PERPETUAL WATERFALL, one of many "impossible objects" conceived by the contemporary Dutch artist Maurits C. Escher, seems to drive a mill wheel endlessly. Mills that produced enough power to recirculate the water needed to drive them were among the first perpetual motion machines proposed in Europe (*see bottom illustration on page 116*). Their designers did not realize that, because of the energy losses due to friction, no mill is capable of pumping all its water supply back to the uphill starting position.

PERPETUAL MOTION MACHINES

Over the past 400 years numerous inventors have proposed marvelous ways of getting something for nothing. All these proposals have foundered on either the first or the second law of thermodynamics

by Stanley W. Angrist

The interwoven tapestry of history sometimes displays odd relationships. Who would think, for example, that two medical men would be leading figures in the history of efforts to make a perpetual motion machine? One of them, the 17th-century English physician Robert Fludd, is usually mentioned as one of the first to propose a perpetual motion machine to do useful work. The other, the 19th-century German physician Julius Robert Mayer, was among those who established as a law of nature the conservation of energy, which dooms proposals such as Fludd's.

The notion of getting something for nothing that underlies all speculations about perpetual motion is as old as Archimedes and may be a good deal older. In classical times, however, there was a tendency to depend on supernatural power sources. A more down-to-earth approach to the subject grew out of economic considerations as the first labor-saving machines, in particular water mills, spread across Europe. Originally used to grind flour, water mills evolved rapidly in later Roman times. Although they were never especially popular in the Mediterranean area, quite the opposite was the case in western Europe. By A.D. 400 water-driven flour mills and sawmills were common in France. Twenty years after the Norman Conquest some 5,600 water mills were operating in 3,000 English communities, and before the end of the 14th century in England waterpower had been harnessed not only to grind flour and saw wood but also to tan leather, to full woolens and to grind pigments for paint. Soon almost every English manor that was situated on a stream—roughly a third of all the manors in the Domesday Book—had its own mill. Elsewhere floating mills were anchored in rivers and tidal mills stood in estuaries.

Villagers and townspeople who had no access to running water naturally sought alternative sources of power. One result was the windmill, a thoroughly practical invention. A less practical result was a series of proposals for closed-cycle water mills such as the one that Fludd put forward in 1618. The proposal must have seemed sensible enough at the time. If the water that turns a mill wheel could be collected from the race at the foot of the wheel and somehow put back into the reservoir above the wheel, the need for a source of running water would disappear. Centuries of experience had shown that mill wheels could turn big grindstones or raise heavy hammers. Why couldn't the wheel also drive a pump that would recycle the mill's water supply? In Fludd's day there was little reason to deny the possibility.

The same was true half a century later, when John Wilkins, Bishop of Chester and an early official of the Royal Society, put forward his views on the subject. In the 1670's Wilkins envisioned three natural power sources that might be harnessed to provide perpetual motion. These, in his words, were "Chymical Extractions," "Magnetical Virtues" and "the Natural Affection of Gravity."

Wilkins' third power source embraces the entire family of overbalanced wheels; that is, wheels that turn because they are perpetually heavier on one side than the other. He specifically mentioned only one formula for chemical extraction; its underlying concept may have arisen from a misunderstood observation of the ceaseless motion of small particles visible in a fluid that we know as Brownian movement. Wilkins also designed, but almost certainly never tried to build, a machine to utilize magnetic attraction. At no point, however, did he suggest a way of obtaining useful work out of the proposed perpetual motions.

As can be judged by Wilkins' leading role in the scientific community, speculation on perpetual motion machines was not yet considered a crackpot activity. Robert Boyle recounted in detail his examination of a fluid, compounded of bituminous oils and similar ingredients, that an engineer of his acquaintance had prepared as a charge for fire bombs. The engineer had mixed the ingredients over a fire and was surprised to find that days after the pot had been left to cool the fluid in it still swirled about. Keeping the pot in his laboratory for a time, Boyle observed that the oilier constituents of the fluid continued to stream, alternately spreading across the surface and then sinking out of sight. Again he made no proposal for harnessing the motion.

How was the tolerant attitude of early scientists toward perpetual motion transformed into today's skepticism? Clearly we now have far more theoretical knowledge and can make much more refined devices such as bearings, linkages and heat exchangers. Cannot this combination of talents close the apparently tiny gap between the designs of earlier times and the construction of actual working models? The answer, of course, is an emphatic no. For a perpetual motion machine to function, whatever its design, would require that it violate either the first or the second law of thermodynamics.

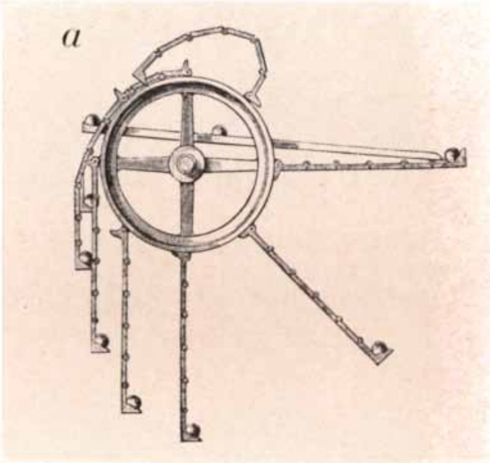
The first law of thermodynamics—the principle of energy conservation that Mayer helped to formulate—can be stated in various ways. One way of putting it says that a fixed amount of mechanical work always gives rise to the equivalent amount of heat. Thus energy can be converted from work into heat, but it can neither be created nor destroyed. There are more complex formulations of the first law but all eventually arrive at the same conclusion: The total energy of the universe is constant.

Even before Mayer, pioneer studies of heat phenomena by the Scottish chemist Joseph Black and the American-born Count Rumford had helped to clear the way for deeper understanding. Black established the vital distinction between heat (as a quantity of something) and temperature (as an index of heat's intensity). The interrelationship of heat, energy and temperature is a complex one that can be explained by an analogy. After rain falls into a lake it is no longer rain but simply water; after heat is transferred to a body (because of a temperature difference between the cool body and its warm surroundings) it is no longer heat but simply energy. If the lake has no outlets, the rain raises the water level; if the body cannot get rid of energy, the heat transfer adds to its total energy and thereby raises its index of heat—its temperature.

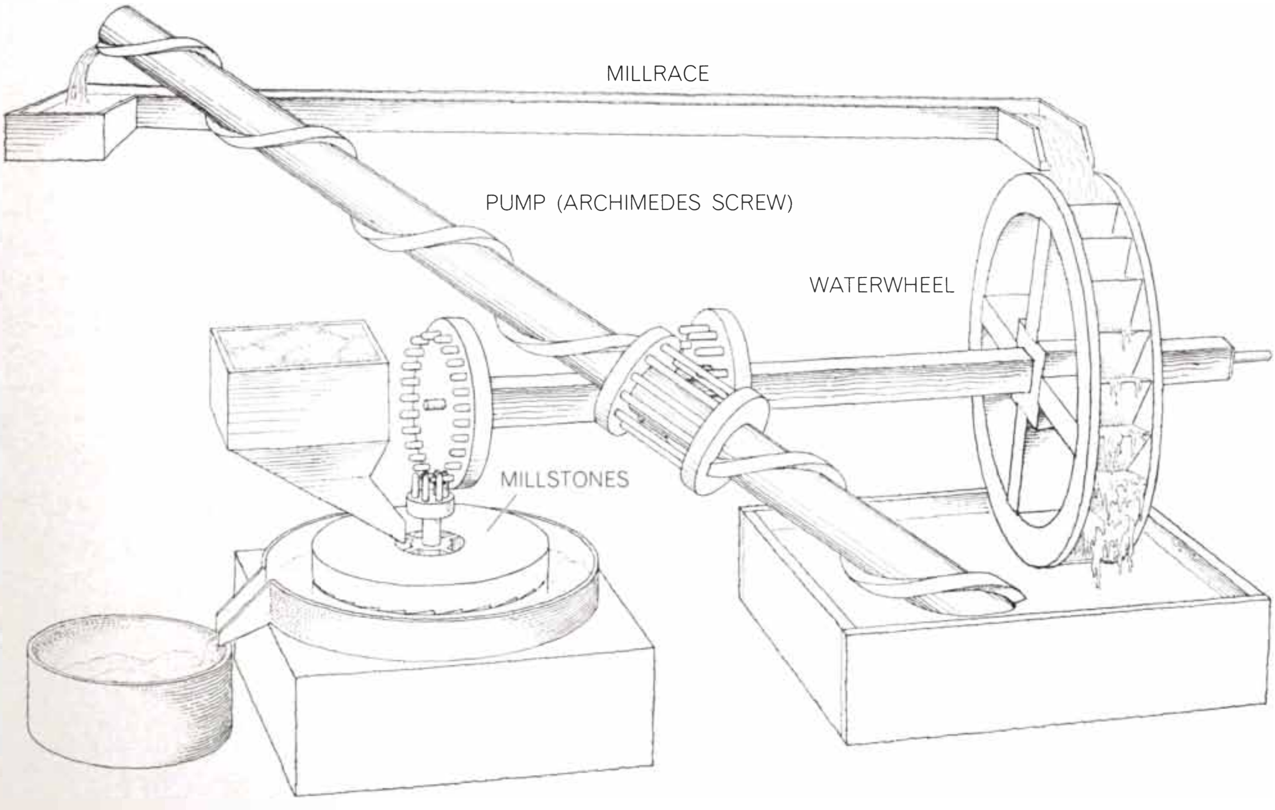
In Black's time variations in temperature and energy were attributed to the presence or absence of the intangible fluid called caloric. Rumford, in turn, struck a deathblow to the concept of caloric with his experiments in a Bavarian cannon foundry. Bringing water to a boil solely with the heat generated by the boring of a cannon barrel, he concluded that the heat was due to friction. This was the first demonstration of the connection between heat and work, but it was soon confirmed by Humphry Davy's experiment in which the rubbing together of two pieces of ice was shown to produce heat. It was a number of years, however, before the equivalence of work and heat was determined with any precision.

This brings us up to Mayer. In 1840, when he was 27, Mayer sailed from Rotterdam as ship's physician on the schooner *Java,* bound for the East Indies. Although it is doubtful that he knew anything about Black's work or Rumford's, he had brought along Antoine Laurent Lavoisier's treatise on chemistry, and he soon became fascinated by Lavoisier's suggestion that animal heat is generated by the slow internal combustion of food.

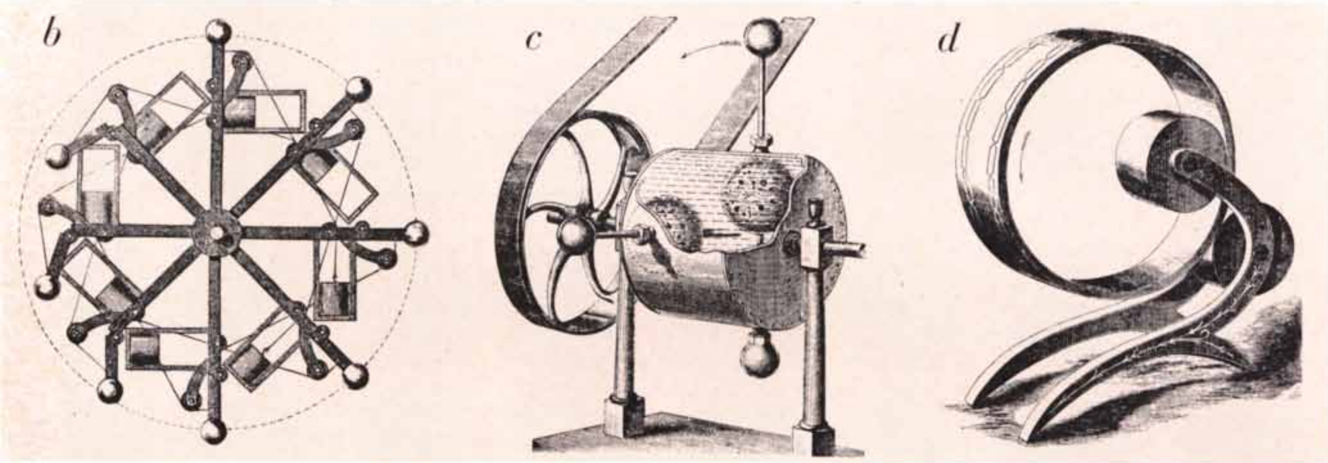
When the *Java* reached the East Indies, 28 of its crew were ill with fever. The treatment for fever in those days was to bleed the patient, and when Mayer did so, he observed that the crewmen's venous blood was bright red rather than the normal dark red—almost as red as arterial blood. Now, one of Lavoisier's comments was that, when the body is in warm surroundings, less internal combustion is required to keep it warm than when it is in cold ones. In support of this view he and others pointed to variations in the color of venous blood. Mayer concluded that his pa-



OVERBALANCED WHEELS have been the most common prime movers of perpetual motion machines. Just as the water's weight overbalances a mill wheel and makes it turn, so various means of apparently adding weight to one side of a wheel were expected



CLOSED-CYCLE MILL was proposed by the English physician Robert Fludd in 1618 as a source of perpetual power in areas that lacked streams. The fact that such devices could not work because they required a violation of the principle of energy conservation, formally known as the first law of thermodynamics, was not recognized by the scientific community until two centuries after Fludd.



to move the four machines shown above. The first device (*a*) was expected to turn when jointed arms, with weights that rolled to their ends, were extended on one side; actually the wheel remains exactly balanced, whether or not the arms are extended. A much more complex wheel (*b*) was designed with the same objective. Like *a*, however, it is actually in balance in spite of its shifting weights. A pair of buoys within a water-filled drum were expected to move weights that would overbalance the next device (*c*). Finally (*d*), a starkly simple design reflects the inventor's conviction that his overbalanced wheel rim would spin between two rollers in spite of its lack of any support. These engravings and four on the following pages appeared in early issues of SCIENTIFIC AMERICAN.

tients' venous blood looked like arterial blood because, like arterial blood, it had a high content of oxygen. It seemed that in the tropical East Indies the crewmen's bodies did not consume as much oxygen as they did in cooler latitudes.

At this point Mayer went a step beyond Lavoisier to conjecture that the body heat evolved by the metabolism of food should be exactly balanced by a combination of two opposing factors. These were, first, the heat lost by the body to its surroundings and, second, the work the body performed. Mayer was soon saying that heat and work are merely different manifestations of energy (which he called "force"), and that the two manifestations are equivalent.

The young physician was not able to obtain experimental proof of his conjecture; he lacked both money and laboratory facilities. He did, however, analyze data collected by other investigators on the specific heat of air, and he managed to calculate a numerical relation between heat and units of mechanical work. In effect he had determined the mechanical equivalent of heat. He offered an account of his work to the foremost scientific journal of his day, *Annalen der Physik und Chemie,* but it was refused. In 1842 a revised account appeared in another journal, and Mayer's version of the first law of thermodynamics was formally put forward. "Once in existence," he wrote, "force cannot be annihilated; it can only change its form."

James Prescott Joule, the son of a prosperous English brewer, was born four years later than Mayer. Joule studied chemistry in Manchester with John Dalton, but soon he developed an enthusiasm for experiments in electricity and electromagnetism, a field in which he was largely self-taught. In the early 1840's he carefully measured the amount of work required to raise the temperature of a pound of water from 60 degrees Fahrenheit to 61 degrees. Joule announced his result in 1843: the amount of mechanical energy required was 838 foot-pounds. In later years he refined this figure to 772 foot-pounds, a value remarkably close to today's standard (778.16 foot-pounds).

Joule had thus quantified the relation between work and heat that Mayer had propounded. Four more years were to elapse, however, before a third young investigator, Hermann von Helmholtz, convinced the international scientific community that the first law was a valid generalization. In 1847, when he was 26, Helmholtz presented his formulation of the first law before the Physical Society of Berlin in a paper titled "On the Conservation of Force." He began his analysis by declaring that perpetual motion machines were axiomatically impossible. In physics, as in mathematics, axioms are distinct from theorems. A theorem is a conclusion that is logically deduced from an axiom. An axiom does not require logical proof. The validity of a physical axiom can be based instead on repeated observations of nature. Thus Helmholtz did not need to prove his axiom; it was enough to point out that no one had yet built a successful perpetual motion machine. Helmholtz observed further that he was not alone in his view. Nicolas Léonard Sadi Carnot, an early student of the theoretical basis for the steam engine, had started with a similar axiom and had reached a number of significant conclusions concerning the dynamics of heat. As we shall see, Carnot's work, particularly his 1824 study "Reflections on the Motive Power of Heat," forms the basis of the second law of thermodynamics.

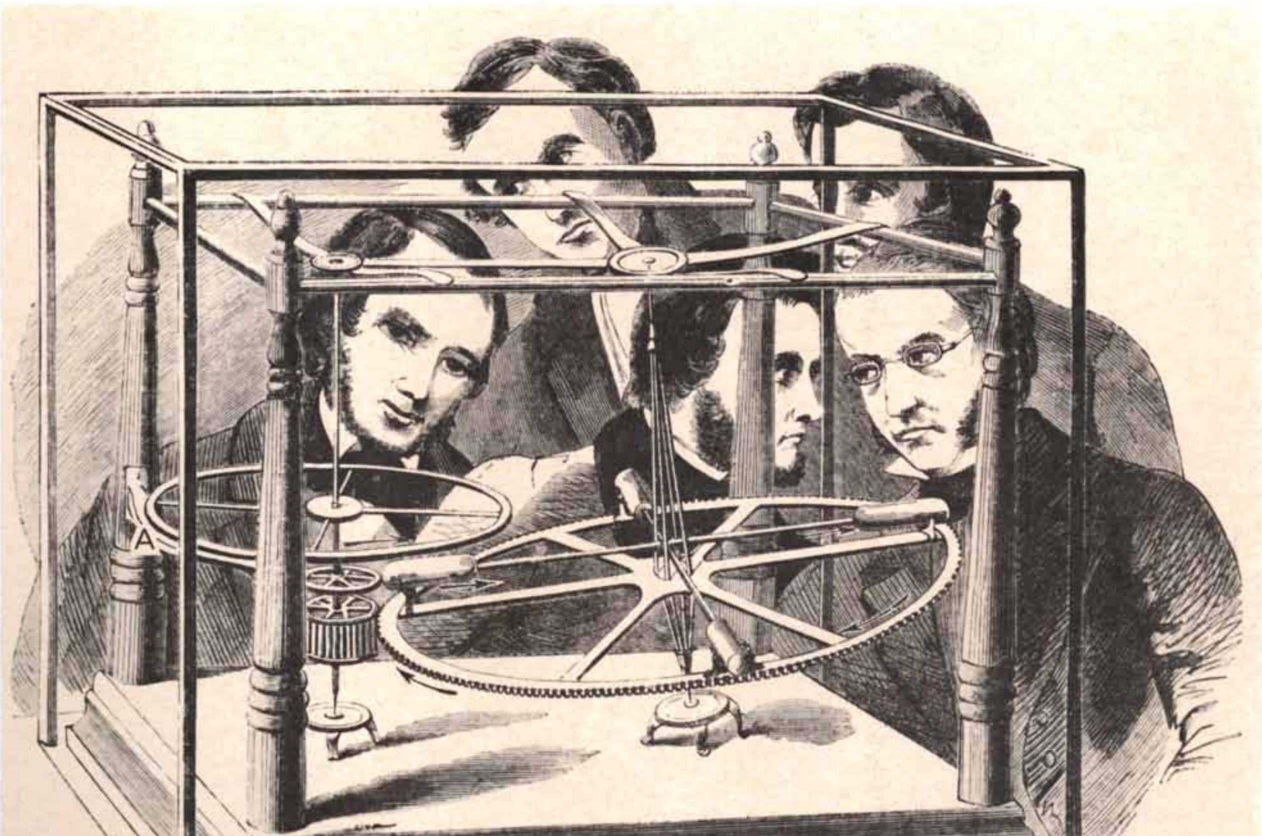
Proceeding from his axiom, Helmholtz next showed that the failure of perpetual motion machines led logically to the conclusion that energy is always conserved. He went on to demonstrate that both heat (regarded as small-scale motion) and work (regarded as large-scale motion) were forms of energy and that what was conserved was the total of the two forms rather than either heat or work taken separately. Helmholtz showed that the findings of Joule's experiments were in general agreement with calculations of the kind made by Mayer. Like Mayer, Helmholtz submitted his paper to *Annalen der Physik und Chemie,* and it too was refused.

I have given this brief history of the first law because it is the law that most would-be inventors of perpetual motion machines attempt to evade. Their expectation is that more energy can be wrung out of some device incorporating falling or turning bodies than is required to restore the device to its original state. Curiously one of the most persistent proposals is Fludd's closed-cycle water mill. As late as 1871 an American patent attorney noted with some asperity that inventors submitted one or another variation on Fludd's mill to him every year, inquiring whether the concept was patentable. Over the years, however, devices that depended for their power on overbalanced wheels gradually abandoned running water in favor of ingenious weight-shifting systems.

Many inventors have preferred power sources more sophisticated than the overbalanced wheel. Both early and late they have turned to magnets, at first natural magnets and then electrically powered ones. Bishop Wilkins' design for a magnetic device depended on a lodestone, which was to be strong enough to pull an iron ball up a ramp. Just before the ball had climbed all the way up to the lodestone, it would drop through a hole and roll back down a curved second ramp. The ball would then pass through a door and reach the first ramp again, where it would resume its upward journey. It is easy enough to find the flaw in Wilkins' proposal today: any lodestone strong enough to pull the ball up the ramp would be too strong to let it fall back to its starting point.

A 19th-century device solved a similar problem by incorporating an electromagnet that was alternately turned on and off. When the circuit to the magnet was closed, the magnet's attraction was supposed to pull a connecting rod that acted through a crank to impart rotary motion to a disk. The spinning of the disk between two brushes was then expected to generate enough electricity to energize the magnet. Once the machine was started by hand the inventor expected it to run forever, or at least until the contact points on the switches wore out. As so often happens in the design of perpetual motion machines, the inventor had made no allowance for the energy lost to friction and, in this case, to electrical resistance as well.

It is scarcely surprising that the chimera of perpetual motion has attracted not only savants and optimists but also rascals. One of the many outright frauds in the history of perpetual motion machines was perhaps the most elegant overbalanced wheel ever built. It was the work of a skilled Connecticut machinist, E. P. Willis. A large gear wheel, mounted at an angle to the horizontal and fitted with a complex system of weights, purportedly drove a smaller hollow flywheel. After the machine had attracted much attention in New Haven, where Willis charged admission for viewing it, he moved it to New York in 1856. There the same attorney who was to comment on the perpetual rediscovery of Fludd's water mill went to see it. The exhibitors, he noted, were careful



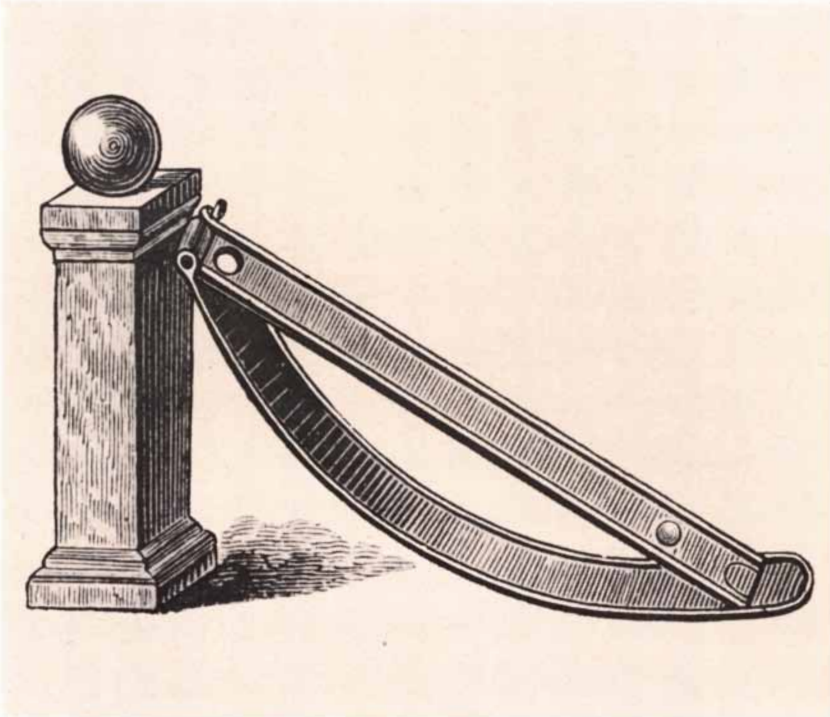
FRAUDULENT MACHINE that purported to demonstrate perpetual motion was built by a Connecticut machinist in the 1850's. Ostensibly each pair of rod-linked weights that rested atop the tilted wheel (*right*) was shifted in position as the wheel turned, so that the uphill weight extended beyond the wheel's perimeter. The resulting imbalance was said to be sufficient to keep the wheel turning and to drive a flywheel (*left*). Actually compressed air passed through a strut (*A*, *far left*), turning both of the wheels.

not to claim that Willis had achieved perpetual motion; rather, they challenged any visitor to provide another explanation for the machine's motion. Although a glass case kept viewers from inspecting the machine closely, the attorney noted that there was a suspiciously nonfunctional strut below the edge of the hollow flywheel. Evidently a steady flow of compressed air, undetectable outside the glass case, kept the flywheel turning. Thus it was actually the flywheel that drove the overbalanced wheel, rather than the reverse.

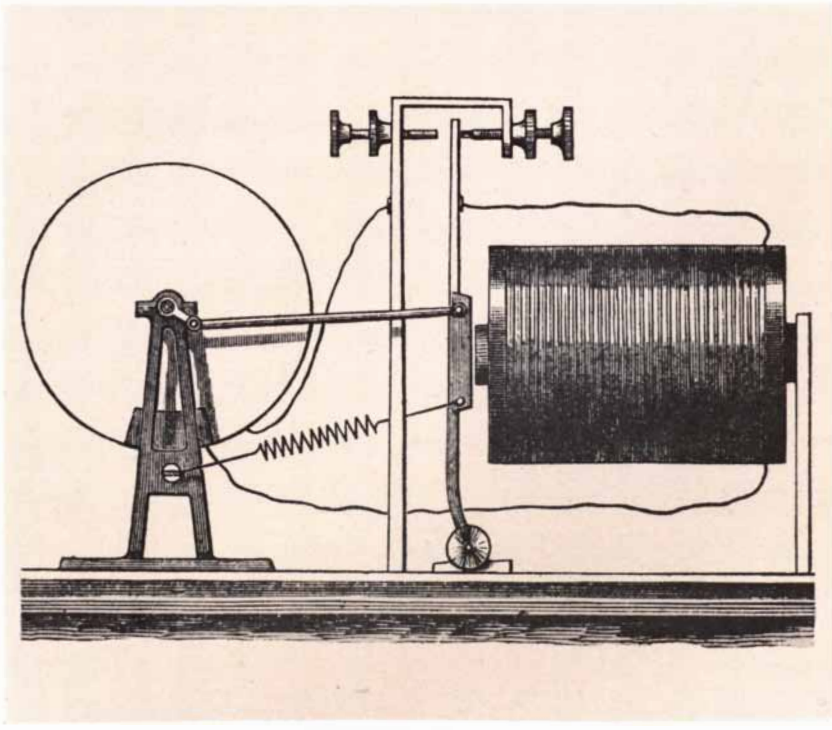
The Willis fraud, Fludd's water mill and all similar devices are based on the assumption that the first law of thermodynamics can be violated. Some perpetual motion machines, however, do not violate the first law; neither friction nor electrical resistance is a significant problem in their design. They are nonetheless impossibilities because they attempt instead to circumvent the second law of thermodynamics.

The foundation of the second law was laid down by the observations of Carnot, and the law was first fully formulated by the German physicist Rudolf Clausius. The first law, as we have seen, demonstrates that a fixed amount of mechanical work can always be converted into the equivalent amount of heat. But the most casual observation of a heat engine in operation—for example a steam engine—makes it plain that the reverse of the first law's axiom is not precisely true: a fixed amount of heat cannot be completely converted into the same amount of work. When heat is transformed into work, some of the initial energy is unavoidably wasted. In the case of a real steam engine operating in the real world, some of the wasted energy goes to overcoming friction, some is lost through warming the engine and the surrounding atmosphere, some through leakage and some through other avenues of dissipation.

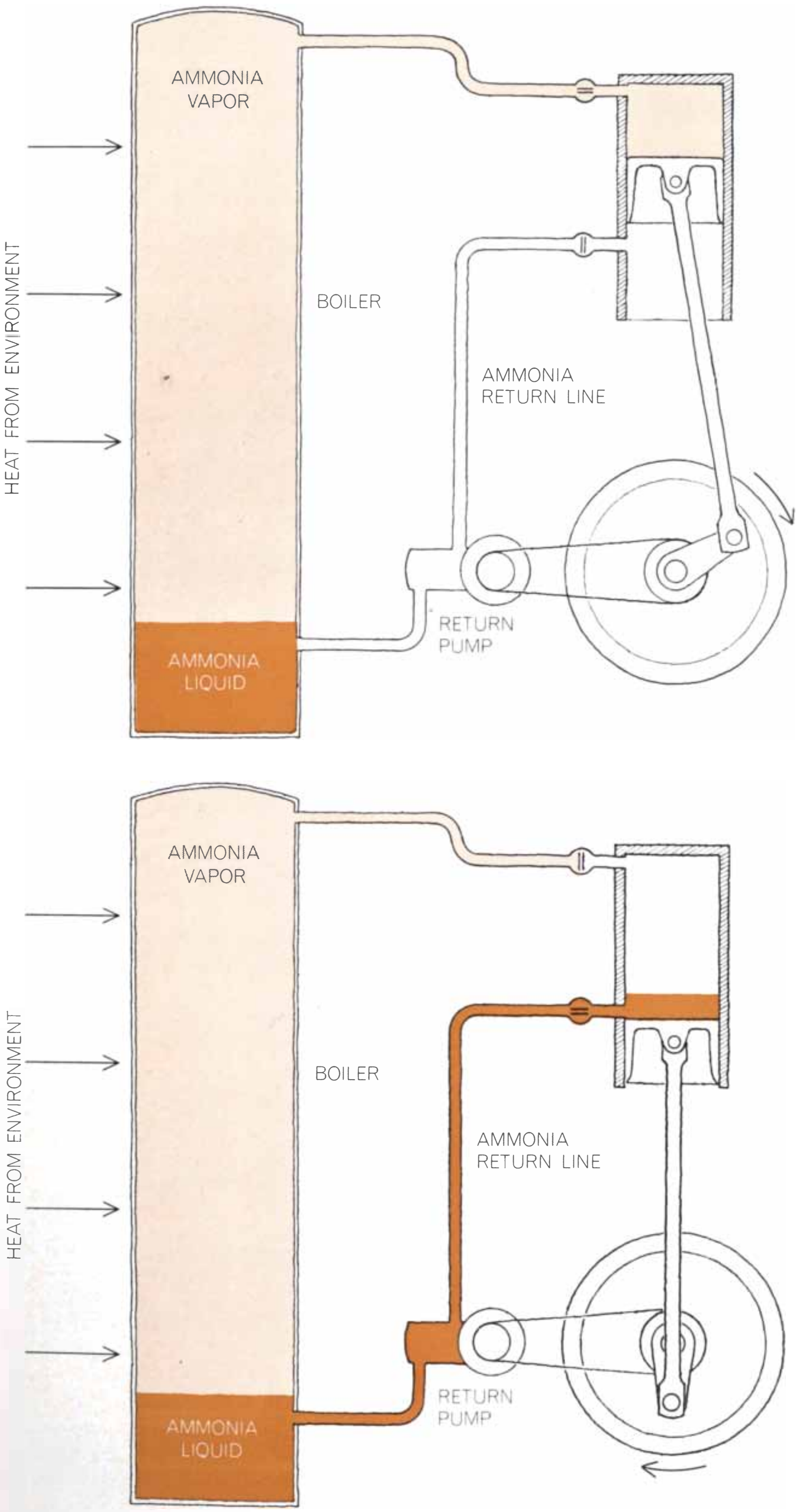
Carnot wanted to find out whether improved design could eliminate all steam engine losses. He created in his imagination an ideal engine; it was leakproof, completely insulated and frictionless. He then ran the imaginary engine through a full operating "cycle" (a concept, by the way, that Carnot was the first to develop). In one ideal cycle water is heated until it vaporizes into steam, and the pressure of the steam forces the engine's piston to move; the cycle is completed when the expanded steam cools and condenses into water again, allowing the piston to return to



PERPETUAL MOTION powered by "Magnetical Virtues" was to be achieved by a steel bullet as it rolled up and down a pair of ramps according to a design proposed by the Bishop of Chester in the 1670's. The lodestone placed on the top of the pedestal was expected to draw the bullet up the straight ramp, whereupon it would fall through a hole and roll back to its starting position. The bishop did not propose harnessing the device to obtain power.



PERPETUAL MOTION powered by electricity was often favored by 19th-century inventors. In this design the attraction of an electromagnet worked through a crank to turn a wheel; the wheel's rotation was then supposed to generate enough electricity to work the magnet. As usual the inventor neglected to allow for the losses from friction and resistance.



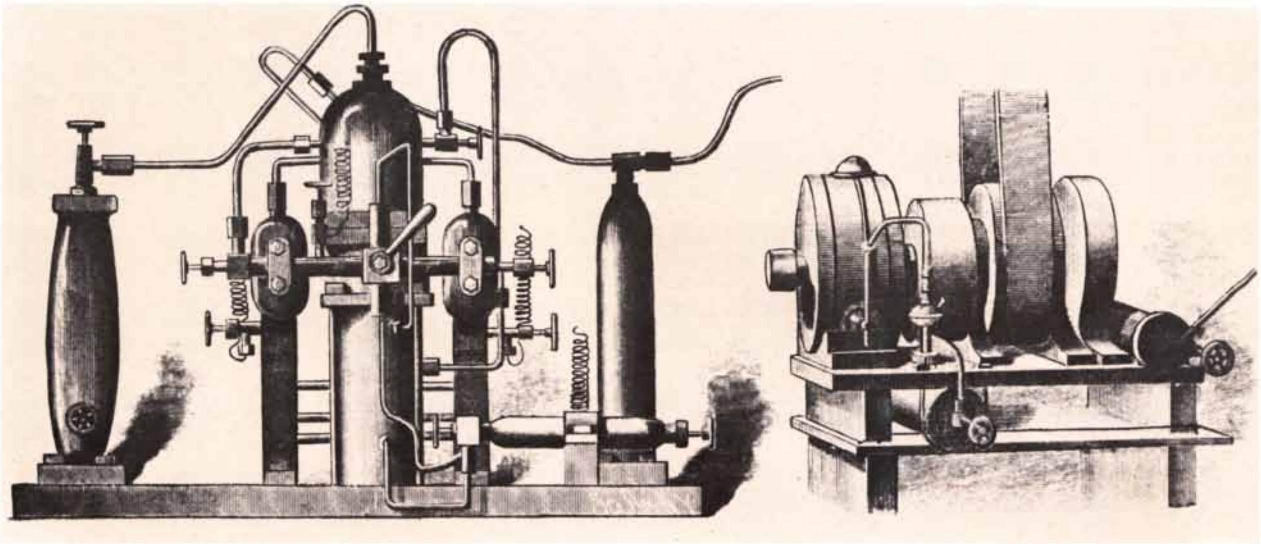
AMMONIA ENGINE of the 1880's, designed by John Gamgee, was based on the expectation that free power would be produced because heat transferred from the surroundings would turn the ammonia from liquid to gas. The gas pressure is enough to drive a piston (*top*). When the gas then expanded in the cylinder (*bottom*), the inventor expected that it would condense spontaneously and return to the boiler as a liquid to repeat the cycle. He did not anticipate the need to refrigerate the return side of his engine in order to convert the ammonia gas to liquid. The energy needed to do this, of course, is more than the engine produces.

its starting position. Thinking through the steps in this ideal cycle, Carnot realized that a complete conversion of heat into work was impossible; an unavoidable loss of thermal energy occurred in the process of cooling and condensation.

The language Carnot used to state his conclusions is strange to our ears because, like others in his day, he talked about heat in terms of caloric. What he had to say was nonetheless the earliest statement of the second law. The transformation of heat into motive power, Carnot wrote, "is fixed solely by the temperature of the bodies between which is effected... the transfer of the caloric." This is to say that, in order to do work, heat must "run downhill" as water does and, just as with water, the farther it runs downhill, the greater the amount of work it does. This is the concept we express today by saying that heat must be transferred from a higher temperature to a lower one to do work.

Building on Carnot, Clausius applied the word "entropy" (from the Greek for "turning") to the index used to measure the amount of heat that is unavoidably lost. The modern formulation of the second law that says that entropy always increases arises from the earlier realization that heat is a downhill flow. Because the supply of energy in the universe is a constant that cannot be increased or decreased, and because at the same time the downhill flow of heat is accompanied by inevitable losses, a time will inevitably come when the entire universe will be at the same temperature. With no more hills of heat and therefore, in Carnot's terms, no further transfers of caloric, there can be no work. This inevitable end, sometimes called the "heat death" of the universe, concerns us here because perpetual motion machines that attempt to violate the second law are expected to achieve a localized halt in the inevitable increase of entropy and produce a decrease of entropy instead.

The fact that, on the average, entropy continually increases does not, of course, rule out the possibility that occasional local decreases of entropy can take place. It is only that the odds against such an event are extraordinarily long. The bed of a river could suddenly cool, yielding its energy to the running water, and this energy could be applied in some way to make the water run uphill. But riverbeds do not cool and water does not run uphill. A similar loan of thermal energy from the river's environment could al-



"GENERATOR" AND "MOTOR" of a supposed perpetual motion device were exhibited in Philadelphia for more than a decade late in the 19th century. The inventor, John E. W. Keely, contended that the generator (*left*) turned tap water into high-pressure "etheric vapor" when "vibratory energy" was applied. After Keely's death the totally fraudulent device was found to run on compressed air.

low the water to dissociate spontaneously into hydrogen and oxygen. But the water does not dissociate spontaneously. Furthermore, an old man on the riverbank, watching the water flow by, could grow younger rather than older, but he doesn't. Rivers continue to flow downhill, H_2O remains water and man inevitably ages. The chemist Henry A. Bent has calculated the odds against a local reversal of entropy, specifically the probability that one calorie of thermal energy could be converted completely into work. His result can be expressed in terms of a familiar statistical example: the probability that a group of monkeys hitting typewriter keys at random could produce the works of Shakespeare. According to Bent's calculation, the likelihood of such a calorie conversion is about the same as the probability that the monkeys would produce Shakespeare's works 15 quadrillion times in succession without error.

It is against these odds that the would-be inventor of a perpetual motion heat engine must struggle. One such inventor was John Gamgee, who was active in Washington, D.C., during the 1880's. He developed a heat engine that he called the zeromotor because its normal operating temperature was zero degrees centigrade. The zeromotor was not unlike an ordinary steam engine except that the working fluid was ammonia rather than water. Liquid ammonia vaporizes into a gas at a low temperature, and at zero degrees C. the gas exerts a pressure of four atmospheres. Gamgee reasoned that the transfer of heat from the environment, rather than the energy supplied by the combustion of fuel, would be enough to transform the ammonia working fluid from a liquid to a gas. He reasoned further that the ammonia gas, on driving the piston back and expanding, would cool, condense and drain into a reservoir, whereupon the cycle could begin again [*see illustration on opposite page*].

Anyone with the slightest knowledge of Carnot's cycle, let alone the second law of thermodynamics, could scarcely take such an idea seriously, yet Gamgee and his supporters were undoubtedly sincere. They had either incorrectly calculated or failed to calculate the zeromotor's temperature requirements. The heat transfer from the environment was indeed sufficient to convert ammonia from a liquid to a gas, but this advantage is nullified in the system as a whole by the cooling of the gas on expansion. Starting at zero degrees C. and a pressure of four atmospheres, the temperature of the gas has fallen to −33 degrees by the time its volume has quadrupled. If the gas is to condense into a liquid, both the condenser and the reservoir must be at a temperature lower than −33 degrees. Gamgee had not provided for this cooling, and if he had, the cooling process would of course have required more energy than the zeromotor could produce.

One of Gamgee's principal supporters was B. F. Isherwood, Chief Engineer of the U.S. Navy. In March, 1881, Isherwood reported favorably on the zeromotor to the Secretary of the Navy, in spite of the fact that scholars had pointed out that the engine fatally violated the second law. Official Washington came close to embracing the inventor. The Secretary of the Navy was not the only high official who inspected a model of the zeromotor with interest; so did other Cabinet members and President Garfield himself. Isherwood's gullibility may be hard to understand, but not his interest. This was an era when in order to keep the U.S. fleet at sea it was necessary to maintain a complicated and expensive network of coaling stations abroad. If the Gamgee engine had worked, coaling stations could have been forgotten and all the energy the Navy would have needed to power its fleet could have been provided by the thermal energy contained in the seawater in which the ships floated.

The surprisingly wide acceptance of proposals such as Gamgee's can be explained, of course, by general ignorance of known principles. As early as 1775 the French Academy of Sciences passed a resolution refusing to entertain any future communications concerning perpetual motion. The U.S. Patent Office has long declined to examine applications for patents covering perpetual motion machines unless the applicant furnishes a working model or "other demonstration...of the operativeness of the invention," a ruling that has produced much hostile correspondence but no working models. In spite of such official opposition public sophistication regarding the possibility of building perpetual motion machines was slow to develop.

Perhaps the most ingenious, and certainly the longest-lived, swindle involving a supposed perpetual motion machine began in 1875, when John E. W. Keely unveiled a combined "generator" and engine at his home in Philadelphia. There was nothing unusual about Keely's engine, which was a variation on the conventional steam engine. Keely's generator, however, was extraordinary. It was an elaborate combination of metal globes, tubes, petcocks, nozzles, valves and gauges, but its operation was deceptively simple. Keely would blow into a nozzle for half a minute and then pour five gallons of tap water into the generator through the same nozzle. After turning various petcocks and valves he would show onlookers a pressure gauge indicating that the generator was full of a mysterious "vapor" with a pressure of 10,000 pounds per square inch. "People have no idea of the power in water," Keely would say. "A bucket of water has enough of this vapor to produce a power sufficient to move the world out of its course."

Keely and his associates formed the Keely Motor Company, capitalized at $1 million. They raised much of the money from gullible New York businessmen. As the years passed, although no engines other than the first one were ever built, Keely's showmanship became more polished. By 1881 he had begun to attribute the production of vapor to "vibratory energy," and he would "vivify" the vapor during demonstrations with a giant tuning fork. By 1884 he had so mastered what he now called the "etheric vapor" or the "interatomic ether" that he demonstrated a new device: a cannon, complete with a "vibrator" near the breech, that was capable of propelling a ball 500 yards with a muzzle velocity of 500 feet per second.

Keely died in 1898. The son of one of his major backers promptly rented his Philadelphia house and explored the premises in the company of reputable witnesses, seeking evidence of fraud. Under the floor of the house the searchers found a three-ton metal tank that had evidently served as a reservoir for compressed air. In the walls were found quantities of brass tubing, and a false ceiling suggested the means by which Keely and his associates had conducted the compressed air to his generator. Whatever other laws he may have broken in his long career, Keely had left the first and second laws of thermodynamics inviolate.

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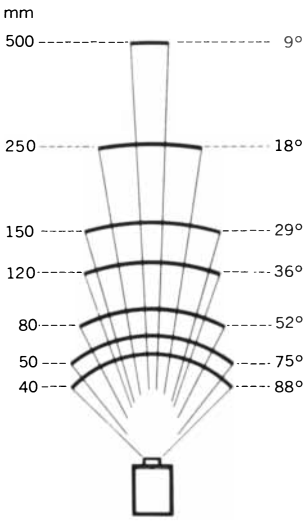
The Hasselblad uses the single lens reflex viewing system. The beauty of this method is that you see the object you are going to photograph on a large 2¼″ square ground glass viewing screen, as you look through the actual lens that will take the picture, so you always know exactly how your finished picture will turn out.

There are three bodies in the Hasselblad System, each one designed and constructed to perform its own particular function better than any other camera of its type.

Firstly, the 500C. This could almost be called the "workhorse" of the Hasselblad System. It is the standard body in the System and takes all the lenses and magazines that are available for the Hasselblad. No single camera has been used and praised more by the top professional and amateur photographers than the 500C. The other two bodies are more "special purpose" cameras. The 500EL, which is an electrically driven camera allowing for rapid exposures and remote control, and the Superwide C wide angle camera. No other camera using the 2¼″ square format has as wide an angle of view as the Superwide C. On its introduction, this camera was hailed as a breakthrough in camera design. There are seven lenses



Interchangeable Lenses. This diagram illustrates the focal length (l.) and the angle of view (r.) of the seven lenses available in the Hasselblad System.

in the Hasselblad System, all by Carl Zeiss, makers of superb quality optical glass for generations. The lenses range from a 40mm wide angle, to a 500mm telephoto. Every lens has a built in Synchro Compur shutter with provision for flash and strobe synchronization at all 10 shutter speeds, from 1/500 of a second to 1 second.

One of the most striking features of the Hasselblad System is the interchangeable film magazines, each one of superb design and construction. The beauty of these magazines is that with just one camera body, a photographer can shoot pictures in black and white. Then, before finishing the roll, change to a magazine loaded with color, shoot a few color shots, then go back to black and white film. One magazine even allows you to make 70 exposures on one roll of film. Hasselblad was the first camera system to offer the advantage of interchangeable magazines.

There are many many accessories in the Hasselblad System, each one designed and built to the same extreme standards of quality and craftsmanship that Hasselblad has become famous for.

Shown below are just a few items in the System.

Like all good things in life, the Hasselblad is expensive, but if you're the kind of person we have been talking about (and you wouldn't have read this far if you weren't) then, who knows, with this kind of camera, perhaps you could live on love alone.

If you would like more information and a free 40 page catalogue, write to: Paillard Incorporated, 1900 Lower Rd., Linden, New Jersey 07036

HASSELBLAD