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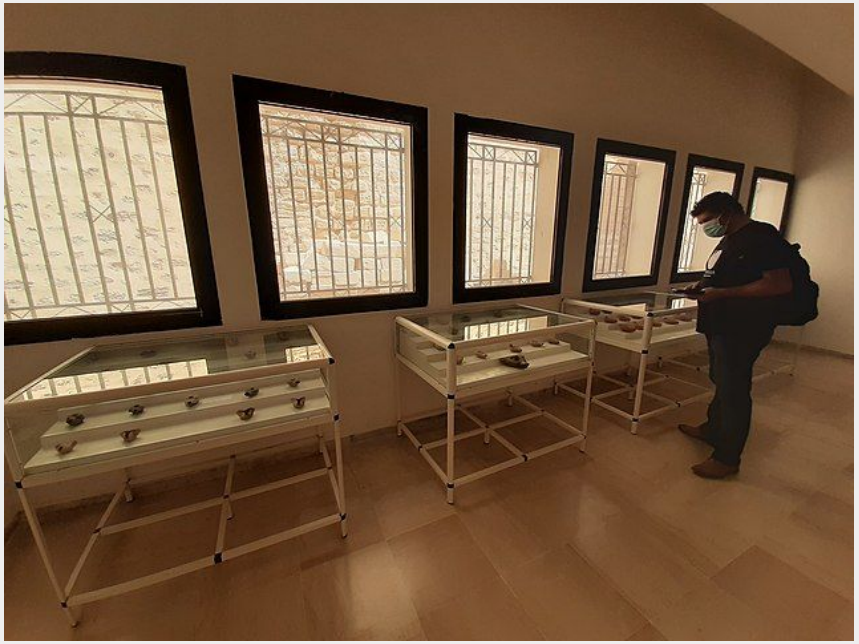
WPI

April 24, 2022

Tower Bridge Bring-Your-Own-Device Pilot Application

Visitor Experiences Must Evolve According to New Audiences and Environments



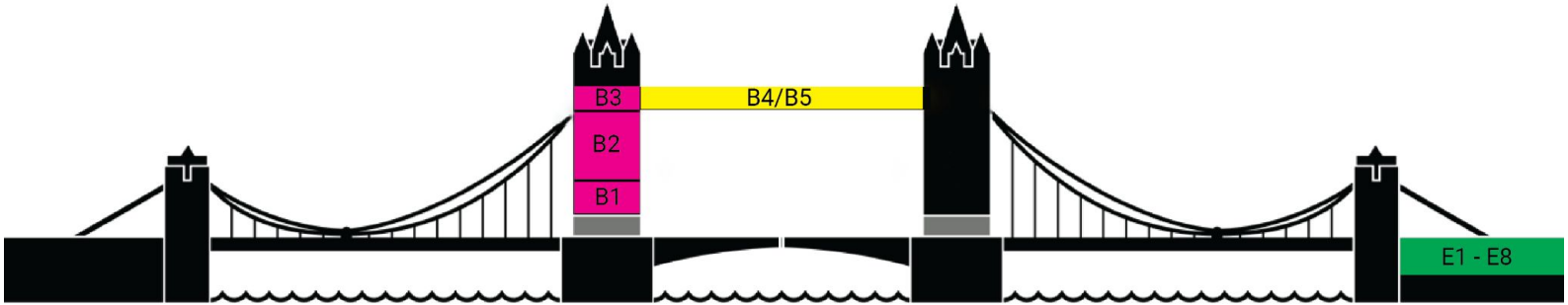
To develop a pilot “bring-your-own-device” (BYOD) application in partnership with Tower Bridge staff that explores new ways of providing interpretation through digital media.

An Engineering & Technology Guided Tour Will Best Serve Our Audience

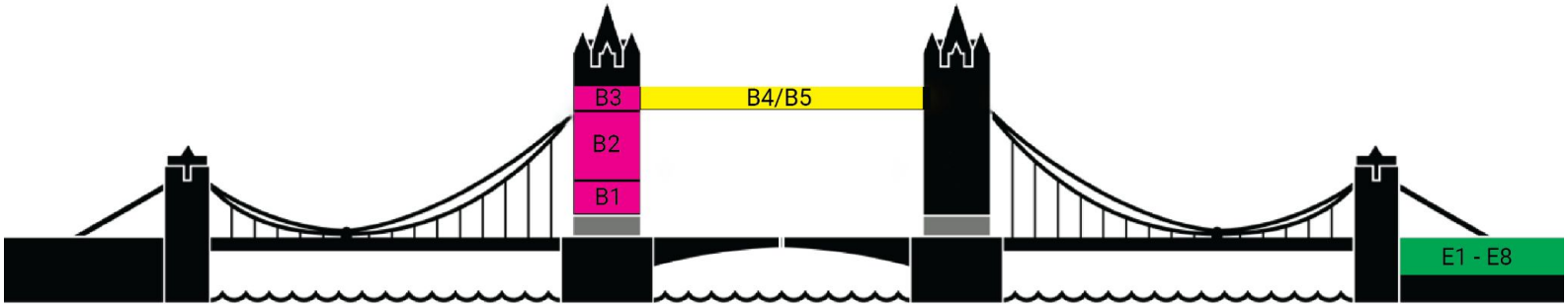
- Target Audience: Visitors interested in engineering, construction, and technology
  - Engineers, architects, contractors, and students
- Targeted Themes:
  - “Building Tower Bridge was a major construction achievement of its age”
  - “Hidden under the architectural magnificence of the bridge, its engines have been working continuously to this day”

The Tour Will Follow the Linear Path of Tower Bridge

Station	Feature(s)
B1 - North Tower Level 2: Caissons	Animation of foundation construction using caissons Additional Information: Caisson construction drawings
B2 - North Tower Stairs: Structure	Animation of North Tower structure construction Additional Information: Tower structure facts and statistics
B3 - North Tower Level 4: Structure	Animation of bridge construction and connection to the North Tower Additional Information: Bridge structure facts and statistics
B4 - East Walkway: Structure	Animation of walkway construction Additional Information: Walkway and glass floors facts and statistics
B5 - West Walkway: Panorama	West Walkway panorama slider West Walkway panorama comparison Additional Information: Building information

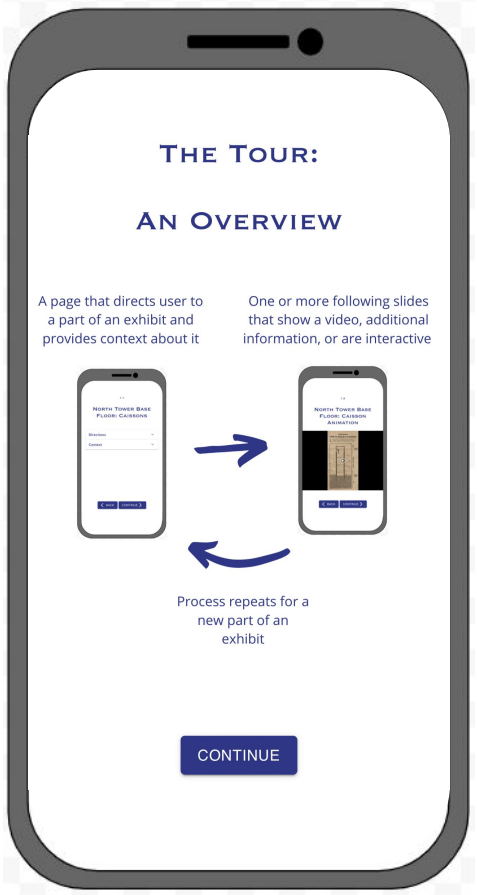


Station	Feature(s)
E1 - Engine Rooms: Boilers	Tap for more information on boiler components
E2 - Engine Rooms: Coal Bunkers	Coal bunkers information
E3 - Engine Rooms: A Engine	Tap for more information on A Engine components
E4 - Engine Rooms: B Engine	B Engine information
E5 - Engine Rooms: Water Tank and Force Pumps	Force Pumps information Tap for more information on Water Tanks components
E6 - Engine Rooms: Engineer's Gallery	None
E7 - Engine Rooms: Accumulators	Accumulator information Additional Information: Accumulator diagram
E8 - Engine Rooms: Bascule Drive Engine	Tap for more information on Bascule Drive Engine components Animation of Bascule Drive Engine braking function

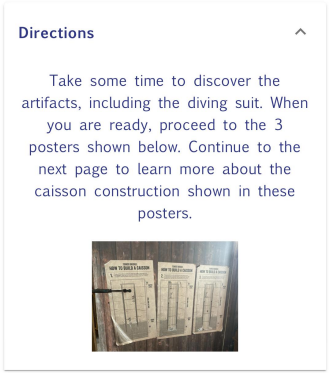



TOWER BRIDGE
TOWER BRIDGE:
A GUIDED TOUR
BEGIN TOUR

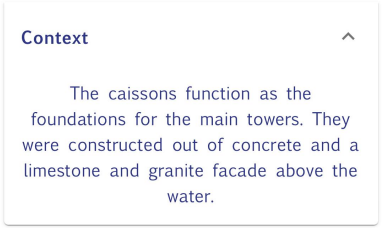
An overview page familiarizes the user with the general app structure to aid in navigation throughout their tour.

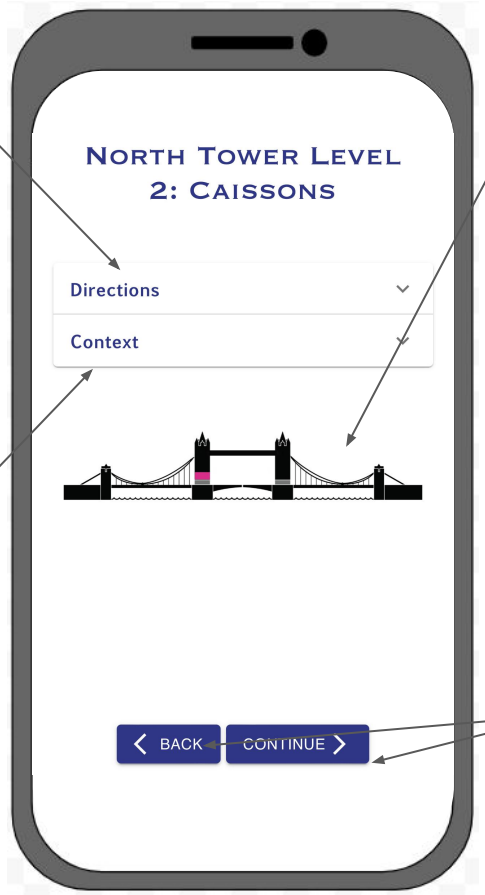


Directions dropdown displays text instructing the user on what to do next



Context dropdown displays information about the specific section of the exhibition

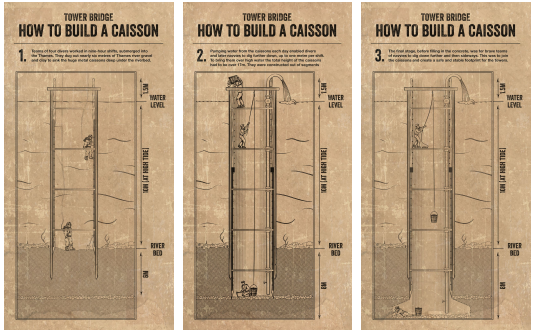




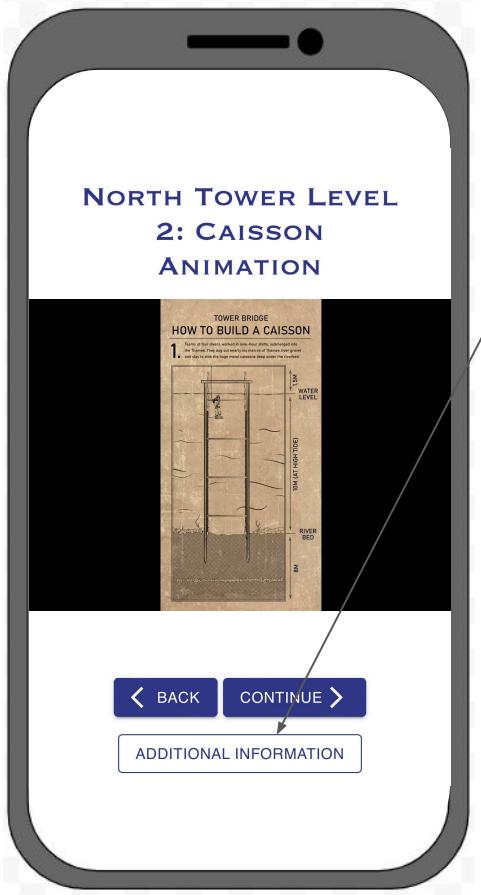
The Tower Bridge schematic displays the user's current location

"Back" and "Continue" buttons allow the user to navigate the app

The animation serves as an extension of the existing posters and maintains a consistent visual language with existing assets



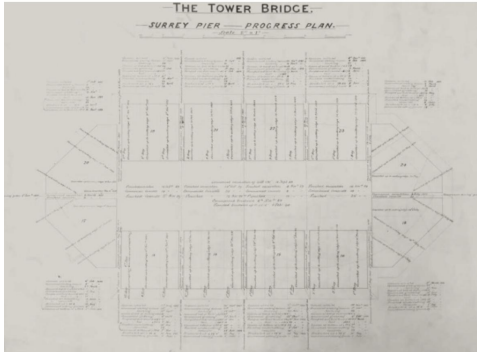
Users are prompted to look at both the posters and animation, encouraging user interaction with existing museum assets



The “Additional Information” button displays technical drawings of caissons for users interested in more detailed information

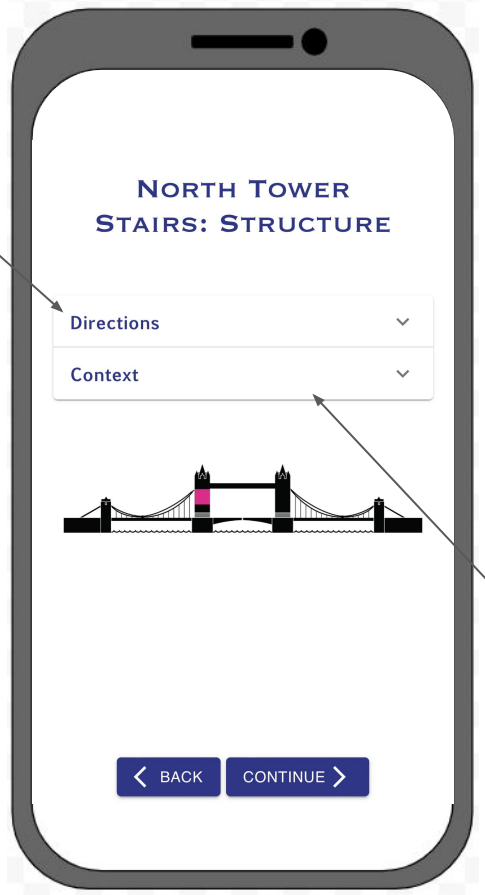
CAISSONS DIAGRAM

This engineering drawing shows the caissons from above. The foundations of the North and South Tower were constructed using 12 caissons, 4 triangular and 8 rectangular. These caissons were later joined through excavation at the base of each.



Directions

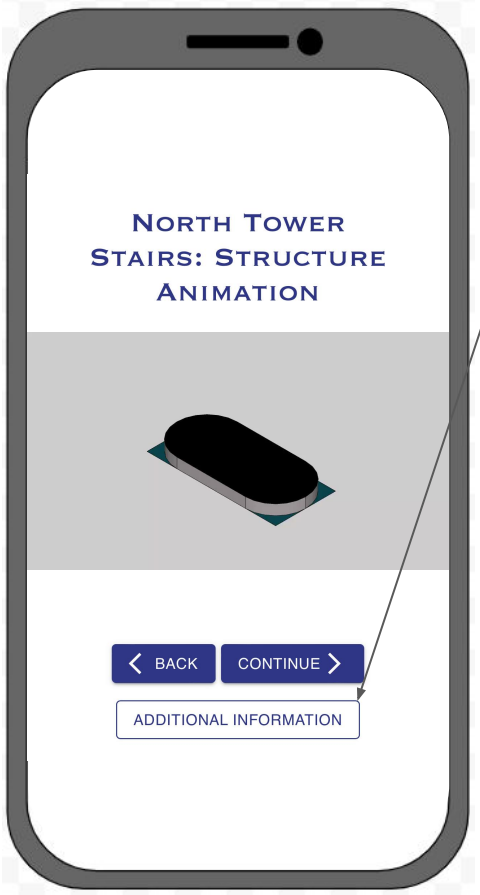
As you climb the stairs, watch the animation on the next page showing the Tower's structure. Keep an eye out for major structural members. Tap the "Additional Information" button to learn more information.



Context

The North Tower is constructed from steel members on top of the concrete foundations. It houses the stairwell and lift, which allow visitors to access the walkways, and carries loads from the rollers and walkways at the top of the tower to the foundations below.

The animation displays the overall structure of the North Tower being constructed from the foundation upward

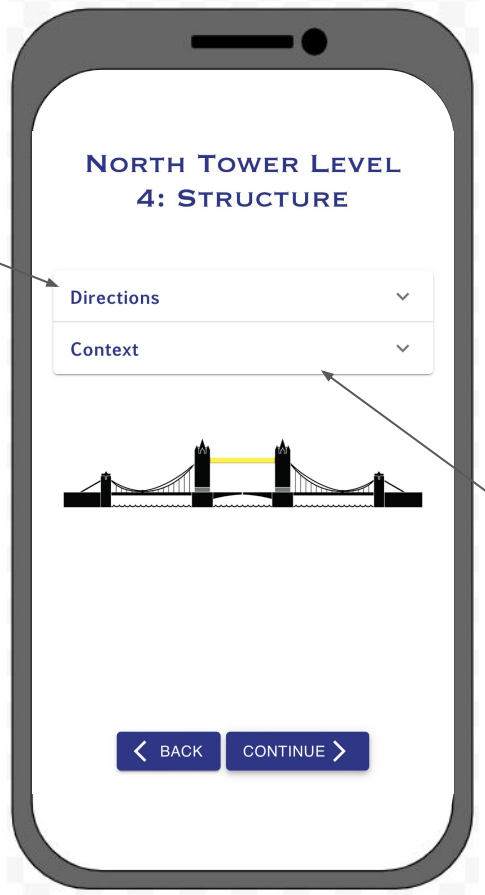


The “Additional Information” page displays facts and statistics about the North Tower

Component	Value (IP)	Value (SI)
Octagonal Columns – 4 per Tower each resting on a granite bed stone	120 foot high 5 foot 6 inches diameter	36.5 metres 1.68 metres diameter
Crests on top of the towers	206 feet above the road 298 feet from foundation base	62.8 metres 90.83 metres
Archway	40 feet high	12.19 metres
Steel Plates – total length in towers & abutments	5 miles	8 Kilometres
L2 (Caisson Exhibition) above road surface (77 steps)	60 feet	18.23 metres
L.3 above L2 (59 steps, from Road Surface - 137 steps)	28 feet	8.53 metres
L4 (Walkway Level) above Trinity High Water (from L3 – 70 steps, from Road Surface – 206 steps)	143 feet	43.58 metres
Attics above L.4 (42 steps – incl. 35 steel spiral steps and 7 wooden steps, from Road Surface – 248 steps)	23 feet	7.01 metres
Diameter of Circular Turrets	9 feet	2.74 metres

Directions

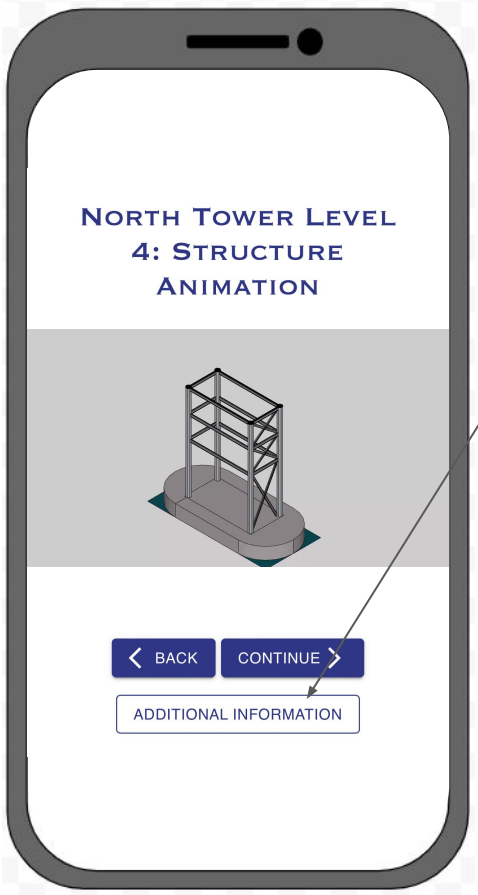
When you get to the top of the stairs, listen to the Welcome Host explain the history of Tower Bridge along with the accompanying video. Then watch the animation continue on the next page to learn how the bridge is supported by the North and South Towers.



Context

Level 4 of the North Tower is where the bridge chains attach to the tower. The chains carry the load of the bridge to rollers, which in turn transfer the load to the tower structure, which carries the load down to the concrete foundations.

The animation displays the overall structure of the bridge at a more digestible scale

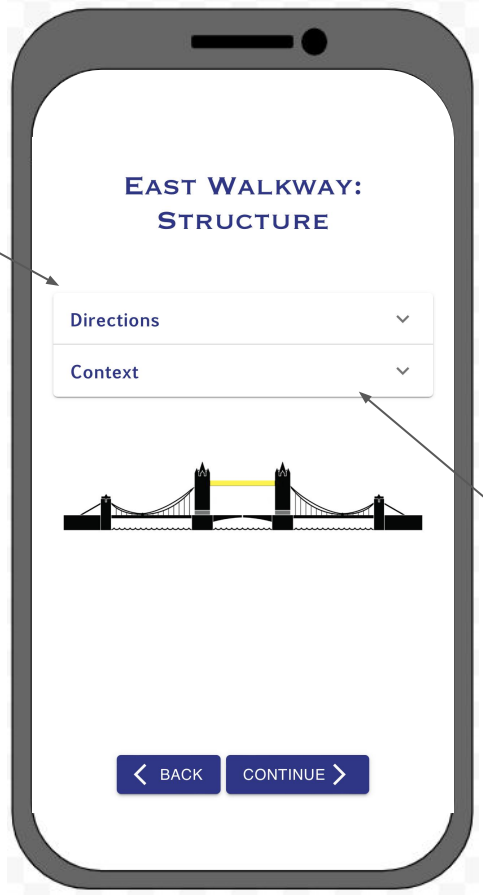


The “Additional Information” page displays facts and statistics about the bridge structure

Suspension Bridge	Value (IP)	Value (SI)
Rods	5.5 to 6 inches diameter	14-15 cms
Chains (Weight)	1 ton per foot	1 tons per 30 cms
Cross Girders - length	61 feet	18.59 metres
Cross Girders – depth	2 foot 3.5 inches	0.7 metres
Cross Girders - weight	22 tons	19.958 tonnes
The Rollers support a fully laden weight of	1000 tons	907.184 tonnes

Directions

As you proceed along the East Walkway, watch the animation on the following page showing how they are constructed, including the glass floors.

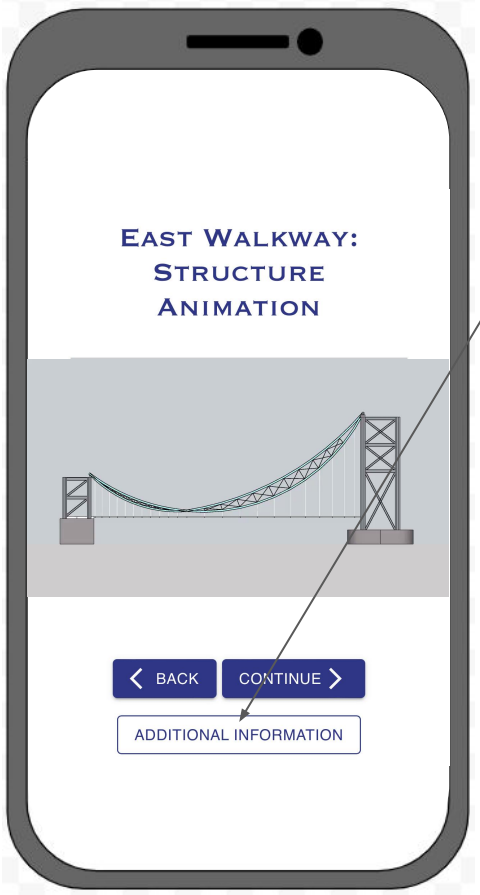


Context

The East Walkway provides an excellent view of London and the Thames. There is also plenty of information on the many designs that were considered for Tower Bridge.

The animation displays the overall structure of the East Walkway with a focus on the glass floors.

Zooming in on a section cut of the walkways displays additional detail.



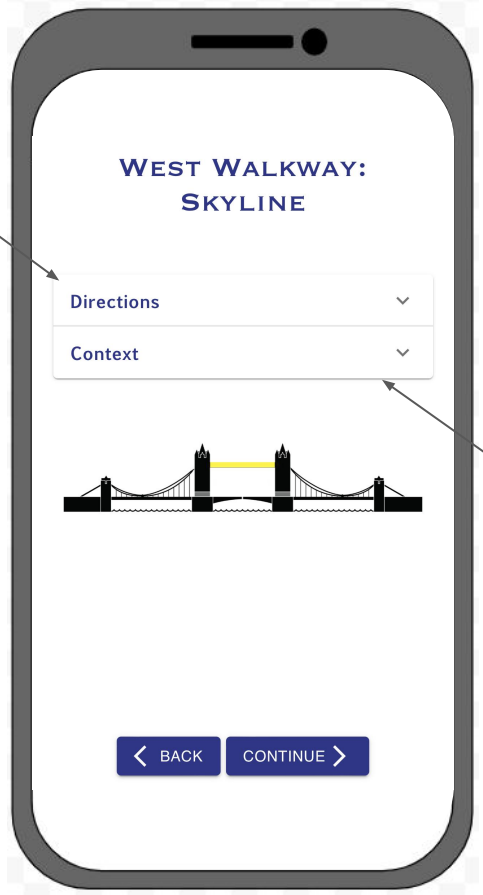
The “Additional Information” page displays facts and statistics about the walkway structure

Walkways	Value (IP)	Value (SI)
Height of walkways above roadway	110 feet	33.53 metres
Height of walkways above Trinity High Water	143 feet	43.59 metres
Width walkways	12 feet	3.66 metres
Length of walkways	230 feet	70.1 metres
Cantilevers	59 feet	17.98 metres
Central Girders	118.75 feet	36.2 metres

Glass Floors	Value (SI)
Dimensions	11.5 x 1.8m
Weight	530kg per panel, ie 3,180kg per glass floor
Weight Bearing Capacity	1.25 tons/sqm 26 tons per glass floor or about 6 male Asian elephants or a tower of £1 coins the height of the Shard
Thickness	80 mm, 7 layers
Cost	Just under £1 million
Funded by	The Bridge House Estates
Glass Specifications	PLANITHERM ULTRA N II low-E laminated glass, DIAMANT extra-flint glass and LITEFLOOR anti-skid glass

Directions

After watching the film at the top of the South Tower, proceed to the West Walkway. Walk towards the center where the glass floor is and look to your left onto the London Skyline. Use the interactive panorama on the next page to see how the skyline has changed over time.



Context

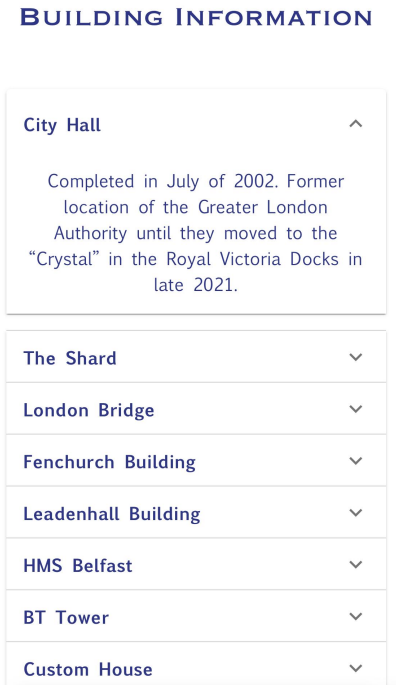
The West Walkway is appreciated for its excellent views of the London skyline and its spectacular glass floors.

Slider adjusts the visibility of each image

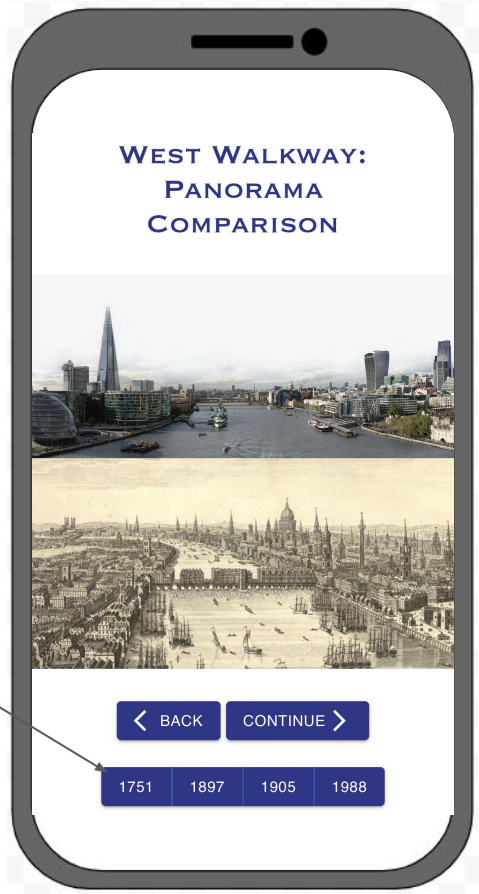
Images can be selected from different years to compare against the present day

“Label Buildings” switch toggles the appearance of building labels

“Additional Information” displays dropdown menus with more information about famous buildings

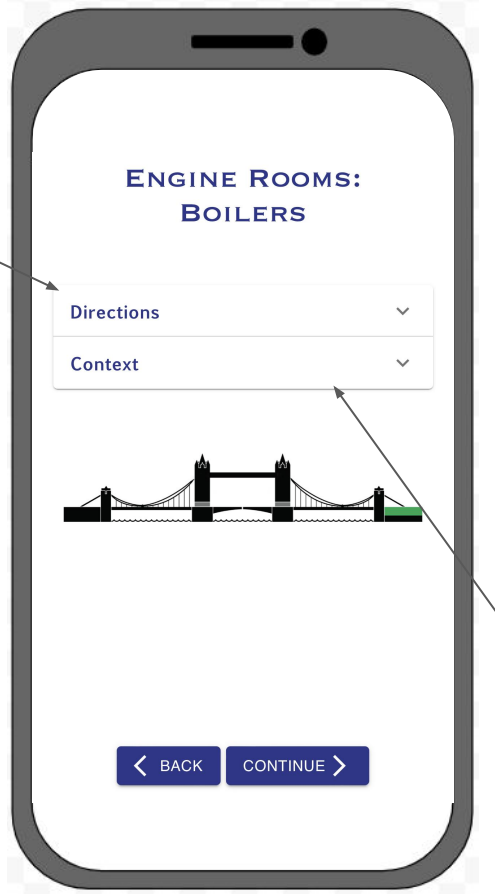


Images can be selected from different years to compare against the present day



Directions

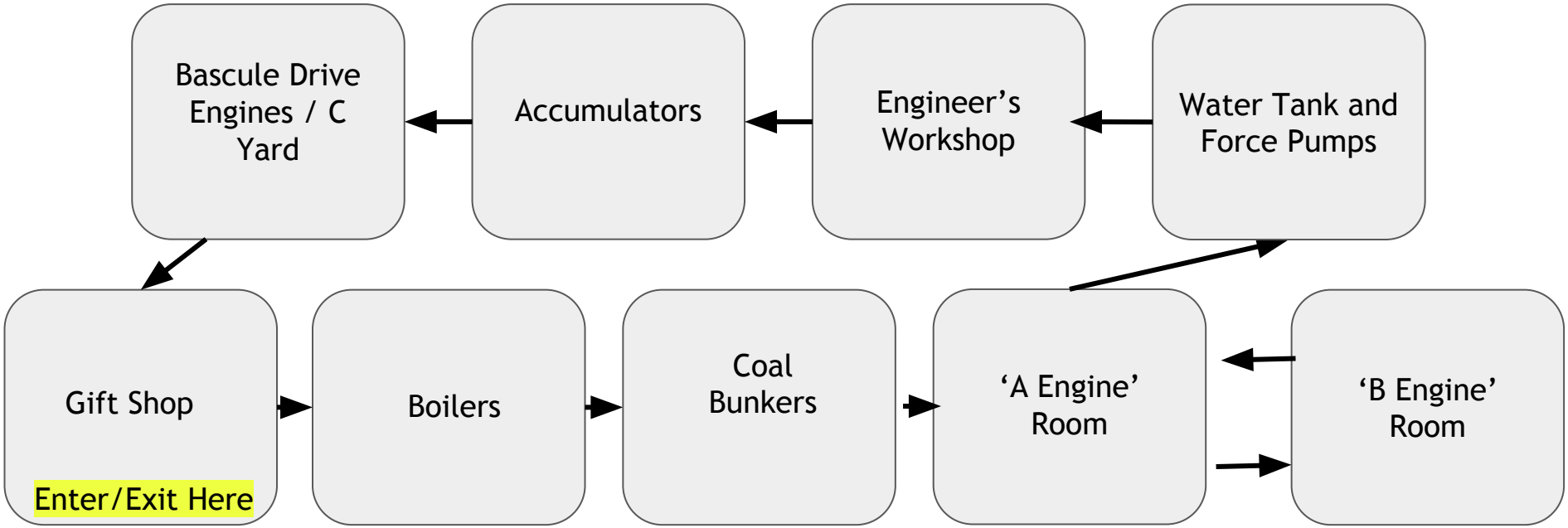
The next stop on this tour is the Engine Rooms. Walk down the stairs and exit the South Tower onto the bridge, noticing the posters and artefacts along the way. Then follow the Welcome Host's instructions and the Blue Line to the Engine Rooms. Once you enter, press continue.



Context

The two boilers in front of you are original Lancashire boilers. There were four boilers originally; boilers 3 and 4 remain in situ while boilers 1 and 2 were removed to make way for the gift shop.

Engine Room Tour Overview



Users tap on different components to display more information about their function and design.

Double Cylinder Feed Water Pump

These engines take in water from the city water mains for use in the boiler. This machine used to be located in the cellar below this room and was relocated up here when the exhibition opened in 1982. These pumps were manufactured by Clarke, Chapman and Co. LTD Gateshead.

BACK

Engine Rooms: Boiler Room Information

- These boilers were among the first with built-in safety features.
- Pressure gauges and release valves were in place to ensure the steam pressure build-up did not cause any sort of explosion.
- Learn more about these components, and others, by selecting the various components on the next page.

BACK

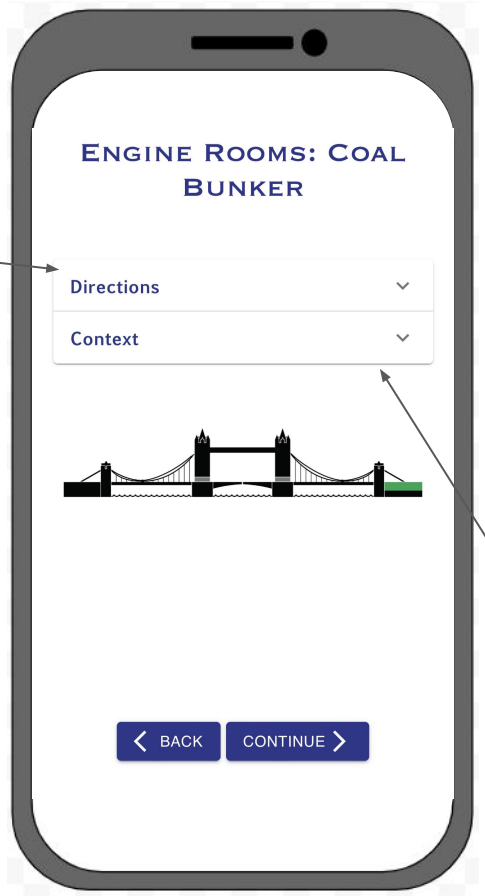
Engine Rooms: Boiler Room Working Conditions

- These rooms were always extremely hot and uncomfortable to work in.
- The Boilers ran 24 hours a day, 7 days a week, so there was never a chance for the air temperature to decrease.
- Recounted stories from the time period described the air as smelling like acid from burning coal.

BACK

Directions

Continue past the boilers into the next room. There should be a mine cart overhead.



Context

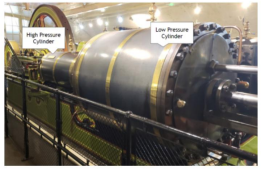
This room is where the excess coal was stored after it was delivered to Portland Wharf.

Engine Rooms: Coal Bunker

A two-level system used to exist where the bathrooms are located now - it was able to store up to 200 tons of coal. The upper bunker was accessed via a hydraulic lift and rail cart, which visitors can still see on the right below.

BACK CONTINUE

Pressure Cylinders



Steam is pumped into the smaller cylinder, the High Pressure cylinder, which pushes the plate on the piston to move the system back and forth. Steam then moves into the Low pressure cylinder (LP) - the bigger cylinder - to use the energy of the steam twice in the piston again.

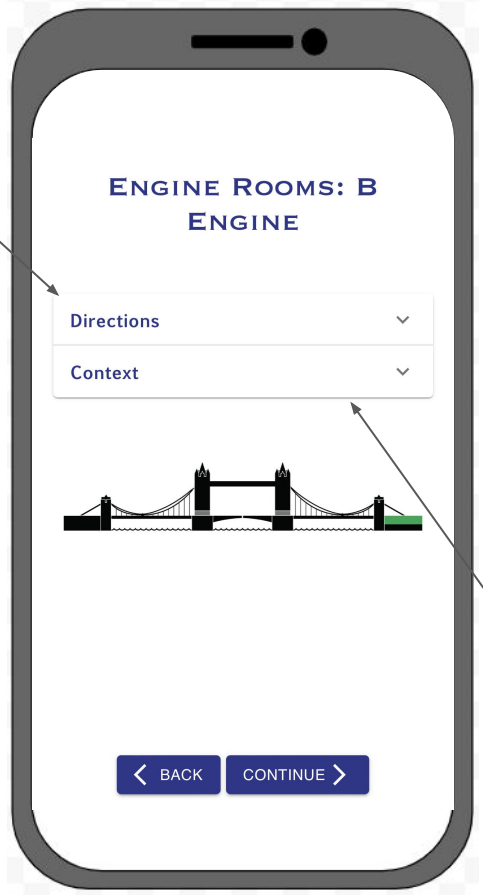
BACK

Engine Rooms: A Engine Information

- These Engines were designed and installed by Sir William Armstrong in collaboration with John Wolfe Barry.
- Armstrong was a famous inventor from the time who developed the original hydraulic accumulator technology that Tower Bridge used.
- These engines are often referred to as the Lungs of the Bridge: steam from the boilers is used to move each piston here.
- The Engines operated on a 6 week cycle - one was always in operation, one on stand by, and one was in maintenance.
- There used to be a third engine, but it was removed in 1974 - it is discussed further in the last room before returning to the gift shop.

Directions

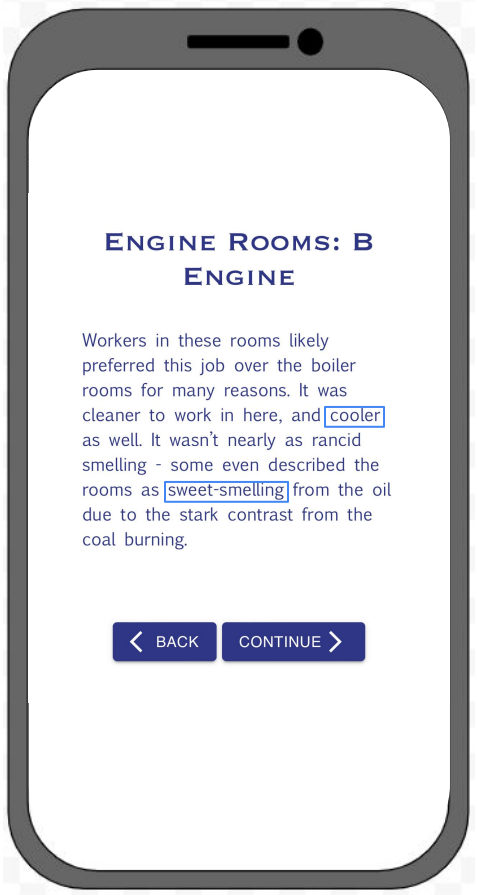
Walk through the first engine room into the second. There should be a similar green engine in this room.



Context

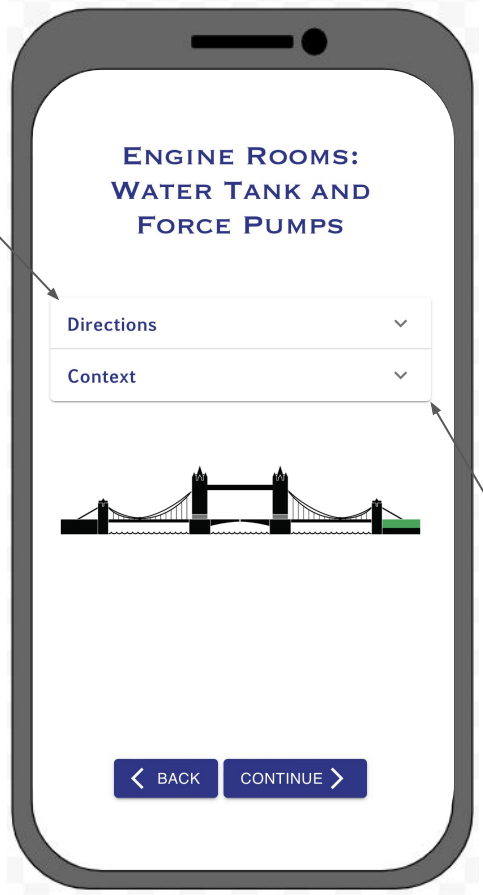
This room is the location of B Engine, which operates identically to A Engine in the previous room.

Describing multiple senses, in this case touch and smell, creates a more immersive, interesting experience for the user.



Directions

Proceed to the rear of A engine, the last space before turning right towards the Engineer's Workshop.



Context

Whether you look to your left or right, you will see two different components. Look left for the Force Pumps and right for the Water Tank and Nose Bolt.

Engine Rooms: Force Pumps

These pumps are known as the heart of the bridge. As the pistons move back and forth, they pull water from the Town Mains Water Tank and push into the hydraulic circuit. This in turn raises the accumulators (seen later); these pumps could lift one accumulator every 67 seconds (a total of 15 minutes to raise all 6 accumulators)

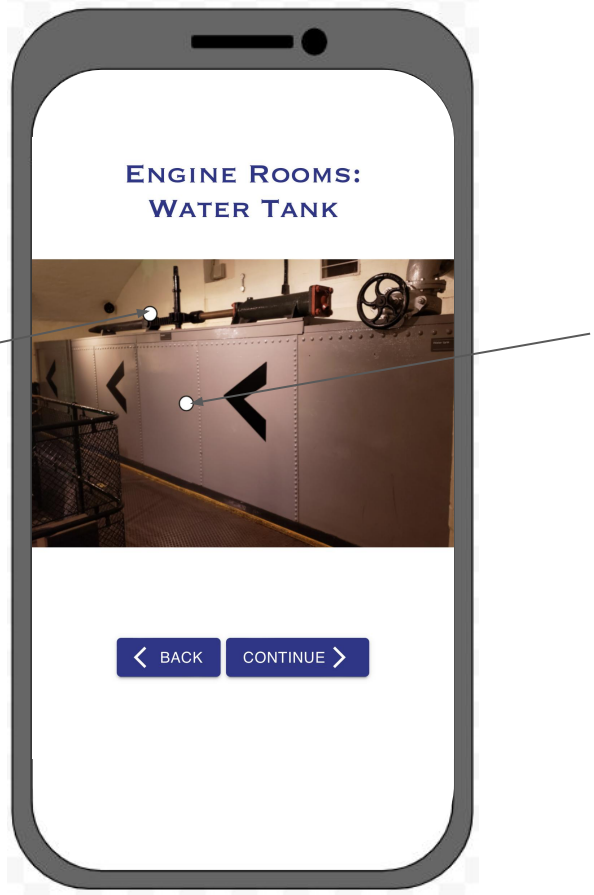
BACK CONTINUE

Nose Bolts

Original Nose Bolts, circa 1930s

These bolts are part of a locking mechanism to prevent the bridge from shifting as traffic crosses it. After a bridge lift is complete and the bascules have fully lowered, these bolts shoot across to connect the two bascules together from below. This original nose bolt was removed and replaced by new ones when the electric hydraulic system was installed.

BACK



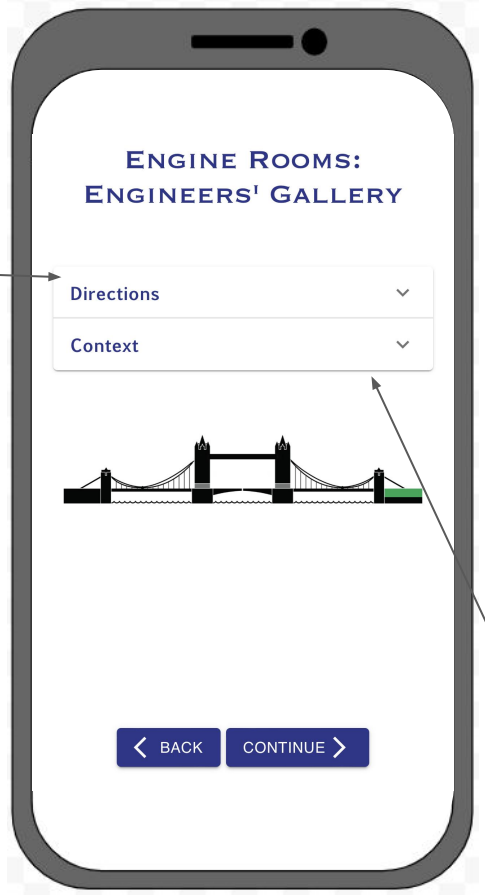
Water Tank

Water for the hydraulic lift system which powered the bascules is stored in these tanks. When required, it is drawn into the force pumps. However, most water is stored in the pipework, which itself could store 32 tons of water. This tank was merely just for bleed.

BACK

Directions

Leave the main engine rooms and follow the wall markings to the next room.

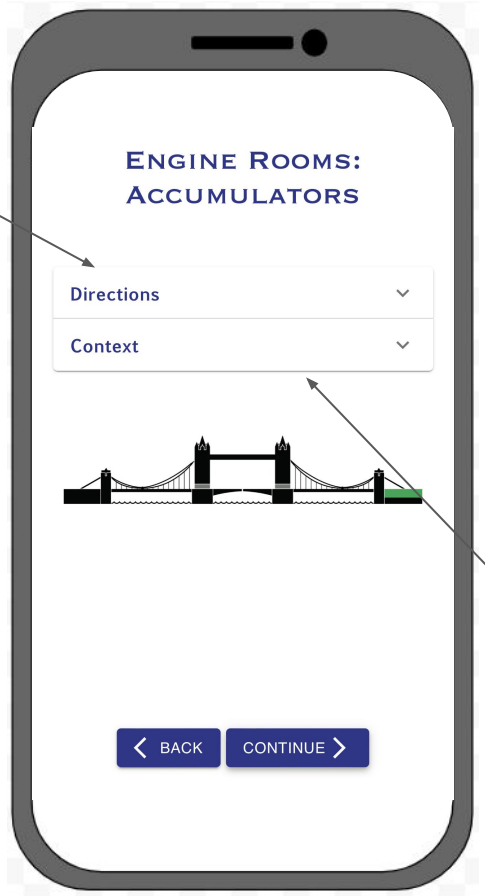


Context

Take some time to appreciate the artifacts to your right and the engineer's stories on the left. Be sure to watch the video to learn more about what it was like to work in Tower Bridge.

Directions

Continue down the hallway on your left. You should come across giant cylinders in a room to your left. These are the accumulators.



Context

These are two of the six accumulators that Tower Bridge used to raise and lower the bascules. These are raised to the ceiling by the force pumps.

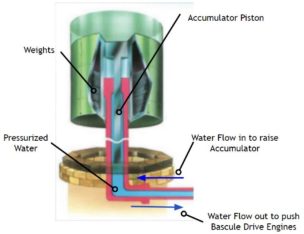
Engine Rooms: Accumulators

Weighing 100 tons each, the accumulators store energy in the form of pressurized water. The force pumps push water into a pipe inside these to raise them. When the bridge needed lifting, the accumulators lowered to push water through the bascule drive engines at a working pressure of 750 psi (52 Bar).

BACK | CONTINUE

ADDITIONAL INFORMATION

Engine Rooms: Accumulators

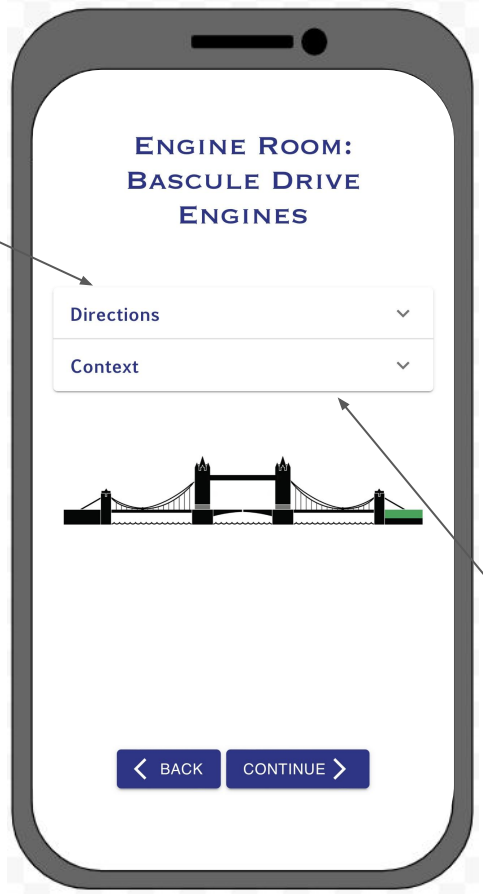


This is what the interior of an accumulator roughly looked like. A piston attached to the accumulator was situated within a water pipe connected to the hydraulic water system. When the force pumps pushed in water, it pushed that piston up continuously and generated the working pressure of 750 psi. Below that is an image of a fully-raised accumulator with the interior water pipes exposed. Valves are used to control the flow of the water into and out of the accumulators.

BACK

Directions

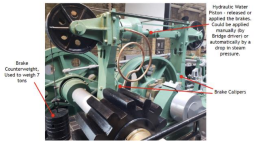
After using the engine room game to your right, proceed to the last piece of machinery before the gift shop.



Context

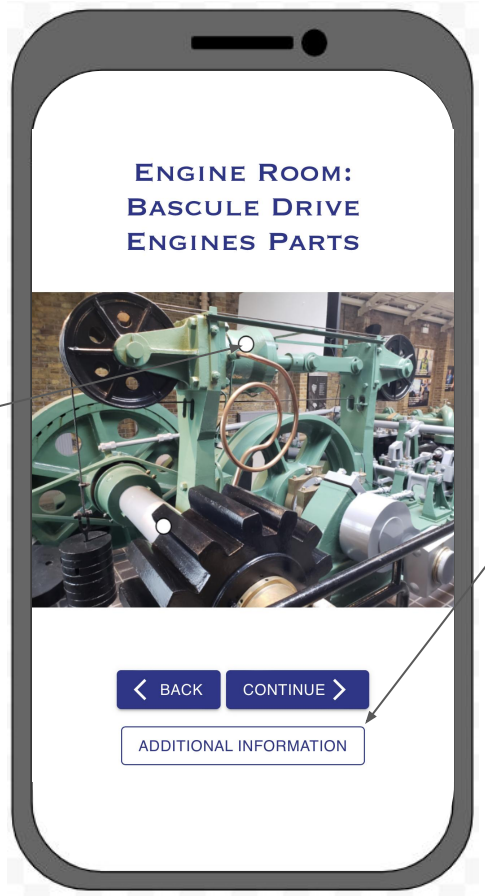
This is one of the original Bascule Drive Engines which rested in the piers. These machines provided the muscle to rotate the bascules up and down at a controlled speed.

Brake System

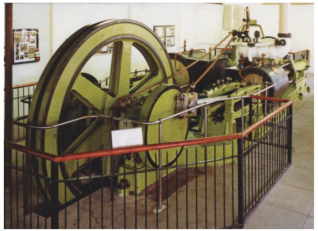


This is the caliper braking system for the pinion wheels - it acts very similar to the breaks of a bicycle. They could be manually engaged during a lift if necessary to prevent the bascules from crashing down - the counterweight at left would pull the two sides together and prevent the wheel from rotating. The breaks were engaged at all times except when the bascules were actively being moved. Watch the animation below to see how the braking system operated.

BACK



Engine Rooms: C Yard Button

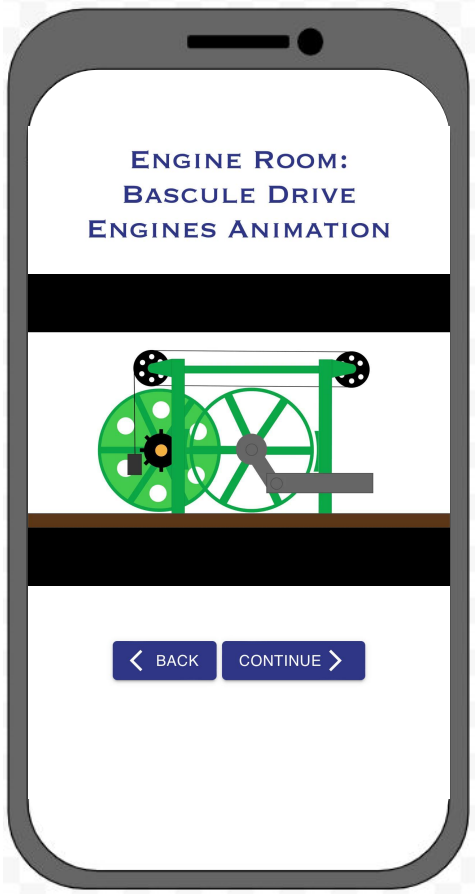


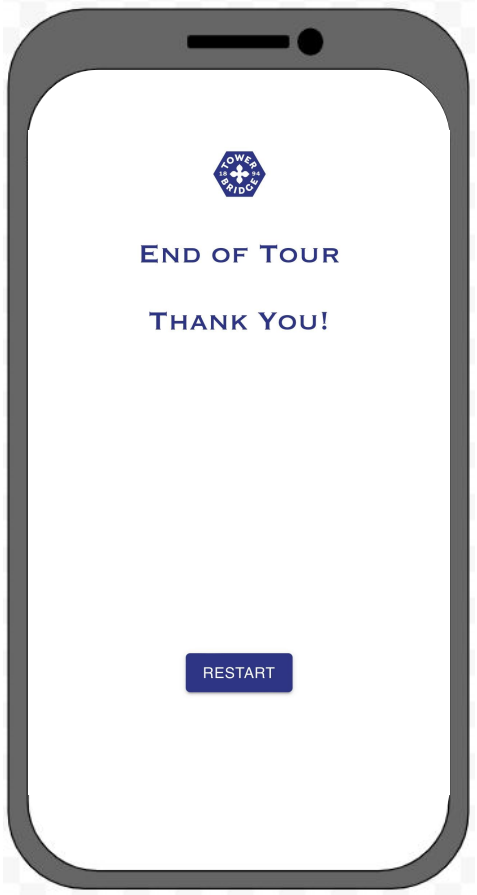
This is the original location of the 3rd Steam engine, which was installed in 1941. It was a different model than the original two engines; it is a Horizontal Cross Compound Hydraulic Pumping Engine built by Vickers Armstrong Ltd. It was decommissioned and sold to the Forncett Industrial Steam Museum in 1974, where it is on display. The funding from this sale helped to open the Tower Bridge Exhibition in 1982. Image from Forncett Industrial Steam Museum.

BACK

This preliminary animation shows the Bascule Drive Engine braking mechanism

It helps users understand an engine that is no longer operational

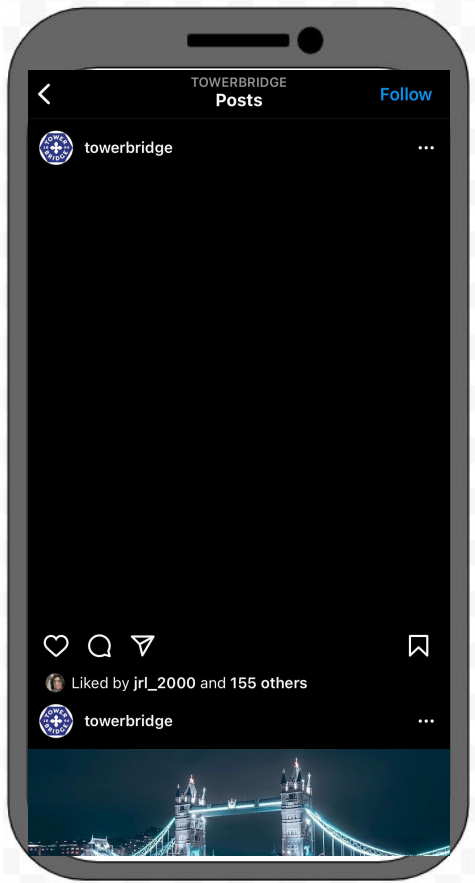



END OF TOUR
THANK YOU!
RESTART

Student Testing

- Procedure
  - We tested the application with 15 other WPI students
  - We tested for functionality, interactivity, and enjoyment
- Key Findings
  - App was enjoyable to use, but needs fine tuning
  - Use of the app did not take away from the existing interpretation
- Recommendations
  - Directions clarification
  - Add more animations, graphics, interactives

Marketing Will Be Essential for Encouraging Visitors to Use the App



QR Codes and Image Recognition Can Play an Important Role

https://tower-bridge-tour.web.app/

Special Thanks To…

The Tower Bridge staff, especially Dirk Bennett, Adam Blackwell, and Iain Stanford

Our advisors, Professors Dominic Golding and Lorraine Higgins

Station	Feature(s)
B1 - North Tower Base Floor: Caissons	Animation of foundation construction using caissons Additional Information: Caisson construction drawings
B2 - North Tower Stairs: Structure	Animation of North Tower structure construction Additional Information: Tower structure facts and statistics
B3 - North Tower Top Floor: Structure	Animation of bridge construction and connection to the North Tower Additional Information: Bridge structure facts and statistics
B4 - East Walkway: Structure	Animation of walkway construction Additional Information: Walkway and glass floors facts and statistics
B5 - West Walkway: Skyline	West Walkway panorama slider West Walkway panorama comparison Additional Information: Building information
E1 - Engine Rooms: Boilers	Tap for more information on boiler components
E2 - Engine Rooms: Coal Bunkers	Coal bunkers information
E3 - Engine Rooms: A Engine	Tap for more information on A Engine components
E4 - Engine Rooms: B Engine	B Engine information
E5 - Engine Rooms: Water Tank and Force Pumps	Force Pumps information Tap for more information on Water Tanks components
E6 - Engine Rooms: Engineer’s Gallery	None
E7 - Engine Rooms: Accumulators	Accumulator information Additional Information: Accumulator diagram
E8 - Engine Rooms: Bascule Drive Engine	Tap for more information on Bascule Drive Engine components Animation of Bascule Drive Engine braking function