A Case Study of British Sabotage

Leibniz, Papin, and The Steam Engine

by Philip Valenti

THE EARLY HISTORY of the invention of the steam engine shows without doubt that the British Royal Society deliberately prevented the industrial applications of steam power for nearly 100 years. In fact, the Royal Society was so intent on burying Denis Papin's 1690 invention of a paddle-wheel-driven steamship, worked out in collaboration with G.W. Leibniz, that it appropriated his work and created a mythical story of how two British heroes invented the steam engine—a myth that has persisted in the history books until today.

Papin, a member of the Royal Society and part of the Continental republican networks that later produced Benjamin Franklin and the European support for the American Revolution, published many papers throughout England on his ideas and inventions, including steam power. Yet, in 1699, nine years after the Papin-Leibniz steam engine was invented and publicized, the British Parliament awarded an "exclusive patent" to the "fire engine" design of one Thomas Savery—a steam engine design that was proven not to work in full scale.

Still later, in 1712, after the Royal Society appropriated all of Papin's work without remuneration and after Papin "disappeared" in England, another British steam engine hero was created—Thomas Newcomen, an ironmonger reportedly working with Savery. Newcomen is now credited throughout the history books with inventing a steam pump that used a piston and cylinder and was restricted to raising water from mines.

Aside from an improvement 50 years later by James Watt, who created a separate chamber to condense the steam, the so-called Newcomen steam engine was used solely for pumping water at mine sites until the late 18th century. There was no attempt made to develop the explicit designs of Papin and Leibniz for all kinds of labor-saving steam-powered machines. Thus, without any explanation or discussion of extending the steam-power concept, the British deliberately held back for nearly a century the transformation of society that took place when the steam engine was finally applied to manufacturing and then to transportation. (A chronology appears on page 46.)

It seems appropriate, then, that Robert Fulton, the American scientist, painter, and diplomat who later brought many of Papin's designs to fruition, proposed in 1798 that the French use steam-powered warships and a submarine against the "monstrous government" of England to aid in republicanizing the nation and ensuring world peace. Fulton, a humanist in the tradition of Papin and Leibniz, understood perfectly well who the enemy was and what had to be done to free the world from the British stranglehold to pursue industrial and technological development (see box page 44).

The story told here of the steam engine is a striking example of how the British hated the very ideas of Continental Science. To Issac Newton's Royal Society, the Leibnizian world view—the knowledge that man will master the coherent laws of nature and in the process create the means to continually better man's material conditions—was anathema. The society's public show of interest in science was intended only to control scientific developments in the interest of the old aristocratic order.

The fact that Leibniz and Papin developed the steam engine based on a theoretical *conception* of how dynamics and force should operate in a totally new machine, as opposed to Newton's empirical inductive method of mechanics and his hatred of hypotheses, is what the Royal Society sought to suppress from circulation.

Even in the 20th century the British found it necessary to continue the steam engine fight by founding the Newcomen Society here in the United States in 1923. Not only did the Newcomen Society promote the myth that

Newcomen invented the steam engine; it also boldly asserted that Newcomen "may truly be designated the founder of the industrial Revolution."

With 17,500 U.S. business leaders as members, the Newcomen Society continues to this day to promote the myth that the steam engine as well as American industry came out of the blue by trial and error and mysterious "market forces." (This is a mish-mash they label as "free enterprise.") According to the Newcomen Society publications, such development had nothing to do with the actual source of industrial capitalism—the organization by Leibniz and later by our Founding Fathers of sovereign republics to promote and protect scientific inventions and industry.

In reviewing the original documents—the correspondence of Leibniz and Papin and the Royal Society papers—one cannot help but think of today's antiscience faction and their determination to implement a new Malthusian order by stopping technological development and theoretical science. In this case, a 100-year delay in the implementation of fusion power and full nuclear development would have devastating consequences for mankind. What America needs now is enough 20th-century Benjamin Franklins and Robert Fultons to get rid of the obstructors of progress for good!

The project of discovering and perfecting a source of power capable of effecting a dramatic human advance was first initiated as a national effort by the minister of the young French King Louis XIV, Jean Baptiste Colbert.

The French Academy of Sciences

In 1666, Colbert established the Academy of Sciences at Paris for this purpose, recruiting the Dutch scientist Christiaan Huygens as its first president. Huygens's proposed 1666 program included "research into the power of gunpowder of which a small portion is enclosed in a very thick iron or copper case. Research also into the power of water converted by fire into steam," as well as experiments with vacuum pumps, wind-powered engines, and the communication of force by the collision of bodies.

In 1672, Huygens acquired two young students and collaborators: Gottfried Wilhelm Leibniz, the 26-year-old diplomat, and Denis Papin, a 25-year-old French medical doctor introduced into the Academy by Madame Colbert. Within a year, Huygens and his new colleagues had sucessfully modified the von Guerike air pump into an engine capable of transforming the force of exploding gunpowder into useful work.

Huygens proposed to create a vacuum within a cylinder under a piston by exploding a charge of gunpowder at the cylinder's base (see Figure 1). After the air was expelled through two valves fitted with leather collars, the collars collapsed, preventing air from reentering the cylinder. The pressure of the atmosphere then was expected to push the piston downwards into the cylinder, the motion

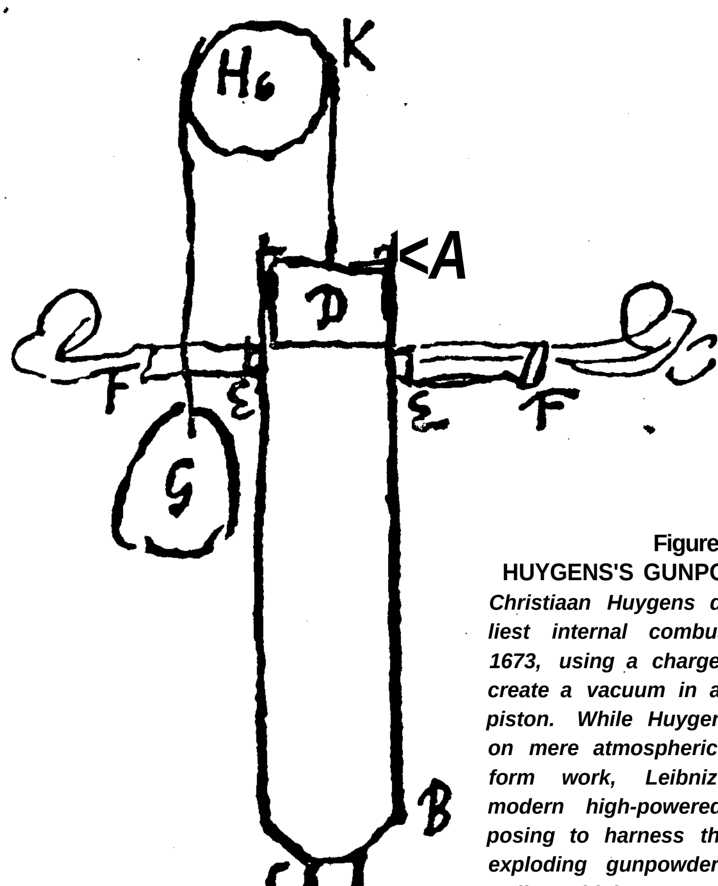
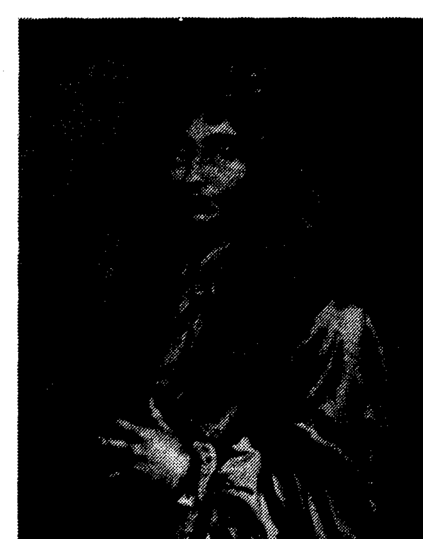


Figure 1
HUYGENS'S GUNPOWDER DEVICE
Christiaan Huygens designed this earliest internal combustion engine in 1673, using a charge of gunpowder to create a vacuum in a cylinder under a piston. While Huygens's device relied on mere atmospheric pressure to perform work, Leibniz anticipated the modern high-powered engine by proposing to harness the direct force of exploding gunpowder or alcohol, as well as high-pressure steam.



Christiaan Huygens

of the piston being applied to perform work. After successfully demonstrating a model gunpowder engine to Colbert, Huygens wrote:

> The violent action of the powder is by this discovery restricted to a movement which limits itself as does that of a great weight. And not only can it serve all purposes to which weight is applied but also in most cases where man or animal power is needed, such as that it could be applied to raise great stones for building, to erect obelisks, to raise water for fountains or to work mills to grind grain < . . . It can also be used as a very powerful projector of such a nature that it would be possible by this means to construct weapons which would discharge cannon balls, great arrows, and bomb shells . . . . And, unlike the artillery of today these engines would be easy to transport, because in this discovery lightness is combined with power.
>
> This last characteristic is very important and by this means permits the discovery of new kinds of vehicles on land and water.
>
> And although it may sound contradictory it seems not impossible to devise some vehicle to move through the air . . . .[1]

While Papin advanced Huygens's work by improving the air pump, Leibniz proceeded, in deliberate fashion, to discover and develop the science of dynamics and its mathematical tool, the differential calculus. Technology-vectored modern science begins with Leibniz's metaphysical discoveries of the 1670-1675 period.

Leibniz wrote that in his youth he freed himself from "the yoke of Aristotle," rejecting scholasticism in favor of the materialist notion of "atoms and the void." Accepting Descartes's concept of matter as mere passive extension, Leibniz attempted to work out a complete physical theory in his 1670 New *Physical Hypotheses.* However, he found that the assumption of a passive, inert matter whose essence consists in merely taking up space resulted in absurdities.

Consider the case, he wrote, of a small body, A, moving in a straight line with velocity, *V.* Suppose that *A* encounters a much larger body, *B,* at rest. Leibniz concluded that since there is nothing in the concept of mere extension to account for inertia, the body *A* will carry the body *B* along with it without losing any of its velocity:

> This is a consequence which is entirely *irreconcilable with experiments* . . . . All of this shows that there is in matter something else than the purely Geometrical, that is, than just extension and bare change. And in considering the matter closely, we perceive that we must add to them some *higher or metaphysical notion, namely, that of substance, action, and force* [emphasis in original].[2]

Leibniz proposed to study the forbidden, "impenetrable" interior of things to discover the true cause of phenomena, much as 20th century scientists have explored the interior of the atom and the interior of atomic "particles" like the "proton." He wanted to replace the materialists' occult quality of "hardness" with a notion of "concurrent movement":

> I believe that matter itself, which is homogeneous and equally divisible throughout, is differentiated by motion alone. We see that even fluids acquire a certain firmness when in motion. Thus a vigorous jet of water will prevent anything from breaking into its own path from without with more force than the same water at rest . . . . We learn from the magnet in an elegant experiment, that things which in themselves are separate and, so to speak, sand without lime, can acquire some firmness by motion alone. When iron filings are placed near a magnet, they suddenly become connected like a rope and form filaments, and the matter arranges itself in rows. It is no doubt also by some kind of magnetism, that is, by an internal coordinated motion,-that other parts of certain bodies are linked together....
>
> [Since] all bodies are agitated by internal motions, the conclusion is that bodies are firm insofar as these motions are concurrent, but remain fluid insofar as the motions are perturbed and not connected by any system. The result is that every body contains some degree of flexibility and of some firmness alike and that no body is so hard as not to have some flexibility, and the converse.[3]

Next, Leibniz pursued his study of the interior of things on the grounds of the infinite divisibility of the continuum. Discrete, hard atoms cannot exist, he said, because there is no reason for the divisibility of the continuum to stop at any given point; that is, physical atoms violate Leibniz's Law of Sufficient Reason. However, where contemplation of the fact of infinite divisibility led others to reject the very existence of individuals in favor of an all-consuming, continuous, unchanging soup, Leibniz instead discovered the grounds for universal progress and the basis of a new science—dynamics.

For Leibniz, the continuum is not divided merely linearly, like marks on a ruler, but in a manner suggestive of the modern Riemannian conception of nested manifolds, "Worlds within Worlds;" As Leibniz develops this in the *Monadology:*

> Each portion of matter is not only divisible *ad infinitum,* as the ancients recognized, but also each part is actually endlessly subdivided into parts, of which each has some motion of its own; otherwise it would be impossible for each portion of matter to express the whole universe.
>
> 66. Whence we see that there is a world of creatures, of living beings, of animals, of entelechies, of souls, in the smallest particle of matter.
>
> 67. Each portion of matter may be conceived of as a garden full of plants, and as a pond full of fishes. But each branch of the plant, each member of the animal,

Gottfried Leibniz

Denis Papin

each drop of its humors is also such a garden or such a pond.

68. And although the earth and air which lies between the plants of the garden, or the water between the fish of the pond, is neither plant nor fish, they yet contain more of them, but for the most part so tiny as to be imperceptible to us.

69. Therefore there is nothing fallow, nothing sterile, nothing dead in the universe, no chaos, no confusion except in appearance ....[2]

Such "infinite divisibility," Leibniz said, can account for the "perpetual and very free progress of the whole universe":

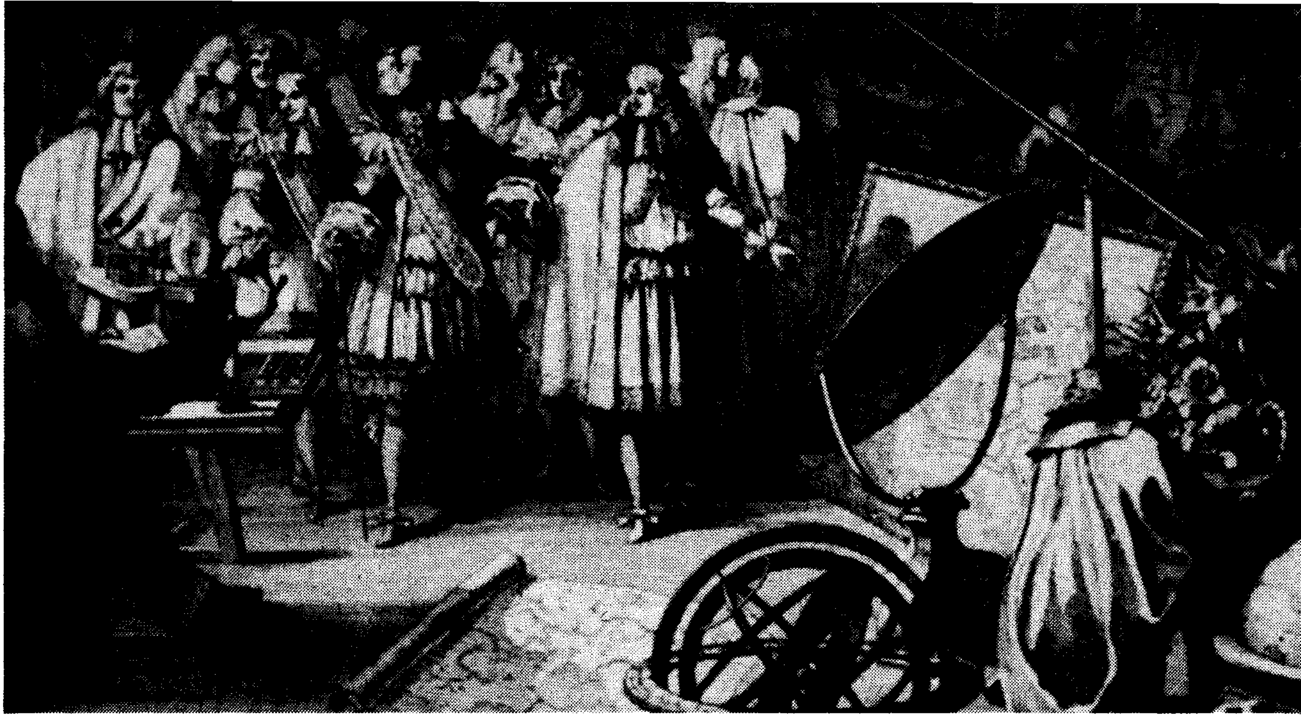
> Even if many substances have already reached great perfection, nevertheless on account of the infinite divisibility of the continuum, there always remain in the depths of things slumbering parts which must yet be awakened and become greater and better, and, in a word, attain a better culture. And hence progress never comes to an end.[2]

The Development of Dynamics

Freed from Descartes's concept of passive matter and equipped with a matter Containing unlimited resources ("slumbering parts which must yet be awakened"), Leibniz transcended the science of mechanics that had dominated Western thinking since Archimedes. Where mechanics pertained to the passive effects of ancient machines, dynamics was conceived as the science of the active, living force *(vis viva,* or kinetic energy) of "violent actions"—like the explosion of gunpowder and rapid expansion of high pressure steam:

> The ancients, so far as is known, had conceived only a science of inactive force, which is commonly referred to as Mechanics, dealing with the lever, the windlass, the inclined plane—pertinent to the wedge and screw—though there is discussion of the equilibrium of fluids and of similar problems; only the effort or resistance of bodies and not the impetus they have acquired through their action, is discussed ....
>
> For I here refer not to any effect, but to one produced by a force which completely expends itself and may therefore be called violent; such is not the case with a heavy body moving on a perfectly horizontal plane and constantly preserving the same force; this is a harmless sort of effect, so to speak, which we can also calculate by our method, but it is not the one we wish to consider now.[2]

Since it is limited to the study of "harmless sorts of effects," mechanics considers the total absolute force of bodies acted upon by ancient machines as directly proportional to the acquired velocity, or $F = mv$. In contrast, Leibniz considered the equivalence of the kinetic energy of a heavy body falling from a given height (violent action) to the work required to raise it to that height, and using Galileo's laws for bodies in free fall, he determined that



Colbert's Academy

the live force of a body in motion is directly proportional to the *square* of the velocity; that is, $F=mv^2$.

Leibniz's subsequent statement of the principle of the conservation of *vis viva*—"the cause and total effect are always equivalent in such a way that the effect, if it were completely turned around, could always reproduce its cause exactly, and neither more nor less"—effectively initiated today's technology-vectored science. Most important, Leibniz's practical goal became to free the most violent actions known for the purpose of advancing the material conditions of man. By applying the law of the conservation of *vis viva* to maximize the conversion of the kinetic energy of such actions into useful work, Leibniz envisioned mastering the *direct force* of explosions to power ships, carriages, airplanes, and factories.

The power of Leibniz's dynamic conception and its useful application stands in stark contrast to the mechanical conceptions of the British, who for nearly 100 years restricted steam power to functioning as some sort of exotic lever simply to pump water from mines.

But how could a scientific establishment possibly invent anything useful while insisting, as the British Royal Society did *throughout the 18th century,* that one's preference between measuring force by *mv* or mv^2 is simply a matter of personal taste, a mere semantic quibble?

From the beginning of his study of the matter, Leibniz had insisted on the practical implications of his dynamics, particularly the issue of mv^2 versus *mv,* for the construction of machines and the perfection of technology. He wrote in 1695:

> These things are not worthless to consider, nor are they quibblings over words, for they are of the greatest importance in comparing machines and motions. For example, if power is obtained from wafer or animals or from some other cause, by which a weight of 100 pounds is kept in constant motion so that within a fourth of a minute it can be made to complete a circle of 30 feet diameter, but someone else maintains that a weight of 200 pounds can in the same time complete half the circle with less expenditure of power, his calculation seems to yield a gain; but you ought to know that you are being deceived and getting only half the power.... [2]

By 1675, Leibniz had begun to engage the leading French Cartesians in debate over his dynamics and with Huygens's help he succeeded in inventing the differential calculus. At this point, the impact of the reactionary shift in the policies of Louis XIV, which began with the French invasion of Holland in 1672, reached Colbert's Academy. The result was a forced exodus of Protestant scientists several years before Louis's 1685 revocation of the Edict of Nantes. Leibniz left Paris reluctantly to accept a post as librarian in Hanover, while Papin left for England.

Papin's Early Inventions

Working with Hooke and Boyle in London, Papin continued Colbert's project. By 1680, Papin made a major breakthrough toward controlling highly compressed steam in the form of his "New Digester for softening Bones, etc."—a steam pressure cooker. This device consisted of a cylinder with thick walls (as prescribed by Huygens in his 1666 program), in which was enclosed water along with bones, tough meat, and so forth. The whole device was then placed on a fire to cook (see Figure 2).

Although Papin's immediate motive was, as he wrote to Huygens, "to relieve poverty, and to get wholesome and agreeable foods from things that we ordinarily reject as useless," his digester was also a major advance toward

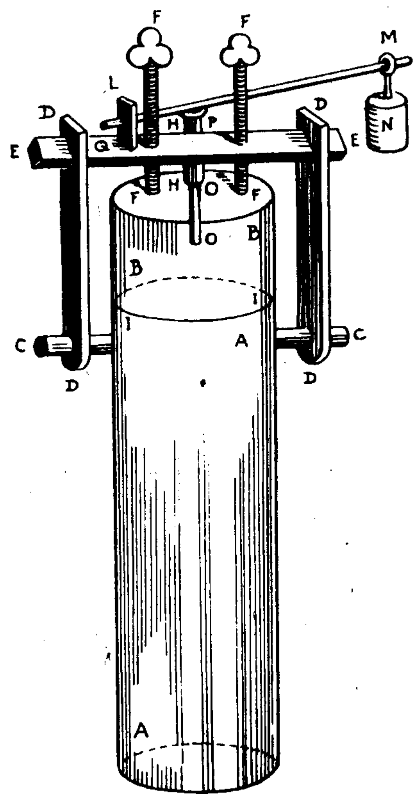


Figure 2
PAPIN'S DIGESTER

Papin wrote a lengthy cookbook for 17th century housewives explaining the operation of his 1680 invention, the steam pressure cooker or "digester." Besides helping to "relieve poverty," Papin's purpose, the digester enabled science for the first time to safely control pressures many times ordinary atmospheric pressure. Papin accomplished this breakthrough by inventing the adjustable safety valve, installed at the top of the cooker.

the steam engine because of a totally new feature—*the safety valve.* This allowed Papin safely to contain pressure many times that of the atmosphere and greater than any pressure previously controlled, limited only by the strength of the cylinder.

That same year Papin was elected a Fellow of the Royal Society, but he was apparently unhappy in London and he soon left for Italy, spending two years as a member of the new Italian Academy of Sciences in Venice. He returned to England, however, and by 1687 he unveiled a new invention to transmit power pneumatically. In order to develop a means of spreading industrialization to areas where water power was not available, Papin proposed two sets of pumps —one set operated by a water wheel, connected by airtight pipes to another set placed in a neighboring town or suburb. Power would be transmitted by the alternate suction and pressure exerted by the first set of pumps (see Figure 3). This idea was hotly opposed in the Royal Society, and Papin left England to accept a chair of mathematics at the University of Marburg in Hesse, bordering Hanover.

In 1690, Papin published an historic article in the *Acta Eruditorum* of Leipsig, "A New Method of Obtaining Very Great Moving Powers at Small Cost/' from which we can precisely date the beginning of the Steam Age. Here, for the first time, Papin proposed using the power of expanding steam to operate an engine. In the new invention, steam replaced the gunpowder charge of Huygens's cylinder, creating a more complete vacuum under the piston and thereby taking advantage of the full force of atmospheric pressure (Figure 4).

Papin's concept was appropriated *in toto* in the Newcomen engine more than 20 years later. However, although Papin mentioned in passing the utility of his invention to "draw water or ore from mines," the article featured a lengthy and detailed discussion of the application of steam power to *propellirig ships* equipped with *paddlewheels:*

> So, no doubt, oars fixed into an axis could be most conveniently driven round by my tubes, by having the rods of the pistons fitted with teeth, which would

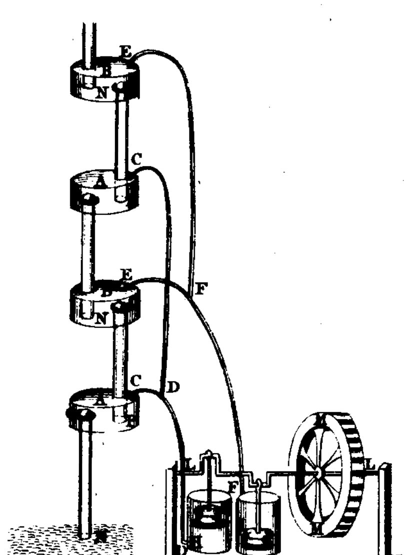


Figure 3
PAPIN'S PNEUMATIC FOUNTAIN

In 1687, Papin illustrated the operation of his pneumatic pump by constructing a model fountain. Water was raised by the alternate suction and pressure exerted by a pair Of air pumps. Papin enclosed his model in a container, allowing his Royal Society colleagues to observe the water spouting at the top but concealing its internal mechanism, and he then challenged the Royal Fellows to guess at its design. The Royal Fellows failed to solve Papin's puzzle and were especially embarrassed since they all had earlier agreed that the pneumatic transmission of power was impossible. Papin found himself suddenly friendless in London and decided to leave for Germany later that year.

force round small wheels, toothed In like manner, fastened to the axis of the paddles. It would only be requisite that three or four tubes should be applied to the same axis, by which means its motion could be continued without interruption [Figure 5].

Papin recognized the problem inherent in such atmospheric engines. Since the source of power is not the steam itself but the pressure of the atmosphere, the only means of increasing power is to increase the diameter of the cylinders:

> The principal difficulty, therefore, consists in finding the manufactory for easily making very large tubes . . . . And for preparing that, this new machine ought to supply no small inducement, inasmuch as it very clearly shows that such very large tubes can be most advantageously employed for several important purposes.[1,4]

The Leibniz-Papin Collaboration

With Leibniz's intervention, Papin solved this problem in 10 years time. For Leibniz, the discussions with Papin were a crucial part of his campaign to win hegemony for dynamics among the most talented of European scientists. By the turn of the century, Leibniz had won over Father Malebranche, the leading French Cartesian and head of the Catholic Oratorian order, thus ensuring the future line of development within France leading to Carnot. Malebranche became convinced of Leibniz's dynamics largely on the basis of metaphysical considerations, but Papin was won over during the course of 15 years of experimentation under Leibniz's direction.

Papin began to tackle the problem of "making very large tubes" by studying the means of refining ores more efficiently, and of manufacturing cylinders with appropriately smooth surfaces. This led him to the invention of an improved furnace capable of reaching higher temperatures with a more efficient consumption of fuel. Papin used another of his inventions, the Hessian bellows, to generate a forceful down-draft in his furnace, thereby eliminating smoke and allowing a complete burn (see Figure 6).

By 1695, Papin had adapted this hotter furnace to the rapid production of high-pressure steam by constructing the furnace so that the fire surrounded the water, allowing the maximum surface area of water to be heated directly.

With this discovery, Papin was prepared to initiate a qualitative technological advance—not a linear extrapolation from his 1690 results, such as building larger atmospheric engines, but a proposal to harness the violent force of the *expanding steam.*

In a letter dated April 10, 1698, Papin apologized to Leibniz for not having written sooner, and explained that a new project, commissioned by his employer, the Landgrave of Hesse, had taken up most of his time:

> Monsgr. le Landgrave formed a new plan, very worthy of a great Prince, to attempt to discover where the salt in salty springs comes from. To reach the bottom of

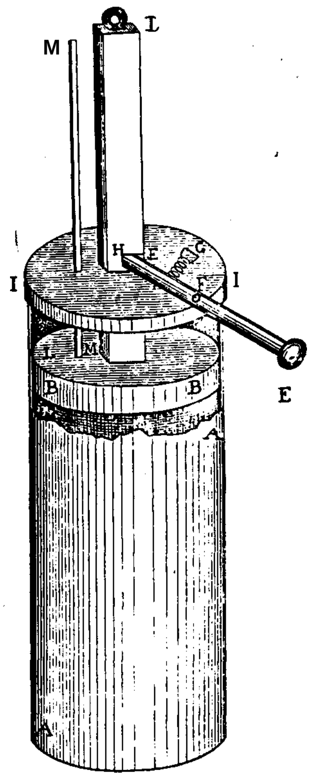
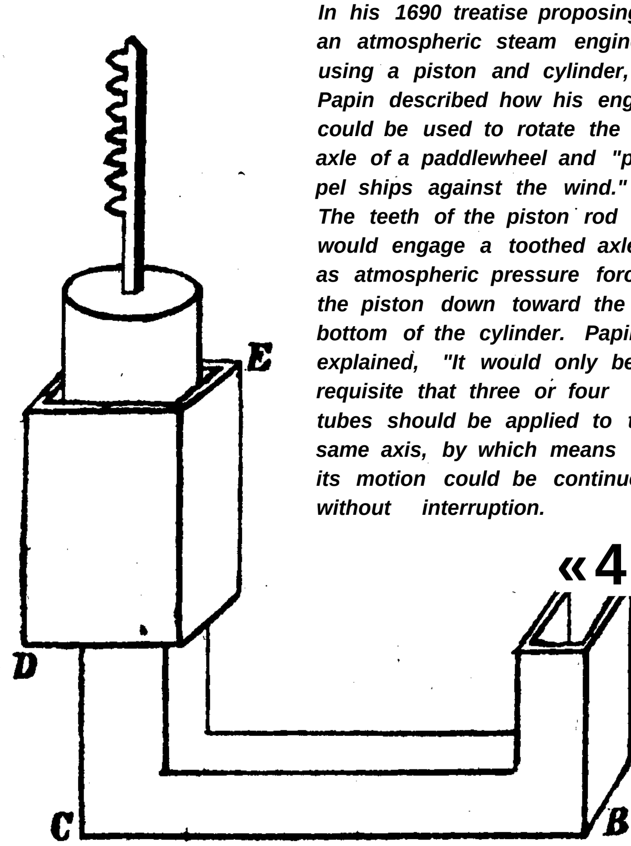


Figure 4
PAPIN'S 1690 ENGINE
The first steam engine using a piston and cylinder was invented by Papin in 1690. Papin proposed to use steam instead of gunpowder to create a vacuum under a piston. Although Papin suggested a means of applying the force of his engine to operate a paddlewheel boat, he realized that the power of an atmospheric steam engine was strictly limited by the diameter of its cylinder.

Figure 5
PISTON WITH TEETH FOR USE WITH PADDLEWHEEL
In his 1690 treatise proposing an atmospheric steam engine using a piston and cylinder, Papin described how his engine could be used to rotate the axle of a paddlewheel and "propel ships against the wind." The teeth of the piston rod would engage a toothed axle as atmospheric pressure forced the piston down toward the bottom of the cylinder. Papin explained, "It would only be requisite that three or four tubes should be applied to the same axis, by which means its motion could be continued without interruption.



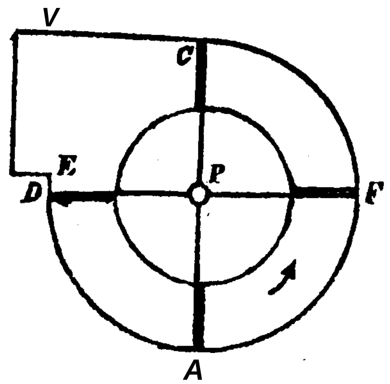


Figure 6
HESSIAN BELLOWS

Papin tackled the problem of manufacturing larger cylinders for his atmospheric steam engine by first inventing a hotter and more efficient furnace to improve the reduction of ores. This furnace utilized a down-draft generated by his "Hessian bellows" (above), which allowed a continuous forceful stream of air to feed the burning fuel. At Leibniz's prompting, Papin applied his hotter furnace to the rapid production of high-pressure steam. This led Papin to abandon the effort merely to scale up his atmospheric engine and instead to begin the crucial project of harnessing the "unbounded" energy of high pressure steam.

this, it would be very advantageous to be able to easily draw out a great quantity of water to a considerable height. I've made many tests to try to usefully employ the force of fire to this task; some succeeded so well that I was persuaded that *this force could be applied to things much more important than raising water.* Consequently, I've given myself totally to this work, knowing the great difficulties always to be met with in such enterprises and which can't be overcome without an extraordinary diligence. I'm presently having a new furnace built of which I've spoken to you before .... I'm building it simply to make certain large retorts of forged iron which will be very useful to produce the great effects that I expect from the force of fire. For this furnace I've also built a large Hessian bellows more perfect than those I've made before. And thus one thing leads to another .... [emphasis added].

In his reply four days later, Leibniz asked if Papin's method of raising water "is based on the principle of rarefaction which you published before, or if it is based on some other principle; I also have a thought about it, but I want to make a little test of it in order to consult you on its performance."

Papin's historic answer follows (July 25, 1698):

The method in which I now use fire to raise water rests always on the principle of the rarefaction of water. But I now use a much easier method than that which I published. And furthermore besides using suction, I also use the force of the pressure which water exerts on other bodies when it expands. *These effects are not bounded, as in the case of suction.* So I am convinced that this discovery if used in the proper fashion will be most useful .... For myself *I believe that this invention can be used for many other things besides raising water. I've made a little model of a carriage which is moved forward by this force:* And in my furnace it shows the expected result. But I think that the unevenness and bends in large roads will make the full use of this discovery very difficult for land vehicles; *but in regard to travel by water I would flatter myself to reach this goal quickly enough if I could find more support than is now the case ....* It gave me much joy to find that you also have some plans to put the moving force of fire to use, and I strongly hope that the little test you told me of succeeded to your satisfaction [emphasis added].

Leibniz's concern for the applications of Papin's work was much greater than simply using the "force of fire" to propel ships and carriages. He saw in Papin's work the *unique experiment* capable of irrefutably establishing the truth of his dynamical science, as well as advancing that science by the process of applying its principles to *the measurement of the thermodynamic efficiency* of Papin's machines. This is the "little test" referred to in the letters above.

Leibniz wrote to Papin (July 29,1698):

I understand very well that the force of expanding water will do much more than air pressure will do when the steam is condensed, and this is exactly what I have thought as well in regard to gunpowder .... But in regard to water the strain of its expansion will be less violent, [so] it would be good to see if there aren't other fluids which would be even better than water. But water has the advantage that it costs nothing, and is available everywhere. My plan would be to do a test to discover if expanding water can usefully raise more than a column of air. But I lack workers here and I'm too distracted .... But I'm now very glad to find out that you've already made the relevant experiment, and that therefore you know approximately what *the force of the steam is relative to the heat and to time* [emphasis added].

Papin replied with a progress report on the construction of his engine, promising that once it was completed:

I will try also to make observations on *the degree of heat [chaleur] required to make a given effect with a given quantity of water.* But up to the present all that I've been able to do, by the expansion of the steam, is to raise water to 70 feet, and to observe that a small increase in the degree of heat is capable of greatly augmenting the magnitude of the effect. And this convinces me that if these machines are perfected so that very great degrees of heat can be used, one will be able to create a greater effect with a pound of water than with a pound of gunpowder [emphasis added].

Vis Viva Versus Mechanics

Consider the implications of the Papin-Leibniz discussion once the word *effect* is translated to the modern term *work.* Both Leibniz and Papin agreed that the useful work performed by a heat engine was to be measured by the height, H, to which it could raise a given quantity of water (work or effect = MgH). In his dynamics, Leibniz had used the example of the equivalence of the work required to raise a heavy body a given height to the *vis viva* acquired by the body in falling from that height. Whereas in the case of the falling body, the *vis viva* is easily measured by the body's velocity, Leibniz proposed to measure the *vis viva* of expanding steam by its *temperature.* Applying the principle of the conservation of *vis viva,* Leibniz developed the following sort of relation:

vis viva consumed by machine = useful work (height a given quantity of water is raised) + heat lost in overcoming friction + heat lost to superfluous cooling + . . . [other inefficiencies]

With this sort of analysis, Leibniz was prepared to *compare* the thermodynamic efficiencies of heat engines by measuring "the degree of heat required to make a given effect." This also led him to the formulation of his unique experiment: demonstrating that steam can "raise more than a column of air."

Let's look at the case of Papin's 1690 steam engine. Here the atmospheric pressure alone, considered as a "column of air" resting on the cylinder, is responsible fpr the motion of the piston. The role of the expanding steam is simply to raise the piston back to the top of the cylinder; that is, in Leibniz's phrase "to raise a column of air." Then the condensed steam leaves a vacuum in the cylinder and atmospheric pressure pushes the piston downward once again.

Leibniz proposed to demonstrate that the *direct force* of expanding steam, unlike mere suction, is *unbounded*—that it can "raise more than a column of air" (Aug. 28, 1698):

> There is nothing which merits development more than the force of expansion *[la dilation];* if one objects that expanded water can do no more than raise a cylinder of air, and that the stronger it [steam] is the higher it [cylinder of air] is raised and that therefore it is sufficient to use the weight of the falling cylinder—I reply that this higher elevation requires more time, allowing the steam to gradually cool, than a *quicker elevation of a heavier weight.* Thus either force is lost or more fire must be used [emphasis added].

Clearly at issue in this "little test" is the validity of the mechanical world view—the universe of inactive force—that threatened to impose itself on emerging technology. Was steam power to be constrained to act passively, slowly pushing and pulling weights like some grotesque Rube Goldberg type of lever or pulley, or was it to be freed in all its violence—maximum *vis viva* to effect a qualitative human advance?

From this dynamical point of view, in fact, Leibniz was by no means convinced that expanding steam was the optimum source of energy for the new technology. For him, even expanding steam was not sufficiently violent or rapid in its action, compared, for example, to exploding gunpowder or, as he suggests elsewhere, to the combustion of alcohol. He argued as well for further work in applying the force of highly compressed air, particularly advantageous for building lighter and more portable engines for vehicles.

The Savery Hoax

Despite the publicity given to Papin's invention, the British Parliament awarded an exclusive patent for "Raising Water by the Impellent Force of Fire" to one Thomas Savery, variously described as a "sea captain" and a "military engineer." The terms of the patent meant that any steam-powered device Papin might invent in England would come under the control of Savery.

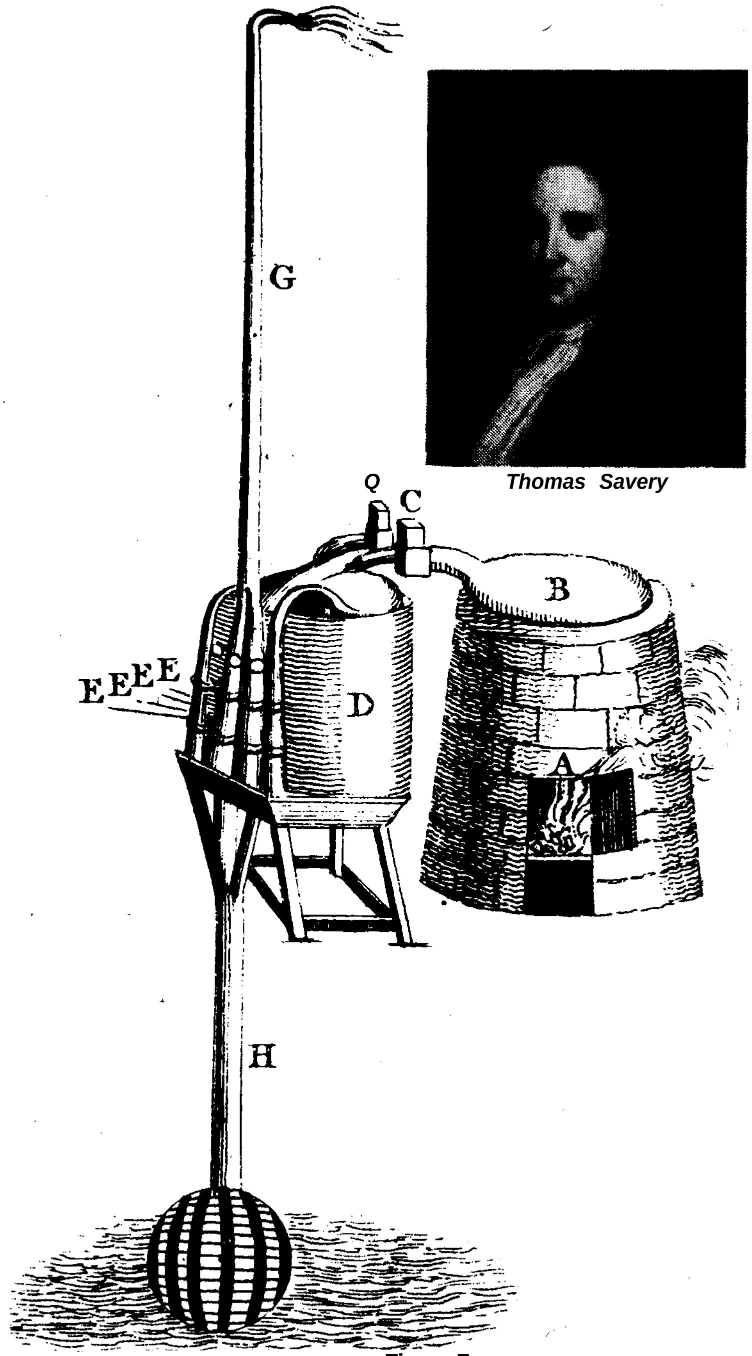
Although news of Savery's patent reached Germany by 1699, it was not until 1704 that Leibniz, via "Hanoverian envoys" in London, was able to acquire some sort of description of Savery's device. Leibniz forwarded a sketch of the English "engine" to Papin, along with an evaluation of its capabilities. Based on further intelligence reports from his envoys, Leibniz concluded—correctly—that Savery's device did not work in full size.

Basically, Savery's engine consists of a chamber connected by a pipe to a source of water below and by another pipe to a separate boiler. Steam enters the chamber from the boiler; cold water is poured on the chamber, condensing the steam and thus creating a vacuum and drawing water up the pipe from below. The steam enters the chamber again, this time for the purpose of pushing the raised water out of the chamber and up another pipe. The steam is then forced to condense once again, creating a vacuum and sucking more water up from below, renewing the cycle (see Figure 7).

For Leibniz and Papin, study of Savery's design provided a unique opportunity to apply and improve their new thermodynamic principles, since Savery was proposing precisely the sort of *containment* of steam power within the conceptual and technological boundaries of mechanics that Leibniz had warfied against.

Papin wrote to Leibniz describing experiments in which he had discovered that using Savery's design, an increase in the temperature of the steam actually resulted in a *decrease* of the work performed (July 23,1705):

> I am persuaded that it will be useless to try to push water to great heights by the immediate pressure of steam: Because when the expanded steam strongly applies itself against the cold water, as is necessary to make it rise to a great height, it isn't possible to



Thomas Savery

Figure 7
THE SAVERY ENGINE

In 1699, Thomas Savery was granted an exclusive patent by the English Parliament covering all conceivable "fire engines," despite the fact that his contraption did not work in full size. Savery claimed otherwise, insisting, for example, that hot steam would not condense upon encountering the cold water in the main chamber of his "engine." Savery further insisted that no engine using a piston and cylinder could ever work because of friction. Nevertheless, Savery's design was guarded as an English state secret, until Leibniz's spies succeeded in smuggling the blueprints to Hanover in 1704.

Source: A. Wolf, *A History of Science, Technology, and Philosophy in the 16th and 17th Centuries,* (New York: The Macmillan Co., 1935).

conserve the force of the steam; but it is immediately condensed by the coldness of the water. And the hotter the steam is the more it violently pushes the valve, in such a way that the valve, being pushed as well by the spring which is behind, causes the water to become very agitated. The water thus agitated is much more likely to cool off a lot of steam than when its surface remains smooth. Thus I firmly believe that this is the reason which makes the elevation of the water decrease when the heat increases . . . .

I therefore believe that the best is to do it so that the steam doesn't directly touch the water, but that it pushes it only by the mediation of a piston which is quickly heated and which consequently only condenses a little steam. And the surface of the piston which touches the steam always stays the same, the new steam which frequently reaches it easily maintains it in a degree of heat all the more great as the steam is hot. Thus there is no fear that the machine's effect will fail to be augmented in proportion to the increase in heat. Experiment has well confirmed my conjecture . . . .

And the more I go forward, the more I wonder at how a small quantity of wood is capable of furnishing such force . . . . But . . . it would be desirable to work at that with more heat than made [now]: seeing principally that the use of this invention isn't limited to raising water, but that it could be applied very well to vehicles and to many other things where force is needed.

Leibniz fully approved of Papin's successful application of his thermodynamics, advising him not to take Savery's claims of success too seriously (Aug. 15,1705):

I am delighted that your fire engine advances so well, because when it is brought to perfection, I consider that it will be very useful. Also, it would be a mere trifle if only one-third of the expense would be saved, as the English author believed, since this advantage would be easily absorbed by other inconveniences which such a great alteration of machines would attract. It is very reasonable also to believe that too-diffuse steam applied directly to cold water will condense and lose its force. Consequently, it is better to keep them self-contained *[renfermées].*

According to the Royal Society myth, this sort of reasoning about the steam engine was not supposed to have occurred until about 1769, when James Watt recognized the problem of loss of force because of superfluous cooling of the steam and invented a separate condenser. Watt was motivated in this invention by the knowledge that the Newcomen engine would operate much more efficiently if its cylinder was kept constantly hot while the condenser was kept constantly cold; that is, "it is better to keep them [steam and cold water] self-contained." (Interestingly, Watt was an ally of Joseph Priestley, a victim of the Crown's terror tactics because of his alliance with Continental Science.)

As for Savery and his understanding of the problem, the only written record available is a little pamphlet Savery published in 1702, *The Miners' Friend,* to interest businessmen in his invention. In the chapter titled "The Manner of Working the Engine," Savery describes how a chamber of his engine, p, has been filled with cold water raised from a mine, as follows:

> . . . turn the handle of the regulator from you again, and the force [of the steam] is upon the surface of the water in *p, which surface being only heated by the steam, it does not condense it, but the steam gravitates or presses with an elastic quality like air;* still increasing its elasticity or spring, 'till it counterpoises, or rather exceeds the weight of the water ascending in *s,* the forcing pipe, out of which, the water in *p,* will be immediately discharged when once gotten to the top . . . [emphasis added].

Incredibly, Savery claimed that the steam is not condensed at all. Since it is probable that he actually knew better, at least from his own failed attempts to scale up the device, such a statement was most likely designed to put something over on some credulous miner.

Beyond the outright fraud involved, consider the manner in which Savery attempted to explain the operation of steam. In groping for some mechanical analogy, he settled for the then-popular occult cause, "gravitation," and the more traditional alternative, "elastic quality." Of course, this primitive mechanical outlook imposed itself on his invention. Although the idea of somehow using the force of steam to push water directly seems to be an advance, in fact, Savery's design predetermined that the more forceful the steam the *less efficient* the engine—a point Papin proved.

As a result, Savery proposed to doom steam to play the role of the ancient horse-driven windlass (hoist) and pulley, slowly *pulling* water up one pipe and *pushing* it out of another, with one significant difference—*Savery's "fire engine" was much more expensive.*

Savery's fraud was recognized as such by crafty miners and his engine was used mostly to raise water for the fountains of more wealthy aristocrats. As even the British historian A. Wolf admits, "It was costly and dangerous, so the mine owners stuck to horses."

Savery included an interesting comment on ships in his second chapter, "Of the Uses That This Engine May Be Applied Unto," indicating that it apparently had been made clear in England that the authorities would frown on any drastic technological advance in this area. As Robert Fulton later understood, a successful steamship could be the greatest threat to continued Anglo-Dutch commercial and naval superiority.

Savery fearfully noted, "5. I believe it may,be made very useful to ships, but I dare not meddle with that matter, and leave it to the judgment of those who are the best judges of maritime affairs."

A few pages later, he added, "As for fixing the engine in ships, when they may be thought probably useful, I question not but we may find conveniency enough for fixing them."

These two timid passages constitute the totality of published British commentary on the steamship during most of the 1700s. Meanwhile, Leibniz had become fully committed to seeing a steam-powered vehicle perfected and built within his lifetime—whether a steam boat, a steam carriage, or an airplane. But while Savery and his colleagues could obstruct science at their leisure in the relative peace and quiet of Gresham College, Leibniz and Papin struggled to advance science as rapidly as possible, living in the direct line of march of an invading French army.

War Pressures

Leibniz had barely dissuaded Papin, pressured by the war situation, from accepting a Royal Society invitation to take up his old post as curator of experiments—an offer made to him, interestingly enough, just after Parliament had granted Savery his exclusive patent in 1699. If Papin had gone to England at that point, all of his experiments in steam power would have come under Savery's legal control.

The situation was so unsettled in Germany that Papin was afraid to visit Leibniz in Hanover for fear that his family would be caught alone in a French attack. He concluded that no continued scientific progress would be possible without an end to the war. He wrote to Leibniz in 1702 describing his experiments with a ballistic air pump capable of throwing "a weight of 2 pounds to a distance of 40 feet" and designed eventually "to facilitate the capture of the strongest [French] positions." Papin argued that this invention not only would help bring peace, but also would be the best enticement for princes and generals to support further research into steam technology.

After a year of strenuous efforts to interest the leaders of the anti-French alliance in his invention, Papin reported to Leibniz (Feb. 25,1704), "It has been possible since then to receive a reply neither from England nor from Holland; therefore all that I can conclude is that there is only some secret reason why no one wants to accept my proposal."

Leibniz continued to maintain friendly pressure on Papin throughout 1704, insisting that he resume research into applying violent force (particularly that of gunpowder) to the propulsion of ships and to carriages, if not to airplanes. Leibniz argued that such a breakthrough would have the greatest world strategical impact:

> Yet I would well counsel [you], Monsieur, to undertake more considerable things which would force *[forçassent]* everyone to give their approbation and would truly change the state of things. The two items of binding together the pneumatic machine and gunpowder and applying the force of fire to vehicles would truly be of this nature.

Papin finally agreed, and in a letter March 13, 1704 he revealed that he had already built a model paddlewheel boat "which can carry about 4,000 pounds" and that he had developed a complete theory of rowing "which can also be applied to land vehicles."

By January 1705, Papin had received Leibniz's sketch of Savery's engine. Of course, this had the expected effect on Papin's thinking, as well as on the attitude of the Landgrave of Hesse who took a renewed interest in Papin's work. In March, a newly self-confident Papin wrote to Leibniz:

> I can assure you that, the more I go forward, the more I find reason to think highly of this invention which, in theory, may augment the powers of Man to infinity; but in practice I believe I can say without exaggeration, that one man by this means will be able to do as much as 100 others can do without it. All that I've done up until now has only been to discover the characteristics of this machine and the different symptoms to which it may be subject [a reference to the analysis of the thermodynamic efficiency of Savery's device discussed above]. But Monseigneur from now on wants to apply it to some real use, and his Highness gave me the honor of commanding me to apply this force to turn a mill to grind wheat . . . . And if after the mill we can proceed to apply this invention to ships *[voitures par eau],* I would believe this discovery incomparably more useful than finding longitudes on the ocean, which has been sought for so long.

By the end of 1706 Papin's experiments had convinced him of the explosive strategic potential of steam technology, which he expressed by an analogy to alchemy in a letter to Leibniz:

> Yet it's a great shame that the things from which the Public could derive such considerable usefulness aren't impelled by heat. Because the advantages which this invention could furnish for sea-going vessels alone, without counting those of land vehicles, would be incomparably greater than all expected from the transmutation of metals.

A Genuine Steam Engine

What Papin achieved within two years of receiving Leibniz's sketch* of the Savery device was a genuine direct-action steam engine capable of being immediately applied to ships. Papin's engine successfully incorporated the dynamical innovations of 40 years of research that began with the project initiated by Huygens in Colbert's Academy. This achievement is fully documented in Papin's 1707 treatise, "New Method of Raising Water by the Force of Fire," published in Latin and French at Cassel. (This booklet is available today in select university libraries because someone in France had the foresight to reprint 250 copies of it in 1914.)

Papin's engine, shown in Figure 8, works as follows, with each step representing an innovation as a result of dynamical considerations. The engine is to be situated such that there is a constant flow of water into the pipe G. In this way, the water to be pumped enters the cylinder *DD* through *H;* the piston *FF* is then raised to the top of the cylinder by the weight of the water.

(1) The copper vessel *AA,* which Papin calls the *retort,* is completely enclosed in a furnace, not shown. The furnace is designed to allow the fire to completely surround the retort, with precautions made to guarantee minimum loss of heat to the outside air.

(2) The retort is supplied with a safety valve *ab* to allow a maximum controlled increase in steam pressure. The robinet, or spigot, £ is opened, allowing the high-pressure steam to rush into the cylinder.

(3) The opening *L* and the receptacle *II* are provided to allow insertion of hot irons in order to increase the violence of the steam, which is allowed to reach a controlled maximum with attention to the second safety valve *ab.*

(4) The fulminating, expanding steam acts directly against the cold water through the mediation of the piston *FF,* arranged so that the surface of the piston encountering the steam remains hot, while the opposite surface remains relatively cold. The action of the steam on the piston forces the water out through *H* and up through the valve T, into the closed vessel *NN.* As *NN* fills with water, the air within *NN* is compressed.

(5) The compression of the air in *NN* is allowed to increase until the robinet at the lower right of the vessel is opened, allowing the raised water to exit forcefully through pipe XX.

(6) The resulting high-velocity jet of water encounters an improved paddlewheel, designed according to Papin's *Fig. 2* (shown here in Figure 8). Papin's figure illustrates the advantages of adding many more blades to a mill wheel in order more completely to convert the energy of high-velocity water into rotative motion—the essential concept of a turbine engine.

With this design, technology entered a new, dynamic universe. In a certain sense, it represents a *transition,* in that modern thermodynamic principles are applied to the ancient task of turning a water wheel. However, Papin intended immediately to apply his new engine to power the model paddlewheel boat, which he had constructed three years earlier. Although there is no published explanation by Papin about how he planned to accomplish this, the following is a likely method:

If the engine is fixed to the lower inside hull of a ship so that the pipe GG passes through the hull and stands on the outside of the ship below the surface of the water, the engine could easily work to pump water to turn a paddlewheel above the ship's deck. It is also easy to imagine that a Papin well-funded and freed of the immediate pressure to raise water could have quickly figured out how to combine his 1690 design with the new engine, so that a piston rod connected to *FF* would directly transmit the force of steam to rotate an axle, without going through the unnecessary bother of raising water at all.

In the preface to his 1707 treatise, Papin gives Leibniz full credit for providing the necessary impetus to advance

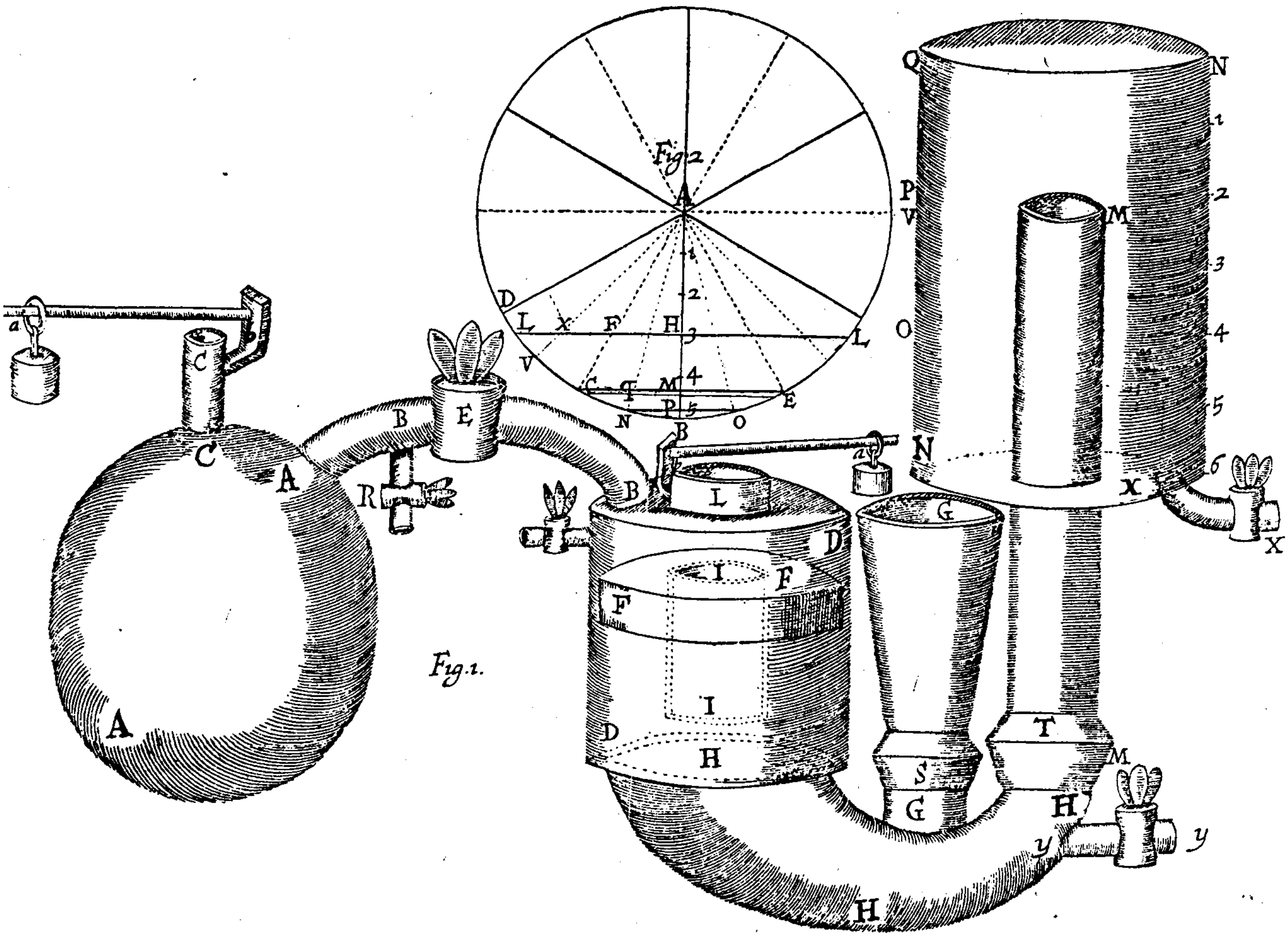


Figure 8
PAPIN'S 1707 ENGINE

Papin invented and successfully operated the world's first direct action steam engine, publishing the results of his experiments in 1707. Papin had also developed a theoretical approach to the construction of ships and to the method of rowing. His study of rowing led him to consider means of maximizing the conversion of energy from a paddle into the forward propulsion of a vessel. He had already constructed a working model paddlewheel boat based on these principles in 1704. Therefore, by 1708 Papin was prepared to combine bis steam engine and his paddlewheeler and build the world's first steamboat—100 years before Fulton.

his experiments. In particular, Papin cites two crucial junctures—the 1698 discussions on harnessing the direct force of steam versus mere atmospheric pressure and the 1705 description of Savery's device that Leibniz's spies procured in London.

The quality of analysis in the treatise also shows the effect of Leibniz's firm *theoretical* commitment to live force, combined with Papin's repeated experimental vW dications of Leibniz's dynamics over the past 40 years. Papin concluded the first chapter, describing the furnace enclosing the retort:

> 5. The reason which obliges us to have such a great care to augment and conserve the heat *[chaleur]* is because it is the heat which makes all the moving force in this machine. Because otherwise in ordinary pumps it is animals,* rivers, the wind or some other thing of this nature which employs their force in order to drive the piston in the pump and expel the water, here it is only the heated steam in the retort *AA* which travels with violence through the pipe *ABB* whenever the robinet *E* is opened, and goes to press the piston in the pump *DD.* And the force of this steam is even greater the more we give it a higher degree of heat.

In chapter 3, Papin commented on the "means to augment the effect of the machine":

> 2. The augmentation of effect of which I have just spoken [that is, increasing the diameter of the pipes,

and so on] is a little thing in comparison to that which could be obtained in augmenting the pressure in the retort *AA:* Because that of which I've spoken until now in order to impel *[pousser]* the water to 64 or 65 feet is equivalent to only two times the ordinary pressure of air: But it's certain that the pressure may be made much greater yet; with digesters or machines to cook bones, which weren't at all completely enclosed in their furnace, as is the retort *AA* here, I sometimes achieved pressures equivalent to 11 times the pressure of air. Thus pne may boldly say that the retort, being as well heated as it is and with the aid of hot irons enclosed in the pump DD, that pressures may be created much more than 6 times greater than that necessary to impel water to a height of 64 feet: and in such a case one man could create almost as much of an effect as 500 others who have only those inventions used up to the present.

As for Savery's design, Papin described in detail in chapter 5 how the Savery device was inferior to his own "in order that there be no misjudgment in the choice that will be made between Mr. Savery's machine and this one." First, Papin noted that since the retort AA is "completely in the fire, it can be heated much more promptly and at less cost than the two vessels that Mr. Savery calls *boillers."*

Second, Papin noted that his piston system ensures that the "steam loses none or very little of its force," compared to the condensation that occurs in the Savery device. Third, Papin described his improvement that "allows the water to enter by its own weight into the pump DD, and not by suction" and said, "without this correction, the inconveniences of which I've spoken about in this section would be enough to render the machine completely useless." Fourth, Papin noted the improvement of introducing hot irons to increase the "violence" of the steam. Then, "in order to incontestably prove that the piston *FF* is necessary to raise water to any considerable height," Papin reported that Savery's method completely failed to pump water "into air which had been a bit compressed. . . . Instead, a good effect is always created with the piston, even if the resistance of the compressed air in *NN* is 10 or 12 times greater than that which was impenetrable without the help of the piston."

Leibniz wasted no time in beginning the process of improving Papin's design. In his test published letter to Papin (Feb. 7,1707), Leibniz not only suggested that the engine be made completely self-acting, and thus more appropriate to moving vehicles, but also proposed practical means of still further increasing the thermodynamic efficiency of the engine by the ingenious use of the so-called waste heat:

I maintain that for stationary machines or for seagoing vessels, it will be difficult to make anything better along similar lines. . . .

I have a thought that perhaps will not displease you, which is to efficiently use the still-hot steam which leaves the pump when the piston is pushed up. Because it would be a great shame to lose it entirely. I imagine that in leaving it yet has much heat, and enough force to issue forth despite the outside air. . . . Then to make good use here of heat, otherwise superfluous, and at the same time of compressed air, in a manner which perhaps has never been used, I would make a sort of mantle or case ZZ around your vessel *QN,* partly filled with compressed air; and within this case I would let the steam enter in such a way that before it streams powerfully into the open air it would be between the case and the vessel. And while it warms this vessel it would as a result contribute towards the work of the compressed air contained therein. I believe that this will be a redoubling of the force . . . . and thus a mediocre vessel *QN* would make a much greater effect. Because it is already certain that heat gives as much force to ordinary air as does compression, and the same heat would give double or triple to compressed air . . . . The continual passage of hot steam would make this vessel extremely hot, almost as if it had been placed on a fire.

I have always had the thought that a great effect could be made and much force placed in a small volume by means of air strongly compressed and then heated. This would be of great use for machines which must be portable.

To say nothing of the superfluous heat of the furnace and the smoke which emerges from it which can be similarly useful among other ways by heating the water of the funnel C and of the tube *H* in order that the coldness of this water harms less of the heat in the pump D or in the vessel *QN. . . .* Furthermore, I have no doubt that you could, if you so desired, easily arrange that the robinets *E* and *n* are alternately open and closed by the machine without having to use a man for this.

Increased Harassment

Although Leibniz and Papin had succeeded in bringing modern dynamical technology into being, making the industrial transformation of society possible for the first time, they were working within an increasingly aversive environment. Leibniz's persistent international efforts in behalf of what he called the "Grand Design" had brought him into increasing conflict with his employer, George Lewis, the Elector of Hanover and future British King George I, who by 1706 at the latest had been won over by Charles Montague on behalf of the City of London. Leibniz considered his position in Hanover to be tolerable, and even advantageous, only because of his close relationship as a teacher to the Electress Sophia, George's mother, who until her death in 1714 was next in line to become Queen of England.

Even before the publication of his treatise, Papin had reported a sharp escalation in harassment by his unnamed enemies in Hesse. By 1706, there had been almost continual warfare in Europe for 35 years, creating conditions favorable to the resurgence of feudalist antiscientific forces. As a result, the relative tranquility of London again became attractive to Papin, and he resolved to go to England to demonstrate before the Court and the Royal Society the incontestable superiority of his steam engine over Savery's device.

Papin's plan was to travel to London in his paddlewheel boat, rowing it by conventional means up the Weser River, through Hanover to Bremen, and across the North Sea. Once in London with his model boat and with sufficient means to build an adequate steam pump, Papin planned to operate the world's first steam-driven ship and navigate it up the River Thames. In fact, the main reason which Papin gave to the Landgrave for his desire to leave for London was that only such a seaport had sufficient depth to apply his engine to a ship.

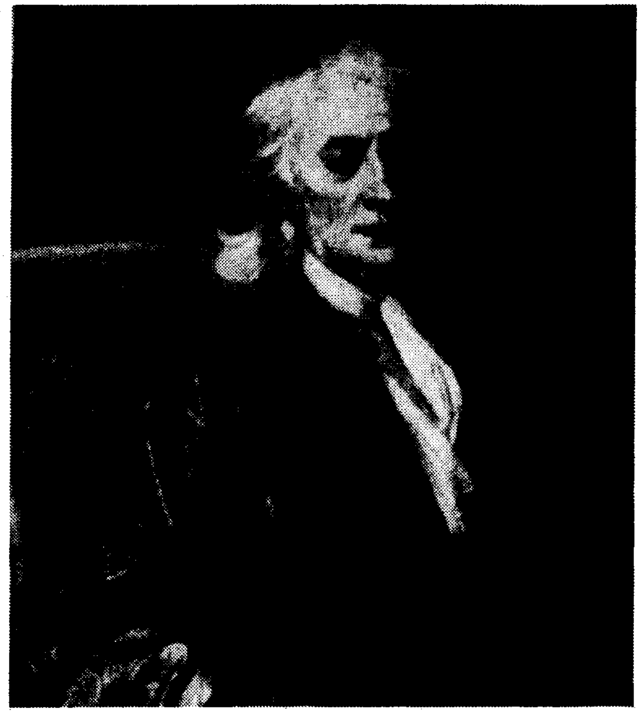
In a letter to Leibniz Sept. 15, 1707, Papin reported on the first successful test of his paddlewheeler:

> At present I will tell you that the experiment of my boat was made and that it succeeded in the manner that I had hoped of it. The force of the river's current was such a little thing in comparison to the force of my oars that it was difficult to recognize that it went faster in descending the current than in climbing it. Monseigneur had the goodness to testify to me of his satisfaction in having seen such a good effect. I am persuaded that if God gives me the grace to arrive safely in London and to make vessels there of this new construction which have enough depth to apply the fire engine to give movement to oars, I am persuaded, I say, that we may produce those effects which will appear incredible to those who will not see them.

In the same letter, Papin renewed a request to Leibniz to help obtain the required permission from the Elector of Hanover for passage up the Weser. Leibniz could expect no cooperation from George but he tried to intervene with his friends among local magistrates along the river. However, Papin got no further than Munden before encountering the ignorant opposition of the Boatmen's Guild, no doubt incited by elements of George's Court. Leibniz received the following report from an official of Munden, Sept. 27, 1707:

> Having been informed by the Doctor Papin, who, coming from Cassel, passed by this town the day before yesterday, that you arepresently to be found in this Court [Berlin], I give myself the honor to advise you, Sir, that this poor man of medicine, who gave me your letter of recommendation for London, had the misfortune to lose here his little machine of a paddlewheel vessel, . . . the Boatmen of this town having had the insolence to stop him and to take from him the fruit of his toil, with which he thought to introduce himself before the Queen of England . . . .

Despite the tragic encounter with this "mob of boatmen," Papin continued on to London, only to encounter an even more vicious mob—the British Royal Society, at the time headed by president-for-life Isaac Newton and by Newton's secretary Hans Sloane.


Isaac Newton

Royal Antiscience

When he arrived in England, Papin presented a copy of his treatise to the Royal Society along with the following proposal, recorded in the *Royal Society Register,* Feb. 11, 1708:

> *Proposition by Dr. Papin, concerning a new invented boat to be rowed by oars, moved with heat*
>
> It is certain that [it] is a thing of a great consequence to be able to apply the force of fire to save the labour of man; so that the Parliament of England granted, some years ago, a patent to Esquire Savery, for an Engine he had invented for that purpose; and His Highness Charles, Landgrave of Hesse, has also caused several costly experiments to be made for the same design. But the thing may be done several ways, and the machine tryed at Cassel differs from the other in several particulars, which may afford a great difference in the quantity of the effect. It will be good, therefore, to find out clearly what can be done best in that matter, that those which will work about it may surely know the best way they are to choose. I am fully persuaded that Esquire Savery is so well minded for the public good, that he will desire as much as any body that this may be done.
>
> I do therefore offer, with all dutyfull respect, to make here an Engine, after the same manner that has

been practised at Cassel, and to fit it so that it may be applied for the *moving of ships.* This Engine may be tryed for an hour and more, together with some other made after the Saveryan method. The quantity of the effect should be computed both by the quantity of water driven out of each machine, and by the height the said water could ascend to . . . .

I wish I were in a condition to make the said Cassellian Engine at my own charges; but the state of my affairs does not [allow] me to undertake it, unless the Royal Society be pleased to bear the expense of the Vessel called *Retort* in the description printed at Cassel; but after that I will lay out what is necessary for the rest, and I will be content to lose that expense, in case the contrivance of the Landgrave of Cassel doth not as much again as that of Esquire Savery; but in case the effect be such as I promise it, I do humbly beg that my expense, time and pains, may be paid, and I reckon this to amount to 15 pounds sterling. If the Royal Society be pleased to honor me with their commands upon such conditions, the first thing to be done is to let me see the place where the Machine must be set, and I will work for it with all possible diligence and I hope the effect will yet be much greater than I have said: [emphasis in original].[4]

By 1708, the Royal Society had abandoned even the pretense of scientific inquiry, and so its attitude toward Papin's proposal (as well as others) for real technological advance was predictably negative. In Papin's case, the repeated mention of the name Leibniz in his treatise was sufficient to trigger Royal Society killer instincts.

The *Transactions of the Newcomen Society,* Volume 17 (1936-37), contain a succinct account of the fate of Papin's proposition:

> Papin, then at Cassel, submitted with his paper, a request for fifteen guineas to carry out experiments, but the Royal Society, like our own, did not hand out fifteen guineas at a time. Instead, *the matter was referred to Savery in 1708, and in his letter of criticism turning down Papin's design there is a passage in which he damned the cylinder and piston, saying it was impossible to make the latter work because the friction would be too great!* [emphasis added].[5]

Even the Newcomen Society found it necessary to punctuate this account with an exclamation mark.

Papin then argued for his proposal before Newton himself, who rejected it on the pretext that it would cost too much. Papin was then stranded in England without any means of support, completely at the mercy of Newton, Sloane, and Savery, whose exclusive patent covering all conceivable "fire engines" was still in effect. Papin's 1707 "Proposition" was thus the last heard of any practical plan for a steamship or for any application of steam power besides pumping mines until well after the American Revolution.

No record remains of Papin's subsequent activity in England besides a mere seven letters to Sloane, mostly repeated requests for money to carry out a variety of experiments. In his last letter to Sloane, Jan. 23, 1712, Papin complained that a number of his inventions presented before the Royal Society had deliberately not been registered under his name:

> So there are at least six of my papers that have been read in the meetings of the Royal Society and are not mentioned in the Register. Certainly, Sir, I am in a sad case, since; even by doing good, I draw enemies upon me. Yet for all that I fear nothing because I rely upon God Almighty.

The Newcomen Fraud

In 1712, Papin apparently vanished without a trace, not even a death notice. That same year, the witchhunt against the Leibnizians was reaching frenzied heights on the Continent as well as in England, and Thomas Newcomen suddenly appeared to build his fabled fire engine "near Dudley Castle."

Newcomen's engine was simply a scaled-up atmospher-

The Newcomen Society Versus the American System

Although the Newcomen Society was founded in 1920 in England (and three years later in the United States) with the aim of promoting U.S.-British friendship, its real purpose has been to lobby against the American System.

In the tradition of the myth of the Newcomen steam engine, the Newcomen Society has tried to get the country to adopt policies that would make American industry vulnerable to the kind of economic disintegration we are now seeing. This aim has been hidden behind the nice-sounding concept of *free enterprise.* As used by Newcomen, this is the idea that each industry or individual like Newcomen, (if he existed) progressed because it stumbled upon good ideas and developed them by hook or by crook, unfettered by scientific theory or by a national purpose. There is no mention of the national credit policy stressed by the Founding Fathers to create the infrastructure necessary for fostering industrial growth.

The results of this free enterprise ideology can be seen all too graphically in the inability of U.S. industry to come up with a coherent counter strategy to the "controlled disintegration in the world economy" promoted by the Council on Foreign Relations, and its members in the Carter administration (see *Fusion,* October 1979 for details).

The author has invited the Newcomen Society to comment on this article, an event which Fusion *columnist Ben Franklin is greatly looking forward to.*

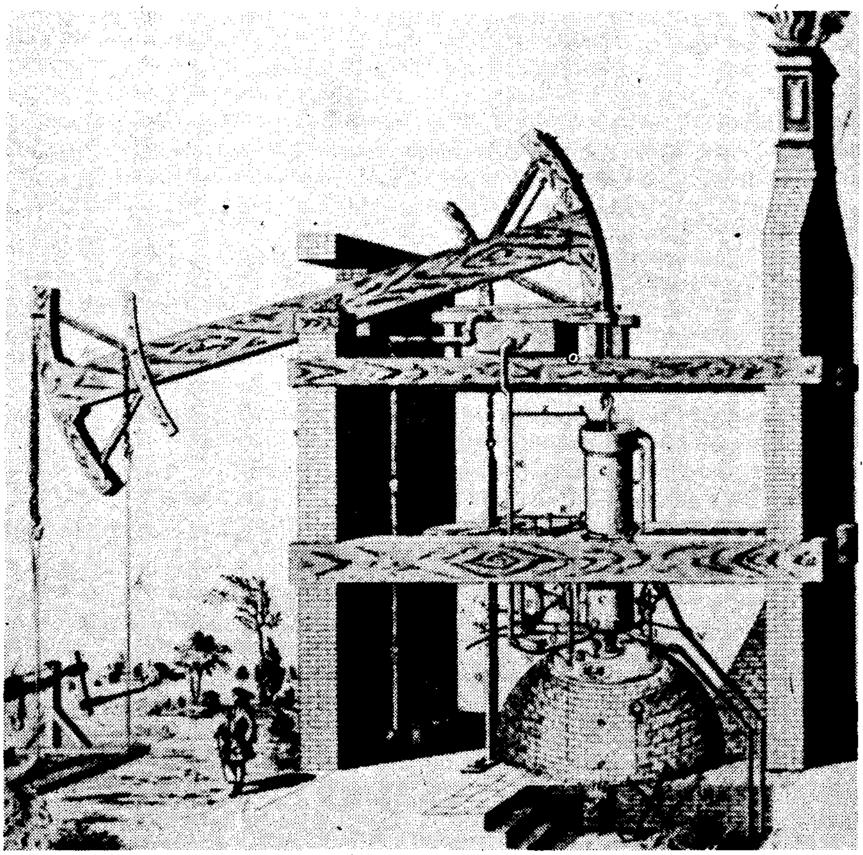


Figure 9
NEWCOMEN'S ENGINE
British historical tradition maintains that Denis Papin mysteriously "drifted into obscurity" in England in 1712. That same year, the "ironmonger" Thomas Newcomen allegedly erected his first engine (shown), limited to pumping water from mines. British historians insist that Newcomen acted entirely alone and that he had no contact whatsoever with any scientist or scientific principles, his work being based exclusively on trial and error ("hypotheses non fingo").
Newcomen published nothing; his exact date of birth and educational background are unknown, and no one knows what he looked like because none of his contemporaries bothered to paint or sketch his portrait. His only extant writings are a few scraps of personal letters to his relatives.

ic steam pump that was based completely on a combination of two of Papin's earlier ideas: (1) the use of steam to create a vacuum and drive a piston (1690); (2) the use of a lever mechanism to transmit power from one pump to another (1687).

In Newcomen's atavistic design, steam enters a cylinder under a piston from a separate boiler (see Figure 9). Cold water is poured over the cylinder or is sprayed inside of it, condensing the steam and creating a vacuum; the piston is forced downwards by atmospheric pressure. In turn, a piston rod pulls down one end of a balance beam that operates an ordinary mine pump attached to the other end of the beam and placed down a mine shaft. Steam reenters the cylinder, merely counterbalancing atmospheric pressure; the piston is then raised back to the top of the cylinder by the weight of the water pump apparatus and the cycle is repeated.

Compared to the level of conception and design achieved by Papin, Newcomen's "exotic lever" is manifestly primitive, a great step backwards. Not only is the force of the engine limited to mere atmospheric pressure, and the design limited to raising water from mines, but Newcomen still insisted on alternately cooling off and heating up the same cylinder, wasting tremendous amounts of steam and consuming massive quantities of fuel. For this reason, his engine was used mainly by owners of coal mines who could afford the fuel. Despite admissions in black and white that Papin was indeed the first to publish the idea of a piston/cylinder atmospheric engine using steam, British historians insist on raising the question, "Did Newcomen know of Papin's work?" To salvage the Newtonian ideology of *hypothe$is non fingo,* these mythmakers manufactured an impossible story to the effect that Newcomen lived in total isolation in a small town in "far-off Devonshire." Thus all theory, all science, all metaphysics must have been irrelevant to Newcomen's "invention of the steam engine," the story goes. Since there is no direct first-hand evidence that Newcomen knew anything of the work of "foreigners," Londoners included, these historians argue that this uneducated, "practical" mechanic must have acted alone.

This argument, of course, obscures the fact that there is no direct first-hand evidence that Newcomen knew anything at all and that there is barely enough evidence to allow one to conclude that Newcomen really existed. In fact, there is more written evidence that Newcomen knew of Papin's work than there is written evidence about almost anything else in Newcomen's life.

Volume 17 of the third edition of the *Encyclopedia Britannica,* published in Edinburgh in 1797, contains an article on the steam engine written by Dr. John Robison that is one of the earliest British efforts at rewriting the history of steam technology. Robison, whose political works are favorably reviewed today by the John Birch Society, crudely slandered Papin:[6]

> Papin made many efforts to employ this force [of steam] in mechanics, and even for raising water. It appears that he had made experiments with this view in 1698, by order of Charles Landgrave of Hesse. For

this reason the French affect to consider him as the inventor of the steam engine .... Whoever will take the trouble of looking at the description which he has given of these inventions . . . will see that they are most awkward, absurd, and impracticable. His conceptions of natural operations were always vague and imperfect, and he was neither philosopher nor mathematician.

Robison even lied that "Papin's first publication was in 1707," all for the purpose of protecting the mythical British steam invention. However, in trying to concoct some sort of explanation for Newcomen's apparent achievement, Robison was compelled to admit that Papin did indeed infJuence Newcomen, if even only indirectly. Robison claimed that Dr. Robert Hooke, Fellow of the Royal Society, had written a letter to Newcomen critical of Papin's "boasted method of transmitting to a great distance the action of a mill by means of pipes" (the pneumatic transmission of power).

Robison explained:

> It would appear from these notes that Dr. Hooke had dissuaded Mr. Newcomen from erecting a machine on this principle of which he had exposed the fallacy in several discourses before the Royal Society. One passage is remarkable. "Could he (meaning Papin) make a speedy vacuum under your second piston, your work is done."
>
> It is highly probable that in the course of this speculation it occurred to Mr. Newcomen that the vacuum he so much wanted might be produced by steam and that this gave rise rise to his principle and construction of the steam engine.

This fanciful account was accepted by historians until 1936, when someone decided that even Robison's story ought to be officially discredited and that any mention of Papin should be eliminated from history. This task was undertaken by the Newcomen Society, then 15 years old, which assigned a member to visit the Royal Society archives and look for the "notes of observations" prepared by Hooke for Newcomen that Robison mentioned. Sure enough, more than 240 years later, no paper by Hooke mentioning Newcomen could be found, although the Newcomen researcher noted that "there was another paper on the same subject (Papin) in similar language, which looked like the draft of a letter to someone, but there was no name or address, only a date."

On this bit of evidence stands the Newcomen Society's claim that Thomas Newcomen not only invented the steam engine but "may truly be designated the founder of the Industrial Revolution."[7]

With this scanty information on Newcomen in mind, I'll review the Papin history:

(1) Papin had been a Fellow of the Royal Society since 1680.

(2) He lived in London for nine years between 1676 and 1687.

(3) He published close to 20 articles in the *Philosophical Transactions* of the Royal Society between 1675 and 1687.

(4) In the years 1684-1687, Papin submitted more than 100 reports to the Royal Society in his capacity as curator of experiments, many of them later published in England.[8]

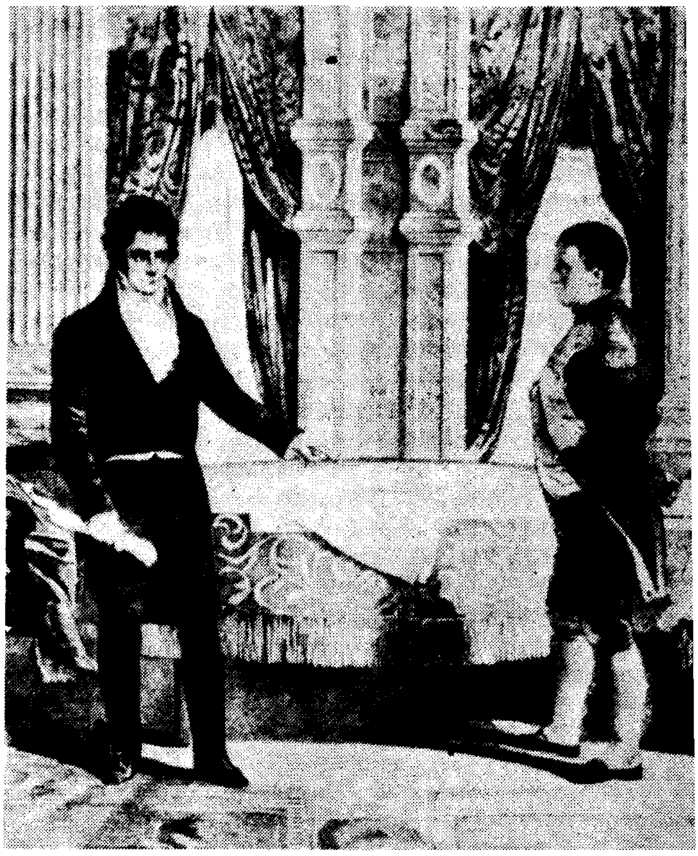
(5) Papin's 1690 Latin article on the atmospheric steam engine was reproduced in his 1695 pamphlet "Recuil de Diverses Pieces touchant quelques nouvelles Machines," which, in turn, was prominently reviewed in the *Ph/7osophical Transactions* of the Royal Society in 1697. (The Newcomen Society concedes that Newcomen himself probably read this review.)

* (6) Papin published more than 40 articles in a variety of European scientific journals from 1682-1707, including five separate pamphlets.

(7) Papin returned to England for at least four years, 1708-1712, during which time Papin and his life's researches effectively became the property of the Royal Society.

(8) The legally recognized "inventor of the steam en-

Robert Fulton and the American System



An American lithograph of Fulton and Napoleon in 1804 gine," Thomas Savery, was a demonstrable fraud, and certainly could be of no help to Newcomeja since he had condemned the whole idea of a piston/cylinder engine in 1708.

There is no way to avoid the conclusion that the British knew Papin very well—well enough to recognize his work as a political and conceptual threat, closely tied to the fight for human progress waged on the Continent by Leibniz. The calculated result was a near 100-year containment of steam technology, overcome only in the aftermath of the American Revolution—a revolution whose European allies established at the Ecole Poytechnique in France and Göttingen University in Germany, the intellectual centers that continued and advanced the mathematical physics of Leibniz.

The lesson of the steam engine should be evident to today's supporters of advanced technology. The fight is still on and the supporters of nuclear power have to recognize and overcome the same kinds of overt and covert obstacles that were used against Papin.

Philip Valenti, a mathematician, became interested in the story of steam power development during the course of a comparative study of Newton and Leibniz's calculus and philosophy. His is the first English translation of the Papin-Leibniz letters and Papin's 1707 work on the steam engine.

Notes

1. Friedrich Klemm, *A History of Western Technology* (Cambridge, Mass.: MIT Press, 1964).
2. *G. W. Leibniz Selections,* ed. Philip P. Wiener (New York: C. Scribner, 1951).
3. *Gottfried Wilhelm Leibniz: Philosophical Papers and Letters,* ed. LeRoy E. Loemker (Chicago: University of Chicago Press, 1956).
4. *Leibnizens und Huygens's Briefwechsel mit Papin,* ed. Dr. Ernst Gerland (Berlin: Verlag der Koniglichen Akademie der Wissenschaften, 1881).
5. Rhys Jenkins, "The Heat Engine Idea in the 17th Century," *Transactions of the Newcomen Society,* Vol. 17, pp. 1-11, (1936-37).
6. Robison's more well-known work that same year was a Tory propaganda sheet that blamed the Jacobin terror in France on the Freemason circles associated with republicans Lafayette and von Steuben, both of whom fought the British in the American Revolution.

Robert Fulton, the American inventor, brought many of Papin's inventions to fruition more than 100 years later, including the steamship and the submarine, with the added feature of the torpedo. Like Papin, Leibniz, and the American patriots who developed the American System in opposition to British Malthusianism, Fulton was a republican who identified labor power, the human mind, as the real source of a nation's wealth.

In 1798, Fulton made two proposals to the French Republic, one for developing small canals to improve French industry and a second for quickly breaking British naval superiority in order to guarantee "an entire liberty of Commerce."

In a letter to Napoleon Bonaparte May 1, Fulton wrote:

"These plans of improvement and my reflections upon Commerce are elaborations of the following ideas, which I regard as the basis of political welfare, and which seem to me worthy of the consideration of all republicans, and all friends of humanity. Labor is the source of wealth of all kinds; it follows that the more numerous the industrious and useful class, the more a country should gain in riches and comfort. It is therefore to the interest of each nation to draw from its natural advantages every feature possible. To that end Governments must apply themselves above all to internal improvements and seek continually to increase the number of useful individuals; only by eliminating as far as possible the causes of war will men be enabled to devote themselves to industrious works and reduce mendicancy . . . .

"If success crowns the efforts of France against England, it will only remain for her to terminate this long war gloriously by granting freedom to trade and by compelling other powers to adopt this system. Political liberty would thus acquire that degree of perfection and of scope of which it is susceptible and Philosophy would see with joy the Olive Branch of Eternal Peace sheltering Science and Industry."

Fulton's specific proposal for defeating England involved the use of his submarine *(Nautilus)* and torpedo design. On October 27, Fulton proposed to the French Directory, then headed by Lazare Carnot, the scientist and military engineer:

"From the report of the Commissioners named by the Minister of Marine it would appear that the machine and the means which I have proposed to destroy the English fleet are pronounced to be practicable. Permit me then to recall to your consideration the consequences which should result from the success of this enterprise. The enormous commerce of England, no less than its monstrous government, depends upon its military marine. Should some vessels of war be destroyed by means so novel, so hidden and so incalculable, the confidence of the seamen will vanish and the fleet rendered useless from the moment of the first terror. In this state of affairs the republicans in England would rise to facilitate the descent of the French or to change their government themselves without shedding much blood and without any expense to France. With England republicanized, the seas will be free. The liberty of the seas will become a guarantee of perpetual peace to all maritime nations."

New York Historical Society, New York City

Robert Fulton in a self-portrait

7. See Thomas Birch, DD., Secretary to the Royal Society, *History of the Royal Society,* a four-volume supplement to the *Transactions of the Royal Society* published in 1757.

8. Standard reference works now include the updated Newcomen myth. For example: "At the end of the 18th century John Robison propagated the belief that Newcomen's achievement somehow depended upon the applications of scientific principles gained through an alleged correspondence between Newcomen and Robert Hooke_____Robison's allegation has been discredited; the records reveal no contact whatever between Newcomen and his contemporaries in science. His invention was a product of a familiarity with technological operations and needs in the mining industry, a close knowledge of contemporary craftsmanship, repeated trials and improvements, and a stroke of luck." (The source is Harold Dorn of Stevens Institute of Technology, writing on Thomas Newcomen in the *Dictionary of Scientific Biography,* Vol. 10, published by the Charles Scribners Sons for the American Council of Learned Societies in 1975.)

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Chronology: Steam Power Versus The Royal Society

1666:
Louis XIV's Minister Jean Baptiste Colbert establishes the Academy of Sciences at Paris, appointing the Dutch scientist Christiaan Huygens as the academy's president. Huygens's program includes "research into the power of water converted by fire into steam."

1672:

Papin and Leibniz join the Academy.

1673:
Huygens successfully demonstrates his gunpowder-fueled engine, suggesting that his invention: "permits the discovery of new kinds of vehicles on land and water. And although it may sound contradictory it seems not impossible to devise some vehicle to move through the air."

1675:
Leibniz completes his development of the differential calculus. Anti-Colbert factions force Papin, Leibniz, and later Huygens to leave France.

1680:
In London, Papin continues research into control of high pressure steam; he invents the steam pressure cooker and safety valve.

1687:
Papin proposes the pneumatic transmission of power from water wheels near rivers to remote regions in order to facilitate the rapid spread of industrialization.

1690:
The Steam Age begins with Papin's invention of the atmospheric steam engine; Papin proposes its application to powering a paddlewheel-driven ship.

1692:
Papin and Leibniz begin intensive correspondence.

1695:
Papin publishes a summary of his inventions, including the Hessian bellows, an improved furnace designed to multiply efficiency, the pumping of mines using the pneumatic transmission of power, the atmospheric steam engine, and the "plunging boat" (submarine).

1697:
Papin's summary is reviewed in the *Philosophical Transactions* of the British Royal Society and circulated throughout England.

1698:
Papin constructs a steam-powered atmospheric pump. Leibniz and Papin begin the project of harnessing the *direct force* of high pressure steam; Papin constructs "a little model of a carriage that is moved forward by this force."

1699:
Thomas Savery is awarded an exclusive patent for the "fire engine" by the English Parliament.

1704:
"Hanoverian envoys" to London smuggle Savery's blueprints back into Germany; Leibniz concludes—correctly—that Savery's design could not work in full size.

1707:
Papin publishes a complete account of his direct action steam engine, and tests it successfully against Savery's design.

1708:
In London, Papin proposes that the Royal Society allocate 15 pounds sterling to allow him to construct his engine "and to fit it so that it may be applied for the *moving of ships.* This Engine may be tried for an hour and more, together with some other made after the Saveryan method." Royal Society president-for-life Isaac Newton, backed by Savery, rejects Papin's proposal.

1708-1712:
The Royal Society appropriates Papin's researches without remuneration.

1712:
Papin "disappears." The first Newcomen engine, limited to pumping water from flooded mines, is erected.

1807:
American artist, inventor, and diplomat Robert Fulton achieves the world's first successful steamship voyage with his Hudson River paddlewheeler *Clermont.* Fulton proposes that his inventions, including the submarine and the torpedo, be applied forthwith to destroy the "monstrous government" of England.