### Powering the Industrial Revolution

**驱动工业革命**

In Britain one of the most dramatic changes of the Industrial Revolution was the harnessing of power. Until the reign of George III (1760-1820), available sources of power for work and travel had not increased since the Middle Ages. There were three sources of power: animal or human muscles; the wind, operating on sail or windmill; and running water. Only the last of these was suited at all to the continuous operating of machines, and although waterpower abounded in Lancashire and Scotland and ran grain mills as well as textile mills, it had one great disadvantage: streams flowed where nature intended them to and water-driven factories had to be located on their banks whether or not the location was desirable for other reasons. Furthermore, even the most reliable waterpower varied with the seasons and disappeared in a drought, the new age of machinery, in short, could not have been born without a new source of both movable and constant power.

在英国，工业革命带来的最大的变化之一就是动力的运用。从中世纪到乔治三世统治时期，用于劳作及行驶的动力一直没有得到发展。当时的驱动力仅限于三种：动物或人力；风力，用于航行或者风车；流水产生的动力。其中只有水力可以用于持续运转的机器，尽管在当时的Lancashire和苏格兰地区水力资源极其丰富，被用于谷物作坊和纺织厂，但这种动力存在一个极大的缺陷：水的流向是由自然因素决定的，因此，不论适不适合工厂选址，利用水利生产的工厂都必须建造在能够提供水资源动力的岸边。再者，即便是最可靠的水资源也会受到季节变化和因干旱而枯竭的影响。总之，没有可持续提供动力并且可移动的能源就没有新机械化时代的产生。

The source had long been known but not exploited. Early in the century, a pump had come into use in which expanding steam raised a piston in a cylinder, and atmospheric pressure brought it down again when the steam condensed inside the cylinder to form a vacuum. This “atmospheric engine,” invented by Thomas Savery and vastly improved by his partner. Thomas Newcomen, embodied revolutionary principles, but it was so slow and wasteful of fuel that it could not be employed outside the coal mines for which it had been designed. In the 1760s, James Watt perfected a separate condenser for the steam, so that the cylinder did not have to be cooled at every stroke; then he devised a way to make the piston turn a wheel and thus convert reciprocating (back and forth) motion into rotary motion. He thereby transformed an inefficient pump of limited use into a steam engine of a thousand uses. The final step came when steam was introduced into the cylinder to drive the piston backward as well as forward thereby increasing the speed of the engine and cutting its fuel consumption.

一直以来，人们很早就了解这种能源，不过没能成功开发。在18世纪早期，泵曾被用于在气缸中使蒸汽推动活塞，气缸内部的蒸汽被压缩形成真空环境，大气压又使得活塞下降，这一由托马斯•赛佛瑞发明并由他的同伴托马斯•纽科门对其进行改良的“大气引擎”，被赋予了革命性的工作原理。但其效率低下且浪费燃料，无法在煤矿以外的地区使用，这与最初的设计期望背道而驰。18世纪60年代，詹姆士•瓦特完善了分离的蒸汽冷凝器，因此不必每次活塞运动后都要冷却气缸；随后，他又发明了一种新的方法，使得活塞可以旋转运动，即从原来的往复运动演变成为循环运动，原本效率低下运用范围有限的活塞式结构从此演变成为得到广泛运用的蒸汽模式。最终，蒸汽被运用于汽缸中将活塞推回，从而加快了机器的运转速度并降低了能源消耗。

Watt’s steam engine soon showed what it could do. It liberated industry from dependence on running water. The engine eliminated water in the mines by driving efficient pumps, which made possible deeper and deeper mining. The ready availability of coal inspired William Murdoch during the 1790s to develop the first new form of nighttime illumination to be discovered in a millennium and a half. Coal gas rivaled smoky oil lamps and flickering candles, and early in the new century, well-to-do Londoners grew accustomed to gaslit houses and even streets. Iron manufacturers which had starved for fuel while depending on charcoal also benefited from ever-increasing supplies of coal; blast furnaces with steam-powered bellows turned out more iron and steel for the new machinery. Steam became the motive force of the Industrial Revolution as coal and iron ore were the raw materials.

瓦特发明的蒸汽机很快地施展了拳脚，把依赖水源的工业解放了出来。通过驱动高效率的泵，引擎可将矿井中的水排出，矿井就能挖掘得更深。煤的便利使用激发了威廉•默多克在18世纪90年代发明了1, 500年以来首例夜间照明设备。新世纪伊始，煤气灯在与冒烟的油灯和忽闪的蜡烛的比较中占尽优势，经济富裕的伦敦人也开始习惯了煤气用作家用照明甚至街道照明。依赖于木炭供应的铁匠们急需燃料，他们也受益于越来越多的煤炭供应。配备有蒸汽动力的鼓风炉使得越来越多的钢铁供应成为可能。蒸汽成为了工业革命中的主要动力，当时的煤矿和铁矿成为了工业的主要原材料。

By 1800 more than a thousand steam engines were in use in the British Isles, and Britainretained a virtual monopoly on steam engine production until the 1830s. Steam power did not merely spin cotton and roll iron; early in the new century it also multiplied ten times over the amount of paper that a single worker could produce in a day. At the same time, operators of the first printing presses run by steam rather than by hand found it possible to produce a thousand pages in an hour rather than thirty. Steam also promised to eliminate a transportation problem not fully solved by either canal boats of turnpikes. Boats could carry heavy weights, but canals could not cross hilly terrain; turnpikes could cross the hills, but the roadbeds could not stand up under great weights. These problems needed still another solution, and the ingredients for it lay close at hand. In some industrial regions, heavily laden wagons, with flanged wheels, were being hauled by horses along metal rails; and the stationary steam engine was puffing in the factory and mine. Another generation passed; before Inventors succeeded in combining these ingredients by putting the engine on wheels and the wheels on the rails, so as to provide a machine to take the place of the horse. Thus the railroad age sprang from what had already happened in the eighteenth century.

到19世纪时，英国已经拥有上千台蒸汽发动机，直到19世纪30年代以前，英国在蒸汽机的生产方面一直处于实质性垄断地位。蒸汽机不仅可以用于织布、炼铁，19世纪早期，蒸汽机的使用同样大大提高了造纸的效率，蒸汽动力生产的产量是一个工人一天产量的10倍。那时，第一个利用蒸汽发动的印刷机的印刷厂1小时就能完成1,000页的印量，而手动印刷机只能完成30页的工作量。蒸汽动力还实现了运河及收费公路无法完全解决的运输问题。货船的确可以负荷重物，但人们无法利用运河在多山的区域实现运输，虽然利用公路可以穿实现在多山区域的运输，但路面的承载能力有限。这些问题都需要其他解决方法，解决问题所需要的条件其实唾手可得。在一些工业地区，四轮马车用于承载重物，它们配备有带凸的车轮，通过马力拉车在铁轨上行驶；静止的蒸汽发动机广泛运用于工厂和矿井之中。直到过了一代，另一批发明家们才将这些条件成功地组合在一起，给车轮配备上蒸汽动力，让轮子在铁路上运转，利用机器替代了原有的马。这就是铁路时代从18世纪既有条件基础上发展起来的过程。