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SEVEN WONDERS

OF THE INDUSTRIAL WORLD



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Seven Wonders Of The Industrial World

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Introduction by series producer Deborah Cadbury



Isambard Kingdom Brunel's colossal ship, the Great Eastern

The great achievements celebrated in this series reveal as much about the human spirit as they do about technological endeavour. The period of over 125 years from the beginning of the 19th century saw the creation of some of the world's most remarkable feats of engineering, from Isambard Kingdom Brunel's extraordinary *Great Eastern*, the "Crystal Palace of the Seas" that he hoped would join the two ends of the British empire, to the Panama Canal, that linked the Atlantic and Pacific oceans more than half a century later.

The slowly evolving industrial revolution was the fertile ground that gave life to these dreams in iron, cement, stone and steel. The pioneers of the age were practical visionaries, seeing beyond the immediate horizon, the safe and the known as they cut a path to the future. Yet their unique masterpieces could never have been built without an army of unsung heroes, the craftsmen and workers also willing to risk their lives as they laboured to bring each dream to life. Not to mention the financiers and shareholders hanging on for the ride as reputations were lost and won.

The journey from the oldest "wonder" featured in the series, the Bell Rock Lighthouse, to the most recent, the Hoover Dam, illustrates the swiftly

moving frontiers of technological progress. Each "wonder" serves as a unique monument, a marker for what was known at the time. The world was a very different place when the Bell Rock Lighthouse was created off the east coast of Scotland between 1807 and 1811.

Robert Stevenson, the grandfather of Robert Louis Stevenson, dreamed for years of making his mark on the world by bringing light to the treacherous Scottish coast. He aimed to take on the most dangerous place of all, the Bell Rock, a large reef, 11 miles out to sea, dangerously positioned in the approach to the Firth of Forth. In 1799, over 70 ships went down in a violent storm that raged along the coast, yet still the authorities opposed his plan. How could anyone build a lighthouse 11 miles out to sea, on a rock which was submerged by up to 16 feet of water for most of the day? Battling against the odds, Stevenson did eventually build his lighthouse and, to this day, it shines out across the North Sea, the oldest offshore lighthouse still standing anywhere in the world.

Isambard Kingdom Brunel's colossal ship, the *Great Eastern*, is the only wonder in this series that has not survived to the 21st century. In the early 1850s, Brunel hoped the *Great Eastern* would be his

masterpiece, which would link the ends of the empire. At a time when most ships moored in the Thames were built to traditional designs in wood and powered by sail, Brunel's "Great Ship", was almost 700-feet long, a floating island made of iron, that he envisaged could carry 4,000 passengers in magnificent style as far as the antipodes without needing to refuel. The design was revolutionary with a double hull that made it unsinkable and powered by enormous engines as high as a house. He faced enormous criticism: his ship was too big, it was too expensive, it would sink, or break its back on the first big wave, if, that is, he could actually manage to launch it on to the Thames. In fact, it was the blue print for ship design for years to come.

In the summer of 1858, while the *Great Eastern* was being fitted out for her maiden voyage, London was in the grip of a crisis: "the Great Stink". The population had grown rapidly during the first half of the 19th century, yet there had been no provision for sanitation. Three epidemics of cholera had swept through London leaving over 30,000 dead. And sewage was everywhere, piling up in every gully and alleyway, in the cellars of houses in poor districts, even seeping through cracks in floorboards.

Leading engineer Joseph Bazalgette proposed a bold scheme to build the London sewers: 82 miles of sewage superhighway linked with over 1,000 miles of street sewers to provide an underground network beneath the city streets. He drove himself to the limits of endurance, struggling to realise his subterranean vision – a task made even more difficult since he was competing with the new underground railway, a network of roads and emerging overland railway systems. But his grand design for a sewer system transformed the city into the first glittering modern metropolis, setting a standard that was quickly copied the world over.

By the middle of the 19th century, the benefits brought by the host of advances of the industrial age were gradually beginning to reach America. One of the most spectacular achievements was the development of railways, notably the Transcontinental Railway, which reached right across the continent. With two teams, one building from the east and the other from California in the



Leading engineer Joseph Bazalgette is played by Mark McGann

west, they battled against hostile terrain, Native Americans, civil war and the Wild West. Yet in 1869, the tracks joined, shrinking the whole continent as the journey from New York to San Francisco was reduced from months to days.

That same year, a brilliant engineer, John Roebling, from Germany, won the contract to build the largest bridge in the world, the Brooklyn Bridge. It would stretch 1,600 feet, in one giant leap across the wide and turbulent East River, which separates New York from Brooklyn. The foundations would reach up to 70 feet below the river. The two mighty towers would dwarf much of New York. At the time, such a bold design seemed a miracle, and all to be built out of a new material: steel.

Yet John Roebling's ambitious dream was to cost him the extreme price of life itself and, unknowingly, he condemned his son to a shadow life. Determined to continue with his father's vision, Washington Roebling and his team had to face the horrors of a mysterious new disease, "caisson disease" – now known as the bends – as they laboured deep beneath the East River. Suffering great pain and paralysis when the great network of cables was spun across the great East River,

Washington could only watch through a telescope from his window.

With the growth in travel and trade, by the late 19th century, shipping was big business. Having completed the Suez Canal in 1869, a Frenchman, Vicomte Ferdinand de Lesseps, dreamed of an even bolder scheme: the Panama Canal. He would cut a path across the Isthmus of Panama and unite the great oceans of the Atlantic and Pacific. The long journey around Cape Horn would become a danger of the past and the world itself a smaller place. But once out in the tropical heat of Panama, the French found themselves facing impenetrable jungle, dangerous mudslides and deadly tropical diseases as it proved to be an undertaking of nightmare proportions. The extravagant dream stole over 25,000 lives and 25 years elapsed before the oceans were finally united.

As people found their way across the vast American continent, they were stopped only by a poor or hostile environment, such as the desert regions of Arizona and Nevada. Even here, in the early 1900s, engineers began to realise it would be possible to make the desert bloom by building a dam across the Colorado River. Sixty stories high and with a larger volume than the Great Pyramid at Giza, the Hoover Dam would break all records. At the height of the depression, poverty-stricken workers earning just a few dollars a day, died from horrific explosions, carbon monoxide poisoning and heat exhaustion. It was Chief Engineer Frank Crowe who built it ahead of schedule and under budget, and notched up one more extraordinary piece of evidence for the ingenuity of man.

By the time President Roosevelt inaugurated the Hoover Dam in 1935, the last “wonder” described in this series, the world was transformed in almost every way possible. People’s standard of living had increased greatly, the average life expectancy had almost doubled in the west and infant mortality had virtually disappeared. The £1 a week that Robert Stevenson had given his labourers to work a 12-hour day, seven days a week, wet or dry, had, by the time the Hoover Dam was lighting up the western deserts, turned into a wage that a working man, increasingly backed by unions, could live on more comfortably.

In one sense, the stories present a romantic view of man – of an individual who struggles to realise his dream and make a mark on the world. As the 19th century progressed, the men of genius took the stage in quick succession, each engrossed in his own creation to the exclusion of all else. Each in turn gave so much of himself, often denying relationships, sleep, basic human comforts and ultimately, in some cases, their lives. Yet the legacy of their great ambition and talent remains to this day. With the exception of Brunel’s Great Ship, all the wonders have survived to the 21st century and are now celebrated as powerful symbols of the modern world. The wealth of inspiration and energy of the 19th century was the catalyst for the huge progress that marked the 20th century as the coming industrial giants stood on the shoulders of an earlier generation.

Programme synopses

Programme 1: The Great Ship



Isambard Kingdom Brunel is played by Ron Cook

In the early 1850s, the world's most brilliant engineer, Isambard Kingdom Brunel, dreamed of creating the largest ship ever built. The *Titanic* of its day at nearly 700 feet, it would be able to sail, without stopping, to Australia and unite the two ends of the empire.

Shipwrights of the day regarded his scheme as utter madness. But Brunel was a genius who had created such spectacular wonders as the Great Western Railway, the Clifton Suspension Bridge and even the first tunnel under the Thames; there seemed no limits to his superhuman ability. Yet his "Great Ship" would destroy him, and all who were associated with it. Many believed it was cursed.

Brunel enlisted the support of brilliant naval architect John Scott Russell and bitter rows soon erupted as Brunel developed a swathe of

innovations with the utter conviction that he was right. This was the most advanced technology of the day with a double hull, 10 water-tight bulkheads and vast steam engines fashioned by newly invented hammers of unprecedented scale. However, nothing proceeded as planned; workers were involved in tragic accidents, there were fires at Millwall docks and Scott Russell was financially ruined. As the great hull finally took shape, plate by plate, the ship, nicknamed "Leviathan", became the biggest tourist attraction in Europe.

Brunel had asked for perfect silence during the launch, but 10,000 people gathered in November 1857 to see the massive 12,000-ton hull shift into the water – the greatest weight mankind had ever attempted to move. Their efforts were to end in tragedy as huge chains snapped and workers were flung to their deaths. Brunel was ridiculed in the press as his massive creation would not budge.

His fate became inextricably mixed with that of his "great babe" and, by the time the *SS Great Eastern* was finally launched, months later, 52-year-old Brunel had become very ill. Moments after choosing his cabin for the maiden voyage, he suffered a severe stroke. As he lay dying at home during the first voyage, he was informed of a horrific explosion on board which burned alive several of the crew. Devastated, Britain's greatest engineer succumbed to a second stroke and died soon afterwards.

However, his ship was to become one of the crowning achievements of the Victorian age by carrying the first transatlantic telegraph cable to link Europe and America. At first, the proposal to span the Atlantic with wire was greeted with incredulity. It was soon established that the *SS Great Eastern* was the only ship to have a large enough hold for such a gigantic cargo and 2,000 miles of cable was coiled into her tanks. The cable snapped half way across the Atlantic and months were to elapse before the mission was complete. With great excitement in 1866, the first shore-to-shore telegram was tapped through the cable.

Despite this triumph, the *Great Eastern* never succeeded as a passenger ship and, in 1889, after a few years as a show boat, it was finally dismantled for scrap. In a macabre twist, it was rumoured that two skeletons were found entombed between the double hull. Many believed that a basher and his mate – a young boy – had been trapped during the construction and literally starved to death. Many said the Great Ship had, indeed, been jinxed after all.

The Great Ship is written and directed by Chris Spencer. Isambard Kingdom Brunel is played by Ron Cook.

Programme 2: Brooklyn Bridge



Washington Roebling is played by George Anton

In the mid 19th century, New York was growing faster than any city in the world. A seemingly impossible scheme was devised to unite Manhattan to Brooklyn, spanning the East River, with the longest suspension bridge ever built.

At 1,600 ft from tower to tower, it would be the longest suspension bridge ever built and the first to be made entirely of steel. The two vast gothic towers would have foundations in the East River, larger and to a greater depth than any before. Giant cables lashed between the towers – each with a breaking strength exceeding anything yet designed – would be held in place by great granite

anchorage of over 60,000 tons. Yet the ambitious dream of brilliant engineer John Roebling fast turned into a nightmare – a technological feat set against greed, corruption and a double family tragedy.

In July 1869, just a few days after Roebling finally won approval for his plan, his foot was crushed in a freak accident. He developed lockjaw and died 16 days later. Before his death, he entrusted his oldest son, Washington, with the construction of the bridge, urging him to use the new technology of pneumatic caissons. Unknown to father and son, this would prove to be a death sentence.

Caissons, or gigantic diving bells, had not been used on such a grand scale in construction before. At 170 x 100 ft, they would form the base of each tower. Working inside them, men toiled away at the river bed to bury the foundations into the bedrock. Their submerged pressurised airtight chamber was described by the master mechanic Edmund Farrington as a Dante's *Inferno*; intense heat and humidity, dimly lit by gas lights. And bizarrely, the workers began to suffer from a mysterious and debilitating illness – which would later be known as the bends.

On December 1870, the first disaster struck. A fire broke out and, in the oxygen-charged, compressed air, it quickly got out of control. Roebling himself spent the entire night fighting the flames – and collapsed the next morning. Unknown to anyone, he'd been struck by his first case of the bends. Soon workers were dying of the mystery illness and Roebling himself suffered such a severe attack that he became semi-paralysed. He could only continue his father's dream by directing operations from his sick bed.

Barely able to speak or move, the only person he could rely on was his loyal wife, Emily, who liaised between Washington and his men to continue the work. Washington could only monitor progress, observing the bridge from his bedroom window through a high powered telescope.

Construction continued at breathtaking speed with great feats of engineering combined with foolhardy stunts. When the first cables connecting the two towers were swung out across the East River, the

daring Farrington was the first to “fly” across on a boatswain’s chair, cheered on by crowds of New Yorkers. Yet this success was followed by the most horrifying accident to occur during the construction of the bridge. While Farrington was supervising the fixing of the wires to the anchors, one of the super loaded cables snapped and whipped through a bunch of workers, maiming two and killing two more.

The entire undertaking was dogged by gross political corruption, with the bridge’s leading investor brought to trial. In a further scandal, it was discovered that substandard wire had been woven into the fabric of the bridge and the cables had to be redesigned at a frighteningly late stage.

When the bridge finally opened in 1883, some 20,000 New Yorkers crammed onto it – in the ensuing crush, 12 people died. For Roebling himself, observing the fireworks from his bedroom window, it was a moment of personal triumph. His great achievement, which had destroyed two generations of his family, was to change the New York landscape forever.

Brooklyn Bridge is written and directed by Paul Wilmschurst. John Roebling is played by Steven Berkoff, Emily Roebling by Debora Weston and Washington Roebling by George Anton.

Programme 3: Bell Rock Lighthouse

The deadly Bell Rock Reef had terrorised seamen for centuries. Eleven miles out to sea, off the coast of Scotland, this vast, treacherous rock lurked deceptively just a few feet below the surface of the water and stretched over a third of mile.

The scene of countless shipwrecks, such was the fear of the reef that, in storms, sailors would risk the rough seas rather than face certain death approaching the Firth of Forth. In one wild night in December 1799, such a violent hurricane raged that 70 ships went down.

Yet one young engineer, Robert Stevenson, dreamed of building the impossible – a lighthouse on Bell Rock Reef. His rivals ridiculed his plan which required building on a rock that was almost



Robert Stevenson is played by Robert Cavanah

constantly submerged, set 11 miles off-shore, in perpetually hazardous seas. Nothing like this had been attempted before. As they predicted, when Stevenson set off with a crew to check out his ideas, the waves and tides were so treacherous around the reef that they could not even reach the site. Taming the seas would prove to be an extraordinary battle against the elements that was to cost both reputations and lives.

Stevenson, a lighting engineer who had worked with his father to light up Edinburgh, was certain he could win – but no one believed him. This is his story, set against the Westminster establishment, distinguished engineers, ever-greedy financiers – and, above all, the elements. During the Napoleonic Wars, as his plans were still thwarted, navy ships continued to go down with countless lives lost. The worst disaster was in 1803 when HMS *York* was shipwrecked on the reef with the loss of nearly 500 lives and 60 guns – yet still no one would listen to the lighting engineer.

Stevenson never lost faith in his plan, and after years of campaigning and researching lighthouse design – not to mention an Act of Parliament – in 1807, he finally won the backing he needed. Out at sea, he pushed his workers to the limit to create the impossible. They lived and worked moored above the dangerous reef for months on end. Men and children died as they were washed out to sea,

working against waves, storms and sea fogs. In one horrific incident, as their boats lost anchor and drifted out to sea against a fast-rising tide, the whole crew nearly drowned. Even as the lighthouse began to take shape, waves 60 feet high crashing against the walls could wash workers out to the sea to their deaths. Stevenson would not be deflected from his course, even when his own children had died back home.

Yet this was to be Stevenson's triumph. By February 1811, the lighthouse was built. In an historic moment, the first keeper, John Reid, lit the lamps which beamed out over the cold grey northern seas – lights which still shine to this day.

Bell Rock Lighthouse is directed by Chris Spencer. Robert Stevenson is played by Robert Cavanah.

Programme 4: Transcontinental Railway

The eastern United States was crowded with immigrants while the west held the tantalising promise of vast riches and gold. Between the two lay a harsh wilderness, Indians and months of wagon travel that few survived. A railway was needed.

In 1862, President Lincoln signed the Pacific Railroad Act authorising the construction of 1,800 miles of track. Two corporate giants were pitched against each other in a race to join the east and west coasts of America – “to shrink the continent and change the whole world”. The Union Pacific Company was led by the corrupt Dr Thomas Durant who was intent on bleeding the railroad dry. The Central Pacific was funded by the “Big Four” Sacramento shop keepers: Crocker, Stanford, Huntington and Leland.

Competition between the two companies was ruthless and uncompromising but an even bloodier battle was fought on the ground. The surveyors who planned the route struggled through wilderness, living off buffalo, elk and antelope. Behind them followed the two workforces of labourers – each the size of Civil War armies. Indian attacks, brutal weather, floods, food shortages and even a war stood between them and success.



Dr Thomas Durant is played by Robert Young

Both companies got off to a slow start. At the Union Pacific, Dr Thomas Durant, a publicity-seeking showman, after spending \$500,000, had only advanced a pitiful 40 miles. The Big Four at the Central Pacific hired slave driver Harvey Strobridge, but even he was defeated by the seemingly impassable solid granite ridges of the Sierra Nevada. A railroad at such high altitudes had never before been contemplated.

While the Central Pacific team was battling with the Sierras, Durant faced another problem in the desolate wilderness of prairies. Native Indians waged guerrilla warfare, desperate to halt progress at any cost. At the bloodthirsty massacre of Plum Creek, Nebraska, they derailed the train and burnt the tracks. The workers who weren't scalped and mutilated, were thrown onto the flames. One worker, Thompson, who miraculously survived, left a horrific account of being scalped alive.

Durant hired the toughest men he could find but this soon made matters worse. In Cheyenne,

Wyoming, murders among the workers – in the “hell on wheels” shanty towns that sprang up at the end of the line – outnumbered accidental deaths. Durant’s henchmen, the Casement brothers, two legendary, gun-swinging cowboys, weren’t afraid to restore order by literally shooting the workers. His railway gave birth to the Wild West.

Meanwhile, Strobridge’s men at the Central Pacific were still struggling to bore the Summit Tunnel. But conditions rapidly deteriorated into one of the worst winters in history, with 44 blizzards. Reduced to emergency food rations, men were trapped as temperatures plummeted to minus 20 degrees and survivors lived in terror of the frequent avalanches which buried entire camps. To speed up progress, a chemist was hired to experiment with nitro-glycerine – an explosive which was five times more powerful and 13 times more destructive than the existing “black powder”. Although tunnelling was faster, accidents were so horrific that the management was forced to abandon its tests.

Far removed, in the city boardrooms, the leading railway engineers and businessmen battled for supremacy – marshalling unprecedented resources and encouraging speed over caution in the fight for funds. Locomotives, rails and spikes were hauled through America and dragged across the plains.

Yet this was a race that both sides won. As both railways converged on Promontory in Utah, they were so hell-bent on clocking up the mileage that they overlapped by 100 miles, until forced by the Government to link up.

On 10 May 1869, 1,800 miles and 21 million hammer blows later, the tracks from east and west were about to be joined. Ironically, Durant was kidnapped on his way to the celebration by rebel workers who hadn’t been paid.

When the final spike, made in gold, was driven in at Promontory Summit, it held the attention of a nation: nothing like this had been seen before. As for the railway pioneers themselves: Dr Durant became very rich – too rich – until an investigation revealed corruption and fraud. The Big Four kept their fortunes – Crocker alone was worth \$40m. And the railway became the catalyst for the vast expansion that was to make America the industrial giant of the world.

Transcontinental Railway is written and directed by Paul Bryers. Dr Thomas Durant is played by Marcus D’Amico.

Programme 5: London Sewers



In the hot summer of 1858, a window was opened in the Houses of Parliament and Britain’s great government suddenly ground to a halt. Disraeli and other leading MPs fled from their chambers, overwhelmed by the fearsome stench of decaying sewerage. Fleeing the “Great Stink” for the country, MPs realised that they had to deal with the horror and filth of London’s sanitation which had been literally building up on their doorstep for centuries.

Despite London’s rapid expansion, little had changed since the “pissing alleys” of Tudor times. The poor were worst affected as sewage seeped through the floors of their homes or ran down the walls. Some even scrounged a hopeless living from sewage: the desperate “toshers” and “mudlarks” – as they were known – who sieved through refuse searching for bits of old tin or oyster shells.

Worst of all, although no one yet knew how or why, killer diseases like cholera swept through the city in a series of epidemics – killing more than 30,000 by the mid 19th century in London alone.

Utterly at a loss, the medical profession added to the problem by supporting the idea that disease spreads through smell. This prompted the reformer, Edwin Chadwick, to call for cesspools to be drained away from houses and into the Thames.

Unwittingly, he poisoned the city's drinking water and sealed the fate of thousands.

Slowly, clues to the cause of cholera were being pieced together in a small surgery in Soho. John Snow was the first to crack the causes of cholera – but nobody believed him. It was to take two more devastating epidemics before the medical establishment was even prepared to test his theory.

This scientific detective story entwines with an epic tale of Victorian construction. As the grotesque smell from the Thames brought London to crisis point, the level-headed Joseph Bazalgette proposed an impossibly ambitious scheme: 318 million bricks would link over 1,000 miles of street sewers with 82 miles of sewerage super-highway.

His vision required extraordinary and novel engineering solutions to set the bricks into watertight tunnels and create vast steam pumping engines, installed in gothic cathedrals of engineering, designed to raise the sewage up to surface levels before it could run under gravity into the sea. London had to be redesigned to accommodate the vast scale of his plan. In 1865, with the first phase of the sewers completed, Bazalgette celebrated with the Prince of Wales in a barge trip down the Thames as Londoners cheered.

Their success was short-lived for cholera was to strike a further deadly blow. On 27 June 1866, a labourer and his wife contracted the disease and soon died. Investigators found their sewage had infected the East London Water Company and unleashed an epidemic that would kill thousands more. After an embarrassing cover-up, it was found that the Water Company was at fault, and not Bazalgette's magnificent system.

This was the last time cholera ever swept through London but, more importantly, this final epidemic provided the proof that the medical establishment needed to accept John Snow's theory. With cholera now conquered and a sewage system fit for a modern metropolis, Bazalgette was deemed to have saved more lives than any other Victorian official.

London Sewers is directed by Ed Bazalgette. Joseph Bazalgette is played by Mark McGann.

Programme 6: The Panama Canal



When French engineer Ferdinand de Lesseps returned triumphantly to Paris after completing the Suez Canal in 1869, he was hailed as a national hero. Thousands raced to invest in his next, even bolder scheme – to build a great canal across Panama.

His dream would cut a swathe across the South American continent and unite the vast oceans of the Atlantic and Pacific. Fortunes seemed assured as shipping would no longer have to face the terrors of Cape Horn to sail from one side of America to another.

In 1879, the Paris Geographical Society set up a committee to investigate how best to turn the plan into reality. De Lesseps favoured a sea-level canal which would slice through the mountains to unite the oceans. In a furious debate, his rival, Baron de Lepinay, claimed this was impossible and proposed a gigantic lake and lock canal system. Ignorant of the dangers, the committee backed the eminent de Lesseps.

On 1 January 1880, de Lesseps set out confidently to Panama with his daughter to dig the first spade of earth at the mouth of the Rio Grande. But times and tides conspired against them and they failed even to find the correct site – an omen of what was to come.

As a symbol of French national pride, thousands trekked to Panama to find themselves facing impenetrable jungle, deep swamps, poisonous snakes, torrential rains and deadly mudslides. De Lesseps put his son, Charles, in charge of daily operations but they were soon to face two more formidable enemies – malaria and yellow fever. Men literally walked off ships to their deaths and thousands succumbed to the horrific conditions of “fever coast”. Nuns unwittingly made things worse by providing breeding sites for mosquitoes in the gardens of their hospital.

With 20,000 dead by the late 1880s, the “Panama Affair” was rocked by financial scandal and brought down the French government. Shares collapsed, investors lost their money and Ferdinand and Charles de Lesseps were both tried for bribery. The dream of the Panama Canal evaporated. Ruined and disgraced, Ferdinand died, shamed and quite insane, in 1894.

Four years later, as America headed to war with Spain, its Navy’s first and only real battleship, *US Oregon*, took 67 days to get from San Francisco via Cape Horn to the Caribbean. By the time it finally reached its destination, the war was practically over. Roosevelt needed little convincing. The idea of the Panama Canal was reborn.

Roosevelt pioneered a new plan and forced the countries of South America to agree terms after a stand-off with a fleet of warships. He personally appointed experienced engineer John Stevens to direct the scheme. Stevens saw it as certain death – every killer disease known to man was endemic in the region – but against his better judgement he agreed to the President’s wish. His first step was to clear the area of malaria and yellow fever. Scientists had finally established that these diseases were carried by mosquito. Through his Chief Medical Officer, William Gorgas, Stevens launched one of the largest all-out assaults on nature – fumigating houses, draining pools and digging ditches – until, by 1905, he’d completely eliminated yellow fever.

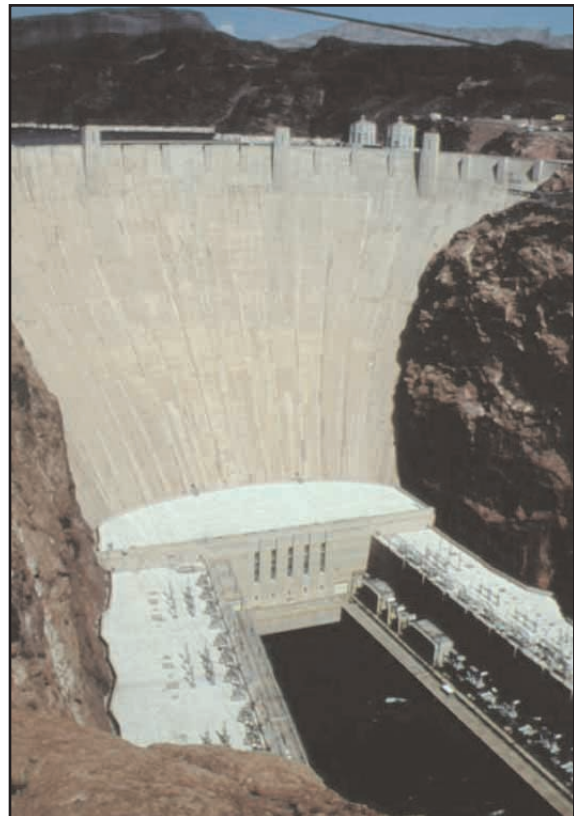
In an historic U-turn, Stevens also reverted to the original scheme proposed by de Lepinay of using a gigantic lake and locks system. His plan would see the creation of the largest artificial lake in the world, the first constructional use of a relatively new material called concrete and the excavation of

the impassable Culebra Cut, or Hell’s Gorge – as it became known. But just when it seemed he might win, he suddenly resigned and the military had to take over.

By 1914, the canal was finally opened – the greatest engineering feat the world had seen. And in France, De Lesseps’ son, Charles, at last saw his father’s name restored to honour and his own reputation cleared.

The Panama Canal is directed by Phil Smith. Ferdinand de Lesseps is played by John Walters.

Programme 7: The Hoover Dam



With its impassable canyons, dangerous rapids and severe seasonal variations that could reduce the western states of the USA to a desert, the Colorado was one of the most dangerous and unpredictable rivers in the world. But in 1902, engineer Arthur Powell-Davis dreamed of creating the largest dam ever and taming the wild river.

The scale of his ambition was matched only by the scale of his plan. At 727 feet, the dam would stand 60 stories high and would have a larger volume than the Great Pyramid at Giza. With electricity and irrigation, the deserts of the west would bloom and the face of America would change forever.

His dreams turned to nightmares as 20 years passed in legal wrangling and funding disputes and he left the project a bitter man. It took the desperate conditions of the Great Depression to revitalise the scheme, which became a symbol of hope for thousands.

Several engineers bid for the project but one man stood out: the ruthless and dedicated Frank Crowe. He had his choice from thousands of poverty-stricken workers, queuing up to labour in desert temperatures of more than 120 degrees for a few dollars.

Many lives were lost as the entire Colorado River had to be diverted to make way for construction. The workers built four mammoth tunnels through nearly a mile of rock, using innovative contraptions called drilling jumbos. These trucks, stacked tall with tiers of 24-30 drills, would back up against the rock face to bore holes for the explosive. Carbon monoxide poisoning and injuries from cave-ins were common as men struggled deep underground with power tools and dynamite.

Safety was sacrificed for speed. To his workers, Frank was both God and the Devil; they nick-named him "Hurry Up Crowe". But by 14 November 1932 – 11 months ahead of schedule – they were finally ready to re-route the raging Colorado.

Work then began on the dam itself. At its base, some of the poorest workers removed over half a million cubic yards of mud before reaching the bedrock foundation – many dying of heat exhaustion.

Most dangerous of all, in spectacular stunts, the "high-scalers" had to swing right out over the sides of the Grand Canyon to blast the canyon walls in order to create a smooth surface for the concrete. In one daring feat of heroism, it is said that Oliver Cowan managed to swing out to catch hold of a falling man, while himself dangling at a precipitous height. The rock face was a maze of live air hoses,

electrical lines and other climbers, and falling objects were the most frequent cause of death. The men soon improvised the first use of hard hats by coating cloth hats with coal tar.

By June of 1933, Crowe was ready to pour the concrete. The men constructed the base, column by column; if the concrete had all been poured at once, the heat it generated would take 125 years to cool down. Crowe chose an unusually dry mix which, although stronger, gave the men little time before it started to harden. To combat this, he pioneered a new complex series of cranes, cables and buckets to guarantee speedy delivery.

For the next two years, workers poured concrete round the clock – 24 hours a day, seven days a week. Six billion kilograms later, the dam was finished. On 1 February 1935, the diversion tunnels were blocked. The Colorado resumed her natural course and the dam went into operation.

Frank Crowe, decked in glory, walked away with a \$350,000 bonus. His great triumph had come at a cost. Throughout the four gruelling years, over a hundred lives had been lost. In a curious twist, shortly after Roosevelt's inaugural speech, a man called Patrick Tierney fell to his death. He was the last to die on the project and his father, 13 years earlier, had been the first.

Hoover Dam is written and directed by Mark Everest. Frank Crowe is played by Jaudon Benedict.

The pioneers

Isambard Kingdom Brunel

Considered to be Britain's greatest engineer, Isambard Kingdom Brunel was born in 1806 to an English mother and a French father. His father, Marc Brunel, himself a celebrated engineer, moved to England at the time of the French Revolution. After a formal education in both France and Britain, Brunel went on to work for his father on the building of the Thames Tunnel. Within four years, and still only aged 20, he was appointed principal engineer of the project. In 1833, Brunel was appointed chief engineer to the new Great Western Railway company working on the line that linked London to Bristol. His work on railways saw him engineer over 1,200 miles of railway with lines constructed across the globe, in Ireland, Italy and Bengal.

Whilst with the Great Western Railway company, Brunel also began his work on ship building, persuading the company to build a steam boat for travel from Bristol to New York. The Great Western was launched in 1838 and was the largest steam ship of its day, over 236 feet in length. From here, Brunel went on to build the Great Britain and finally the Great Eastern, which was designed to carry over 4,000 passengers.

He was married in 1836 to Mary Horsley. Brunel died in 1859, aged 54, having been taken ill while preparing for the maiden voyage of the Great Eastern in 1858.

John Roebling

Born in 1806 in Muhlhausen, Thuringia, Prussia (now Germany), John Roebling was educated in the public schools of Muhlhausen before attending the Royal Polytechnic School in Berlin. Graduating in 1826 with a degree in civil engineering, Roebling was obliged to spend three years in service to the State, working on road-building projects.

He emigrated to America in 1831 along with his brother. They settled in Pennsylvania where they

sought to establish a farming community. When the farming venture failed, Roebling resumed his engineering work, taking on canal and railway building projects. In 1841, Roebling invented twisted wire rope cable which preceded the use of wire rope supports in the construction of suspension bridges.

He constructed his first suspension bridge in 1845 and went on to build numerous others, the most famous being the Brooklyn Bridge. He died in 1869 after a freak accident – whilst surveying the site for the Brooklyn Bridge his foot was crushed and he later succumbed to lockjaw. His son, Washington, oversaw the continuing work on the Brooklyn Bridge which was completed in 1883.

Robert Stevenson

Robert Stevenson was born in Glasgow in 1772, to Alan Stevenson and Jean Lillie. After the death of his father in 1794, his mother subsequently remarried Thomas Smith, whom she met through her church activities.

Stevenson began his work on lighthouses whilst in the employ of his stepfather, assisting in the supervision of lighthouses around the Scottish coast. After working hard to qualify as a civil engineer, Robert built up the family business of lighthouse construction and civil engineering, with his greatest achievement being the building of the Bell Rock Lighthouse.

Stevenson married Jean Smith (the daughter of his stepfather by an earlier marriage) and had a large family. Continuing the family tradition, three of his sons followed him into the lighthouse-building business, with his eldest son, Alan, becoming engineer to the Northern Lighthouse Board.

Stevenson died in 1850.

Dr Thomas C Durant

Born in 1820, Thomas C Durant made his name building railroads, notably the Mississippi and Missouri railroad across Iowa. He came to the Union Pacific Railroad as Vice President and General Manager and set about establishing support and financing for its construction. A successful and driven man, Durant also used his position to further his own gains and was often accused of bribery and corruption.

Durant died in 1885.

Joseph Bazalgette

Joseph Bazalgette was born in Enfield in 1819. He began his career working on railway projects and was later appointed Chief Engineer of the Metropolitan Board of works in 1855, having previously been employed by the Metropolitan Commission of Sewers.

His greatest achievement was the building of the London Sewers network, which began after the “Great Stink” of 1858. Taking eight years to build, between 1859 and 1865, Bazalgette oversaw the construction of 82 miles of sewage super highway, which were linked to a thousand miles of street sewers.

He was also responsible for the building of the Thames Embankments, and Battersea, Hammersmith and Putney Bridges, doing perhaps more than anyone of the time to transform London into a modern city.

Bazalgette died in 1901.

Ferdinand de Lesseps

Hailing from a family of distinguished French diplomats, Ferdinand de Lesseps was born in 1805 in Versailles. After studying law, he went to work with his uncle, then the French ambassador to Lisbon. He later served with his father in Tunis and, after his father’s death, he spent time in Egypt, Rotterdam, Malaga, Barcelona and Madrid.

Having befriended the new Viceroy of Egypt, Mohammed Said, many years before, de Lesseps was given the job of overseeing the construction of the Suez Canal. When the canal opened in 1869, he was hailed as a hero, both in Egypt and France.

Several years later, he expressed his desire to build an inter-oceanic canal. 1 January 1880 saw de Lesseps and his young daughter dig the first spade of earth in the construction of the Panama Canal. The venture suffered numerous setbacks in the shape of weather, disease and financial mismanagement, leading to its failure in 1889. De Lesseps died five years later in France, having fallen from his celebrated position.

Arthur Powell-Davis

Born in 1861, in Decatur, Illinois, Arthur Powell Davis earned a Bachelor of Science degree in Civil Engineering from Columbian (now George Washington) University in 1888. Davis gained work as a topographer for US Geographical Survey through the help of his uncle, John Wesley Powell, who was its director and who conquered and explored the Colorado River.

Davis progressed through the Government ranks and, in 1906, became Chief Engineer of the Reclamation Service, a position he held until his appointment to Director on December 1914. During his tenure as Director, Reclamation outlined the development of the Colorado River basin before Congress in 1922. Davis was the first to recommend construction of multipurpose dams.

He died in Oakland, California, in 1933, before the Hoover Dam came into operation.

The actors

Ron Cook plays Isambard Kingdom Brunel

Ron Cook has starred in numerous productions on both stage and screen.

His film credits include appearances in *Chocolat*, alongside Dame Judi Dench and Johnny Depp; Mike Leigh's *Topsy Turvy* and *Secrets And Lies*; and in Peter Greenaway's *The Cook, The Thief, His Wife And Her Lover*.

His theatre work includes productions at the Royal Court, the National Theatre and the Royal Shakespeare Company, whilst his television roles include appearances in Dennis Potter's *The Singing Detective*, *Tom Jones* and *Black Adder*, all for the BBC.

Steven Berkoff plays John Roebling

Steven Berkoff is known not only as an actor but also as a director, playwright and author.

After studying drama in London and Paris, he made his London stage debut in 1959 in a production of Arthur Miller's *A View From A Bridge*. He later went on to establish the London Theatre Group in 1968.

His numerous film credits include Stanley Kubrick's *A Clockwork Orange*, *Octopussy*, *Beverly Hills Cop* and *Rambo II*. He has also published a variety of books including: *Gross Intrusion* and *Graft: Tales of An Actor*, both collections of short stories; *I Am Hamlet*; and his autobiography, *Free Association*.

Robert Cavanah plays Robert Stevenson

Scottish actor Robert Cavanah has starred in numerous television productions with appearances in *Silent Witness*, *Murder In Mind* and *The Bill*. He is perhaps best known for his portrayal of Heathcliff in a television production of *Wuthering Heights*, where he played opposite Orla Brady.

His theatre work includes playing Mark Anthony in Shakespeare's *Julius Caesar* at London's Young Vic.

Mark McGann plays Joseph Bazalgette

Born in Liverpool, Mark's resemblance to John Lennon saw him play the former Beatle on stage in the musical *Lennon* and then on screen in the film *John And Yoko: A Love Story*. His other film credits include a role in *Let Him Have It*, alongside Christopher Eccleston.

Also interested in music, Mark formed a band along with his brothers, Joe and Stephen, called The McGanns, releasing an album in 1999.

The production team

Jill Fullerton Smith Executive Producer

Jill Fullerton Smith has been making documentaries for 20 years and is now a BBC executive producer.

Amongst many highlights in her career before she joined the BBC, Jill Fullerton Smith was specially selected by Steven Spielberg's producers, Frank Marshall and Kathleen Kennedy, to work with them directing documentaries over a period of three years. Her work included *Alive – Twenty Years On*, which won an Emmy and held the record for two years as the highest-selling, non-fiction home video in America.

Jill Fullerton Smith has been responsible for a wide variety of programming. She is particularly interested in using special effects and graphics to bring stories to life and has found cutting-edge, new techniques to do this. Many of her films have won awards for graphic design. She has also won a large number of other awards and nominations as a producer/director, including BAFTA, Emmy, RTS and Glaxo.

Deborah Cadbury Series Producer

Deborah Cadbury is an award-winning writer and documentary film maker.

Working as a BBC documentary maker for 20 years, Deborah Cadbury has specialised in strong, journalistic programmes. For *Horizon* she has been awarded 15 international awards, including an Emmy. Her programme, *Assault On The Male*, launched a world-wide scientific research campaign into the hormone-mimicking chemicals that are harming human health.

She has now published four books. *The Dinosaur Hunters* recreates the remarkable story of the bitter rivalry between the early fossil hunters who pieced together the extraordinary evidence of a prehistoric world. "A wonderful writer," says *The Times*, "who keeps you turning the pages as if her book was a thriller." *The Dinosaur Hunters* has been turned into a TV drama series. Deborah Cadbury's most recent book, *The Lost King Of France*, tells the tragic story of Marie Antoinette's favourite son. According to historian Alison Weir, it is: "... absolutely stupendous. This is history as it should be. It is stunningly written. I could not put it down." This is now under development as a film by Lynda La Plante. Deborah's book to accompany the series, *Seven Wonders Of The Industrial World* publishes in September.



Where to find out more

www.bbc.co.uk/history

Discover more about the seven industrial wonders and the driving passions behind the people who made them by visiting the multi award-winning BBCi History website.

Visitors to the site can find out more by looking at original articles by leading experts; playing games and animations that bring the industrial world to life; and checking out the message board discussions. The site also features biographies of the key players and other related website links. There is also an opportunity to win the book that accompanies the series.

BBC Learning

To celebrate Britain's industrial heritage, BBC Learning is co-ordinating events across the country, in association with the Open University, to enable people to find out more about the Industrial Revolution. Visitors can choose from a host of activities, including workshops, lectures, canal walks and drama presentations. Events and over 40 industrial heritage sites are listed on the campaign poster and on the website at www.bbc.co.uk/history

Accompanying book

A book to accompany the series will be published by Fourth Estate in September. *Seven Wonders Of The Industrial World* is Deborah Cadbury's fourth book. She is the author of *The Feminization Of Nature*, *The Dinosaur Hunters* and *The Lost King Of France*. She has won numerous international awards as a TV producer for the BBC, including an Emmy for *Horizon*. She is also the series producer for *Seven Wonders Of The Industrial World*.