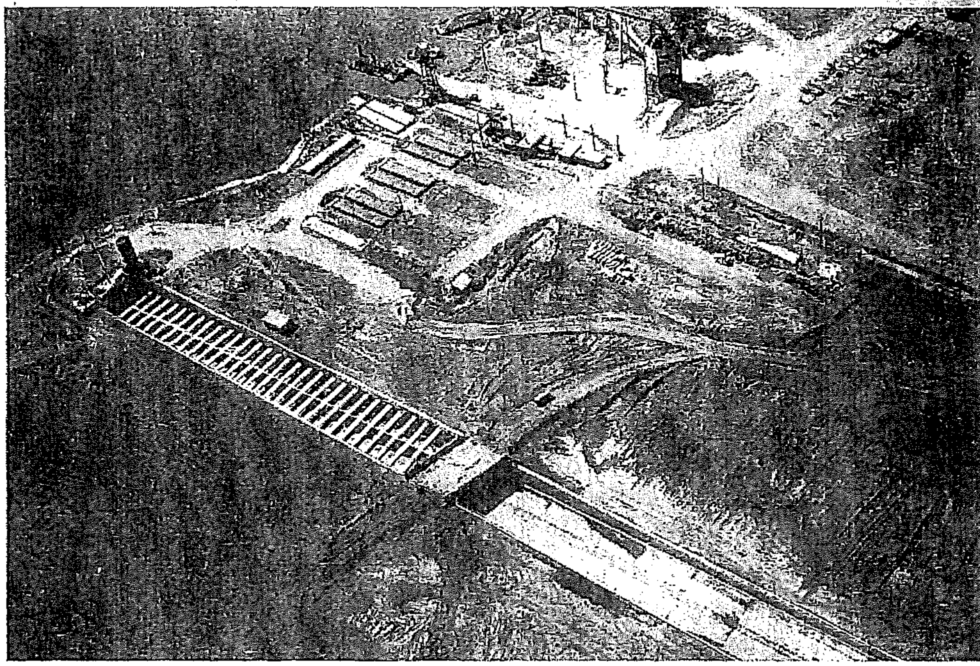
ments and the verbal reports of divers. We'd hoped to achieve accuracy within one quarter of an inch; we actually made it plus or minus one eighth. Before the last section was sealed in place, I'd almost worn out my knuckles knocking on wood."

Crossing only a short distance from where the river pours into the Pacific, the new tunnel is 25 miles from the Canada-U.S. border, and is linked to Highway 99 to the south and the Trans-Canada Highway to the east. It connects Lulu Island (from which two bridges lead to Vancouver) with the mainland, and cuts across the end of Deas Island, after which it has been named. Together with its approaches, it is 8000 feet in length with 2100 feet of tunnel. The two 24-foot roadway tubes are 60 feet beneath the surface at the lowest point, allowing navigable water with a depth of more than 40 feet above.

Although it was patterned after the Maas

Concrete sections nearing completion in drydock; each is 344 feet long, 24 feet high and weighs 18,500 tons





Sun screens over approach prepare drivers' eyes for dimmer interior; dark stack is from ventilation building

Tunnel, the Deas Island Tunnel is of vastly improved design and has many modern features usually associated only with freeways of the future. The maximum flow of 7000 cars per hour is controlled by attendants aided by a maze of safety systems, including magnetic traffic detectors in the roadbed, loudspeakers every 50 feet, and 14 TV cameras placed at strategic points. Emergency telephones are located at 177-foot intervals; there's a sprinkler for every 120 square feet of interior surface, and a number of emergency traffic-signal and fire-alarm push buttons.

Long, troughlike approaches, rather than a continuation of the tunnel, were originally designed mainly to simplify ventilation, but they also make possible one of the more important traffic safeguards. Each has a system of huge sun screens that cause a gradual transition in light intensity from exterior to interior. These serve a double purpose in that they prevent re-entry of vitiated air.

Ventilation buildings at each end are independently founded on slabs and almost completely below ground level; soil pressure around them is the same as that under the approaches. Power for ventilation is provided in both buildings, but each can handle the full load. There is also an emergency storage-battery unit. Variable-speed fans are controlled by time clocks set to suit the traffic pattern, but can be overidden automatically by carbon-monoxide meters, visibility meters or the fire-alarm system. The fans can also be operated manually.

Throughout the tunnel there are STOP ENGINE signs, which will flash on when the amount of oxygen in the air begins to drop toward the danger point. Abnormal conditions with any degree of frequency are not anticipated, because tests have shown that the ventilation system will normally renew tunnel air every two minutes.

The prefabricated underpass was

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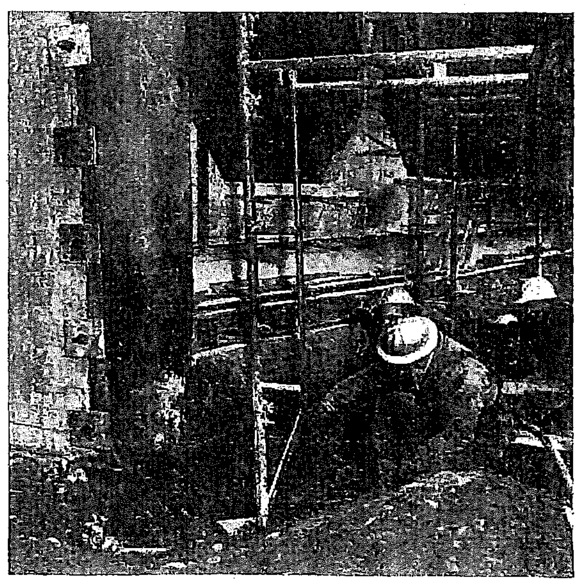
Workman inspects rubber pneumatic seal at the end of section



A Prefab Tunnel Conquers A Tough River

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constructed ashore in sections. Instead of tunneling under the river bed, a 40-foot-deep trench was sucked out and the sections were then floated into position, sunk, and sealed together on top of a padding of gravel. The first step in connecting them was the linking of a huge hook-and-eye arrangement. In the past, tunnels have been circular, because of the erroneous belief that they were easier and cheaper to build that way, but the Deas Island Tunnel was built on the square.

"The height of a circular cross section is governed by the width required to accommodate the necessary roadway," Ole Bentzen explains. "Whereas, that of a rectangular cross section depends solely on the vertical clearance required for the traffic lanes. Also, for the same navigable depth, a circular tunnel must be carried deeper, which means longer and deeper approaches and, therefore, greater cost."

Construction, which was started in March of 1957 and was completed late last year, cost $16,600,000. It involved the use of $2,000,000 worth of equipment, 100,000 cubic yards of concrete and 12,000 tons of steel. Excavation and backfill totaled 2,500,000 cubic yards. As many as 800 men were employed at one time, but the crew averaged between four and five hundred. Not the least significant record established was that of safety, which resulted from the wearing of lifejackets as well as hard hats by all workmen on or near the water, plus weekly safety meetings throughout the term of the project. Although 90 percent of the work was dangerous, there was never any serious time loss and no loss of life.

This fact is brought into sharp focus when contrasted with the record of another B.C. construction job of similar magnitude, the $16,000,000 Second Narrows Bridge, an intercity link connecting Vancouver with its main suburb, North Vancouver, across Burrard Inlet. This structure and approaches, with a total length of almost two miles, was originally scheduled to be completed about the same time as the tunnel, but was tragically delayed last June. Two 70-foot sections of the mile-long bridge gave way, workers fell 200 feet to the water and 22 men were killed.

The Deas Island Tunnel probably set a new record for attracting sight-seers, since as many as 10,000 local citizens and tourists served as sidewalk superintendents on week ends. The first act of the big show

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was the construction of the elements by Narod, Dawson & Hall. Scene 1 was a huge excavation, 684 by 933 feet, 20 feet below the surface of the Fraser and separated from it by an earthen dike. This open cut was used as a drydock during the building of reinforced-concrete sections, each 344 feet long and 24 feet high, weighing 18,500 tons. When they were completed, it was converted to a graving dock by simply breaking through the dike. The flooded sections were then pumped out so they could be floated to the outfitting jetty where their waterproofing, a combination of built-up bituminous and light-steel mantles, was checked by an automatic leak-testing system. Each section was then fitted with a 70-foot stack supporting a shaft with a 6-foot manhole, to allow access after sinking.

Foolproof System Necessary

One of the problems was to keep the sections watertight while workmen went inside to break away temporary bulkheads and finish off the joins with concrete. The sealing system used in constructing the Maas Tunnel had been far from satisfactory, and there was no intention of undertaking the Deas Island job unless a foolproof system could be devised. Company after company turned it down, but Gutta Percha & Rubber Ltd. of Canada tackled it.

Months of exhaustive experimenting led to the development of huge rubber pneumatic seals, resembling colossal inner tubes, each 80 feet long, 26 feet high and 30 inches thick. Designed to withstand pressures up to 4000 tons, these were installed at the ends of five of the tunnel sections. The air space was filled with water and the section was sunk and moved into position near the previously positioned one. Water was then pumped out, the sections were pushed together and the seals kept workmen perfectly safe while permanent joins were secured. While the rubber will deteriorate in about 18 months, this will have no adverse effect, because all joins will have hardened.

Besides, the tunnel is well-encased by concrete "mattresses," timber lagging, sand jetting and backfilling, so that neither ocean nor river action will disturb it. Also, it should easily withstand the most severe earthquake shocks to be expected in the area. Each section is anchored in place by four 37-ton concrete blocks, interconnected in pairs with 12-inch steel pipe, and secured by cable suspension. The whole tunnel is tied to several 3100-pound Dutch anchors (looking like inverted umbrellas, with 7-foot flukes that open when a pin is pulled after they have been placed 30 feet beneath the bed of the river) and three 7000-pound Navy anchors.

The "sinking fleet" was made up of 14 equipment carriers. Key vessel was a "floating rig" formed from four steel scows, which was used to ease the sections to location and maneuver them into position above a predetermined center line. The rig was hooked up to a complicated system of winches and land and river anchors, and movement was controlled inch by inch as engineers eyed instruments that measured river velocity, tide elevation and the stress on every cable. Typical of the extreme caution with which the sinking operations were carried out is the fact that the top recommended speed of movement was six inches per second, but the first element was moved only 12 inches per *hour*.

"Anything to do with the Fraser presents problems," Fred Knez, one of the project managers points out. "It's a most difficult body of water. More than anything else, the project required patience. It took three hours just to move one of the sections into the floating rig, seven more to arrange the winches and anchors preparatory to sinking. From outfitting jetty to final position, the first section kept us busy for almost 14 hours."

The actual placing operations were commanded by K.P. Kitchen, a Kiewit riverman of 50 years' experience. While four divers described underwater progress every foot of the way, Kitchen issued instructions by radio from a control room aboard the floating rig—calling for a cable to be clinched here, a pump to be started or stopped there, a jack to be operated somewhere else.

Serving over 3,000,000 residents of the Lower Fraser Valley and 650,000 in Vancouver, the tunnel was built for the Department of Highways and will be operated by the Toll Authority. Maintenance and operation are estimated at $50,000 annually, and the toll will be 25 cents. Its effect has already been felt on Vancouver Island, where tourist trade is of great importance.

It's more than possible that the success of the tunnel will eventually lead to a similar but much more ambitious project—an underwater passage linking Vancouver Island to the mainland. In any case, the amazingly accurate engineering and almost faultless design of the Deas Island Tunnel have added to the wonders of the modern world. ★ ★ ★

¶Floating on water that is more than 2000 feet deep, Ross Ice Shelf in the Antarctic is about 1000 feet thick and about as large as France.