with the perpendicular, it glances off at an equal angle on the other side.

516. *Absorption of Radiant Heat.*—Radiant heat is absorbed by dull and dark-colored surfaces. Good reflectors are bad absorbents and radiators; bad reflectors are good absorbents and radiators.

Of the colors, black is the best absorbent of heat, and violet the next best; white is the worst, and yellow next to the worst.

Lay two pieces of cloth, one white and the other black, on a snow-bank, in the sunshine. Under the black piece, which absorbs the heat that strikes it, the snow melts rapidly; not so under the white cloth, for by it the heat is reflected. Dark-colored clothing is therefore best adapted to winter.

Dark mould absorbs the sun's heat; hence one cause of its fertility. White sand reflects the hot rays; hence it burns our faces when we walk over it in summer. Hoar-frost remains longer in the morning on light than dark substances: this is because light colors reflect the sun's heat, while dark colors absorb it, and thus melt the hoar-frost, which is nothing more than frozen dew.

517. *Transmission of Radiant Heat.*—Transparent substances, or such as allow light to pass through them, for the most part transmit heat also. The sun's rays, for instance, falling on the atmosphere of the earth, which is a transparent medium, are transmitted through it to objects on the surface. More or less heat is absorbed in the act of transmission.

518. Substances that transmit heat freely are called Di-a-ther'-ma-nous. Those that absorb the greater part and transmit little or none are called A-ther'-ma-nous.

519. All transparent substances are not diathermanous. Water, for example, which offers but little obstruction to rays of light, intercepts nearly all the heat that strikes it. Alum is another instance in point.

equal? 516. By what surfaces is radiant heat absorbed? What is said of good reflectors? What, of bad reflectors? What color is the best absorbent of heat? What, the next best? What color is the worst absorbent? What, the next worst? Prove by an experiment the difference in absorbing power between white and black. Why is dark-colored clothing best adapted to winter? What is the difference between dark mould and white sand in absorbing power? Why does hoar-frost remain longer in the morning on light than dark substances? 517. What substances, for the most part, transmit heat? Give an example. 518. What are Diathermanous substances? What are Athermanous substances? 519. Name a transparent substance that is not dia-

All diathermanous substances are not transparent. Quartz, though it may intercept light almost entirely, transmits heat quite freely.

As a general rule, the rarer transparent substances, such as gases and vapors, transmit heat the best; the denser ones, such as rock-crystal, transmit it the least freely. The farther the rays have to pass through a given substance, the more heat is intercepted.

Effects of Heat.

520. The effects of heat are five in number: Expansion, which changes the size of bodies; Liquefaction and Vaporization, which change their form; Incandescence, which changes their color; and Combustion, which changes their nature.

521. Expansion.—Heat expands bodies.

Insinuating itself between the particles of bodies, it forces them asunder, and thus makes them occupy a greater space. Heat, therefore, opposes cohesion. Solids, in which cohesion is strongest, expand the least under the influence of heat; liquids, having less cohesion, expand more; gases and vapors, in which cohesion is entirely wanting, expand the most. Heat converts solids into liquids, and liquids into gases and vapors, by weakening their cohesion. It turns ice, for example, into water, and water into steam.

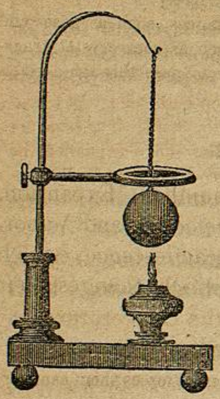
522. *Expansion of Solids.*—All solids except clay are expanded by heat; but not equally. Of the metals, tin is among those that expand most. Clay is contracted by baking, and ever afterwards remains so; this is supposed to be owing to a chemical change produced in it by heat.

The expansion of solids is illustrated with the apparatus represented in Fig. 214. A brass ball is suspended from a pillar, to which is also attached a ring just large enough to let the ball pass through it at ordinary temperatures. Heat the ball with a lamp placed beneath, and it will expand to such a degree that it can not pass through the ring. Let it cool, and it will go through as before.

523. A sheet-iron stove in which a hot fire is quickly kindled or put out, sometimes makes a cracking noise, in consequence of the rapid ex-

thermanous. Name a diathermanous substance that is not transparent. As a general rule, what transparent substances transmit heat the best, and what the worst? 520. State the effects of heat. 521. What is the first of these? How is it that heat expands bodies? What force does it oppose? Which expand the most under the influence of heat, solids, liquids, or gases,—and why? Into what does heat convert solids? Into what, liquids? 522. What solids are expanded by heat? What metal is expanded more than most of the others? What is the effect of heat on clay? Illustrate the expansion of solids with the apparatus represented in Fig. 214. 523. Why

Fig. 214.



pansion or contraction of the metal. A blower placed on or taken from a hot fire produces a similar noise for the same reason. New furniture standing in the sun or near a fire is apt to warp and crack in consequence of the expansive effects of heat.

When boiling water is poured into china cups and glass vessels, they often crack. This is because the inner surface is expanded by heat, while the outer is not, china-ware and glass being bad conductors. The unequal expansion cracks the vessel. Cold water poured on a hot glass or stove produces the same effect. On the same principle, glass chimneys are apt to crack, when brought too suddenly over the flame of a lamp or gas-burner. A cut made in the bottom with a diamond allows an opportunity for expansion, and prevents the chimney from breaking.

When a glass stopper becomes fastened in a bottle, it may often be withdrawn by placing the neck of the bottle in warm water. The neck is expanded before the heat reaches the stopper.

524. The force with which a body expands when heated and contracts when cooling, is very great. In iron bridges, therefore, and other structures in which long bars of metal are employed, there is danger of the parts' separating, unless provision is made for the expansion caused by a rise of temperature. The middle arch of an iron bridge has been known to rise an inch in the summer of a temperate climate. So, when great lengths of iron pipe are laid for conveying steam or hot water, sliding joints must be used, or the apparatus will burst in consequence of the expansion of the metal.

525. The fact that heat expands bodies and cold contracts them, is often turned to practical account. Coopers, for instance, heat their iron hoops, and while they are thus expanded put them on casks which they just fit. As they cool, they contract and bind the staves tightly together. The wheel-wright fastens the tire, or outer rim of iron, on his wheel in the same way.

The contraction of iron, when cooling, has been ingeniously used for drawing together the walls of buildings that have bulged out and threaten to fall. Several holes are made opposite to each other in the walls, into which are introduced stout bars of iron, projecting on both sides and terminating at each end in a screw. To each screw a nut is fitted. The bars are then heated by lamps placed beneath, and when they have expanded the nuts are screwed up close to the walls. As the bars cool, they gradually contract, and with such force as to bring the walls back to a perpendicular position.

do a sheet-iron stove and a blower sometimes make a cracking noise? What causes new furniture to warp? What makes glass vessels crack when boiling water is poured into them? When are glass chimneys apt to crack? How may their cracking be prevented? When a glass stopper becomes fastened in a bottle, how may it be withdrawn? 524. What is said of the force with which bodies expand and contract? What precautions must be taken in consequence? 525. What practical use is made of the fact that heat expands bodies and cold contracts them? What ingenious application has been made of the contraction of iron when cooling? Give an account of the process.

526. *Expansion of Liquids.*—Liquids, when heated, expand much more than solids, but not all alike. Thus water, raised from its freezing-point to the temperature at which it boils, has its bulk increased one-twenty-second; alcohol, between the same limits, increases one-ninth.

The higher the temperature, the greater the rate at which liquids expand.

527. In proportion as heat expands liquids, it rarefies them, the same quantity of matter being made to occupy a larger space. This fact is shown in the process of boiling, described in § 501.

528. Water at certain temperatures forms a remarkable exception to the general law that liquids are expanded by heat and contracted by cold. As it cools down from the boiling-point, it contracts, and consequently increases in density, till it reaches 39 degrees, or 7 degrees above its freezing-point. Below this temperature, it expands.

The expansion of water in freezing is proved every winter by the bursting of pipes, pitchers, &c., containing it. The force with which it expands is tremendous. An iron plug weighing three pounds and closing a bomb-shell filled with water, has been thrown 15 feet by the freezing and expansion of the liquid within. Immense masses of rock are sometimes split off by the freezing of water which has insinuated itself into minute fissures.

The expansion and consequent rarefaction of water in freezing, afford a

526. How does the expansion of heated liquids compare with that of solids? Compare the expansion of water with that of alcohol. On what does the rate at which liquids expand depend? 527. Besides expanding liquids, what does heat do to them? 528. What exception is there to the law that liquids are contracted by cold? How is the expansion of water in freezing proved? What cases are cited, to show the great force with which water expands in freezing? How does the expansion

striking proof of the goodness of Providence. The great body of a large mass of water never becomes cold enough to freeze; it freezes only on the top, where it comes in contact with very cold air. As it is, the ice formed on the surface remains there on account of its superior rarity, and protects the water below and the fish that inhabit it from further cold. If water continued to contract and increase in density as it approached the freezing-point, the ice first formed would sink; the fresh surface exposed to the air would in its turn freeze, and another layer of ice would sink; and this would go on till even in a mild winter every body of water would be converted into a solid mass, and all living things therein destroyed.

529. Iron, zinc, and several other metals, when cooling down from a melted to a solid state, expand like freezing water. This is because the particles assume a crystalline arrangement, by which greater interstices are left between them.

530. *Expansion of Gases and Vapors.*—Aëriform bodies expand equally under a given increase of temperature. At the boiling-point of water, their bulk is one-third greater than at the freezing-point.

531. Fill a bladder with air, tie its neck, and place it before a fire; the heat will soon expand the confined air to such a degree as to burst the bladder.

The popping of grains of corn, the bursting open of chestnuts when roasting, and the crackling of burning wood, are caused by the expansion of the air within them. Porter-bottles have to be kept in a cool place in summer, lest the heat expand the carbonic acid in the porter and break the bottles.

532. Liquefaction.—Heat melts solids. This process is called Liquefaction.

Some solids, such as wax and butter, require but little heat to melt them. Others, like metals and stones, melt only at the highest temperatures that can be produced. Such substances are called *refractory.*

Even substances that are liquid at ordinary temperatures may be looked upon as melted solids, for they can be reduced by cold to the solid state.

533. When a solid is converted into a liquid, sensible heat is absorbed. When a liquid is converted into a solid,

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of water in freezing exhibit the goodness of Providence? 529. How do we account for the expansion of several of the metals, when cooling down from a melted state? 530. What is said of the expansion of aëriform bodies? How great is their expansion, when they are raised from the freezing-point to the boiling-point of water? 531. How may we illustrate the expansion of air by heat with a bladder? What familiar examples are given of the expansion of air by heat? 532. What is Liquefaction? What difference is there in solids, as regards their capability of being melted? How may substances that are liquid at ordinary temperatures be looked upon? 533. By what

latent heat is given out. This is another merciful provision, for thus extremes of temperature and their effects are modified.

When a solid is rapidly melted, so much heat is absorbed by the liquid that intense cold is produced. This is the principle on which freezing mixtures operate. Ice cream, for instance, is frozen with a mixture of salt and snow or pounded ice; the latter is rapidly melted, and so much heat is absorbed in the process that the cream is brought to a solid form.

534. Vaporization.—Heat converts liquids into vapors. This process is called Vaporization.

Heat, applied to a solid, first expands it, then melts it, and finally turns it into vapor. Some solids pass at once into vapor, without becoming liquids.

535. A great degree of heat is not essential to vaporization. At ordinary temperatures, wherever a surface of water is in contact with the air, vapor is formed. This process is known as Spontaneous Evaporation. By its means the atmosphere becomes charged with moisture, and clouds and dew are formed. The drier the air, and the more it is agitated, so as to bring fresh currents in contact with the liquid, the more rapidly does evaporation take place.

536. A drop of water let fall on a cold iron moistens its surface; let fall on a very hot iron, it hisses and runs off without leaving any trace of moisture. In the latter case, the water does not touch the iron at all, but is separated from it by a thin layer of vapor into which part of the drop is converted by the heat radiated from the iron. Laundresses try their irons in this way, to see if they are hot enough for use. On the same principle, jugglers plunge their hands into melted metal with impunity, by first wetting them. The moisture on their hands is converted into vapor, which keeps the seething metal from their skin.

537. When vapor is formed, sensible heat is absorbed, and cold is produced.

Hence when the skin is moistened with a volatile liquid (that is, one that readily passes into vapor) like alcohol, a sensation of cold is soon experienced. So, a shower or water sprinkled on the floor cools the air in sum-

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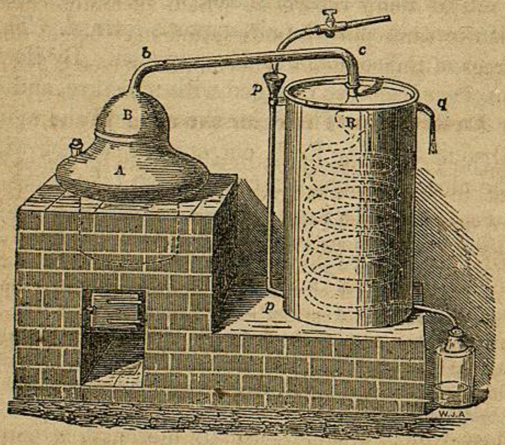
merciful provisions are extremes of temperature modified? On what principle do freezing mixtures operate? 534. What is Vaporization? What are the successive effects of heat on solids? 535. What is Spontaneous Evaporation? What are the effects of evaporation on the earth's surface? To what is the rapidity of evaporation proportioned? 536. Explain the principle on which laundresses try their irons. What use do jugglers make of this principle? 537. With what phenomena is the formation of vapor accompanied? Give some examples of cold produced by the former.—Green wood does not make so hot a fire as dry, because, when the moisture it contains is converted into vapor, a large amount of sensible heat is absorbed and carried off.

538. CONDENSATION.—The turning of vapor back into a liquid state is called Condensation.

539. *Distillation.*—Some substances are converted into vapor at lower temperatures than others. This fact is taken advantage of in Distillation.

Distillation is the process of separating one substance from another by evaporating and then condensing it. It was known to the Arabians at an early date. Fig. 215 represents a Still, or apparatus for distilling.

Fig. 215.



A STILL.

540. A is a *boiler*, resting on a furnace. In its *head*, B, is inserted a pipe, *b c*, which enters the *worm-tub*, R, and there terminates in a *worm*, represented by the dotted lines. The substance to be distilled having been placed in the boiler and a fire kindled beneath, vapor soon rises. Passing through the pipe *b c*, it enters the worm, in which it is to be condensed. The worm is surrounded with cold water, with which the vat is filled, and the vapor is soon cooled down into a liquid form, and issues from the lower extremity of

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mation of vapor. Which makes the hotter fire, green wood or dry,—and why? 538. What is meant by the Condensation of vapor? 539. What is Distillation? On what fact is the process based? To whom was distillation early known? What is an apparatus for distilling called? 540. With the aid of Fig. 215, describe the still,

the worm, falling into a vessel prepared to receive it. To condense the vapor, the water in the vat must be kept cold. For this purpose, a stream is kept flowing into it through the pipe *p p*, while a similar stream of water partially warmed by the hot vapor as constantly escapes at *q*. By this process water may be obtained perfectly pure, as the earthy matter dissolved in it is not converted into vapor, but remains behind in the boiler. With a similar apparatus, spirituous liquors are distilled from grain.

541. INCANDESCENCE.—When a body is raised to a certain very high temperature, it begins to emit light as well as heat. This state is called Incandescence, or Glowing Heat.

An incandescent body becomes successively dull red, bright red, yellow, and white. All solids and liquids, not previously converted into vapor by heat, become incandescent. The temperature at which incandescence commences is the same for all bodies, and may be set down at 977 degrees of Fahrenheit's Thermometer (see § 544).

Instruments for measuring Heat.

542. The expansion of bodies by heat furnishes us the means of measuring changes of temperature. Liquids, which are easily affected, are used for measuring variations in moderate temperatures. Solids, which require a higher degree of heat to expand them perceptibly, are used for measuring variations in elevated temperatures. Hence we have two instruments, the Thermometer and the Pyrometer.

543. THE THERMOMETER.—The Thermometer is an instrument in which a liquid, usually mercury, is employed for measuring variations that occur in moderate temperatures.

The thermometer (see Fig. 216) consists of a tube closed at one end and terminating in a bulb at the other. The bulb and part of the tube contain mercury, above which is a vacuum, all air having been excluded before the top of the tube was closed. Expanded by heat, the mercury rises in the

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and its mode of operation. 541. What is Incandescence? What colors mark the successive stages of incandescence? What substances become incandescent? At what temperature does incandescence commence? 542. What means have we of measuring changes of temperature? In what cases are liquids used? In what, solids? Name the instruments used for measuring changes of temperature. 543. What

Fig. 216.

THE THERMOMETER.

tube; when the temperature falls, the mercury, contracting, falls also. The tube is fixed in a stand or case, and has a graduated scale beside it for measuring the rise and fall of the mercury. This scale is formed in the following way:—The thermometer is brought into contact with melting ice, and the point at which the mercury stands is marked. It is next plunged in boiling water, and the point to which the mercury rises is also marked. The interval is then divided into a number of equal spaces, called *degrees.*

544. As the thermometer does not indicate the amount of heat in a body, but merely its changes of temperature, the number of degrees into which the interval between the freezing and the boiling mark is divided is arbitrary. Three different divisions are in use: Fahrenheit's, in the United States, Great Britain, and Holland; Reaumur's [*ro'-murz*], in Spain and parts of Germany; and the Centigrade, the most convenient of the three, in France, Sweden, &c.

In Fahrenheit's scale the freezing-point is called 32, the boiling-point, 212; when, therefore, the mercury stands at 0, or zero, it is 32 degrees below the freezing-point. In Reaumur's scale the freezing-point is called 0, the boiling-point 80. In the Centigrade the freezing-point is 0, the boiling-point 100. When degrees of the thermometer are mentioned, it is usual to indicate the scale referred to by the letters F., R., or C., as the case may be. Thus 40° F. means 40 degrees on Fahrenheit's scale; 15° R., 15 degrees on Reaumur's scale, &c. In this country, when no scale is mentioned, Fahrenheit's is meant.

545. Imperfect thermometers were in use at the beginning of the seventeenth century. It is uncertain whether the honor of their invention belongs to Sanctorio, an Italian physician,—Drebbel, a Dutch peasant,—or Galileo. Various liquids have been tried; the astronomer Roemer was the first to use mercury, the advantages of which are such that it has superseded all others.

546. *The Differential Thermometer.*—This instrument,

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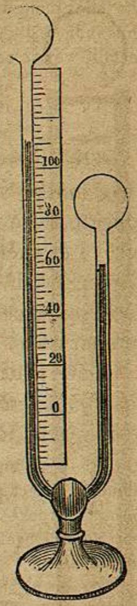
is the Thermometer? Of what does it consist? How is the scale of the thermometer formed? 544. What is said of the number of degrees into which the scale is divided? Name the three principal scales, and tell where each is used. What are the freezing-point and the boiling-point respectively called in Fahrenheit's scale? What, in Reaumur's scale? In the Centigrade scale? How are the different scales indicated? 545. When were thermometers first used? To whom does the honor of their invention belong? What liquid has superseded all others in the thermometer? Who

represented in Fig. 217, measures minute differences of temperature.

Fig. 217.

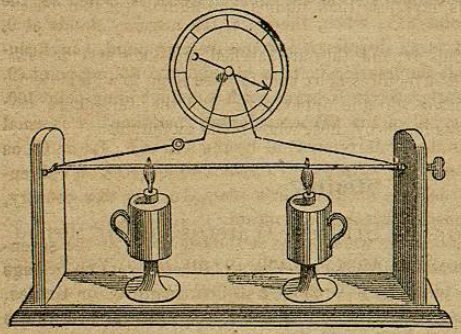


THE DIFFERENTIAL THERMOMETER.

It consists of a long glass tube, bent twice at right angles, somewhat in the form of the letter U. One arm is furnished with a scale of 100 degrees, and each terminates in a bulb. The tube contains a small quantity of sulphuric acid, colored red, and so disposed that when both bulbs are of the same temperature it stands at 0 on the scale. Let either bulb be heated ever so little more than the other, and the expansion of the air within will drive the liquid down and cause it to ascend the opposite arm to a distance measured by the scale. Ordinary changes of temperature do not affect the instrument, because both bulbs are acted on alike.

547. THE PYROMETER.—The Pyrometer (see Fig. 218) is used for measuring variations in elevated temperatures, and comparing the expansive power of different metals for a given degree of heat.

Fig. 218.



THE PYROMETER.

A metal bar is fixed in an upright at one end by means of a screw, and left free to expand at the other. It there touches a pin projecting from a rod which rests against an opposite upright, in a circular support at each side. This rod terminates at one end in an arm bent at right angles, which is connected by a cord and pulley with an index traversing a scale marked with degrees. Near its extremity is a ball, the weight of which, under ordinary circumstances, keeps the index at the highest point of the scale. When lamps are placed beneath and the bar expands, it pushes against the pin, turns the rod

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first used it? 546. For what is the Differential Thermometer employed? Describe the differential thermometer, and its operation. 547. For what is the Pyrometer more or less around, and thus raises the arm containing the ball and moves the index along the scale. The relative degree of heat applied to the bar is thus indicated. By keeping the heat the same, and using rods of different metals, we can ascertain their relative expansive power.

Specific Heat.

548. Put a pound of water and a pound of olive oil in two similar vessels, and apply heat. It will take twice as long to raise the water to a given temperature as it will the oil. Let them cool, and the water will be twice as long in parting with its heat as the oil. Water, therefore, must receive twice as much heat as olive oil in reaching a given temperature.

The relative amount of heat which a body receives in reaching a given temperature is called its Specific Heat, or its Capacity for Heat.

549. In estimating the specific heat of bodies, that of water is taken as a standard. Reckoning the specific heat of water as 1, that of iron is about $1/9$, and mercury only $1/33$. As a general thing, the densest bodies have the least specific heat; solids have less than liquids, and liquids less than gases and vapors.

550. As the elastic fluids expand, they are rarefied, and their specific heat becomes greater,—that is, it requires more heat to raise them to a given temperature. This is one reason why the upper regions of the atmosphere are colder than the lower, as is found by those who ascend mountains.

Steam.

551. Generation of Steam.—Water is rapidly turned into steam at its boiling-point, which in an open vessel at the level of the sea is 212° F. After it commences boiling, water can not be raised to any higher temperature, because all the heat subsequently applied is absorbed by the steam and passes off with it.

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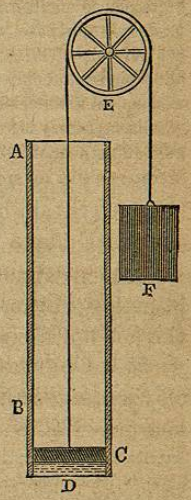
used? Describe the Pyrometer. 548. How is it proved that water must receive twice as much heat as olive oil in reaching a given temperature? What is meant by Specific Heat? 549. In estimating the specific heat of bodies, what is taken as a standard? What is the specific heat of iron? Of mercury? As a general thing, what bodies have the least specific heat? 550. Under what circumstances is the specific heat of elastic fluids increased? What fact is thus explained? 551. How is steam generated? Why can not water, after it commences boiling, be raised to any higher

If the water is in a close vessel, the steam first formed, being confined, presses on the water and prevents it from boiling as soon as before. It may now be raised to a more elevated temperature, for heat is not withdrawn by the formation of steam till it reaches a higher point.

552. Steam has the same temperature as the water from which it is formed, the heat absorbed in the process of formation becoming latent. When it is generated from water in an open vessel, its temperature is 212°; in a confined vessel it will be higher, according to the pressure on the surface of the water.

553. Steam is colorless and invisible. When cooled by contact with the atmosphere, it begins to turn back into a liquid state, and assumes a grey mist-like appearance. Look at the spout of a tea-kettle full of boiling water. For half an inch from the extremity nothing can be seen; beyond that, the steam, cooling and beginning to condense, becomes visible.

Fig. 219.



554. The generation and properties of steam may be understood from Fig. 219. AB represents the inside of a tall glass tube, the section of which has an area of one square inch. The tube is closed at its lower end, and contains a cubic inch of water, D, and resting on it a tightly-fitting piston, C. A cord, fastened to the piston, is carried round the wheel E, and attached to the weight F. F is made just heavy enough to counterbalance the piston and its friction against the tube. Suppose a thermometer to be placed in the water, and apply heat at the bottom of the tube. As soon as the thermometer indicates a temperature of 212°, the piston begins to rise, leaving a space apparently empty between it and the water. The fire continues to impart heat to the water, but the mercury in the thermometer remains stationary at 212°; the piston keeps rising, and the water begins to diminish. If the process were continued and the tube were long enough, the piston would at last reach a

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temperature? Under what circumstances may water be raised to a higher temperature than 212°? 552. What is the temperature of steam? 553. What is the color of steam? Explain the mist-like appearance a short distance from the spout of a boiling tea-kettle. 554. With the aid of Fig. 219, show the process of generating steam, and height of nearly 1,700 inches, by which time the water would entirely disappear. If the tube were then weighed, though nothing could be seen in it but the piston, it would be found to have exactly the same weight as at first. The water would simply be converted into steam, and thus increased in volume 1,700 times. The piston, with the pressure of the atmosphere on it (which is 15 pounds, the area of the piston being one square inch), would be raised 1,700 inches.

All the time steam is forming, a uniform amount of heat is applied to the tube. As the mercury in the thermometer rises no higher than 212°, it is evident that the heat imparted after it reaches that point is absorbed by the steam and becomes latent. To determine the amount of this latent heat, we must compare the time required to raise the water from the freezing to the boiling point with the time that elapses from the commencement of boiling till the water disappears. We shall find that the latter interval is $5^1/_2$ times as great as the former; and, since from the freezing-point (32°) to the boiling-point (212°) is 180°, we conclude that the amount of heat absorbed is $5^1/_2$ times 180°, or nearly 1,000 degrees. That is, the heat applied would have raised the water to a temperature of nearly 1,000°, if it could have remained in the liquid state.

555. If, besides the pressure of the atmosphere on P, a weight of 15 pounds were placed on it, it would be said to have a pressure of *two atmospheres*. Steam, in this case, would not commence forming till the water reached a temperature of $251^1/_2$ degrees; and, when the whole was evaporated, the piston would stand only about half as high as before. Under a pressure of three atmospheres, the piston would be raised about one-third as high, &c.; the mechanical force developed in the evaporation of a given quantity of water remaining nearly the same. This force, for a cubic inch of water, is sufficient to raise a ton a foot high.

556. Steam has a high degree of elasticity and expansibility. Under a pressure of two atmospheres, or 30 pounds to the square inch, it would raise the piston in the above experiment about 850 inches; if 15 pounds were removed from the piston, the expansive force of the steam would drive it up 850 inches farther.

557. Condensation of Steam.—Steam retains its form only as long as it retains the latent heat absorbed. The

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describe some of its properties. When water is converted into steam, how many times is its volume increased? How is this proved with the apparatus just described? Prove that heat becomes latent in the steam. How can the amount of latent heat be determined? 555. When is steam said to have a pressure of two atmospheres? How high would the piston then be raised? How high would the piston be raised under a pressure of three atmospheres? How great is the mechanical force developed in evaporating a cubic inch of water? 556. Prove the expansibility of steam. 557. How long does steam retain its form? When is it condensed? Show

moment it is forced to part with this heat, it is turned back into the liquid form, or *condensed.*

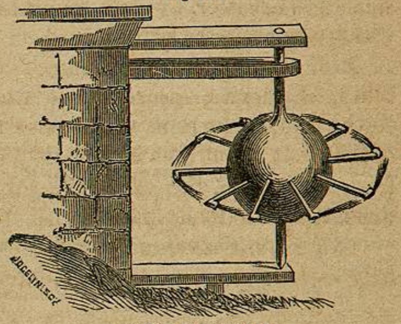
In the above experiment, after the piston has been raised 1,700 inches, let the fire be removed, and cold water be applied to the surface of the tube. The latent heat will be abstracted, and the steam will be condensed and form once more a cubic inch of water at the bottom of the tube. As the steam condenses, successive vacuums are produced; and the piston, forced down by the pressure of the atmosphere, descends, and finally rests on the water as at first.

By applying heat again, the process may be repeated. An up-and-down motion may in this way be communicated to the piston; and the piston may be connected with machinery, which will thus be set in motion by the alternate evaporation of water and condensation of steam. This was the principle of the Atmospheric Engine, which was once extensively used, but has now been superseded.

The Steam-Engine.

558. Hero's Engine.—Steam and some of its properties appear to have been known to the ancients centuries before the Christian era. Hero, of Alexandria, who flourished about 200 years B. C., has left us a description of a steam-engine by which machinery could be set in motion.

Fig. 220.



HERO'S STEAM-ENGINE.

Fig. 220 represents Hero's engine. A hollow metallic globe is supported by pivots, and provided with a number of jets equally distant from the pivots, and bent at right angles near their outer end. As soon as steam is introduced into the globe, it issues violently from the mouth of each jet, while on the opposite side of each it presses without being able to escape. This unbalanced pressure makes the globe revolve. Machinery may be set in motion by means of a band connected with this apparatus.

559. Hero's was a simple rotatory engine. No use was made of it for

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how it may be condensed in the above experiment. What follows the condensation of the steam? How may an up-and-down motion be communicated to the piston? What engine was constructed on this principle? 558. How long ago was steam known? Who has left us a description of a steam-engine? Describe Hero's engine.