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Bacon. Natural History.

The Pentecosts prepar'd at Carleon in his court,
That table's ancient seat; her temples and her groves,
Her palaces, her walks, baths, theatres, and *stoves.*
Drayton. Poly-olbion, song 4.

He commanded the very walls of his baines and *stouves* to be perfumed with pretious ointments.
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Stove. By this word we understand a fire-place, or a place in which fire is kindled for the production of artificial heat; also a hot-house, or building heated artificially to a high temperature. (See the Treatise on Horticulture in this Encyclopædia.) The use of this word in the latter signification, though now of general acceptation, does not appear to have been recognised by our earlier philologists: for the term *hot-house*, now generally applied to a building used for the cultivation of plants, was formerly expressive of a sudorific bath;* the use of hot-houses for the purposes of horticulture being an invention of comparatively a recent date. At the beginning of the XVIIth Century hot-houses were used for the cultivation of orange trees, and were considered a mark of royal magnificence.†

The stoves used by the ancients appear to have been very different from those of modern times. The Romans used portable furnaces, containing embers and burning coals, to warm the different apartments of the house, which were placed in the middle of the room.‡ These were sometimes made to contain water, which was heated by the fuel of the furnace; and probably they were also used for cooking. One of these boilers and furnaces, found at Herculaneum, was in the shape of a castle with four towers.* The usual kind of stoves, however, were nearly in the form of our braziers. They were mostly elegant bronze tripods, supported by satyrs and sphinxes, with a round dish above for the fire, and a small vase below to hold perfumes, which were thrown into the brazier to correct the smell of the coals. A square stove of bronze, of the size of a moderate table, found at Herculaneum, rested on lions' paws, and was ornamented upon the border with foliage. The bottom was a strong iron grating, walled up with bricks above and below, so that the fire could not touch the sides of the stove, nor fall through the bottom. It was similar to those still used in large rooms in Italy.† Cicero mentions a Greek stove (*authepsa*) sold in an auction as dear as an estate; and sometimes, it appears, they were made of silver.‡

As the ancients are supposed to have had no chimneys for carrying off the smoke, this mode of heating rooms must have been very unpleasant. Wood was the fuel generally burnt by the Romans, the smoke from which was less disagreeable than that from coals; and they were at great pains to dry it, and anoint it with the lees of oil, (*amurca,*) to prevent the smoke as much as possible.§ They likewise furnished the winter rooms differently from those of summer, in order that the furniture might not be injured by the smoke:|| and the images which were in the halls were called *Fumosæ*, and *December Fumosus*, from the use of fires in that month.¶

But the ancients adopted other means of warming their rooms which were far more perfect than this. Pliny the younger, in the description of his villa, Laurentinum, mentions that his bedchamber (*cubiculum*) was warmed by a small *hypocaustum.*** This was also the mode employed by the ancients for heating their baths. The hypocaustum was placed lower than the room to be heated. It appears to have been a kind of long furnace or flue, and a number of narrow arches

* Fosbroke, *Archæology*, vol. i. p. 275.
† Beckmann, *History of Inventions*, vol. i. p. 169.
‡ Adams, *Roman Antiquities*, p. 454.

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|| Castell, *Illustrations of the Villas of the Ancients*, p. 8.
¶ Horace, *Sat.* 1. 5. 81; Vitruvius, 7. 3. &c.
** Castell, *Illustrations*, p. 13.

Intent he hears Penelope disclose
A mournful *story* of domestic woes,
His servants' insults, his invaded bed,
How his whole flocks and herds exhausted bled,
His generous wines dishonour'd shed in vain,
And the wild riots of the suitor train.

Pope. Homer. Odyssey, book xxiii.

It is *storied* of a priest of Neptune, the reputed god of the sea among the heathens, that when he shewed to one of Neptune's votaries the many offerings hung up in his temple, of those that by their devotions to him had been saved from shipwreck; the votary answered, "But where are the offerings of the many more worshippers of Neptune that have perished in the waves of the sea and been lost in the deep?" But in the present case we may reverse the *story*.

Bull. Sermon 17. vol. ii. p. 53.

Ye Naiads! blue-ey'd sisters of the wood!
Who by old oak, or *story'd* stream,
Nightly tread your mystic maze,
And charm the wandring Moon.

Logan. Ode to a Fountaine.

A *story* in which native humour reigns
Is often useful, always entertains;
A graver fact enlisted on your side
May furnish illustration, well applied
But sedentary weavers of long tales
Give me the fidgets, and my patience fails.

Cowper. Conversation.

STOT, A. S. *stod-hors*, a *steed*, *q. v.* applied to oxen; Sw. *stut;* Dan. *stud.* A steer.

——— Grace of hus goodnesse. gaf Peers foure *stottes*.

Piers Plouhman. Vision, p. 380.

This reve sate upon a right good *stot*,
That was all pomelee grey, and hight Scot.

Chaucer. Prologue, v. 617

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STOVE. (*testudines alvei*) received the fire of the hypocauston, and were placed under the bath, that the water might be longer kept hot.* Sometimes a great many short columns or pillars supported the floor instead of these arches. They were set in four rows very close together, and the flame of the furnace passed between them, as appears by some very perfect specimens which have been discovered.† When the Thermæ of Rome were built, other means of heating them were adopted besides the hypocauston, which have been described by Seneca.‡ The water in the bath was heated by passing it through the fire in a brass pipe of a serpentine form, thence called *Draco*. The most approved method was to employ the *Miliarium*,§ which appears to have been a leaden vessel of large circumference, the middle part being open for the spiral pipe and for the draught of the fire to pass through. This vessel of water that surrounded the flame was also placed upon part of the same fire, and for that reason the bottom was obliged to be made of brass, as were also the pipes.||

Although the Romans must have introduced their methods of warming buildings into England at a very early period, the inhabitants of Britain long contented themselves with contrivances of the rudest and simplest character. Among the ancient Britons, in each dwelling there was only one place for a fire, which was merely a hole in the centre of the floor. In the time of the Anglo-Saxons, the ordinary plan was to place the ignited fuel on the hearth in the middle of the floor, and an opening in the roof, immediately above, permitted the escape of the smoke. In the better class of buildings an ornamented turret was erected in the centre of the roof for carrying off the smoke ; while in ordinary houses the opening in the roof was merely defended from the weather by luffer (*louvre*) boards, in the manner now practised in many of our commonest buildings used for manufactories.

The earliest records of the invention of chimneys show that they were first used in the XIVth Century. They were introduced into England during the reign of Richard II. ; and one of the first, perhaps, was at Bolton Castle, built in this reign.¶ It was long before they came into general use ; but in the XVIth Century nearly every room in respectable houses was furnished with one.**

It is uncertain at what time stove grates were first used, though probably they were not invented until coals became the ordinary fuel. Coals were known to the ancient Britons before the arrival of the Romans, who had not even a name for coals, though Theophrastus described them very accurately at least two centuries before the time of Cæsar, and states that they were used by the workers in brass.†† The Anglo-Saxons knew and partly used them ; but they are not mentioned either under the Danes or the Normans till the time of Henry III., who in 1234 granted a charter to the inhabitants of Newcastle to work them. In 1306 they were prohibited at London as a nuisance ; but in 1321 they were used at the palace, and became soon after an important article of commerce. In 1512 they had not

* Castell, *Illustrations*, p. 9.
† *Phil. Trans. Abrid.* vol. v. p. 290 ; and vol. viii. p. 532.
‡ Seneca, *Nat. Quæst.* lib. iii. cap. xxiv.
§ Palladius, lib. i. tit. 40.
|| Castell, *Illustrations*, p. 10.
¶ Fosbroke, *Archæology*, vol. i. p. 113.
** *Ibid.* vol. i. p. 112.
†† *Ibid.*

come into general use, because, not having got to the main stratum, it was found they would not burn without wood. Even in the XVIIth Century their use was confined to the lower orders, except for the working of metals ;* and such was the dislike entertained against them that, in the middle of the XVIth Century, in the reign of Elizabeth, an attempt was made to prohibit all persons from using them in London during the sessions of Parliament, as it was supposed that the air was rendered unwholesome by their use.†

The usual mode of burning wood was to place it on crooked pieces of iron called fire-dogs ; and this plan is still pursued by the rustic population in many parts of England. After the improved method of burning fuel under open chimneys was introduced, the chimney was used not only as the receptacle for the fire, but it also became the ordinary place of resort for conversation and conviviality for all the inmates of the house. The chimney corner was the post of honour ; and the custom of the whole family sitting under the chimney breast is not even yet exploded in some of our rural disticts.

Until the close of the XVIIth Century these enormous chimneys were universally employed ; but in 1715 Dr. Desaguliers published a translation of a French work on the methods of improving fire-places, which had been a few years previous given to the world by an author under the assumed name of Gauger, though the real writer of this work is supposed to have been the Cardinal de Polignac. This treatise, which is now become scarce, contains a most lucid explanation of the methods of economizing fuel, based on the soundest principles of philosophy. It appears to have been the first attempt which had been made to apply the known laws of heat to the construction of fire-places ; and though, in consequence of wood being the fuel universally used in France, and this fuel being always burnt upon the hearth, the author made no mention of stoves, the translator, Dr. Desaguliers, added a chapter on the stoves to be used in these improved fire-places, and the work in its new form was a complete epitome of all those principles which Franklin, and after him Count Rumford, so successfully brought under the public notice.

The various elegant forms given to the stove grates of the present day are quite a modern invention. Formerly they were called " cradles of iron for burning sea coal,"‡ from which we should suppose them to have been very different in construction to ours : and even those described in Dr. Desaguliers' work, as late as the beginning of the XVIIIth Century, are nothing more than a few bars bent into a semicircle, and fastened to the back. How far the utility of stoves has been affected by the modern alterations of form we shall presently endeavour to show. Recent inventions, however, have greatly economized fuel ; and within the last few years several entirely new methods of distributing artificial heat have been invented which will demand our attention. In order, therefore, to elucidate the subject in as systematic a manner as possible, we shall examine,

First, The various descriptions of stoves used for the warming of buildings, and for general domestic purposes, together with the scientific and mechanical principles of their construction.

Secondly, The several methods of distributing artifi-

* Fosbroke, *Archæology*, vol. i. p. 372.
† Adams, *Philos. Lectures*, vol. i. p. 83.
‡ Fosbroke, *Archæ.* vol. i. p. 268.

STOVE. cial heat, which have been most successfully employed in stoves or hot-houses.

Thirdly, The leading principles to be observed in the construction of buildings used for applying stove heat, whether for horticultural, manufacturing, or other purposes; and,

Lastly, We shall consider the chemical and physical changes produced in atmospheric air by the several methods of heating buildings, and the effects of these several changes on the physiology of animal and vegetable life.

Sect. 1.—*On the Construction and Philosophical Principles of various Descriptions of Stoves.*

Previous to the publication of M. Gauger's treatise on fire-places in 1709, chimney fire-places were generally made in the form of a large square recess, and the breast of the chimney was of the same size as the recess itself. The error of this construction was pointed out, in the work alluded to, by a reference to the known laws of heat. Radiant heat is subject to the same law as light; namely, that the angle of reflection is equal to the angle of incidence. Hence it follows, that a ray of heat falling perpendicularly on the flat sides of the chimney recess will be reflected back upon itself: if it forms an angle with the side, it must, if vertical, be reflected up the chimney; and if horizontal, the angle must be so small that it cannot be reflected forward beyond the jambs of the mantel-piece. On these principles M. Gauger recommended that the back of the recess should be contracted, so that the sides being inclined towards the back, they should reflect all the radiant heat into the room at a greater angle, by which much more effect would be produced. He likewise recommended a considerable contraction of the breast of the chimney, by which less heat would escape through the funnel or shaft of the chimney, while, at the same time, he proved that the smoke would escape with equal facility as before. Another improvement which he suggested was in making the hearth and back of the fireplace hollow, by means of metal plates, so that, by having these hollow spaces to communicate with the external air, the air in passing through them would be warmed before it entered the room, and prevent the cold currents of air which otherwise would enter through the crevices of the doors and windows. This construction of fireplaces was intended for the burning of wood; and as the fire was therefore merely to be laid on the hearth, the effect produced by these hollow spaces would of course be very considerable, by warming a large quantity of air.

Subsequent inventors have been much indebted to this work by M. Gauger. Franklin acknowledged the great assistance he had derived from it; and the methods of economizing fuel afterwards so successfully introduced by Count Rumford, in his improved stoves, are all similar in principle to the plans recommended by the French author.

In the year 1796 Count Rumford published his essays on the management of fire and the economy of fuel; and he there described those improvements which have ever since that time been followed in the construction of stove grates. The error shown by M. Gauger to exist in the construction of fire-places, by making the sides parallel to each other, was, at the time when Rumford wrote his treatise, still continued. In pointing out the error of this mode of construction, Count Rumford showed that, in order to obtain the greatest effect from the fuel, the sides of the fire-place ought to be placed at an angle of 135° with the back of the grate, or at an angle of 45° with an imaginary line passing across the front of the fire-place. That this angle must cause the greatest number of rays of heat to be reflected into the room is certain; the difference of effect between this mode of construction and that of the parallel sides being very great. The reduction of the size of the throat of the chimney was likewise another improvement which he effected; though this also had been recommended by M. Gauger nearly a century previous. The angular covings for the sides of fire-places Rumford considered should not be formed of iron, but of some more non-conducting substance, such as fire clay, in order that more heat might be reflected from them into the room. A circular form for these sides or covings he considered produced eddies or currents, which would be likely to cause the chimney to smoke; and he likewise objected to the old form of register or metal cover to the breast of the chimney for the same reason, because they sloped upwards towards the back of the chimney, and thereby caused the warm air from the room to be drawn up, and impede the passage of the smoke. The dimensions of the fire grate itself he also recommended to be much less than formerly; the best size for the chimney recess being, that the width of the back should be equal to the depth from front to back, and the length of the front, or the opening between the jambs, to be three times the length of the back.

The correctness of these principles in the construction of fire grates caused the *Rumford stoves* to be almost universally adopted. Improvements, however, have since been made, by combining with these stoves an improved form of register tops, a plan, in fact, which Rumford himself recommended in his later Essays.* The top of the register, or cover for the stove below the breast of the chimney, is now made to slope downwards towards the back, which impedes the entrance of heated air from the room into the chimney, and obviates the objections against the old form of register. It also has the advantage of reflecting a portion of the radiant heat downwards to the floor of the room, when the flap or cover is not made so high as to be hid by the projecting front of the grate.

Although the very best form for register stoves has now for several years past been adopted, the desire of novelty has caused the true principles of construction to be frequently departed from; and we accordingly find, in the more modern stoves, considerable deviations from these principles. Fig. 1, plate 50, is a section of a register stove constructed on the best possible plan for diffusing heat into the room. The sides are a right angle of 90°, A B C; and the bars, *d e*, describe a quadrant of a circle whose radius is half the length of the sides of the angle. If now we wish to follow Rumford's rule of making the back one-third the width of the front, we obtain this by taking with the compasses one-third the length of the side of the angle, and cutting off this one-third as at *f*, *g*; the back of the stove is then represented by the line *f*, *g*, which is just one-third of the width of the front A, C. By this arrangement it will be perceived that the sides of the stove form an angle of 135° with the back; and all the rays of heat which fall

Register stoves.

* Rumford, *Eleventh Essay.*

STOVE. upon these sloping sides will therefore be reflected into the room nearly in right lines. The falling cover or register top of the stove should also form an angle of 135° with the back, by which a large portion of heat will be radiated into the room.

This construction of stoves, however, is fast giving place to others of a much less scientific and efficient form. Fig. 2, plate 50, is the section of a form of stove now very generally used : *a*, *b*, *c* is the back, *f*, *g* the bars, *e*, *f*, *g*, *h* are the cheeks or sides, which are generally placed at a very acute angle with an imaginary line running across the front of the stove. If what has already been stated respecting the laws which govern the radiation of heat be correct, it is evident that much less heat will be radiated by this stove than by the one previously described ; and as, with any description of open stove, it is merely the radiant heat which is effective in warming the room in which it is placed, it is evident that this form must be greatly inferior to the other. For the same reason more heat will be given out from a stove with bright cheeks than from one of which the cheeks are black ; and more from burnished steel than from bright iron, because more heat is reflected, and therefore less is absorbed by bright surfaces than by those which are unpolished and dark coloured.

Various methods have been contrived to render available some further portion of the heat which is given off by the fuel during combustion in these stoves, in addition to that which is obtained by radiation. These contrivances are nearly all of them mere modifications of that pointed out by M. Gauger by means of the double back and hearth of his improved fire-places. Notwithstanding this invention, therefore, is at least 130 years old, it has, during the last thirty years, been repeatedly brought forward by different persons as a new invention. The principle has been the same in all the different cases, with but very little difference in the mode of applying it. A current of air is brought from the external atmosphere, and is made to pass through a small box at the back of the stove, the back of the stove itself forming one side of the box ; and in order to prevent the air from escaping into the room before it is sufficiently warmed, the box is divided by several partitions, in order to check the passage of the air, which is carried successively through them all before it escapes into the room. This mode of warming the air is exceedingly useful, and it is surprising that it has not been more generally adopted ; for it is not only economical in fuel, but it is very efficacious in remedying smoky chimneys, and in preventing those cold draughts from doors and windows which are so exceedingly unpleasant and unhealthy.

The register stoves that have been described may be considered as the representatives of the entire class of open fire grates ; and when constructed on correct principles, they are a most efficient means of warming rooms of any moderate size. Various modifications of them have been adopted by different manufacturers. An ingenious plan was proposed some years since under the name of Cutler's Torch stove. The object proposed was to form a stove that should burn its own smoke ; and this was accomplished by means of a deep box placed within the bars of the grate, sinking down into the hearth. This box was filled with coals, which were lighted on the top, and as the coals burned away, the box was raised higher by chains passing over a rack and pinion, placed out of sight in the interior of the stove. By this means the fuel only burned at the top ; and the quantity to heat could be regulated at pleasure according to the height to which the box was raised. For as the sides of the box were solid, and therefore no air could pass through the fuel contained in it, the combustion only took place in that part of the fuel which was raised up to the level of the bars of the grate ; and as the top of the fire always burned clear, the fresh fuel being supplied from below, the smoke was consumed by passing through the red-hot fuel on the top of the grate. When the fuel on the top was nearly burnt out, the box containing the coals had to be raised by means of a handle, and the stove then appeared to be fully charged with fuel. This plan, however, never came into general use. The stoves had rather a clumsy appearance, and there was an inconvenience with them in consequence of the difficulty of relighting the fire, when the fuel contained in the box was not sufficient to last for the entire day.

Cutler's Torch stove.

Another modification of the register stove, the invention of Mr. Sylvester, is shown in fig. 3, plate 50. In this stove the hearth consists of a great number of hollow bars B, B fitted into an appropriate frame. These hollow bars not only form the hearth, but also the grating on which the fuel is laid. On the end of these bars A, A, nearest to the back of the stove, the fire is kindled ; and the air, to support the combustion, passes through the hollow bars as well as through the front of the fire. The bars on which the fire lies become hot, and radiate their heat to the air of the room ; and in addition to this the sides of the stove, which are placed at an angle with the back, as already described, radiate a very considerable quantity of heat into the room in consequence of the fire being placed so much lower down than usual. The smoke escapes from this stove in rather a different manner from the usual plan. A number of openings S, S, placed something like luffer boards, allow the smoke to pass between them ; the whole or only a part of these openings being used as the quantity of smoke given off from the coals requires. On ordinary occasions the top opening D is the only escape required for the smoke. The ashes from the stove fall into a recess sunk under the bars A, A, which requires to be emptied about once in a week.

Sylvester's radiating stove.

A most efficient form of stove is shown in fig. 4, plate 50. Although this stove is not very generally used, it is now becoming more known and better appreciated. It is a register stove, exactly such as that already described, but with an exterior case entirely enclosing it in every part except the front. Between this case and the surface of the stove the air has a free passage, and by thus coming in contact with the heated surface of the stove the air is moderately warmed, and passes through the upper ventilators of the stove into the room. This stove requires to stand forward in the room, about twelve inches or more in advance of the mantel-piece ; and perhaps this may be considered by some persons to produce an awkward effect. With this exception the stove is exactly similar to any other register stove, and it is extremely efficient in warming a room. In fact it unites the advantages of a register stove with those of a hot air stove ; and if the external air be made to communicate with the air-chamber of the stove, instead of the air of the room only circulating through it, its efficiency will be still further increased, and probably it will be found the most economical and effective stove with an open fire of any yet introduced to public notice.

Register stove with a case.

The latest invention for warming air in this manner, by an open fire, is a plan proposed by Mr. Jeffrey, the inventor of the respirator, an instrument intended for

Jeffrey's stove.

warming the air before receiving it into the lungs. This stove is something similar in principle to the plan of the respirator, as nearly so at least as the difference of circumstances will allow. It is merely an ordinary open stove, projecting considerably into the room, in the manner of that last described, with a portion of the sides removed, as shown fig. 5, plate 50. The entire back of the stove above the fire consists of a series of flat tubes, one inch wide and about nine inches deep, which are placed edgeways one inch apart from each other, so as to present alternately a close and an open space of one inch. These tubes are about eighteen inches long, and reach quite to the top of the stove, and pass through the mantel-piece as shown at A, B. The only means by which the smoke can escape into the chimney is by passing through the openings left between these flat tubes, which are so connected as to prevent the smoke passing into the room at A, B. The lower end of these tubes opens into a small air-chamber which communicates with the external atmosphere, and the air therefore passes from this chamber through the flat tubes, and escapes at an elevated temperature into the room at A, B, being warmed in its passage through the tubes by the heat which has been abstracted from the smoke by the surface of the tubes. Nothing new in principle is obtained by this arrangement; the only difference between this plan and that of the many previous contrivances for the same purpose, is, that in this the heat which warms the air is derived from the smoke, in the others it is obtained by bringing the air into contact with the surface that is heated directly by the fuel contained in the stove itself. The method employed by Mr. Jeffrey appears very likely to cause the chimney to smoke unless the draught is particularly good; for the smoke must have so large a portion of its heat abstracted by passing between the flat tubes, that its power of ascending must necessarily be very much reduced, it being well known that it is merely the expansion by heat which causes the smoke in any chimney to ascend. The open sides also greatly increase the liability of the stove to smoke, by causing currents of air to cross each other, as Count Rumford long since pointed out. This stove also presents some difficulties in removing the soot from the chimney; at present the method of accomplishing this object is to remove a portion of the marble jambs of the fire-place.

The last two kinds of stoves which have been described, owe a considerable portion of the effect which they produce, to the heat being communicated by conduction to the air as it passes over the heated surface of the stove. This plan, we have already seen, was recommended and used upwards of one hundred and thirty years ago. Dr. Franklin in 1744 invented a stove for burning wood, in which this method of warming the air was one of the principal features.* This stove was called by its inventor the Pennsylvania stove. The form is that of an oblong box with the front removed. At about three or four inches from the back of this box a flat close chamber is fixed, three inches deep, the whole width of the stove, and reaching to within about four inches of the top. The smoke escapes over the top of this flat chamber, and passes downwards between it and the back of the stove before it finally escapes up the chimney. This hollow chamber communicates underneath the stove with a tube opening into the external atmosphere, and a considerable

Franklin's Pennsylvania stove.

* Franklin, *Works*, vol. ii. p. 225, *et seq.*

quantity of air thus passes through the flat chamber, and escapes into the room through small holes made at the sides after traversing the length of the chamber three or four times, by means of divisions placed across it for that purpose. The air rises through this chamber in consequence of being lighted when thus warmed, and it passes into the room at a moderate temperature. The stove is intended to stand prominently forward in the room, and therefore, in addition to the large quantity of hot air which passes through the chamber at the back, the air of the room is warmed by impinging against the sides of the stove; and a further portion of heat is also given off by radiation from the burning fuel, and from the surface of the stove itself. For the purpose of burning wood these stoves appear to be very economical and efficient; and some, nearly similar to them, have been adopted in England, in those parts of the country where wood is plentiful.

Franklin's vase stove.

A very elegant contrivance for a stove which burns coal, and at the same time consumes its own smoke, was invented by Dr. Franklin in 1771. Nearly a century previous to that time M. Delesme, a French engineer, described an exceedingly rude contrivance, on a similar principle, which was afterwards mentioned by Dr. Leutmann in a work on stoves published by him in Germany in 1723. Dr. Franklin acknowledged that this stove of Delesme's gave rise to his invention.* Fig. 6, plate 50, is a drawing of the stove as recommended by Dr. Franklin; and fig. 7 is a section of the same. This stove is capable of being made of the most elegant forms; in the figure, the top of the stove opens at A, B for the admission of fuel; C is the grate which supports the fuel; D is a square box forming the pedestal of the stove, at the bottom of which another grate is fixed to allow the ashes to fall into the box E. This box is open at the back, and communicates with the hot air passages *f*, *f* and *g*, *g*, through which the heated gaseous matter given off from the fuel passes before it enters the chimney. It will be perceived that the draught of this stove is *downwards;* that is, the air enters at a small hole, about one and a half inch diameter, at the top of the stove, passes through the fuel in the vase, and escapes, together with the gaseous products of the fuel, through the pedestal D, the box E, and the hot air passages *f*, *f* and *g*, *g*. That portion of the fuel which lies on the grate C is always red hot; and the smoke given off from any fresh fuel having to pass through this heated medium is consumed, and the gases pass off in a clear and almost invisible state, so that no smoke lodges either in the air passages or in the chimney. The operation of lighting the fire is, however, sometimes troublesome, particularly when the stove has not been used for a short time, and the chimney is quite cold. The stove requires, besides, a chimney which draws well; but with proper management, and by regulating the admission of air through the top of the stove, the fire may be made to burn without attention for a great many hours, and with an extremely small consumption of fuel.

This stove, with some slight variations, has within the last two or three years been again brought before the public as a new invention. The principal difference between Dr. Franklin's stove and the modern imitation of it, is, that in the latter a smoke pipe is placed about two-thirds of the way down the side of the vase, and

* Franklin, *Works*, vol. ii. p. 300.

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therefore as the smoke does not pass through the fire it is only partially consumed. A fire is perhaps easier kindled in this latter stove than in Dr. Franklin's, but it is very decidedly inferior to Dr. Franklin's both in the economy of fuel and in the effect produced, as well as in the regularity of its heat and the duration of its action. A full description of the stove invented by Dr. Franklin is given in his philosophical essays;* and perhaps if some slight alterations were made in it, by employing a fire clay lining to the lower part of the vase, where the fuel must heat the surface very highly, so as to reduce the temperature of the exterior case of the stove, and an effective method of regulating the supply of air at the top were employed, it would be one of the most economical stoves ever invented.

The objections which apply to close stoves, would of course be equally great with this as with all others which do not admit of a current of air passing through them, and without this the ventilation of a room is almost always defective, and the room therefore extremely unwholesome. It is certainly very possible to give complete ventilation to a room by other means wholly independent of the apparatus employed for warming it, but as this is rarely or never done in private dwelling-houses, the objection remains with all its force.

Perkins's stove.

Mr. Jacob Perkins some years since proposed a stove not very dissimilar in principle to Dr. Franklin's. The form of it was like an inverted syphon; the fuel was placed on a grating near the top of the shorter leg of the syphon, and therefore the draught being of course downwards, the smoke was consumed as in Dr. Franklin's stove, and the intensely heated gaseous matter passed off through the longer leg of the syphon, which was enclosed in another tube of larger diameter, to allow a current of air to pass between the two tubes. This plan however has never been applied except in a few cases for experiment.

Holland stove.

The Holland stove is a close plain case or box of iron, with a flue from the top, and a pipe to carry off the smoke. It is generally known by the name of the German stove, though the real German stoves are of a very different construction, and will be described in the next section of this Article. These Holland stoves are now nearly superseded by the stoves which are known by the name of hot air stoves, for which there are many excellent and ingenious plans.

Hot air stoves.

The general principle of the hot air stoves is that of an inner and outer case, the air being warmed by passing between the two cases. When the temperature of the stoves is not raised too high they afford a very useful and efficient means of heating buildings; but to avoid the ill effects of the air passing over an intensely heated surface, the dimensions of the stove ought to be very large in proportion to the fire box which contains the fuel. For the larger the surface of the stove is in proportion to the size of the fire box, the lower will be the temperature of the heating surface, and therefore the less injurious the effect produced upon the air. Owing to the rapid conducting power of iron, it allows of various methods, being employed to increase the extent of the heating surface of the stoves, and thereby to reduce their temperature, while, at the same time, the total effect is increased. One of the most recent inventions for this purpose is shown in figures 8 and 9, plate 50, for which a patent has recently been obtained by Mr. Sylvester.

Sylvester's hot air stove.

A, B, C, fig. 9, is a hollow cast-iron box, on the outside of which are cast several ribs *a*, *a*, *a*, &c., which are about three-fourths of an inch thick, and project three or four inches beyond the surface of the box. The object of these ribs is to increase the surface; for the fire being lighted in the hollow of the box, the conducting power of the iron causes the whole exterior case of the box, together with the projecting ribs, to become heated. This box is placed inside the ornamental case, fig. 8, the sides and top of which are fretted with lattice-work, to allow free access to the air, which enters through the lattices at the sides, and escapes from the top of the stove, passing in its passage over the ribbed surface of the heated fire box. The grating on which the fuel lies is formed from a number of loose bars fitted together into a frame, which are prolonged into the hollow bars A, B, C, &c., and which answer the double purpose of conveying air to the fuel, and of radiating heat into the room. They form an ornamental hearth to the stove, while they radiate a considerable quantity of heat, in consequence of being kept hot by the fire resting on their extremity. The advantage of this stove consists in the very great extent of surface which it exposes to the air; and no part of it acquires such an excessive temperature as to injure the quality of the air, while at the same time the effect produced by it in warming a room is very considerable. Another recommendation is, that it possesses an open fire, without which no stove can be completely healthy.

Cockle stoves.

The method of heating by cockle stoves is but little more than a modification of the ordinary hot air stoves adapted to a larger scale. Mr. Strutt of Belper, in Derbyshire, appears to have been the first person to introduce an improved method of heating by cockle stoves; and from the year 1792, when he first warmed his large cotton factories in this manner, various improvements have been made in these stoves, which, without at all altering their principles, have rendered their application more general.

The cockle stove consists of an iron case, which forms the top and sides of the furnace: this case or cockle is enclosed in another case of brick or stone, with appropriate openings for the admission of the cold air at the bottom, and for the emission of the hot air at the top,* which is from thence conveyed through channels or pipes to any place which is required to be warmed. A vast number of ingenious contrivances have been proposed for the improvement of this apparatus, and for many years it was the principal method of warming all the large buildings in England. Our limits prevent a particular description of the various improvements in cockle stoves; and it is the less necessary to describe them, for, from the injurious effects which are now generally acknowledged to be produced on the health of persons much exposed to the influence of these stoves, they have been in great measure superseded by the more approved methods of warming which will be described in the second section of this Article.

Bernhardt's hot air furnaces.

An invention somewhat similar in principle to the cockle stoves has been proposed by M. Bernhardt. In this method of heating, the fire is contained in a brick furnace of the ordinary construction: the further extremity of the furnace communicates with a sereis of sheet iron pipes, about six inches diameter, which are bent backwards and forwards, so that the smoke and

* Franklin, *Works*, vol. ii. p. 296, *et seq.*

* *Quarterly Journal of Science*, vol. ii. p. 201, and vol. xviii. p. 337.

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inflamed gases pass successively through them all before the smoke escapes into the chimney. The pipes are generally laid in pairs; so that the smoke from the furnace enters two pipes at once, and then leads into two more, and so on. These pipes, when thus arranged, are enclosed in a chamber a little larger than the space occupied by them, and openings are made in the lower part of the chamber for the admission of cold air, and at the top for the emission of the hot air. The air thus passing over the surface of the pipes is heated to a high temperature, and is then conducted into the rooms required to be warmed. By this arrangement the pipes which are nearest to the fire, and which first receive the smoke and inflamed gases from the furnace, become intensely heated, and produce all the bad effects which result from the worst kind of cockle stoves. They also have the disadvantage of being exceedingly troublesome to clean, from the large deposition of soot which takes place, and they also very rapidly wear out, in consequence of the thinness of the material of which they are constructed.

Dr. Nott's stove.

A hot air stove, which was invented by Dr. Nott of Philadelphia, has been found to produce very considerable heat with a small expenditure of fuel, and requiring but little attendance. This stove is usually something of a pyramidical form. The lower part, which forms the fire box, is lined with fire bricks, and the stove is divided vertically into two compartments. The fuel is put into the stove through an opening near the top, which forms a reservoir for the fuel and occupies the front part of the stove, and the smoke passes downwards through a grating placed at the bottom, and then escapes through the back part of the stove into the chimney. The air for the support of the combustion enters the stove principally on the top of the fuel, and a small portion also enters below. As the fuel burns but slowly, in consequence of the small quantity of air admitted, the fire box and reservoir when once filled will supply fuel for several hours, and give a very great heat. In fact the heat is generally so considerable, and the air is thereby rendered so arid, that it is extremely unpleasant and unwholesome to those who are exposed to its influence.

Dr. Arnott's stove.

One of the most economical stoves as regards the consumption of fuel that has yet been invented, is that which has been introduced by Dr. Arnott. This invention is an improvement upon Dr. Nott's stove above described, the principal difference in it being the limiting the admission of air, by which the combustion is regulated, and the excessive heat is in a great measure avoided. This plan of regulating the admission of air was, long previous to its application by Dr. Arnott, employed for limiting the intensity of the heat of furnaces, for which invention Dr. Ure some years since obtained a patent. Dr. Arnott's stove consists of an external case of iron, of any shape that fancy may dictate; within this case a fire clay box, to contain the fuel, is placed, having a grating at the bottom, and a space is left between the fire box and the exterior case so as to prevent, as much as possible, the communication of too much heat to the exterior case. The pedestal of the stove forms the ash-pit, and there is no communication between the stove and the ash-pit, except through the grating at the bottom of the fire-box. A small external hole in the ash-pit, covered by a valve, admits the air to the fire, and according as this valve is more or less open, the vividness of the combustion is increased or diminished, and thence the greater or less heat produced by the stove. The quantity of air admitted by this valve is governed by a self-regulating apparatus, either by the expansion and contraction of air confined by mercury in a tube, or by the unequal expansion of different metals, on the plan proposed by Dr. Ure. The smoke escapes through a pipe at the back of the stove; very little smoke, however, is eliminated in these stoves, the fuel being always either coke or anthracite coal. By adjusting the regulator so as to admit only a small quantity of air, the temperature of the stove is kept within the required limits; and owing to the slow conducting power of the fire clay, of which the fire box is formed, the heat of the fuel is concentrated within the fire box, and the fuel burns with less air, and therefore more slowly than it would otherwise do. But this slow combustion of the fuel produces a large quantity of carbonic oxide, which is liable to escape into the room; and being a strong narcotic poison, is attended with considerable danger to those who breathe it. The escape of this gas from these stoves has been experimentally ascertained by Dr. Ure: he attached to the ash-pit of a stove a glass vessel containing a solution of subacetate of lead, which was speedily acted on by the carbonic gas, and formed into the insoluble carbonate of lead.* Carburetted hydrogen gas is also frequently formed in these stoves, and many dangerous explosions have in consequence occurred. The endeavours to prevent these explosions have hitherto been unsuccessful; and so long as the principle of the extreme slow combustion and small admission of air is preserved, it will probably be impossible to prevent these occurrences occasionally taking place. They appear to arise from the inflammable gases generated during the combustion of the fuel being detained in the stove and in the chimney, by the want of a sufficient draught; and they particularly occur when the chimney is very large, or, if it consist merely of an iron pipe, when it is much exposed to the cooling influence of the atmosphere. In such cases the heat which escapes into the chimney is insufficient to warm the materials of which it is composed; and therefore the ascending gases are cooled in their passage too much to allow them to pass off with sufficient velocity to prevent their admixture with the atmospheric air; they therefore form in the stove and in the chimney explosive compounds, the effects of which become visible whenever the constituent gases mix together in certain proportions. The mixture of carburetted hydrogen and atmospheric air will explode whenever the carburet is not less than one-twelfth, and not more than one-sixth of the whole mass. The explosion of the carbonic oxide only takes place under particular circumstances; but a piece of red-hot charcoal will cause it to explode when mixed in the proportion of two measures of oxide to one of atmospheric air;† and it will also explode under certain circumstances, as Dr. Dalton has remarked,‡ when mixed in other proportions, the carbonic oxide being not less than one-fifth and the oxygen not less than one-thirteenth of the whole mixture. By increasing the admission of air and the rapidity of the draught in the stove, the liability to explosion will probably be lessened; but the temperature of the stoves would then be so much increased as to render them far more unwholesome than

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* Ure, *Dictionary of Arts, &c.*, Art. *Stove.*

† Dr. Henry, *Chemistry*, vol. ii. p. 347.

‡ *Chemical Philosophy*, p. 373.

the ordinary hot air stoves; for even with the present limited supply of air, the temperature is almost always sufficiently great to render the air both disagreeable and unwholesome.

Many alterations have been suggested by different manufacturers of these stoves, but hitherto without attaining any very decided advantages. In some instances a double case to the stove has been used, so as to admit air between them, which can either be applied to produce ventilation, or to prevent the exterior case attaining too high a temperature; but it remains yet to be proved whether this alteration is sufficient for the intended purpose. Considerable difficulty has been experienced in obtaining a thermometric regulator, simple in its construction, and sufficiently durable to withstand the high temperature and rough usage to which it is exposed in these stoves. Numerous plans have been proposed; but a patent for an improved regulator for this purpose has lately been obtained by Mr. Huxley, which, from its simplicity of form, appears likely to accomplish the desired objects. Various other alterations have been proposed by different manufacturers, but it is not necessary to specify them here.

Gas stoves.

The application of a method of burning carburetted hydrogen or coal gas, for the production of artificial heat for warming buildings, is an invention of rather recent date. The apparatus by which this is effected is very simple. A metallic ring, pierced on its upper side with a great number of holes, of very small size, is connected with a pipe communicating with the gas main, and is placed within a double drum or cylinder of iron, raised an inch or two from the floor, on small legs. This double drum is so made, that there is a space between the inner and the outer cylinder of about two inches; and in this space, near to the bottom, the ring pierced with holes is fixed. A stop-cock in the pipe connecting the pierced ring with the gas main shuts off the supply of gas when the stove is not in use. On opening this cock, and applying a light to the pierced ring, a brilliant ring of flame is immediately produced, which soon warms both the inner and the outer case of the stove, by the heat generated during the combustion of the carburetted hydrogen gas. The top of the drum is covered with a large open ventilator, by which the heated air that passes through the *inner* cylinder is allowed to escape into the room; and the exterior cylinder being likewise heated by the gas, warms the air which passes over its surface, and also radiates a quantity of heat into the room. By this arrangement it is evident the products of the combustion of the gas escape from the bottom of the stove into the room. This having been found exceedingly unwholesome, a plan has been contrived by which a considerable portion of the products of the combustion are carried off; the space between the two cylinders being closed at the top, and a pipe inserted which conveys away the gaseous products into the open air. By this latter arrangement, however, the quantity of heat received from the stove is reduced very nearly one-half. A moderately small stove of this description burns about fifteen cubic feet of carburetted hydrogen gas per hour; the combustion being produced by the oxygen of the air uniting with the *carbon* of the gas, forming carbonic acid gas; a further portion of oxygen uniting with the *hydrogen* of the gas and forming water. This latter product of the combustion first assumes the elastic state of steam, and it therefore contains a large quantity of latent heat; if this steam escapes before it is condensed, the whole of the *latent* heat is lost, besides a large quantity of heat from the other gaseous products of the combustion which also escape into the air. The stove under these circumstances becomes too expensive for ordinary use; for it is found, under the most favourable circumstances, to cost at least five times as much for fuel as a common hot air stove; and when the products of the combustion are carried off by a pipe, it is ascertained by calculation* that the stove costs for fuel about ten times as much as an ordinary hot air stove.

Joyce's stoves.

The apparatus invented by Mr. Joyce for burning charcoal is one of the latest methods that have been proposed for distributing artificial heat in buildings. The particular form of this apparatus is unimportant; generally it consists of a thin metal case in the form of an urn or vase. Through the bottom of this there is a small pipe which rises for two or three inches into the body of the stove, and terminates about the centre of the stove in a conical-shaped funnel, closed at the top and pierced with holes. The object of this pipe and funnel is to convey air to the burning fuel; and at the top of the stove there is a valve, or regulator, by which the rate of combustion can be controlled; for no more air will enter the lower pipe than is sufficient to replace the volume of gas given off from the valve at the top of the stove. A small quantity of ignited charcoal being placed in the stove, the remaining space is filled up with more charcoal, which is not ignited, and the combustion is slowly carried on by the air which enters at the lower pipe. The whole of the charcoal, when burned, is of course converted into carbonic acid gas, the effects of which on the animal economy we shall presently have occasion to show. Little or no smell is emitted by these stoves, the charcoal being deprived of its pungent quality by reburning it in a close oven, and quenching it while hot with an alkaline solution. Independent of all other considerations, these stoves are an expensive mode of producing heat, owing to the high price which charcoal always bears in this country.

These stoves are remarkable chiefly for the extraordinary interest which they excited on their first introduction to public notice; it being generally believed that the fuel, by the peculiar mode of preparation which was adopted, was deprived of all unwholesome qualities. This question excited much public discussion; but the result of various experiments proved that, although the mode of preparing the fuel prevented the disagreeable smell which usually attends the burning of charcoal, the unwholesome qualities of the charcoal were not at all lessened. The high anticipations, therefore, which were at first entertained of the utility of these stoves, have been entirely disappointed, and their use reduced within very narrow limits.

Russian stoves.

Stoves of a totally different character from any of the preceding are very generally used in Russia and Sweden. The shape of these stoves is usually either square or oblong; and they are divided by partitions into different compartments, so as to increase the surface over which the smoke and heated gases pass before they finally escape into the chimney. The surface of these stoves is generally formed of brick or stone, or some other slow conducting substance, the object being to obtain a large body of materials which will retain the

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* Hood, *Practical Treatise on Warming Buildings by Hot Water*, p. 199.

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Of the various descriptions of stoves used for cooking the limits of this article prevent any thing like a particular account. The contrivances for this purpose are almost innumerable. The ordinary kitchen ranges are, perhaps, the most wasteful method of producing heat of any thing hitherto invented; for probably not one-twentieth part of the heat given off by the coals is, in many cases, applied to any useful purpose. A great variety of cooking stoves have been invented, which are far more economical in fuel than the ordinary kitchen ranges. In nearly all of them steam is employed for the operations of cookery, and many are of very ingenious construction. Their great cost, however, is an objection to their more general introduction.

Anglo-Belgic stoves. A cooking stove that is much used in Belgium has been introduced here, with some slight improvements, which unites great economy in fuel with extreme simplicity of construction. Fig. 10, plate 50, represents a stove of this kind: A, B, C, D is a close oblong iron case; E, F is a cast-iron cover, with a flue between it and the case beneath, extending over the whole top of the case. G is the cover to a cast-iron fire pot, in shape like a crucible, which is seen in section at fig. 11; and H, I are two covers, which, on being removed, admit cooking utensils to fit into these openings. K and L are two doors, which open to admit any thing into the capacious chamber which forms the body of the stove. M, N are soot doors, and O the flue which passes into the chimney. The fire pot Z (fig. 11) receives the fuel through the opening at G: when it is filled with coke, and the fire lighted, the heated gases, flame, and smoke pass out through the opening *y*, in the side, and along the flue, over the whole length of the stove, making the top of the flue, E, F, sufficiently hot to perform upon it all ordinary operations of cookery. The fire pot Z becomes red hot; and not only can meat be roasted by the radiant heat from this highly heated body, but, at the further end of the large chamber, which is of a lower temperature than in the immediate vicinity of the fire pot, baking can readily be performed. The air which supports the combustion of the fuel enters the bottom of the fire pot through an opening at X. In economy of fuel, perhaps, this exceeds almost all other cooking stoves; an extremely small quantity of fuel being consumed in it. It is likewise much more simple in its operation than many contrivances of greater pretensions. Various modifications of this stove have already been brought before the public, of which the advantages are yet doubtful. They are mostly based on the principle of converting the stove into a large oven; and for this purpose the radiant heat of the fire pot is intercepted, thereby preventing the operation of *roasting;* although in the original form of the stove this operation can be performed with extreme facility.

Count Rumford, in his essays on heat, showed the great advantages of cooking by close stoves. The various apparatus he invented for the purpose were perhaps liable to some objections, although the effects he produced by them were decidedly in favour of such a mode of applying heat, as well for roasting as for all the other operations of cookery. The stoves last described appear to combine all the advantages of the plan suggested by Rumford, in addition to greater economy and compactness of arrangement. In fact these stoves are an invention which, when improved in some few particulars, promises to be of considerable value.

One of the most obvious improvements of which these stoves are capable, is the admission of a current of hot air through the oven or heated chamber during certain stages of the operation of roasting. The difference between roasting and baking appears to be not only in the different degrees of heat of the two operations, but also in a more free admission of air in the former case than is required in the latter. Count Rumford recommended, in reference to his improved apparatus for roasting, that a current of air should be passed through a highly heated pipe, by which it was to be admitted into the lower part of the roaster, and to escape from the top, carrying off the moisture with it. Some valuable information on this subject is contained in his tenth essay,* with various hints that may be usefully applied to the improvement of this stove, and the mode of cooking by it most advantageously. A singular fact noticed by him in his experiments may be mentioned. When meat was boiled in an oven, so that the water, though boiling hot, did not enter into violent ebullition, the water did not extract any thing from the meat, but remained perfectly clear after the meat was boiled; and therefore, when an extract of the meat was required to be made—as in soup—violent ebullition was necessary,† and for that reason some operations of cookery could not be satisfactorily performed in the apparatus invented by him. In the stove before us this inconvenience is avoided; and perhaps there is no operation of cookery which cannot be performed in it.

The stoves which have been described comprise nearly all that appear to claim attention either for their general utility or for any peculiarity of principle. Many others might have been added, had it been deemed desirable to describe all the different forms and constructions which have been proposed; but many of these are mere modifications of previous plans, and possess no merit as original inventions. Frequently the same plans have been brought forward at several different periods as new inventions; and we may instance, in proof of this, the method proposed in 1709 by M. Gauger, for bringing a current of air from the external atmosphere, and causing it to pass over the heated surface of the stove. Since that period, this plan, with but trifling modifications, has been repeatedly brought before the public as a new invention; and the same might be said of several other proposals for the improvement of stove grates. We shall presently have occasion to inquire into the effects produced on the animal economy by the several kinds of stoves that have been here described, but, previously, we shall proceed to consider a few other methods of distributing artificial heat.

Sect. 2.—*On the various Methods of producing artificial Heat in Stoves or Hot-houses.*

The invention of warming buildings by flues is of great antiquity. It was well known to both the Greeks and the Romans, and was used by them in the warming of their baths at a very early period. The inhabitants of northern China employ a somewhat similar method of

* *Essays* by Count Rumford, vol. iii. p. 97—191.

† *Ibid.* p. 183—188

 warming their houses in winter.* For this purpose the floors are double, and composed of tiles; and, by an ingenious arrangement of the tiles, the smoke and heated gases pass along the whole of the under surface of the floor, which, by its slow conducting power, diffuses an equable and permanent heat to the room.

For warming horticultural buildings, flues have long been used in England with considerable success. The principal defects of this mode of heating are, that the warmth is not regular in all parts of the building, and that noxious effluvia often escape from the flues, generally in consequence of some fissure caused by the unequal heating and cooling of the materials of which they are composed. The length to which these flues can be extended is limited; depending entirely upon the height of the chimney, which regulates the draught.

The method of heating by cockle stoves has frequently been adopted for stove rooms, particularly those used for manufactures. Of this kind are the different kilns and drying rooms; buildings for fermenting; and various other operations requiring a high temperature and large space.

On the general introduction of steam at the close of the last and the beginning of the present century, it was scarcely likely but that this powerful agent should be adopted as a means of distributing artificial heat. As early, indeed, as the year 1745 Colonel William Cook proposed a plan for heating the rooms of a house by steam from a copper boiler placed on the kitchen fire:† and before the close of that century other plans of generating steam for warming buildings were proposed, though they never obtained a general or successful introduction until within the last few years. In 1807 an excellent treatise on warming buildings by steam was published by Mr. Buchanan. At that period several large buildings had been warmed by steam with the most perfect success; and the extreme salubrity of the air when warmed in this manner, and the great economy of fuel, caused this invention soon afterwards to be very generally employed. Within the last twelve years, however, the plan of employing hot water circulating through iron pipes has been very extensively introduced; and at the present time it has almost entirely superseded the use of steam for the purpose of warming buildings. This method of circulating hot water was employed in France by M. Bonnemain in 1777; but it does not appear to have been used by any other person for a very long time afterwards. The Marquis de Chabannes introduced it into England in the year 1814, and he erected a few apparatus in different places on this principle. Very few buildings, however, for practical purposes were warmed on this plan until more than twelve or fourteen years after this period, when a considerable modification took place in the form of the apparatus, though not in the principle of its operation: and from that time until the present, the employment of this method of distributing artificial heat has been rapidly extended to a vast number of useful purposes. Not to protract this article to a greater length than is necessary, we shall confine our remarks to this latter method of heating buildings, as it appears likely that it will entirely supersede the use of steam, as well as the plan of using flues. Those who wish for information on the best plan of applying steam heat will find ample information in Buchanan's treatise on heating by steam, and also in Tredgold's work on the same subject.

The great advantages which the hot-water apparatus possesses over that in which steam is employed, consists in its superior simplicity, safety, economy, and permanence of temperature. It is likewise far less liable to casual derangement, and requires even less management than a common fire. With these advantages it is not surprising that it should now be so very generally used for warming large buildings, and particularly those that are used for horticultural purposes.

The principle of this apparatus is extremely simple. Suppose an apparatus to consist of a boiler, communicating by an upper and lower pipe with an upright pipe the same height as the boiler. Now on heat being applied to the boiler, the column of water in it becomes lighter than that in the upright pipe; therefore the pressure on the water in the lower pipe being less at the end nearest to the boiler than it is at the other end, a portion of the water in this lower pipe moves forward towards the boiler, which causes a corresponding quantity to pass along the upper pipe in a contrary direction to supply the deficiency. This motion will necessarily continue as long as the column of water in the boiler is hotter, and therefore lighter, than that in the upright pipe; and this must be the case so long as the boiler continues to receive heat from the fire, and the pipes to part with their heat to the air, and thereby cool the water contained in them. In whatever form the hot-water apparatus is constructed, this difference of pressure of the two columns of water is the cause of the circulation; and although in some forms of the apparatus this may not at first clearly appear, it will be found on examination to be rigorously correct of every variety of construction which can be given to the apparatus.

It is very desirable always to obtain as rapid a circulation of the water through the apparatus as possible. The cause of the circulation being the difference of the specific gravity of the two columns of water, it is evident that the greater the *height* of these columns the greater will be the difference of pressure; and therefore the principal means of increasing the rapidity of the circulation, is by increasing the vertical height of the pipes above the boiler. By allowing the water to cool a greater number of degrees before it returns to the boiler, the difference of pressure is likewise increased; but as this is principally effected by reducing the diameter of the pipes, the friction is so much increased, that comparatively but little additional velocity is gained by this means.

The actual amount of motive power, or, in other words, the real amount of difference of pressure in this kind of apparatus, is usually very trifling. The difference of temperature between the flow and the return pipe seldom exceeds a very few degrees, and therefore the differenee of pressure must necessarily be very small. It is capable of being made the subject of tolerably accurate calculation, and it is found that frequently the motive power, which puts in motion sometimes several hundred gallons of water, does not exceed one ounce in weight, and very often it is not one-half or that amount.

The theoretical velocity of circulation can also be obtained by calculation; but we have not sufficient knowledge of the diminution of velocity sustained by water in flowing through pipes under different and

* Franklin, *Works*, vol. ii. p. 292.

† *Philosophical Transactions, Abridg.* vol. ix. p. 125.

complicated arrangements, to be able to deduce accurately the velocity which will actually be obtained in any complicated form of the apparatus. One great impediment to the circulation—and indeed it is a circumstance which frequently stops the circulation entirely—is the accumulation of air in the pipes and other parts of the apparatus. The extreme levity of air compared with water causes it always to occupy the highest parts of the apparatus; and when once it lodges there, it cannot be made to descend so as to pass an obstruction, or to escape through a vent at a lower level than the place where it has lodged. Want of attention to this fact has caused innumerable failures in the hot-water apparatus; and it requires great care, and some knowledge of the dynamics of fluids, to place the vents in proper parts of the apparatus to carry off the air which always requires to be discharged from it.

It is extremely important to ascertain correctly the quantity of heated surface which is necessary to warm any building to the required temperature. The loss of heat in buildings arises principally from the glass used for the windows. Brick, of which the walls of most buildings are constructed, is a slow conductor of heat; and, from the thickness which brick walls usually possess, the loss of heat by this cause is very small. But glass, in consequence of its extreme thinness, although it is likewise a bad conductor of heat, cools the air of a building with great rapidity. By experiments made for this purpose, it appears that glass of the thickness of ·0825 of an inch—which is about the average thickness generally used for windows—will cool 1·279 cubic feet of the air of a room as many degrees *per minute* as the temperature of the room exceeds that of the external atmosphere;* so that this quantity of air will be cooled by each square foot of glass as many degrees per minute as the internal exceeds the external temperature.

In ordinary buildings it is scarcely necessary to make any allowance for the heat lost by the conducting power of the walls, as this is generally extremely small; as likewise is that which arises from the imperfect fitting of doors and windows. But in extreme cases all these causes of loss must be taken into account in estimating the extent of heated surface required to warm the building; and whenever there is any ventilation the amount must be carefully computed, as the loss in this way is generally very considerable. (See Article VENTILATION.) When the quantity of air to be warmed per minute has been ascertained, the necessary extent of surface of the hot-water pipes can be calculated with considerable accuracy.

From experiments made on the heating power of iron pipes containing hot water,† it has been deduced, as a result, that one square foot of surface will heat 222 cubic feet of air 1° per minute, when the difference between the temperature of the heated surface and the air is 125°. Hence we obtain an easy rule for calculating the surface required, at any other difference of temperature, as follows:—Multiply 125 by the *difference* between the temperature at which the room is purposed to be kept when at its maximum, and the temperature of the external air, and divide this product by the *difference* between the temperature of the pipes and the proposed temperature of the room; then the quotient, thus obtained, when multiplied by the number of cubic feet of air to be warmed per minute, and this product divided by 222, will give the number of square feet of heated surface which will produce the desired effect.*

By this method of calculation it might appear that, by only allowing sufficient heating surface to compensate for the actual loss which occurs by the radiation from the glass and by the escape of the heated air from the room, the room itself will not become heated. But a little consideration will show that this is not the case. The heat lost by the room must at first be extremely small; and until the room reaches its maximum temperature the pipes continue to radiate more heat to the air of the room than the room itself loses, therefore, whatever quantity of heated surface will suffice to balance the loss sustained by the room at its maximum heat, will necessarily be sufficient to warm it in the first instance.

A considerable difference will obtain in the lengtn of time necessary to heat any building according as large or small pipes are used for the purpose. The effect produced is of course, in all cases, proportional to the rapidity with which the water contained in the pipe or other vessel cools. This rate of cooling is always *inversely as the mass divided by the superfices*, which in the instance of comparing pipes of different diameters with each other, is exactly equal to the *inverse of the diameters;* therefore pipes of two inches diameter will heat a building in half the time that pipes of four inches will do, if the same extent of surface be employed in both cases. But as the rate at which the pipes themselves cool, is in the same proportion as that in which they heat the building, small pipes will retain their heat a much shorter time than large ones after the fire is extinguished; and hence it often becomes desirable to sacrifice something of the rapidity with which a building may be warmed, in order to secure the advantage of retaining the temperature with but little variation when the intensity of the fire has become reduced, or the fire wholly extinguished. Under any circumstances, however, a building heated by hot water will retain its temperature very much longer than it would if it were heated by steam. If the same sized pipes were used in both cases, the difference would be nearly in the proportion of six or eight to one.

The extremely small size of the boilers used for the hot-water apparatus is another great advantage which this method of heating possesses over steam heat. The best dimensions for boilers, under ordinary circumstances, are to allow one square foot of surface to be exposed to the *direct* action of the fire for sixty square feet of radiating surface of pipe. With a very small apparatus, however, the proportion of boiler surface must be considerably larger, on account of the difficulty of making a small fire act upon the whole surface exposed. In calculating the surface of the boiler exposed to the fire, the flues should only be reckoned at one-half their actual measurement, because the action of the fire not

* Hood, *On Warming Buildings, &c.* p. 104.

† *Ibid.* p. 111.

* Let p be the temperature of the pipe, and t the temperatute the room is required to be kept at; then $\frac{125}{p-t} = x$, which will re present the number of square feet of heated surface that will warm 222 cubic feet of air 1° per minute, when $p - t$ is different to the proportions given above. If d represents the difference between the internal and the external temperature of the room, and c the number of cubic feet of air which are to be warmed per minute, then $x \cdot \frac{d\ c}{222} = F$ will be the number of square feet of heated surface, which will warm any quantity of air per minute according to the calculations given above.

 being *direct* upon them, the effect is proportionably less.

One of the characteristic features of this apparatus is, that the water in some part or another has a free communication with the atmosphere, so as to prevent the formation of steam of greater elasticity than the ordinary atmospheric pressure. In this consists its perfect safety; for the instant steam is generated it escapes from the apparatus, and thus prevents the possibility of explosion.

Several modifications of the hot-water apparatus have been adopted by different persons. A very ingenious plan has been invented by Mr. Kewley on the principle of the syphon. A pipe is made to dip into an open boiler, reaching only an inch or two below the surface of the water, and passing round the room to be warmed, returns to the boiler and dips again into the water, descending quite to the bottom of the boiler. An air-pump is connected with this pipe by a small tube; and the air in the pipe being exhausted by this means, the water rises into the pipes above the level of the boiler by atmospheric pressure, and the circulation then takes place, by the hot water ascending through the pipe at the top of the boiler, and passing through the whole circuit of the pipe, it returns through the other end of the pipe which reaches to the bottom of the boiler.

One of the inconveniences of this form of the apparatus is, that the pipes cannot be carried to any considerable height above the boiler. The atmospheric pressure will raise the water in the pipes thirty feet above the top of the boiler; but in the operation of this apparatus another cause comes into action which considerably modifies the result. The boiling point of liquids varies with the pressure; so that when the pipes rise a few feet above the boiler, the water contained in them will boil and form steam, when the temperature is many degrees below 212°, the usual boiling point of water. For it will be evident that if the atmospheric pressure will only raise the water thirty feet high in a vertical pipe, the water above that height must be without any pressure at the top of the pipe, just as though it were in vacuo. At fifteen feet above the boiler the pressure will be one-half the ordinary atmospheric pressure, and so on for other heights. By Wollaston's experiments with his barometric thermometer it appears that a diminution of pressure equal to about five feet of water will cause the boiling point of that fluid to be about 9° lower than under the ordinary atmospheric pressure. Other differences of pressure will also be in proportion to this: and Professor Robison's experiments show that in vacuo the boiling point of water is even as low as 88° only.

When the pipes, of this form of the hot-water apparatus, rise to any considerable height above the boiler, if the water becomes by any accident too hot, steam is formed in the pipes, and the water is forced down into the boiler and causes it to overflow. This inconvenience is peculiar to the syphon principle, which otherwise appears to answer the intended purpose extremely well; and where the pipes are not required to rise much above the boiler, no inconvenience of this kind can occur.

A form of apparatus which has been a good deal used is that which is known as the high pressure principle. This apparatus consists of a spiral coil of small iron pipe built into a furnace, the pipe being carried from the upper part of the coil, and continued round the room intended to be warmed, forming a continuous pipe when again joined to the bottom of the coil. The size of this pipe is usually only half an inch diameter internally, and one inch externally. A large pipe of about two and a half inches diameter is connected, either horizontally or vertically, with the small pipe, and is placed at the highest point of the apparatus. This large pipe, which is called the "expansion pipe," has an opening near to its lower extremity, by which the apparatus is filled with water, the aperture being afterwards secured by a strong screw; but the expansion pipe itself cannot be filled higher than the opening just named. After the water is introduced the screw is securely fastened, and the apparatus becomes, as it were, hermetically sealed. The expansion pipe, which is thus left empty, is calculated to hold about one-tenth or one-twelfth as much water as the whole of the small pipes, this being necessary in order to allow for the expansion that takes place in the volume of the water when heated, and which would otherwise inevitably burst the pipes, however strong they might be.

The temperature of the pipes when thus arranged can be raised to a very great extent, because, as the steam cannot escape, the only limit to the temperature is the strength of the pipes to resist the expansive force of the water and the steam. The pressure, however, in this apparatus is enormous; it is found to vary according to the heat of the furnace, sometimes reaching as high as twelve hundred pounds on the square inch. A great difficulty arises in apportioning the proper size of the expansion pipe; for if this pipe be made too large, the water is driven out of the coil into the expansion pipe, and the coil is then destroyed by the intense heat of the fire; if, on the other hand, the expansion pipe be not sufficiently large to allow for the expansion of the water, the apparatus must inevitably burst. To fix the exact size for this expansion pipe is therefore an important point; but as its required capacity must vary with the temperature of the water in the pipes, and as this temperature has no fixed limit, it is extremely difficult to assign any standard proportion which it ought to bear to the rest of the apparatus.

It will be observed at once that this apparatus differs in all essential particulars from the ordinary hot-water apparatus. By its extremely high temperature all the unpleasant effects that arise from a vitiated state of the atmosphere are produced, the same as from the use of the hot air stoves; and it possesses none of that uniformity and permanence of temperature which characterise the apparatus with large pipes, and which form such important features in that system of diffusing artificial heat.

The hot-water apparatus invented by Mr. Price differs but little from that of the ordinary form. The principal difference lies in the substitution of large flat boxes or chambers filled with hot water for the round pipes ordinarily employed. These boxes or chambers, which are from thirty to thirty-six inches square, and about two and a half or three inches deep, are usually fixed vertically, several being placed together, separated by an interval of about one and a half or two inches, and all connected together, so that they are supplied simultaneously with hot water from the boiler, another pipe conveying the cooler water from them back again to the boiler. By this plan a large heated surface is exposed to the air, which is therefore quickly heated; but, from the large size of the apparatus, it is generally necessary to place it in a vault or room below that which is to be warmed, and to heat the room or building by admitting

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Another form of apparatus was invented by Mr. Busby. It differs from all the others previously described; its principal feature being, that the hot water *descends*, and the cold water *ascends*, in consequence of a very simple mechanical arrangement. An open boiler has a circular float, nearly as deep as the boiler, placed within it, the leaves of which move round a vertical axis. The spindle of the float rises considerably above the boiler, and a fly-wheel is attached to it, passing into the chimney, similar to a smoke-jack. On motion being given to this float by the smoke of the furnace, the water in the boiler obtains a rotatory motion, and it rises higher at the circumference than at the centre of the boiler in consequence of its centrifugal force. A pipe is fixed near the bottom of the boiler, on one side, and after passing downwards to any required depth—say fifty or one hundred feet—it returns up again, and enters the boiler close to the centre of the bottom. As the water, in consequence of its centrifugal force, stands at a higher level at the sides of the boiler than it does at the centre, the end of the pipe which is placed at the side of the boiler has a greater pressure upon it than that at the centre, and therefore the water *descends* through the pipe issuing from the side of the boiler, and returns back again through that placed at the centre. The depth to which the water can be made to descend in this manner is very considerable, and it depends upon the velocity with which the float revolves. This apparatus is a happy application of dynamical principles to produce an effect which at first appears contrary to the laws of gravity; and the invention, although hitherto but little used, is capable of easy application in cases where the same object cannot be produced by more simple means.

Such is a general description of some of the most usual forms of the hot-water apparatus. Although the application of hot water circulating in iron pipes for the warming of buildings is of comparatively a recent date, yet the principle of this kind of circulation was well known to the ancient Romans, having been employed by them in the Thermæ at Rome for heating the water of the baths. The plan adopted by them was so exactly similar to the most approved method employed for the same purpose at the present day, that were it not for the difference in the furnace, it would be difficult to imagine that the figures given of the Roman baths* were not those of modern times. It is certain, however, that the application of this principle of the circulation of hot water to the warming of buildings is of comparatively modern date, having been first used in the latter part of the last century; but it appears so completely to accomplish all the desiderata which theory suggests, that in the course of time it will probably supersede most other plans in all those cases where a large space is required to be heated.

Sect. 3.—*On the Construction of Stove-rooms and Hot-houses.*

The construction of stove-rooms and their application to manufactures and the arts, are not less important than are hot-houses for the purposes of horticulture. Stove-rooms being employed chiefly for the purposes of drying, their efficiency depends principally upon the methods of warming and ventilation. It is but very seldom, however, that perfect ventilation is adopted in buildings of this description; for it is generally imagined that the process of drying is dependent merely upon the quantity of heat which is produced, whereas, in fact, it can be easily demonstrated that good ventilation, with a moderate heat, will perfect the process of drying far better and quicker than an intense heat with imperfect ventilation. It is evident that the process of drying is merely the evaporation of moisture. The air is the medium by which the moisture is carried off; but if the air be not changed as fast as it imbibes the moisture, it soon becomes saturated, and cannot then absorb a further quantity. Hence it is that, in badly constructed drying rooms, the process of drying is exceedingly slow, notwithstanding they are maintained at a very elevated temperature. This error is extremely prevalent. There are innumerable stove-rooms used in various branches of manufactures which are kept at a far higher temperature than the occasion requires, under the idea that this high temperature is necessary in order to perfect the process of drying. Many processes connected with the printing and dyeing of silks, muslins, and calicoes, with various operations of an analogous nature, are performed in rooms of a far higher temperature than is necessary, in order to compensate for defective ventilation; and it may be taken as a general rule, that increasing the quantity of dry air which passes through a drying room of any kind, produces a much greater effect than increasing the temperature of the room. The method of warming such rooms is also a matter of some importance. By heating the air very highly by cockle stoves, or other means, the chemical properties of the air are in some degree changed, and produce an effect upon many of the colours used in dyeing and printing; but by employing the mild and genial heat from steam or hot-water pipes, no injury whatever can result to the most delicate colours; and with efficient ventilation the process of drying can be effected even in a far shorter time with this mild and moderate heat, than by the old methods of constructing drying rooms.

The subject of ventilation is fully discussed in the article under that head; it is therefore unnecessary to enlarge upon it here. In drying rooms, however, on account of the large quantity of moisture which is generally carried off with the air through the ventilating tubes, it is necessary to construct these tubes in such a manner, and of such materials, that the vapour shall not be condensed in passing through them; for the vapour under these circumstances is very readily condensed, and when this occurs an inconvenience arises in carrying off the water of the condensed vapour.

For the construction of hot-houses for horticultural purposes innumerable plans have at different times been proposed. It has sometimes been recommended to form the walls double and hollow, so as to prevent the waste of heat by conduction through the brick walls. But when we consider the large quantity of glass which it is necessary to have in horticultural buildings, it may perhaps be questioned whether it is worth the while to incur the expense of this mode of construction, in order to save a quantity of heat, which can scarcely be appreciated in buildings where such an enormously greater quantity is lost by the cooling power of the glass; for a

* Castell, *Illustrations of the Villas of the Ancients.*

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The inclination with the horizon, which the slanting roof of glass possesses, makes a material difference in those houses where the whole of the heat is not produced artificially. The greatest effect from the sun's rays is produced when they fall perpendicularly on the glass; and a greater or less proportion of these rays is reflected according to the angle of incidence at which they fall. It is evident, therefore, that the inclination of the roof which will produce the greatest effect will vary both with the latitude of the place, and with the season of the year at which it is desired to take advantage of the heating influence of the sun's rays. By taking the latitude of the place, and *subtracting* from it the sun's declination at the particular time, if it be north, or *adding* it if it be south declination, the result will be the angle which the roof ought to make with the horizon, in order to receive the largest number of the sun's rays.*

The best manner of glazing the roofs of hot-houses is a subject which has been much discussed. It has been proposed to make them air tight, and thus prevent any loss of heat by the escape of air through the laps of the glass. But it seems to be now generally allowed, although experiments have proved that plants will live for very long periods in air-tight receptacles, that a moderate degree of ventilation is desirable for preserving plants in a healthy condition, and that this ventilation can be given more equably by means of the small escape of air through the laps of the glass in the roof than by any other means.

It was formerly an object of considerable importance to obtain a self-acting apparatus for regulating the temperature of hot-houses, and many inventions have been proposed for this purpose. The old method of heating by flues, and also the plan of employing steam, were so liable to sudden variations of temperature, that frequently the loss of the entire produce of a house resulted from a sudden and unforeseen alteration of the temperature of the house. The introduction of the method of heating these buildings by hot water, appears, however, to have rendered unnecessary any plan of this kind; for the temperature of houses warmed by hot water is so equable and permanent, that it is scarcely possible, under any circumstances, for injurious alterations of temperature to occur in houses heated on this plan. Indeed, so great in this particular are the advantages of this method of warming buildings, that were it possessed of no other recommendations but those of the equality and permanence of temperature, they would alone be sufficient to ensure its adoption in all buildings used for horticultural purposes.

Sect. 4.—*On the Chemical and Physical Changes produced in Atmospheric Air by the several methods employed for warming buildings, and the Physiological Effects which thereby result to the animal and vegetable organization.*

In considering the various methods used for distributing artificial heat, if we regard merely the quantity of heat evolved, or the amount of fuel consumed, without reference to the physiological effects which result from the different plans, we shall frequently form a very erroneous estimate of the value of any particular invention. There are many methods of warming buildings, which accomplish all that can be desired, as far as regards the quantity of heat evolved; but when we consider their physiological effects, we shall perhaps find them to be of a most destructive character. These effects are principally owing to the changes which are produced in the composition of the air by the various methods of warming it; and this subject is so important to all who employ artificial heat, that we shall here examine it at some length.

The constituents of atmospheric air, although nearly uniform in their proportions, are liable to continual variations within certain narrow limits. Dr. Dalton, from a series of observations continued for many years, has found the maximum proportion of oxygen in atmospheric air to be 21·12 per cent., and the minimum 20·58 per cent., when the air is pure and uncontaminated by respiration, or by artificial means.* The quantity of carbonic acid gas which exists in the air has been found on an average to be about 0·1 per cent., or about 1-1000th part of the mass; and the vapour of water which constitutes the moisture of the atmosphere varies from about 1·5 to 6 grains in each cubic foot of air. These substances, with the addition of about 79 per cent. of nitrogen, constitute the natural elements of the atmosphere. Other substances, however, are always present in it, in a greater or less degree, and these foreign matters greatly affect the wholesomeness of the air, and produce some very important physiological effects.

Many of these foreign substances are extremely difficult of detection by the most refined methods of chemical analysis; and yet we possess the most indubitable proofs of their presence. Thus by the sense of smell we frequently discover these substances to be present in the air when they exist in quantities far too minute for detection by chemical means. The offensive effluvia from decomposed animal and vegetable matter; the miasmata arising from infection; the fragrant perfume from odoriferous bodies; are all equally owing to the presence of foreign substances in the air, generally so minute in quantity as to be inappreciable by any chemical tests. But another of our senses also affords proofs of this fact. The myriads of motes which float in the sunbeams are matter in its first stages of decomposition, before it has assumed the true state of gasefaction. Many of these minute particles are of vegetable and animal origin; and a very moderate degree of heat decomposes these substances, and resolves them into their various elementary gases. Hence many of the methods of producing artificial heat are materially affected, as regards their wholesomeness, by the fact whether or not they are capable of decomposing or chemically altering these floating particles of matter.

The unpleasant smell produced by various kinds of hot air stoves and cockles is almost entirely produced by the decomposition of these extraneous substances contained in the air; and the gaseous products which are formed from these decompositions vary according to the nature of the substances, and the degree of heat to which they are exposed. But in addition to this source of deterioration of the air by the use of highly heated

* Tredgold, *Treatise of Heating by Steam*, p. 202.

* *Phil. Transactions*, 1837; and *Lond. and Edin. Phil. Mag.* vol. xii. p. 402.

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metallic surfaces, there is another which is of still more importance. We have already seen that the air always contains a quantity of vapour of water; this by passing over highly heated iron is decomposed, the *oxygen* uniting with the iron and forming oxide of iron, the *hydrogen* being eliminated and mixing with the air of the room.

The effects of breathing hydrogen gas are exceedingly injurious. Signor Cardone inhaled about thirty cubic inches of this gas, and was immediately affected with an oppressive difficulty of breathing, painful constriction at the superior orifice of the stomach, followed by abundant perspiration, tremor of the body, heat, nausea, and violent headach; his vision became indistinct, and a deep murmur confused his hearing. Other persons have been similarly affected; and in one recent instance the experimentalist was so much injured by it, that for several months afterwards he suffered most severely from its effects.

One of the injurious effects produced by highly heated surfaces arises from the greatly increased capacity for moisture which it produces on the air. The capacity of air for moisture increases with the temperature; at 32° air contains a quantity of vapour equal to 1-160th part of its weight; at 59° it contains 1-80th of its weight; and at 86° it contains 1-40th; its capacity for moisture being doubled by each increase of 27° of Fahrenheit. But when air is artificially heated, without being in contact with water, it is prevented from acquiring this additional quantity of vapour, and it then possesses a harsh and arid feel, which is exceedingly oppressive and injurious to the animal economy. When air in this state is received into the lungs, its excessive dryness causes it to absorb so much moisture, that the pulmonary discharge becomes excessive, and therefore exceedingly injurious. Besides this, the air rapidly absorbs the moisture from the skin; and this evaporation, by its refrigerating effect, contracts the blood-vessels at the surface, while other parts not being exposed to this influence become in consequence surcharged with the fluids which are repelled from the extremities.* The consequences of these effects are frequently very visible on those much exposed to their influence. Dr. Ure examined a great number of the gentlemen attached to the Customs department in London, where the rooms are heated by large cockle stoves, and which stoves, from their excessive temperature, produce an extremely dry state of the atmosphere. He found these individuals all affected in the same way: tension of the head; flushings of the countenance; throbbing of the temples; vertigo, and occasional confusion of ideas; together with coldness of the extremities, languid pulse, and various other effects of a similar character, were the usual sensations which they all experienced.

Effects such as these, however they may be disregarded as occasional symptoms, become of much importance when they are the result of causes in constant operation. A case which came under the notice of the author of these observations, exhibits in a still stronger manner the injurious effects of breathing such an atmosphere. An apparatus which had been erected for warming a school was found to produce effects extremely prejudicial to the health of those exposed to its influence, and the author was requested to give his opinion respecting the cause of the evil complained of. The apparatus in question was a cockle stove of the ordinary construction, but possessing a very strong draught; the furnace, so that the cockle was almost always, when in use, at a red heat. The air passed over this intensely heated surface through a tunnel constructed for the purpose communicating with the exterior of the building, and it then entered the room through large ventilators placed about two feet above the floor. The vapour of the air, by passing over this intensely heated surface, was partly decomposed, as were also the floating particles of matter contained in the air. The capacity of the air for moisture was also at the same time greatly increased by being so highly heated. The effects produced by breathing this factitious atmosphere were remarkable. A sensation of tension of the head, accompanied with excessive languor and faintness, made the children continually ask permission to go into the fresh air to relieve these sensations; and so imperative was the necessity for this, that on several occasions when it had not been complied with, the children dropped from off their seats in fainting fits, and were carried out of the room in a state of insensibility. Those children who were placed nearest to the hot air tubes suffered from these effects in the greatest degree; and the usher of the school, a strong and healthy young man, likewise experienced the same sensations; and on one occasion he fell down in the school in a fainting fit, and it was a considerable time before animation returned, on the application of various restoratives.

It requires no arguments to prove that effects such as these cannot long be permitted to operate on the human frame without causing considerable derangement of the animal organization, and that they must lay the foundation of permanent valetudinarianism, and shorten the duration of life.

These effects are not peculiar to the apparatus just described; they always result from using, as a means of distributing artificial heat, any very highly heated metallic surfaces. For although the arid condition of the atmosphere may be remedied by artificially distributing moisture to the air, still, the mere fact of attempering its excessive dryness by fresh supplies of moisture, will not counteract the effects of the extraneous gases which are eliminated, by the decomposition of the vapour and floating particles of matter originally existing in the air. If, therefore, the heating surface is of a sufficiently high temperature to produce these decompositions, the air is permanently injured in its vital qualities, and it can in no wise be restored to its pristine healthiness by artificial means.

These remarks apply to all the various kinds of hot air stoves; as also to Bernhardt's and to Dr. Arnott's stoves; and in short to any apparatus of which the temperature much exceeds the boiling point of water. In Dr. Arnott's stoves, however, another source of deterioration of the air arises, in consequence of the slow combustion of the fuel and the small draught of the air through the stove. By a slow combustion of coke a considerable quantity of carbonic oxide is generated, which is extremely liable to escape into the room, in consequence of the draught of the stove being insufficient to carry off the gases formed by the combustion of the fuel. This gas is highly injurious to animal life, and asphixia is produced by it, even when it is largely mixed with atmospheric air. It is considered by some physiologists to be even more prejudicial than the carbonic acid gas, of which we shall presently have occasion to speak more at large.

* Dr. Ure *on Ventilating, &c. Phil. Trans.* 1836.

STOVE.

The gas stoves produce effects that are of a totally different character to those which have been stated to result from the use of hot air stoves. By the gas stoves a moist heat is produced; for the carburetted hydrogen gas which is consumed forms by combustion two new compounds; the *carbon* uniting with a portion of the oxygen of the air, and forming carbonic acid; the *hydrogen* uniting with another portion of oxygen and forming water. A small-sized stove of this description burns about fifteen cubic feet of gas per hour, and the products of this combustion are fifteen cubic feet of carbonic acid gas and a pint and a quarter of water, besides one hundred and twenty cubic feet of nitrogen which is separated from the atmospheric air, and which, being deprived of its oxygen, is unable to support animal life.

The effects produced by these stoves give rise to some interesting questions of pathology which demand a few remarks.

Carbonic acid gas, when inhaled into the lungs, it is well known, produces instantaneous suffocation. Even when the quantity is insufficient to produce this result, the effects are very injurious to the human constitution. Intense headach, and a sensation of syncope, are the most common effects of breathing an atmosphere containing any considerable quantity of carbonic acid gas. For in this case the blood is not sufficiently decarbonized by the air passing through the lungs, and it rises to the brain unfit for its purpose. An excess of venous blood in the arteries of the head necessarily follows, immediately producing confusion of ideas; and if the exciting cause be of sufficient force and duration the brain becomes gorged with the venous blood, syncope, and, finally, death, follow as the natural results. The effect appears to be precisely identical with many cases of apoplexy, where the only apparent change which takes place is in the *quality* of the blood contained in the head, the *quantity* being always the same* under ordinary degrees of atmospheric pressure. And so delicate is the organization of the brain, that the effect of any such change in the blood instantly produces the most serious consequences.

The effects of nitrogen on animal life appear to be of a negative character. It is unable to effect the sanguification of the blood, and its presence in atmospheric air, in an undue quantity, must lessen the proportion of oxygen, and therefore deprive the air of its power of carrying on the vital functions. For unless atmospheric air contains more than ten per cent. of oxygen the process of respiration cannot separate *any* oxygen from it; and as from four to eight per cent. of oxygen, according to circumstances, is required to be absorbed by the lungs from all air that passes through them, and we have seen that air contains only about twenty per cent. of this gas, it follows that if such an undue quantity of nitrogen be added to the air, or, which is the same thing, if so much oxygen be abstracted by combustion as shall considerably reduce the natural proportions which exist in atmospheric air, the proper quantity of oxygen cannot be separated by respiration, and the consequence must be that the blood will be only partially decarbonized in its passage through the lungs, and similar results will occur as though carbonic acid gas were inhaled.†

The presence of a large quantity of vapour of water in the atmosphere, which is another of the products of the combustion of the gas in these stoves, although detrimental to the animal economy, owes its deleterious action to a different cause to that of the gases we have been considering. Vapour of water is known to exist in the air in the same manner as in a vacuum. It is an addition to the air, but it in no way affects the relative proportions of its constituents. But when warm air is saturated with moisture it is unable to carry off the due quantity of perspirable matter from the skin and lungs and the natural exhalations are thus prevented. All physiologists agree as to the injurious effects of a heated atmosphere saturated with moisture; and the prevailing diseases of different countries and seasons have been generally attributed by medical writers to the variable quantity of moisture contained in the air. Hippocrates, by a comparison of the prevailing diseases with the state of the weather, and particularly as respected the moisture of the air, drew conclusions which the observations of succeeding ages have fully confirmed. Excessive dryness, or an extraordinary degree of moisture, equally destroys the salubrity of the air; though the diseases produced by these opposite states are, as might be imagined, of a very different character;* and the history of nearly all endemic diseases is evidence of the truth of this proposition. The Monsoon, or rainy season of India, the Campsin, or southerly wind of Egypt, and the Simoom, or hot dry wind of the Asiatic continent—which is still more destructive than either—are some among the numerous instances which might be adduced to prove the effects of various excessive degrees of heat, moisture, and dryness of the air. But we also possess the most satisfactory statistical evidence of the unhealthiness of extraordinary degrees of moisture in the air. M. Quetelet, in his celebrated work on Man,† states, in reference to the effects of climate on the duration of human life, that the deaths annually in different localities are as follows:—

Departement de l'Orne . . .	1	death in	every	52·4	inhabitants.
„ de Finisterre .	1	„	„	30·4	„
Province of Namur	1	„	„	51·8	„
„ of Zealand (Netherlands)	1	„	„	28·5	„

This great excess of mortality in the last-named place M. Quetelet attributes to the extreme and constant humidity of the atmosphere, which produces an immense number of fevers and other maladies.‡ The observations of M. Bossi also confirm this opinion; for by dividing the *Departement de l'Ain* into four districts, he found the deaths annually to be as follows: §

In the mountainous parts .	1	death in	every	38·3	inhabitants.
On the banks of rivers . . .	1	„	„	26·6	„
On the level parts sown with corn	1	„	„	24·6	„
In parts interspersed with ponds and marshes . . .	1	„	„	20·8	„

and it can be shown that, in England also, the rate of mortality follows nearly the same ratio from the same causes.‖

Enough, however, has been stated to prove the ex-

* Arnott, *Elements of Physics*, p. 558.

† For further remarks on this subject see Art. VENTILATION.

* Dr. Arbuthnot, *On the Effects of Air on Human Bodies;* and Dr. Paris, *Pharmacologia*, vol. i. p. 197, 325, &c.

† *Sur l'Homme, et le Développement de ses Facultés, &c.; par* A. Quetelet.

‡ *London Statistical Journal*, vol. i. p. 176.

§ *Ibid.* p. 177. ‖ *Ibid.* p. 178.

STOVE. treme unwholesomeness of an unusually humid atmosphere, and therefore any method of producing artificial heat which causes a large quantity of moisture to be exhaled must prove exceedingly injurious. But, by the use of gas stoves, there is still another source of deterioration in the air, besides those already mentioned, arising from a portion of the carburetted hydrogen gas escaping unburnt from the stove. This always occurs in a greater or less degree; and that it is exceedingly prejudicial has been proved by various experiments. Sir Humphry Davy nearly lost his life by breathing this gas. The effects which he experienced show that the extreme danger of it arises from its powerful influence in reducing the vital action:* and he was of opinion, that if, instead of taking, as he did, three inspirations of this gas, he had taken four or five, the vital action would have been so much reduced that death must inevitably have ensued.

What has already been stated respecting the effects of carbonic acid gas will sufficiently explain the result that will be produced by Joyce's patent charcoal stoves; and it would be almost unnecessary again to allude to these effects, were it not that many persons imagine charcoal can be deprived of its destructive qualities by some process of preparation. By subjecting the wood from which charcoal is formed to the action of fire for a longer time than usual, or by reburning common charcoal, the acrid fumes which arise from common charcoal are entirely got rid of, as they only arise from the pyroligneous acid, and other constituent principles of the wood, not being entirely volatilized. But when charcoal has been thus purified it equally forms carbonic acid gas when burned in atmospheric air, as well as the most impure charcoal that can be used; but as pure carbonic acid gas is without either colour or smell, it can only be detected by its effects. Some recent experiments, however, have rendered it highly probable that carbonic acid gas is not the only deleterious compound produced from burning charcoal. Another substance has lately been detected to arise from its combustion; and although sufficient evidence has not yet been obtained to enable a positive conclusion to be drawn, the substance in question appears to partake of the character of hydrocyanic or prussic acid, a compound which exerts on the nervous system the most powerful and destructive action of any known poison.

Having considered the physiological effects produced by various methods of distributing artificial heat, we shall now be the better able to appreciate the advantages which some plans possess over others. Whenever fire is directly applied to the surface which is employed for radiating heat, the heating surface attains so high a temperature that it renders the air exceedingly unpleasant, and frequently it becomes excessively unwholesome. This applies in a greater or less degree to all hot air stoves, particularly the cockle stoves and those which have close fires. Dr. Arnott's stoves are also liable to the same objections; and still worse are those on Dr. Nott's construction. But there are means of *indirectly* applying fire heat to metallic surfaces, either by steam or hot water, which we have already described, that are entirely free from these objections, and which in no way affect the salubrity of the air. The best praise that can be pronounced of any apparatus in this particular is its negative qualities; for as we cannot improve the salubrity of the air by any of the methods of heating it, it is the best recommendation of any plan that it produces no changes whatever upon the constitution of the atmosphere. We may, indeed, in certain states of the air, improve its salubrity, by adding to or subtracting from its moisture; but if we use an apparatus (such, for instance, as the gas stove) which always produces moisture, we shall frequently be adding to the air that which it perhaps already possesses in excess, and thereby render it deleterious; and the same may be said of other methods of heating which lessen the quantity of vapour, or which eliminate extraneous gases that mix with the air. With an apparatus in which steam or hot water is made the medium of distributing heat, none of these sources of deterioration exist. The temperature of the radiating surfaces is too low to produce any change in the composition of the atmosphere; and it appears, as nearly as possible, to accomplish all that theory points out to be necessary for securing a wholesome atmosphere of any required degree of temperature.

Whatever method be adopted for heating rooms used for habitation, it is desirable to expose the heating surfaces as much as possible in the room intended to be warmed instead of placing them in another apartment and conducting heated air into the room. When a room is warmed by heated air it requires a temperature of 60° and upwards to render it comfortable; but if the radiating surfaces be placed in the room, a temperatnre several degrees lower will be sufficient, because the *radiant heat*, which, at the moderate temperature of hot water or steam pipes, constitutes about one-third of the total effect,* warms the clothing of those persons who are in the room, and heats all the solid matter of the apartment, without sensibly raising the temperature of the air. A much cooler atmosphere therefore will, in this case, be breathed by those persons who are in the room, which has been shown by Lavoisier, Seguin, Crawford, and De la Roche, to produce a considerable difference in the quantity of oxygen consumed;† the difference in this respect being much greater than the mere expansion of the gases by heat will account for; and both Crawford and De la Roche found that the blood is less decarbonized by passing through the lungs when they are supplied with hot air, than when they inhale that which is colder. This is probably one of the causes of the enervating effects produced by a highly heated atmosphere. Another reason is the relaxation of the animal fibres by heat; by which the fluids of the body are less compressed, the circulation altered, and various other pathological effects produced.‡

As the capacity of air for moisture always increases in proportion to the temperature, the air will necessarily possess the characteristics of a dry atmosphere, when its temperature is artificially raised from near the freezing point to 55° or 60° of Fahrenheit. This is wholly independent of any effect produced by the heating surface on the chemical composition of the air; it results entirely from a physical law, by which air absorbs moisture proportional to its temperature. In this case it is exceedingly beneficial to persons of weak lungs to add artificial moisture to the air; and Dr. Paris states that he has frequently recommended this

* Paris, *Life of Davy*, vol. i. p. 101 Paris, *On Diet*, p. 294.

* Petit and Dulong's *Experiments on Heat, Annals of Philosophy*, vol. xiii. p. 112, *et seq.*

† Murray, *Chemistry*, vol. iv. p. 480.

‡ Dr. Arbuthnot, *On Air, &c.* p. 48, 171, &c.

plan in the course of his medical practice with great success.* This subject, however, as well as others relating to heat and moisture, and the effects produced on the animal economy by various physical changes in the air, in addition to those which have already been explained, the reader will find discussed in the Article on VENTILATION.

We may here, however, briefly inquire into the effects produced on vegetable physiology by the various chemical changes of the atmosphere which we have ascertained to arise from different methods of distributing artificial heat. We possess, indeed, far less knowledge on this branch of physiology than on that which relates to the animal organization; and some facts appear to be almost of an anomalous character.

The effects of a factitious atmosphere are less injurious to vegetable than to animal life. Vegetables appear to have a power of accommodating their functions, in some degree, to the nature of the gaseous elements by which they are surrounded; and some gases which are destructive to animal life vegetables decompose and convert into healthy aliment, although nature has primarily destined both animals and vegetables to live in the same atmosphere.

That solar light has a powerful effect on vegetables has long been acknowledged; and under this influence they exhale large portions of oxygen and moisture. Dr. Daubeny has ascertained that the same action is produced in the absorption of moisture by the roots, and the exhalation of it by the leaves of plants, whether they are exposed to a strong light, or, with a smaller degree of light, they receive a considerable portion of radiant heat.† So powerful indeed is the action of light that M. Condolle has found that plants during the day, and when exposed to the light, are wholly uninjured by the action of gases which quickly destroy them at night; and even the application of chlorine and other deleterious substances to the roots of plants is innocuous during the day, though they are presently destroyed by a similar treatment at night. Sulphuretted hydrogen, nitrous acid gas, muriatic acid gas, and chlorine, were severally tried in this manner, with similar results in each case.‡

It has been generally supposed that plants exhale carbonic acid gas during the night; but this, by Dr. Dalton's experiments, does not appear to be the case; for he states that by numerous analyses of the air of hot-houses, he has always found it to contain during the day, as well as during the night, the same proportions of carbonic acid gas.* These experiments, however, are directly contrary to the conclusions which other physiologists have arrived at; and they well deserve further investigation.

That plants have the power of decomposing carbonic acid gas, when exposed to the light, and of applying the pure carbon to promote vegetation, has been generally acknowledged; and the opinion sometimes held, that the carbonic acid is merely absorbed during the day and again exhaled unchanged at night, is not borne out by Dr. Dalton's analyses of air.

The action of fruits on the air has been stated by M. Berard, in his Essay which received the prize from the French Academy of Sciences, to produce a constant elimination of carbon, under all circumstances.† This opinion has been controverted, and as it is supposed, successfully, by M. de Saussure, who states that green fruit has the same influence on the air as the leaves have; the action of the former being rather less intense; but in proportion as the fruit ripens its power to decompose carbonic acid gas becomes feebler.‡

Although it appears by these remarks that the purity of the air is not of so much importance to vegetation as it is to the animal economy, still, as many of the gases which are innocuous to plants during the day are deleterious to them in the night, it becomes necessary to prevent any considerable deterioration of the air, in order to preserve them in a healthy state. Hence it becomes an important matter, when it is an object to obtain fruits and flowers of the finest descriptions, to employ only such means of producing artificial heat as do not eliminate extraneous gases to the air; and experience has proved that since the general introduction of the plan of heating buildings by hot water, horticulturists have found their plants to be more healthy and productive than with the old methods of warming buildings.

The general principles of physiology which have here been discussed will enable a correct opinion to be drawn as to the effects on organic life of any method of producing artificial heat. It is not to any particular invention that these remarks apply, they equally affect all; and when any new plans for heating buildings are brought under the public notice, it will be well for those who value their health to test the merits of these inventions by the general principles which have here been explained. (See also Article VENTILATION.)

MISCELLANIES.

Stoves.

Fig. 1.

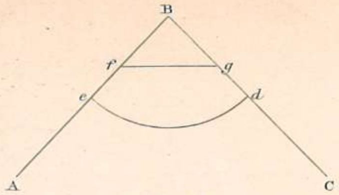


Fig. 2.

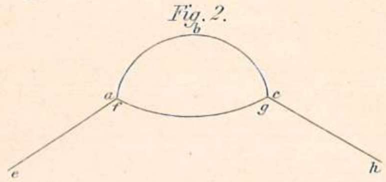
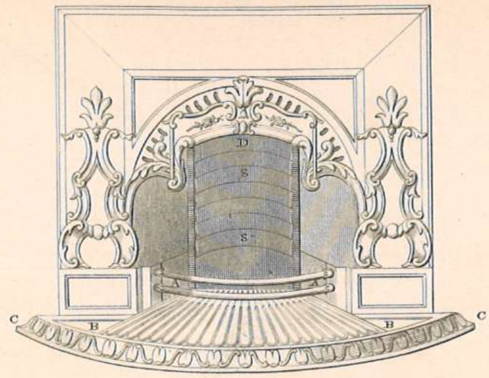


Fig. 3.



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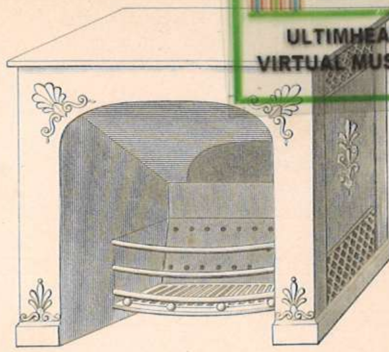

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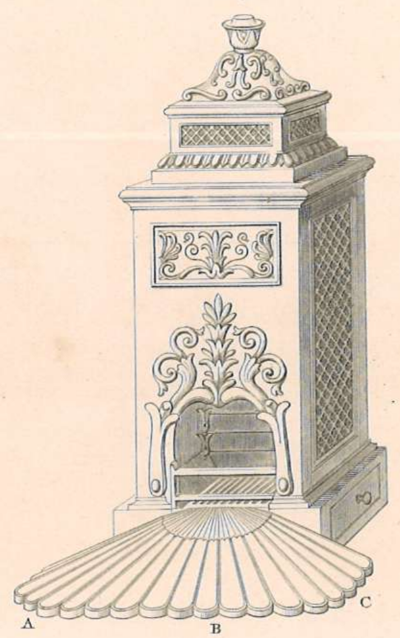

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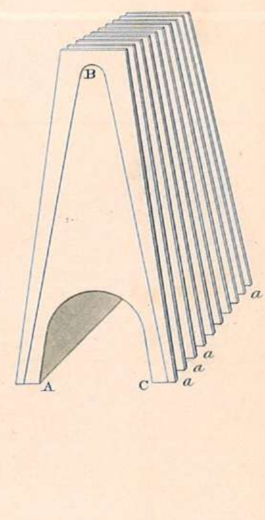

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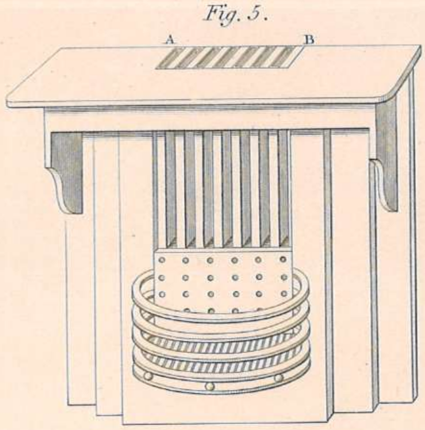

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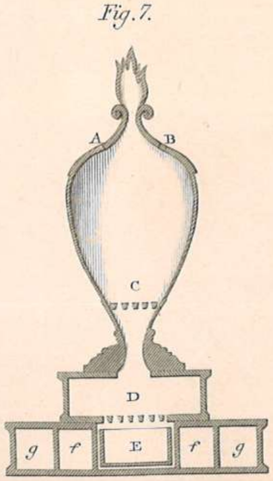
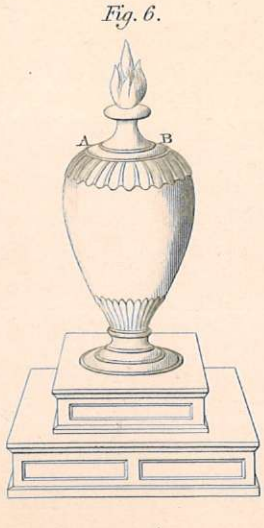


Fig. 6.



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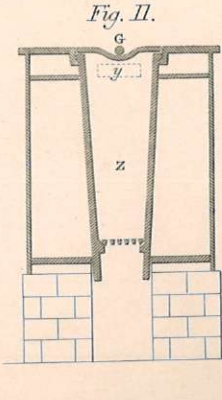
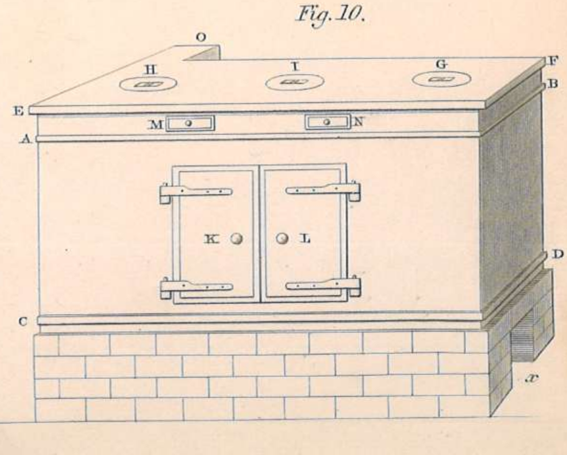


Fig. 10.



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