Tucholsky Wagner Zola Scott Sydow Fonatne Freud Schlegel
Turgenev Wallace
Twain Walther von der Vogelweide Fouqué Friedrich II. von Preußen
Weber Freiligrath
Kant Ernst Frey
Fechner Fichte Weiße Rose von Fallersleben Richthofen Frommel
Hölderlin
Fehrs Engels Fielding Eichendorff Tacitus Dumas
Faber Flaubert
Eliasberg Ebner Eschenbach
Feuerbach Maximilian I. von Habsburg Fock Zweig
Ewald Eliot Vergil
Goethe London
Elisabeth von Österreich
Mendelssohn Balzac Shakespeare Ganghofer
Lichtenberg Rathenau Dostojewski
Trackl Stevenson Doyle Gjellerup
Tolstoi Hambruch
Mommsen Lenz Droste-Hülshoff
Thoma Hanrieder
von Arnim
Dach Verne Hägele Hauff Humboldt
Reuter
Karrillon Rousseau Hagen Hauptmann
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Gerstäcker Raabe Gibbon Tschechow
Löns Hesse Hoffmann Gogol Wilde Vulpius
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Luther Heym Hofmannsthal Morgenstern
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James W. Steele

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STEAM STEEL AND ELECTRICITY

By

JAMES W. STEELE

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THE STORY OF STEAM

That which was utterly unknown to the most splendid civilizations of the past is in our time the chief power of civilization, daily engaged in making that history of a new era that is yet to be written in words. It has been demonstrated long since that men's lives are to be influenced not by theory, or belief, or argument and reason, so much as by that course of daily life which is not attempted to be governed by argument and reason, but by great physical facts like steam, electricity and machinery in their present applications.

The greatest of these facts of the present civilization are expressed in the phrase, Steam and Steel. The theme is stupendous. Only the most prominent of its facts can be given in small space, and those only in outline. The subject is also old, yet to every boy it must be told again, and the most ordinary intelligence must have some desire to know the secrets, if such they are, of that which is unquestionably the greatest force that ever yielded to the audacity of humanity. It is now of little avail to know that all the records that men revere, all the great epics of the world, were written in the absence of the characteristic forces of modern life. A thousand generations had lived and died, an immense volume of history had been enacted, the heroes of all the ages, and almost those of our own time, had fulfilled their destinies and passed away, before it came about that a mere physical fact should fill a larger place in our lives than all examples, and that the evanescent vapor which we call steam should change daily, and effectively, the courses and modes of human action, and erect life upon another plane.

It may seem not a little absurd to inquire now "what is steam?" Everybody knows the answer. The non-technical reader knows that it is that vapor which, for instance, pervades the kitchen, which issues from every cooking vessel and waste-pipe, and is always white and visible, and moist and warm. We may best understand an answer to the question, perhaps, by remembering that steam is one of the three natural conditions of water: ice, fluid water, and steam.

One or the other of these conditions always exists, and always under two others: pressure and heat. When the air around water reaches the temperature of thirty-two degrees by the scale of Fahrenheit, or ° or zero by the Centigrade scale, and is exposed to this temperature for a time, it becomes ice. At two hundred and twelve degrees Fahrenheit it becomes steam. Between these two temperatures it is water. But the change to steam which is so rapid and visible at the temperature above mentioned is taking place slowly all the time when water, in any situation, is exposed to the air. As the temperature rises the change becomes more rapid. The steam-making of the arts is merely that of all nature, hastened artificially and intentionally.

The element of pressure, mentioned above, enters into the proposition because water boils at a lower temperature, with less heat, when the weight of the atmosphere is less than normal, as it is at great elevations, and on days when, as we now express it, there is a low barometer. Long before any cook could explain the fact it was known that the water boiling quickly was a sign of storm. It has often been found by camping-parties on mountains that in an attempt to boil potatoes in a pot the water would all "boil away," and leave the vegetables uncooked. The heat required to evaporate it at the elevation was less than that required to cook in boiling water. It is one of the instances where the problems of nature intrude themselves prominently into the affairs of common life without previous notice.

This universal evaporation, under varying circumstances, is probably the most important agency in nature, and the most continuous and potent. There was only so much water to begin with. There will never be any less or any more. The saltness of the sea never varies, because the loss by evaporation and the new supply through condensation of the steam—rain—necessarily remain balanced by law forever. The surface of our world is water in the proportion of three to one. The extent of nature's steam-making, silent, and mostly invisible, is immeasurable and remains an undetermined quantity. The three forms of water combine and work together as though through intentional partnership, and have, thus combined, already changed the entire land surface of the world from what it was to what it is, and working ceaselessly through endless cycles will change it yet more. The exhalations that are steam become the water in a rock-cleft. It changes to ice with a force almost beyond measurement in the orderly arrangement of its crystals in compliance with an immutable law for such arrangement, and rends the rock. The process goes on. There is no high mountain in any land where water will not freeze. The water of rain and snow carries away the powdered remains from year to year, and from age to age. The comminuted ruins of mountains have made the plains and filled up and choked the mouth of the Mississippi. The soil that once lay hundreds of miles away has made the delta of every river that flows into the sea. The endless and resistless process goes on without ceasing, a force that is never expended, and but once interrupted within the knowledge of men, then covered a large area of the world with a sea of ice that buried for ages every living thing.

The common idea of the steam that we make by boiling water is that it is all water, composed of that and nothing else, and this conception is gathered from apparent fact. Yet it is not entirely true. Steam is an invisible vapor in every boiler, and does not become what we know by sight as steam until it has become partly cooled. As actual steam uncooled, it is a gas, obeying all the laws of the permanent gases. The creature of temperature and pressure, it changes from this gaseous form when their conditions are removed, and in the change becomes visible to us. Its elasticity, its power of yielding to compression, are enormous, and it gives back this elasticity of compression with almost inconceivable readiness and swiftness. To the eye, in watching the gliding and noiseless movements of one of the great modern engines, the power of which one has only a vague and inadequate conception seems not only inexplicable, but gentle. The ponderous iron pieces seem to weigh nothing. There is a feeling that one might hinder the movement as he would that of a watch. There is an inability to realize the fact that one of the mightiest forces of nature is there embodied in an easy, gliding, noiseless impulse. Yet it is one that would push aside massy tons of dead weight, that would almost unimpeded crush a hole through the enclosing wall, that whirls upon the rails the drivers of a locomotive weighing sixty tons as though there were no weight above them, no bite upon the rails. There is an enormous concentration of force somewhere; of a force which perhaps no man can fairly estimate; and it is under the thin shell we call a boiler. Were it not elastic it could not be so imprisoned, and when it rebels, when this thin shell is torn like paper, there is a havoc by which we may at last inadequately measure the power of steam.

We have in modern times applied the word "engine" almost exclusively to the machine which is moved by the pressure of steam. Yet we might go further, since one of the first examples of a pressure engine, older than the steam machine by nearly four hundred years, is the gun. Reduced to its principle this is an engine whose operation depends upon the expansion of gas in a cylinder, the piston being a projectile. The same principle applies in all the machines we know as "engines." An air-engine works through the expansion of air in a cylinder by heat. A gas-engine, now of common use, by the expansion, which is explosion, caused by burning a mixture of coal-gas and air, and the steam-engine, the universal power generator of modern life, works by the expansion of the vapor of water as it is generated by heat. Steam may be considered a species of *gradual* explosion applied to the uses of industry. It often becomes a real one, complying with all the conditions, and as destructive as dynamite.

It cannot be certainly known how long men have experimented with the expansive force of steam. The first feeble attempt to purloin the power of the geyser was probably by Hero, of Alexandria, about a hundred and thirty years before Christ. His machine was also the first known illustration of what is now called the "turbine" principle; the principle of *reaction* in mechanics. [Footnote: This principle is often a puzzle to students. There is an old story of the man who put a bellows in his boat to make wind against the sail, and the wind did not affect the sail, but the boat went backward in an opposite direction from the nozzle of the bellows. There is probably no better illustration of reaction than the "kick" of a gun, which most persons know about. The recoil of a six-pound field piece is usually from six to twelve feet. It can be understood by supposing a gun to be loaded with powder and an iron rod longer than the barrel to be left on the charge. If the outer end of this rod were then placed against a tree, and the gun were fired, it is manifest that the gun would become the projectile, and be fired off of the rod backward or burst. In ordinary cases the air in the bore, and immediately outside of the muzzle, acts comparatively, and in a measure, as the supposed rod against the tree would. It gives way, and is elastic, but not as quickly as the force of the explosion acts, and the gun is pushed backwards. It is the turbine principle, running into hundreds of uses in mechanics.] He made a closed vessel from whose opposite sides radiated two hollow arms with holes in their sides, the holes being on opposite sides of the tubes from each other. This vessel he mounted on an upright spindle, and put water in it and heated the water. The steam issuing from the holes in the arms drove them backward. The principle of the action of Hero's machine has been accepted for two thousand years, though never in a steam-engine. It exists under all circumstances similar to his. In water, in the turbine wheel, it has been made most efficacious. The power applied now for the harnessing of Niagara for the purpose of sending electric currents hundreds of miles is the turbine wheel.

[Illustration: THE SUPPOSED HERO ENGINE.]

Hero appears to the popular imagination as the greatest inventor of the past. Every school boy knows him. Archimedes, the Greek, was the greater, and a hundred and fifty years the earlier, and was the author of the significance of the word "Eureka," as we use it now. But Hero was the pioneer in steam. He made the first steam-engine, and is immortal through a toy.

The first *practical* device in which expansion was used seems to have been for the exploiting of an ecclesiastical trick intended to impress the populace. There is a saying by an antique wit that no two priests or augurs could ever meet and look at each other without a knowing wink of recognition. Hero is said to have been the author of this contrivance also. The temple doors would open by themselves when the fire burned on the altar, and would close again when that fire was extinguished, and the worshippers would think it a miracle. It is interesting because it contained the principle upon which was afterwards attempted to be made the first working low-pressure or atmospheric steam-engine. Yet it was not steam, but air, that was used. A hollow altar containing air was heated by the fire being kindled upon it. The air expanded and passed through a pipe into a vessel below containing water. It pressed the water out through another pipe into a bucket which, being thereby made heavier, pulled open the temple doors. When the fire went out again there was a partial vacuum in the vessel that had held the water at first, and the water was sucked back through the pipe out of the bucket. That became lighter again and allowed the doors to close with a counter-weight. All that was then necessary to convince the populace of the genuineness of the seeming miracle was to keep them from understanding it. The machinery was under the floor. There have been thousands of miracles since then performed by natural agencies, and there have passed many ages since Hero's machine during which not to understand a thing was to believe it to be supernatural.

[Illustration: THE TEMPLE-DOOR TRICK.]

From the time of Hero until the seventeenth century there is no record of any attempt being made to utilize steam-pressure for a practical purpose. The fact seems strange only because steam-power is so prominent a fact with ourselves. The ages that intervened were, as a whole, times of the densest superstition. The human mind was active, but it was entirely occupied with miracle and semi-miracle; in astrology, magic and alchemy; in trying to find the key to the supernatural. Every thinker, every educated man, every man who knew more than the rest, was bent upon finding this key for himself, so that he might use it for his own advantage. During all those ages there was no idea of the natural sciences. The key they lacked, and never found, that would have opened all, is the fact that in the realm of science and experiment there is no supernatural, and only eternal law; that cause produces its effect invariably. Even Kepler, the discoverer of the three great laws that stand as the foundation of the Copernican system of the universe, was in his investigations under the influence of astrological and cabalistic superstitions. [Footnote: Kepler, a German, lived between 1571 and 1630. His life was full of vicissitudes, in the midst of which he performed an astonishing Even the science of amount of intellectual labor, with lasting results. He was the personal friend of Galileo and Tycho Brahe, and his life may be said to have been spent in finding the abstract intelligible reason for the actual disposition of the solar system, in which physical cause should take the place of arbitrary hypothesis. He did this.] medicine was, during those ages, a magical art, and the idea of cure by medicine, that drugs actually *cure*, is existent to this day as a remnant of the Middle Ages. A man's death-offense might be that he knew more than he could make others understand about the then secrets of nature. Yet he himself might believe more or less in magic. No one was untouched; all intellect was more or less enslaved.

And when experiments at last began to be made in the mechanisms by which steam might be utilized they were such as boys now make for amusement; such as throwing a steam-jet against the vanes of a paddle-wheel. Such was Branca's engine, made nine years after the landing of our forefathers at Plymouth, and thought worthy of a description and record. The next attempt was much more practical, but cannot be accurately assigned. It consisted of two chambers, from each of which alternately water was forced by steam, and which were filled again by cooling off and the forming of a vacuum where the steam had been. One chamber worked while the other cooled. It was an immense advance in the direction of utility.

About 1698, we begin to encounter the names that are familiar to us in connection with the history of the steam-engine. In that year Thomas Savery obtained a patent for raising water by steam. His was a modification of the idea described above. The boilers used would be of no value now, nevertheless the machine came into considerable use, and the world that learned so gradually became possessed with the idea that there was a utility in the pressure of steam. Savery's engine is said to have grown out of the accident of his throwing a flask containing a little wine on the fire at a tavern. Concluding immediately afterwards that he wanted it, he snatched it off of the fender and plunged it into a basin of water to cool it. The steam inside instantly condensing, the water rushed in and filled it as it cooled.

We now come to the beginning of the steam engine as we understand the term; the machine that involves the use of the cylinder and piston. These two features had been used in pumps long before, the atmospheric pump being one of the oldest of modern machines. The vacuum was known and utilized long before the cause of it was known. [Footnote: The discoverer was an Italian, Torricelli, about 1643. Gallileo, his tutor and friend, did not know why water would not rise in a tube more than thirty-three feet. No one knew of the *weight of the atmosphere*, so late as the early days of this republic. Many did not believe the theory long after that time. Torricelli, by his experiments, demonstrated the fact and invented the mercurial barometer, long known as the "Torricellian Tube." This last instrument led to another discovery; that the weight of the atmosphere varied from time to time in the same locality, and that storms and weather changes were indicated by a rising and falling of the column of mercury in the tube of the siphon-barometer. That which we call the "weather-bureau," organized by General Albert J. Myer, United States Army, in 1870, and growing out of the army signal service, of which he was chief, makes its "forecasts" by the use of the telegraph and the barometer. The "low pressure area" follows a path, which means a change of weather on that path. Notices by telegraph define the route, and the coming storm is not foretold, but *foreknown;* not prophesied, but *ascertained.* If we have been led from the crude pump of Gallileo's time directly to the weather bureau of the present with its invaluable signals to sailors and convenience to everybody, it is no more than is continually to be traced even to the beginning of the wonderful school of modern science.]

But in the beginning it was not proposed to use steam in connection with the cylinder and piston which now really constitutes the steam-engine. Reverting again to the example of the gun, it was suggested to push a piston forward in a tube by the explosion of gunpowder behind it, or to repeat the Savery experiment with powder instead of steam. These ideas were those of about 1678-1685. The very earliest cylinder and piston engine was suggested by Denis Papin in 1690. These early inventors only went a portion of the way, and almost the entire idea of the steam-engine is of much later date. Mankind had then a singular gift of beginning at the wrong end. Every inventor now uses facts that seem to him to have been always known, and that are his by a kind of intuition. But they were all acquired by the tedious experience of a past that is distinguished by a few great names whose owners knew in their time perhaps one-tenth part as much as the modern inventor does, who is unconsciously using the facts learned by old experience. But the others began at the beginning.

[Illustration: EARLY NEWCOMEN PUMPING ENGINE. STEAM-COCK, COLD WATER
COCK AND WASTE-SPIGOT ALL WORKED BY HAND.]

In 1711, almost a hundred years after the arrival at Jamestown and Plymouth of the fathers of our present civilization, the steam-engine that is called Newcomen's began to be used for the pumping of water out of mines. This engine, slightly modified, and especially by the boy who invented the automatic cut-off for the steam valves, was a most rude and clumsy machine measured by our ideas. There appears to have been scarcely a single feature of it that is now visible in a modern engine. The cylinder was always vertical. It had the upper end open, and was a round iron vessel in which a plunger moved up and down. Steam was let in below this plunger, and the walking-beam with which it was connected by a rod had that end of it raised. When raised the steam was cut off, and all that was then under the piston was condensed by a jet of cold water. The outside air-pressure then acted upon it and pushed it down again. In this down-stroke by air-pressure the work was done. The far end of the walking-beam was even counter-weighted to help the steam-pressure. The elastic force of compressed steam was not depended upon, was hardly even known, in this first working and practical engine of the world. Every engine of that time was an experimental structure by itself. The boiler, as we use it, was unknown. Often it was square, stayed and braced against pressure in a most complicated way. Yet the Newcomen engine held its place for about seventy-five years; a very long time in our conception, and in view of the vast possibilities that we now know were before the science. [Footnote: As late as 1880, the steam-engine illustrated and described in the "natural philosophy" text books was still the Newcomen, or Newcomen-Watt engine, and this while that engine was almost unknown in ordinary circumstances, and double-acting high-pressure engines were in operation everywhere. This last, without which not much could be done that is now done, was evidently for a long time after it came into use regarded as a dangerous and unphilosophical experiment, hardly scientific, and not destined to be permanently adopted.]

In the year 1760, James Watt, who was by occupation what is now known as a model-maker, and who lived in Glasgow, was called upon to repair a model of a Newcomen engine belonging to the university. While thus engaged he was impressed with the great waste of steam, or of time and fuel, which is the same thing, involved in the alternate heating and cooling of Newcomen's cylinder. To him occurred the idea of keeping the cylinder as hot as the steam used in it. Watt was therefore the inventor of the first of those economies now regarded as absolute requirements in construction. He made the first "steam-jacket," and was, as well, the author of the idea of covering the cylinder with a coat of wood, or other non-conductor. He contrived a second chamber, outside of the cylinder, where the then indispensable condensation should take place. Then he gave this cylinder for the first time two heads, and let out the piston-rod through a hole in the upper head, with packing. He used steam on the upper side of the piston as well as the lower, and it will be seen that he came very near to making the modern engine.

Yet he did not make it. He was still unable to dispense with the condensing and vacuum and air-pressure ideas. Acting for the first time in the line of real efficiency, he failed to go far enough to attain it. He made a double-acting engine by the addition of many new parts; he even attained the point of applying his idea to the production of circular motion. But he merely doubled the Newcomen idea. His engine became the Newcomen-Watt. He had a condensing chamber at each end of the stroke and could therefore command a reciprocating movement. The walking-beam was retained, not for the purpose for which it is often used now, but because it was indispensable to his semi-atmospheric engine.

[Illustration: THE PERFECTED NEWCOMEN-WATT ENGINE.]

It may seem almost absurd that the universal crank-movement of an engine was ever the subject of a patent. Yet such was the case. A man named Pickard anticipated Watt, and the latter then applied to his engines the "sun-and-planet" movement, instead of the crank, until the patent on the latter expired. The steam-engine marks the beginning of a long series of troubles in the claims of patentees.

In 1782 came Watt's last steam invention, an engine that used steam *expansively*. This was an immense stride. He was also at the