PURE
AIR, OZONE AND WATER

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PURE

AIR, OZONE AND WATER

A PRACTICAL TREATISE OF THEIR UTILISATION AND VALUE IN OIL, GREASE, SOAP, PAINT, GLUE AND OTHER INDUSTRIES

BY

W. B. COWELL

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Publishers of Technical Works

19 LUDGATE HILL, E.C.

1900

D. VAN NOSTRAND COMPANY,

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PREFACE.

As the necessity of the obtainment of a supply of pure air and water is essential to the life and growth of all organic matter, so in like manner is it important that those industries dealing with such substances should receive a similar treatment in the course of their manufacture into the various compounds for which they are employed.

A practical treatise, therefore, of the purification of air and water, also the generation of ozone, and their utilisation in oil, grease, soap, paint and glue manufacture, and the benefits derivable therefrom, must necessarily prove of intrinsic value to those trades, likewise to other industries requiring similar commodities.

The value of pure air for oxidation, purification, etc., is well known, but its practical utilisation by means of cheap methods have not until recent years been fully realised.

The methods of utilisation herein described will be found very simple in application—at the same time most effective.

The importance of using soft water is fully realised in all departments of manufacture, as the destructive power of hard water is considerable.

Every degree of hardness destroys 1·7 lb. soap, 1½ oz. caustic soda, 1¾ oz. carbonate soda per 1,000 gallons water respectively.

Hard water is most deleterious to colours, imparting thereto a dull appearance instead of the brilliancy desired.

The incrustation of boilers, etc., and the detrimental effects of using hard water for almost any purpose, renders it most necessary to employ means for its purification before usage.

These must, however, be cheap, and it will be found that the processes described herein not only fully comply with this demand, but are likewise fully effective in their operation.

The book is written solely for manufacturers, and will be found thoroughly practical throughout.

The language used in describing the various methods is as simple and comprehensive as possible, every phrase of technicality being carefully avoided.

In submitting same for their consideration and approval, the writer trusts that some, at least—if not all—of the information contained therein will be found serviceable for their respective industry.

I should like to express my indebtedness to Mr. George H. Hurst, Analytical Chemist, the author of several valuable works on the paint and allied industries, for useful help rendered by him in the preparation of this work and in the reading of proofs.

CONTENTS.

CHAPTER I.

ATMOSPHERIC AIR.

THE value of air as an accessory in manufacturing processes was, until recent years, practically unknown.

The discovery of the process of oxidation of oils by atmospheric air, however, opened up a wide field for its use, which has grown to such an enormous extent that the process has now become quite an established and valuable appendix to the trade.

In the manufacture of colours which require to undergo oxidation during the process atmospheric air is now also being used, and has been found very profitable and efficient, specially with Prussian blues.

With these exceptions, and those of the few up-to-date manufacturing firms, the use of atmospheric air is still very limited; but, considering the multitudinous purposes to which it can be employed, and the unlimited quantities everywhere obtainable, there should be nothing to hinder it being universally adopted, as the cost for pumps, etc., is not great and the saving in cost of labour, etc., would speedily repay the outlay.

There are two ways in which atmospheric air can be used, viz., wet and dry. The wet method is available where moisture is not a detriment, and the air pressure, therefore, can be obtained by the direct aid of steam injectors; whereas, if the air is required dry, the service of an air pump is necessary.

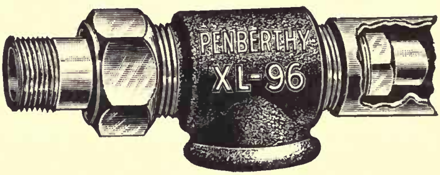

FIG. 1.

THE WET METHOD.

An X L ejector shown in Fig. 1 is the simplest, cheapest, and most effective piece of mechanism to use, as it can be utilised either for agitation or lifting at will. When fixed to coppers, pans or vats, the best way is to place the ejector on the main steam pipe leading thereto; and, if direct steam is also required, to secure it by attaching a by-pass from each side of the ejector with the aid of tees, bends and steamcocks. It is advisable to run a pipe from the suction end of ejector through the roof or wall into the open, so as to secure pure air, taking the precaution of always protecting the inlet with wire gauze, otherwise a bird or other matter may be sucked therein and give trouble. A tap or check valve must also be placed in this pipe, so as to stop back pressure when steam alone is required.

Agitation.

In this way thorough agitation is procurable at any desired temperature up to 180° F., and sustained thereat for an indefinite period, and will be found most suitable in carrying out the following work :—

Washing and clarifying of oils, fats, etc.

Simmering of bones, rough stuff, dregs, etc., for extraction of fat.

Agitation and boiling of soaps.

Manufacture and blending of colours and mordants.

Extraction of dyes from bark, dyewoods, etc.

Resin and tar distillation.

Lixiviation of lye, softening of water, etc.

The great superiority of air agitation over that of manual labour is so marked that there is practically no comparison between the two.

However perfectly the work may be done by hand, the mixing of the mass is only partially accomplished ; whereas, by the use of the air agitation described above, complete permeation is immediately obtained, also a perfect, continuous commingling achieved for hours, if desired, without cessation. Some manufacturers use mechanical stirrers, but these are not very satisfactory. The following are some of the great advantages derivable from the usage of steam and air in conjunction, viz. : increased purifying and sweetening power, especially when applied to animal or other organic matter ; the absolute control and suppression of offensive smell which unavoidably arises from open pans (a matter of great importance to manufacturers whose works are situated in or near towns) : a twofold vexatious evil is thus successfully overcome; the exacting requirements of the sanitary authority (a body very difficult to please) are successfully met; while an immense advantage is secured to the men who, under the old manual system, have to stand over the pans, coppers and vats continually whilst working, and so inhale the noxious fumes arising therefrom. These frequently overpower them, especially during hot weather, and are the cause of much illness. These benefits alone are a great desideratum, and should induce manufacturers to adopt the system. But there is still another great boon—the saving of labour. By the use of steam and air a couple of men would be able to do the work of at least half a dozen men by the ordinary method, and to do it more comfortably, speedily and effectually. Such an immense saving would alone rapidly repay the necessary outlay, leaving out of consideration entirely the other benefits specified. These advantages, therefore, should lead to the immediate adoption of the system by all manufacturers.

The size of the ejectors most suitable to use are as under :—

For vats up to 5 tons, $\frac{3}{4}$ in. inlet and 1 in. discharge is sufficient.

For pans and coppers where simmering is only desired, $\frac{3}{8}$ in. inlet and $\frac{1}{2}$ in. discharge will be found ample for such work.

The most suitable material to use for carrying away the noxious fumes is ordinary cast-iron stove pipe, which is light, cheap and readily obtainable.

The two sizes required are 6 in. and 8 in., the latter being used for the main discharge and the former as tributary thereto.

This arrangement, however, only applies to small coppers and pans; for larger vessels it is necessary to use the 8 in. throughout.

The main pipe should be placed over the coppers, etc., and fixed at such an elevation as to operate on the whole plant.

Care must be taken to give this pipe a slight drop toward the discharge end; also, in making any connection therefrom, to fix the T-piece in a horizontal position, so that the condensed vapour is carried away without the possibility of flowing into any of the other pipes.

This latter precaution is very essential, as otherwise, in working one vessel, the next in rotation would receive the condensation therefrom.

The hoods for round vats, etc., are best made funnel-shape, the bottom end being sufficiently large to overlap the sides some 2 in. and the top to just slip over the main discharge pipe, so that it can be telescoped thereon when required to be raised.

This can be done mechanically by attaching a ring on each side of the funnel, and by means of ropes or chains run through an overhead pulley and counterweighting the same, thereby enabling the cover to be easily raised or lowered at will.

It will not be found necessary, however, to raise the hood whilst working, as, the apex of discharge being central, the vapour or steam is drawn to that point, therefore permitting observation holes to be made in the cover.

These can be made disc-shape or otherwise with a swing or sliding cover as preferred, the circular shape, however, being much stronger and less liable to buckle.

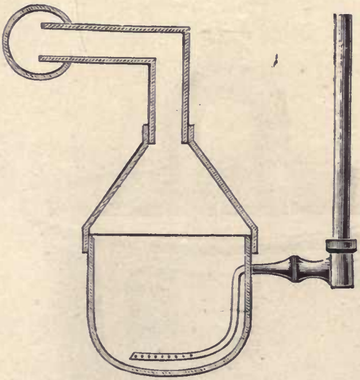

FIG. 2.

In Fig. 2 is given a sketch of a round pan so fitted.

With square or oblong tanks roof-shape covers will be required.

The materials best adapted for this class of work are thin charcoal plates riveted together, which are very light and durable.

In respect to small pans and coppers the covers for these are generally made of wood, but this material is most objectionable, as it speedily gets saturated and often smells worse than the contents.

Cast-iron covers from $\frac{1}{8}$ in. to $\frac{1}{4}$ in. thick are the most serviceable.

To enable the exhaust pipes to be fitted, it will be necessary to have at least one-third of the cover bolted on to the rim of the pan and the other part

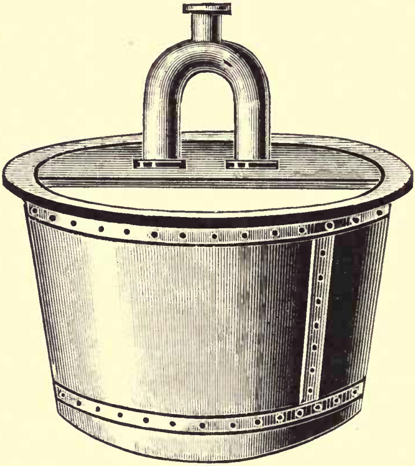

Fig. 3.

attached thereto by means of claws or hinges, so that it can be raised up and down by the same arrangement of a pulley, etc., as already described.

For the purpose of support and stability it is advisable, in fitting the exhaust from pan to the main discharge pipe, to duplicate it at the pan end.

This is done by means of two bends and a T-piece, as shown in Fig. 3, but if a number are required it will be cheaper to have them cast in one, which would enable flanges to be added to the bottom orifices. If, however, stock pipes are used, drawn flanges of soft steel will have to be made and sweated on in the usual way to enable the fixing thereto of the cover.

The T from the main pipe will require one end reduced to 6 in.

An elbow or bend connected thereto, with the necessary straight length added, will enable the junction with pan to be completed. A good caulking composition, composed of 3 parts white lead, 1 part red lead, and 1 of silicate of soda (100 Tw.) in conjunction with spun yarn (free from jute), will be found to make good tight joints.

The silicate of soda must not be added to the mixture of the white and red leads until actually required, as it sets hard in a few minutes.

Having explained the method of connecting the vats, coppers and pans to the main exhaust pipe, the final discharge must now be considered.

This should be carried so that it can be finally connected into a boiler flue or shaft; or in the event of vertical boilers, under the furnace, the latter being preferable in every case where possible, as by this means everything passes through the fire and is consumed.

In the event, however, of volatile matter of an inflammable nature being worked, an independent shaft should be erected.

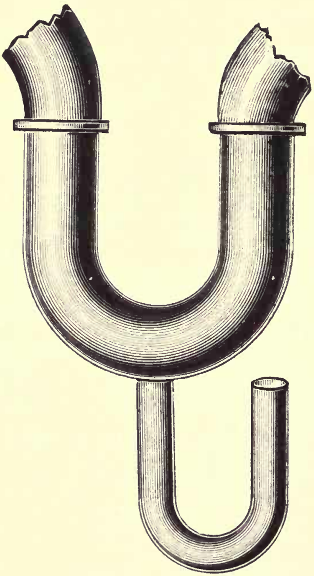

Fig. 4.

By this means the necessary vacuum is attained, but to prevent any surplus condensed aqueous matter passing through as well, the discharge pipe, before finally connected into the shaft, etc., should be made **U** shape so as to catch such matter.

At the bottom of the U, drill a 2 in. hole and insert therein a bend. On to this screw a duplicate so as to form a U also, as shown in Fig. 4. By filling this with water it will act as a seal and enable any accumulation in the larger pipe to run away automatically and continually without further supervision. Should, however, the vacuum prove too strong, make the seal deeper until the water is retained, keeping the return to the original height, but do not go higher, otherwise water will always lie in the main pipe, which it is desirable to avoid.

Thus the whole of the vapour and fumes arising from the vats, pans and coppers are completely and successfully carried away.

Lifting of Liquids.

For charging or discharging of any vessel the X L ejector will be found of great service. The most effective way to utilise the ejector for this purpose is to place it at the bottom of the tank in which it is required to work, thereby keeping it cool, the pressure of the liquid also assisting in enabling it to "fetch" the liquid and retain it.

It is not to be depended upon, however, if the temperature of the liquids exceeds 120° F., but below this it will readily lift to a height of some

25 ft. and throw to a distance of 60 ft., especially if the steam pressure equals or exceeds 60 lb.

In Fig. 5 is shown the method of using the

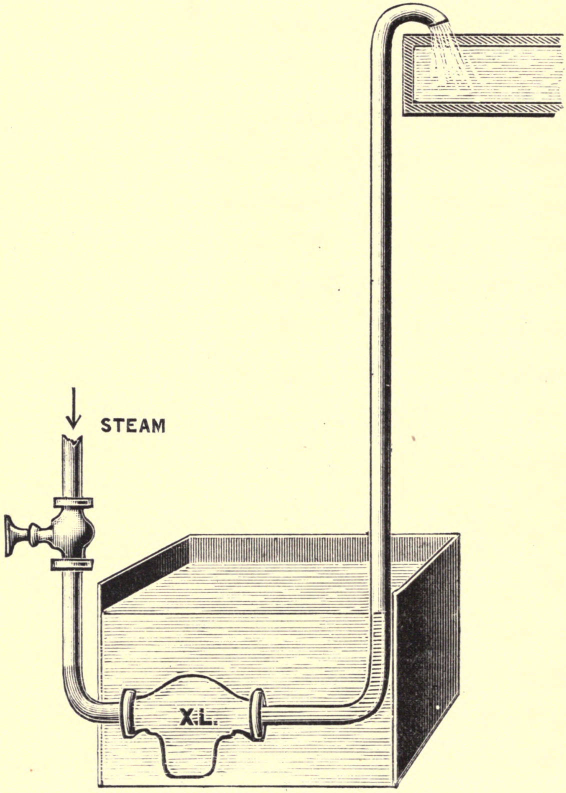

FIG. 5.

ejector for lifting liquids from one tank to another.

For liquids above this temperature, also for those which require to be kept free of moisture, the lifting must be done with an air or donkey pump.

This can be achieved either by suction or pressure—the latter by means of a closed tank. If the former is adopted, the pump should be placed below the level of the tank from which it is operating, so that the liquid can feed thereto by its own gravity, otherwise it will not work satisfactorily.

The Dry Method.

In oil and grease factories the great saving of labour and time attainable, and the numerous uses to which dry air can be applied, renders its use imperative—that is, if the principals desire to hold their own in open competition. By its use the ordinary filtration for the purpose of clarification becomes a thing of the past. Filter presses (except where liquids from solids have to be separated) become obsolete, as by the use of atmospheric air what formerly required some ten days to clarify is now achieved in less than two hours.

There is also the saving of cloths, breakages, etc., that commonly occurs when working filter presses. By this method brighter oils, etc., are obtained, very sweet in smell and much superior to those obtained by ordinary filtration.

At 160° F. air will evaporate 4 grammes moisture per minute, *i.e.*, one-seventh of an ounce.

For the production of a current of dry air it is best to use either a blower or an air-pump.

Fig. 6 is a drawing of a blower worked by a

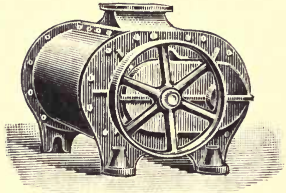

FIG. 6.

belt from a shaft. This blower gives a good current of air at a fair pressure and with a steady running of the power at a uniform flow, which is much to be desired in this kind of work.

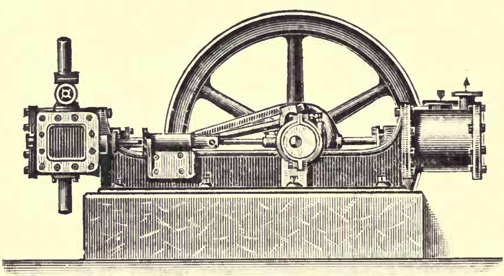

FIG. 7.

Fig. 7 is a drawing of an air-pump or air compressor worked direct from a steam engine. It is always advisable when using such pumps to connect them with a storage tank or accumulator in which the air can be kept under any required pressure, and from which it is conveyed by pipes to the pans or tanks containing the oil, etc., to be operated on.

Fig. 8 shows a form of air compressor which may be driven by belting from a main shaft—a method which is often more convenient than direct steam driving.

Under no circumstances should holes be per-

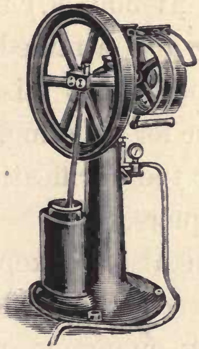

FIG. 8.

forated in the coil on the side butting against the wall of tank, etc.; otherwise holes will sooner or later appear in the tank, on account of the continuous impinging of the steam or air thereon.

This is a most important point to note, otherwise the contents of a tank may one day be found missing.

With circular tanks, when the bottom is made funnel-shape (a pattern now almost universally adopted), a straight central pipe extending nearly to the bottom and ending cup-shape is by far the most effective agitator to use, on account of its cyclonic action, thereby thoroughly permeating the whole contents.

By passing the air after leaving the pump through the boiler flues (in large boilers these sometimes stand at 500° F.) by means of a coil a great saving is also attained.

For blowing operations this will be found very beneficial, likewise for blending, mixing and melting purposes, also for the clarification of oils and fats, evaporation of liquors, etc.

Oil tanks can also be kept warm during the winter months, and articles of all kinds can be dried. There are numerous other uses to which it could be profitably employed, as very little steam would be required for driving the air-pump continually, if so desired.

The service of steam-jacketed pans become thus practically unnecessary.

A by-pass would have to be fitted or a separate pump employed when the air is required cold for cooling purposes, or the temperature of the hot air reduced.

For the rapid cooling of oils, bone grease, melted stuff, tallow, etc., blowing cold air through is invaluable, thoroughly breaking the grain of the fats, imparting a bright appearance, the whole of the moisture practically being driven off in the operation, giving them also an agreeable smell, and thereby increasing their market value.

Do not exceed a temperature of 170° to 180° F. in the drying or blowing of oils, otherwise the colour will suffer considerably.

In thickening or drying oils "gate" or full way valves are the best to use, as the full force of the air is thus obtained.

It is also advisable to insert an automatic check valve as near the tank as possible, specially when the air-pump is driven by a belt, as instances have occurred where, owing to the belt breaking or skidding, the whole of the contents have syphoned back.

Pressure and Vacuum.

Judging by the erratic way in which some manufacturers work with pressure and vacuum, one would suppose it was a matter of chance rather than a natural law.

The saving of time has always been the excuse for such procedure, but when it is accomplished at the risk of fire and life the risk is too great.

Pressure may be safely used to its maximum obtainable degree, provided provision is made for the control of the corresponding vacuum, which is always exactly half the pressure obtainable, or *vice versâ*.

The best and simplest way is to connect the pressure and vacuum pipes, placing a tap in the centre of the connection, which thus enables the operator to control same at will.

Suction Process.

Besides blowing dry air direct through fats and oils, which necessitates the use of a blower or pump, air may be drawn through by a suction process, using an ejector. On this principle is constructed Korting's apparatus for bleaching palm oil shown in Fig. 9. It consists of a closed iron vessel, on the upper part of which is fixed a steam ejector, C, so arranged that the steam entering at **a** draws air out of the vessel at **g**. **b** is a valve for regulating the admission of steam. K, K, K, L, is a copper steam coil for heating the oil, and keeping it in a melted condition. E is an open air pipe, partly outside and partly as a coil inside the vessel;

this latter portion is perforated with a number of small holes. The action of the ejector is to produce a vacuum in the upper part of the vessel, and in order to reduce this vacuum air enters through the pipe E, and issuing from the small holes in the distributing pipes passes through the oil, with which

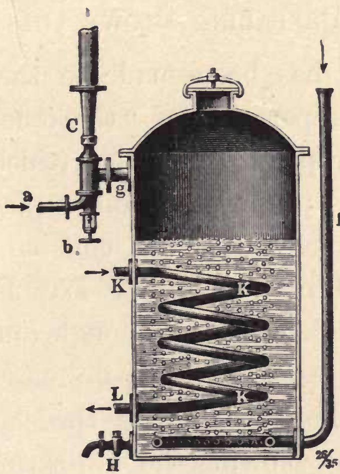

FIG. 9.

it comes into very intimate contact, and the oxygen it contains can exert its full bleaching action. The operation takes about two hours; when, as a rule, the palm oil will be bleached to a good white colour. A few minutes' attention at the start of the operation to see that the oil is melted and that a good current of air passes through it is all that is needed. Towards the end of the operation samples may be drawn from the cock, H, to see if the oil be properly bleached.

Practically the same apparatus may be used for clarifying oils, for removing water from oils and fats, blending and brightening oils.

Preparing Blown Oils.

Reference has been made to the blowing of oils or the preparation of "thickened oils," such as thickened rape oil or lardine (thickened cotton oil). For this purpose the oil is placed in a tank fitted with a closed steam coil, so that the oil can be heated to from 160° to 170° F. The latter temperature is quite high enough and should not be exceeded, especially if pale oils are wanted. The higher the temperature the darker the oil becomes. For blowing the air through, either a blower or an air-pump may be used, and the blowing is carried on until a sample taken out and tested by an hydrometer shows that it has acquired the desired degree of gravity. This may vary from 0·960 to 0·975 at 60° F., according to requirements; at temperatures of 150° to 170° F. the gravity will be less, and if the oil is being prepared at 150° F. then an allowance of 0·031 may be made. That is, if the oil shows at 150° F. a gravity of 0·929, it will have at 60° a gravity of 0·929 + 0·031 = 0·960. For 160° F. the allowance is 0·035, and for 170° F., 0·038.

The blowing of the oils is accompanied by a bleaching action more or less, and the lower the temperature at which the work is carried on the paler will be the resulting oil. In the case of lardine the appearance and odour will depend largely on the quality of the cotton oil used, the freer this is from stearine the less odour will the thickened lardine oil have.

Preparing Siccative Drying Oils.

The blowing of hot air through linseed oil, while it is being boiled for the preparation of drying or boiled oil for painting, will enable the process to be carried on quicker and a better product obtained.

Aerification.

A great deal of trouble has been experienced by many manufacturers in their effort to use atmospheric air, which has resulted, in some instances, in its temporary abandonment; but on investigation, the failure in every case has been traced either to insufficiency of the pumping power employed for its utilisation, or to the excessive head pressure of the substance under treatment.

The author has succeeded, by a very simple method, in overcoming these difficulties, as shown in Fig. 10.

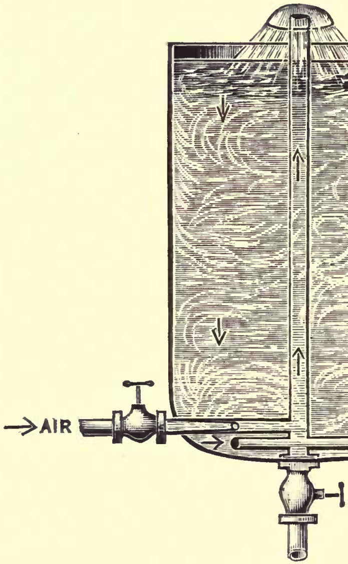

FIG. 10.

It will be seen there that the method of application is totally different to that ordinarily employed, the agitation in general practice being invariably set up from below, and forced upward through the whole bulk of the liquid requiring power proportionately to the head pressure present, whereas here it is confined to a very small circle, and consequently retains its original pressure throughout.

The benefits derivable therefrom are readily conceivable.

The air-pump employed can be much smaller than that required by the ordinary way, whilst the agitation being wholly confined to the surface achieves a threefold action, viz., dual aerification and purification, whilst the liquid is continuously being cooled throughout the whole operation.

Practically the action is that of an ejector, the whole of the liquid being carried round and round, thus ensuring every part being brought into actual contact with the air, which facilitates considerably the desired end, and is therefore invaluable for the following :—

Clarification of oils, fats, etc.

Evaporation and condensation of liquors, such as size, etc.

Oxidation of lubricating and siccative oils.

Rapid cooling of tallows, greases, etc.

Saturation of solids with aqueous or chemical solutions, such as hides, etc.

Washing, dyeing or bleaching of fabrics.

Extraction of gelatinous and fatty matter from bones, etc.

Effective mixing of liquids and compounding of oils; also for numerous other purposes.

In the treatment of solids it will be necessary to fix a false bottom in the tank for the saturating liquid, which should be perforated so that the liquor can return thereto after percolation of the substance under operation. By this means same not only becomes saturated, but is drained also. The air and suction pipes must of course extend below the false bottom for such work.

In the blowing of lubricating and siccative oils for the purpose of oxidation, cooling water is entirely dispensed with, the subjected temperature, especially if hot air is employed, being most uniform.

Sufficient has been said to fully demonstrate that in the adoption of atmospheric air there lies quite a *multum in parvo* of benefits derivable therefrom.

Further, its acquisition is obtained without additional cost after the first outlay.

Waste energy is also utilised, and everything as far as possible carried out by mechanical means.

Manufacture is carried out at less cost and in a much shorter time. The sanitary condition of the factory is also vastly improved.

Labour and fuel are greatly reduced and workmen are made comfortable.

CHAPTER II.

COMPRESSED AIR.

THE compressing of air is making rapid strides, and is adopted in all classes of manufacture.

The variety of uses to which it is now being put is very large; and, judging by the increasing demand, it will be used much more extensively in the future, as its tensive power exerts great energy in utilisation.

It is compressed up to 1,000 lb. per square inch, according to the class of work for which it is required to operate.

It will be found most suitable for the following purposes :—

Raising of acids.
Cleansing of factories.
Whitewashing.
Ventilation.
Cooling of liquids.
Drying of solids.
Paint spraying.
Cranes, elevators, etc.

For these classes of work a pressure of some 75 lb. would be found ample.

In the cleansing of factories it is very effective in removing all dust, etc., from walls and roofs.

The whitewashing of walls is thereby accomplished easily and rapidly.

In using it for this purpose an X L ejector can be utilised for lifting the lime-wash in the same way as with steam and air, connecting on the delivery side a strong armoured hose fitted with tap and spray spreader, or other suitable appliance, as shown in Fig. 9.

The same method could be adopted in paint spraying. Painting in this way is very satisfactory —a very thin and even coat being spread by this method.

The conveyance of cold liquids (except acid) could also be speedily and effectually achieved in like manner.

For ventilation, drying and cooling, the low temperature of the air would prove of great service.

In the lifting of acids the safest way is by direct pressure from a closed tank.

WHITEWASH.

The following mixture will be found most advantageous to use where organic matter of any description is present: 40 lb. lime, 14 lb. salt, 2 lb. naphthalene, made up after slacking to 100 gallons.

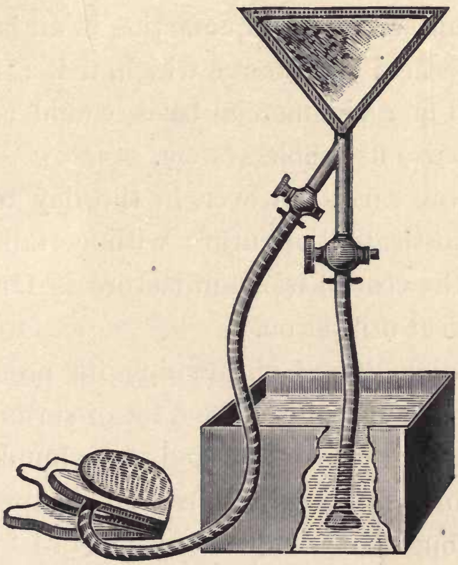

FIG. 11.

CHAPTER III.

LIQUID AIR.

The recent successful liquefaction of air has opened up such a field of resource which, if it can ever be produced on a commercial basis, would completely revolutionise its whole system.

It is too early, however, in the day to be able to prognosticate the future with certainty, as at present the cost of its manufacture is far too high for practical utilisation.

The difficulty of cheapening its production is very great, and will require a lot of surmounting.

"Twenty-three thousand five hundred foot-pounds of work are required to compress 1 lb. air," although "it is calculated that in 1 foot-pound liquid air there is stored 139,100 lb. energy."

Accepting these figures as correct, the cost of manufacture is still much too high for practical utility.

The critical temperature of air is so low (− 158° C.) that its attainment alone is very difficult ; and, as the liquefaction point is still lower, the energy expended in compressing is considerable.

The line adopted by Professor Dewar is, in the writer's opinion, the only feasible method whereby ultimate success may be obtained, viz. :—

Retrocession.

Liquid carbonic acid was used by him in the primary stage through which the air is passed by the aid of an inner tube whereby the heat of one was transferred to the other by simple substitution.

The air by this means was thus reduced to a temperature of $-$ 79° C. or $-$ 110·2° F. at a very small cost as in practice the gasified carbonic acid could be re-liquefied over and over again.

This temperature, however, is far above the liquefactive point, but, if other suitable substances could be used in conjunction, the gradual liquefaction of air might be eventually accomplished commercially, and would prove a grand chemical attainment.

Flowery descriptions of its available application should at present be received with extreme caution and in a measure only conditionally accepted until further research has been made thereon.

The liquefaction of hydrogen was a feat even more difficult to attain, and its successful accomplishment therefore encourages us to wait patiently before expressing ourselves definitely either way.

CHAPTER IV.

PURIFICATION OF WATER.

WATER plays a most important part in industrial operations of almost every kind. For the purpose of raising steam for motive power its use is universal, while it is an essential element in many manufacturing operations. A supply of pure water is therefore most essential, not only for use in boilers, but also when it enters into industrial processes. Natural waters are rarely pure, but contain various metallic salts in solution. It is a matter, therefore, requiring the closest attention, as otherwise the injurious influence arising from the use of impure qualities of water may not only retard operative results, but may also become a costly item in the way of general manufacture by increasing the costs of certain processes.

The water supplied to towns by the water companies is no doubt the safest source of supply generally procurable, but the high price often charged prohibits its common use. Therefore works have to provide their own supply from any available source.

The cost of sinking artesian wells is very small where river or spring water is unavailable, and rapidly repays the outlay.

Factories should always be built on the water side, as the benefits derivable from such a position are many.

The principal impurities generally found in water are :—

Carbonate lime.
Sulphate do.
Carbonate magnesia.
Sulphate do.

with traces of iron, silica, alumina, salt, etc.

The carbonates of lime and magnesia and the sulphates of those bases which are invariably present in natural waters impart what is known as "hardness," a property more readily appreciated than described. The presence of these compounds in water, when it is used for steam-raising purposes, leads to the formation of scale which is very deleterious, while they sometimes interfere with other operations.

The degree of hardness—temporary and permanent—varies very much, from 4° or 5° to 18° to

20° in water supplied by London water companies, and is most detrimental to boilers, etc.

The effectual removal of the lime and magnesia compounds from water has been a very vexed question, upon which much time, energy and money has been expended with only a limited amount of success. With hard waters it is advisable to adopt means to prevent them forming hard scale in boilers.

The market is continually flooded with compositions for the removal or prevention of incrustations in boilers, none of which can, however, be recommended as being perfectly satisfactory, as it is practically impossible to effectually blow out the mud, etc., from a boiler so deposited, as the clearance radius rarely extends more than 3 feet from the blow-off hole, on account of the vortex formed by the head pressure on the point of discharge.

The accumulation of some deposit is therefore unavoidable, and, if allowed to materially develop and form hard masses is most injurious to the boiler, specially if it be fitted with Galloway tubes, their shape seeming to make them adapted for the retainment of such deposit.

Scale in boilers leads to two evils: corrosion of the boiler plates and increased cost of raising steam, for scale is a very bad conductor of heat, and a scale ½ inch thick will more than double the coal bill.

The only way to accomplish its complete removal is to use a scale preventive that will keep the deposit in the form of a fine mud, which can be removed by placing along the bottom of boiler, from end to end, a perforated pipe fitted with a T-junction passing through the upper half of the boiler shell, and fitted with a screw valve, to which can be affixed a rotary pump or other lifting appliance, by which means the whole of the deposit can be periodically drawn off.

Wherever possible, it will be found cheaper to purify the water before use, by which the whole difficulty is practically overcome in one operation.

For softening water the erection of two store tanks is necessary, each of sufficient size, if possible, for the whole day's requirements, so that whilst one is in use the other can be undergoing preparation for the next day.

Old boilers are very suitable for this purpose.

For boiler use an independent feed tank of some 1,000 gallon capacity will be found very beneficial, as then the exhaust pipe from engines, etc., could be passed through the same, thereby achieving a twofold benefit of heating the feed water and so saving fuel under the boiler and condensing without cost. This water can be used over again in the boiler, and will also be found very useful in various other ways wherever it is found essential to use a soft water, but it is advisable to first run it into a separate tank so as to allow any grease or oily matter to separate therefrom before utilisation.

Some manufacturers use steam traps, whilst others pass the exhaust into water direct, neither of which is, however, profitable on account of the enormous back pressure which is thereby produced.

Out of the multitudinous compounds available and used for the removal of impurities from water, the writer has found a mixture composed of the following ingredients to achieve the best all-round results of any :—

98 °/₀ Powdered caustic soda . .	10 lb.
Permanganate potash . . .	2½ oz.

dissolved in 10 gallons water.

The quantity required to be used for each 1,000 gallons of water will vary from ½ to 2 gallons, and depends upon the amount of impurities contained therein.

To gauge this exactly take 70 C.C. of the water which is to be softened and pour it into a 250 C.C. glass flask.

Having done this, fill a burette (50 C.C. being a suitable size) with a standard solution of soap. Drop the soap solution from the burette into the water in the flask, shaking at intervals until there are signs of a soapy appearance, and a permanent lather is obtained, which should not disappear for at least five minutes after treatment.

The number of cubic centimetres used of the soap solution gives the number of degrees of hardness of the water and approximately the number of grains of carbonate and sulphate of lime per gallon.

Roughly, 1 grain of the purifier given above will neutralise 1 grain of carbonate or sulphate of lime, and so the number of cubic centimetres used represent the number of grains of purifier to be added to 1 gallon of the water. The liquid purifier herein given contains about 8,000 grains of active purifying properties per gallon, so that it becomes comparatively easy to calculate how much to add to each 1,000 gallons of water.

For instance, a water on testing shows that it has 12 degrees of hardness, therefore 12 × 1,000 equals 12,000 grains of purifier to be added to 1,000 gallons of the water. One gallon contains 8,000 grains so that 12,000 divided by 8,000 gives 1·5 gallons as the quantity of purifier to be added.

Should the water contain, as most river waters do, a large quantity of suspended matter, its clarification will be greatly facilitated by using in addition to above $\frac{3}{4}$ lb. sulphate alumina to each gallon of the purifier required. This must not, however, be added to the purifier, but introduced separately.

The tank being filled with water and the quantity gauged, it is well agitated by blowing air and the requisite amount of purifier added, and the agitation continued for about an hour, and then allowed to settle.

Water treated in this way will be found very soft and suitable for almost any description of work.

The permanganate potash oxidises all organic matter commonly present in rivers, etc., removing also the flatness from sluggish or stagnant water.

Air agitation also may be very beneficially used for this purpose.

This purifier is also excellent as a preventative of scale in steam boilers. Owing, however, to the varied sources from which canal and river waters come, and their liability to contamination by extraneous substances, especially when flowing through manufacturing districts, it is not found possible to fix definitely upon a purifier that will answer universally for all waters. It is advisable, therefore, at first to ascertain by analysis the exact nature of the impurities present, so that the purifying agents used may have a direct affinity to the substance required to be extracted. These are of various kinds, but are limited somewhat by reason of cost, those generally used being as under :—

Caustic lime,
Caustic soda,
Carbonate soda,
Sulphate alumina,

by which, either alone or combined, the purification of most waters is accomplished.

Caustic lime is used in the form of lime water.

This is prepared by first slacking the lime and then mixing it in the ratio of 1 lb. to each 120 gallons water, and kept well agitated for about half an hour, after which it is allowed to settle until it becomes clear, when it is ready for use, 100 gallons for each 1,000 gallons river water being the quantity generally required. Caustic and carbonate soda are generally used in solutions of 1 per cent. strength, the quantity requisite for river water being about 1½ and 1¾ lb. respectively.

Sulphate of alumina.—The quality generally used for water purification is that known commercially as aluminoferric, but it is a question whether it is not cheaper to pay the small additional price charged for the pure article, as it is more effective, and consequently requires the use of a smaller quantity.

This article is used in conjunction with either lime or soda, the quantity required per 1,000 gallons river water being about 8 oz. dissolved in 10 gallons water.

The following combinations are found to give very satisfactory results, and will enable manufacturers to choose the most suitable method for their particular requirements :—

1. Lime and Alumina.

100 gallons lime water.
10 gallons alumina solution.

2. Lime, Soda and Alumina.

50 gallons lime water.
1 lb. 98 °/o caustic soda (dissolved in the lime water).
10 gallons alumina solution.

3. Caustic Soda and Alumina,

15 gallons caustic soda solution,
15 gallons alumina solution.

Carbonate of soda is rapidly falling into disuse for the purification of water, as its action is too slow, especially where the process is continuous; also because it cannot be mixed with the lime water like caustic soda.

The quantities given above are sufficient for the treatment of 1,000 gallons water containing 12 degrees of hardness.

The sulphate of alumina must never be mixed with the other ingredients, but added separately, otherwise they will be decomposed thereby, and consequently rendered ineffective.

If the quantity of water required necessitates a continuous process being employed, it will be necessary for the purifying agents to be run into the softening tank in proportion to the inflow of water, for which purpose tanks of sufficient capacity must be provided, fitted with cocks, so that the requisite flow can be gauged respectively.

These should be placed directly over the softening tank at places most convenient for working.

Those for the lime water should be duplicated, so that whilst one is operative the other can be recharged.

The tank for the alumina should be made either of slate or wood with a lead lining, and not put into iron tanks as it corrodes them.

To rapidly clarify the water, filtering tanks should be placed below the level of the softening tank, which can be filled with coke or other suitable filtering medium to within a few inches of the overflow. A double blanket is then laid thereon, between which a sheet of fine calico is placed, and the whole clamped down with perforated iron plates specially made so as to exactly cover the whole surface.

The feed thereto from the softening tank is fixed on to the bottom, so that the water is thereby forced upward through the filtering area by its own weight, and passes from thence direct into the store tank for utilisation.

In drawing the water from the softening tank always take it from the top, as by this means a large proportion of the impurities settle therein, and so render the filters more effective.

This is best achieved by dividing the tank into three sections.

Into the first section the impure water is treated with the purifying agents and well agitated with air, which then overflows into the second chamber. In its passage to the third section the inlet thereto is reversed, entering from below, through which it rises until it reaches the overflow pipe or pipes leading to the filters.

To flush the filters a T-piece should be inserted into the pipe leading from the softening tank, so that the water can be diverted and enter from above when so desired. A T-piece should also be fitted below, so that by means of adjustable cocks the deposit laying in the filters can be washed away.

By this means large quantities of water can be purified with satisfactory results.

The standard soap solution referred to on page 36 is made by dissolving 10 grammes Castile soap in one litre (1,000 C.C.) of 35 per cent. alcohol, *i.e.*, 700 C.C. distilled water, 300 C.C. of 60 O.P. methylated spirit. The soap is cut into small pieces and carefully weighed. It is then added to the alcohol, and a gentle heat applied thereto by means of a water bath until the whole is completely dissolved.

Water Hardness.

Quantities of the various bodies generally found in impure water required to produce one degree of hardness :—

	Grammes.
Calcium oxide	·0057
,, chloride	·0114
,, carbonate	·0103
,, sulphate	·0140
Magnesium oxide	·0042
,, chloride	·0050
,, carbonate	·0088
,, sulphate	·0125
Sodium chloride (common salt)	·0120
Sodium sulphate (Glauber salts)	·0146
Sulphurous acid	·0073
Carbonic acid gas	5 cubic centimetres.

CHAPTER V.

FLESHINGS AND BONES.

UP-TO-DATE methods in this important branch of manufacture seem to be receiving very scant attention at present, judging by the primitive methods still employed in some of the large works, thereby severely handicapping their position in competing with foreign productions obtained by using the latest known methods, and with the best labour-saving machinery obtainable.

To conduct business handicapped in this way, without the employment of methods used in the most modern works, means eventual ruin, or at the best only a comatose existence. It is therefore with the object of removing some of the lethargy now existing that this chapter is written, the time being specially opportune by reason of the increased demand and the improved prices now prevailing.

Atmospheric air, either alone or in conjunction with steam, plays the principal part in accomplishing these improvements, the effect in some instances being simply marvellous. Special attention is therefore directed to the descriptive particulars for its utilisation and usage.

The drying of gelatine and glue is always a very delicate process, but by the use of air it can be carried out with rapidity and confidence.

It is well known also that by the continuous boiling of chondrine it is convertible into gelatine, especially if made from fresh material, but by the use of air oxidation this change is considerably facilitated, with profitable results.

The quantity of sulphurous acid required for bleaching of glues, etc., is considerably reduced if not wholly superseded by air, any remaining impurities being taken away by the use of a powerful oxidising agent, such as permanganate potash, or an astringent as sulphate alumina, *but not alum.*

Very weak solutions, containing not more than 1 lb. in 10 gallons, should be used, and the exact quantity required for the bulk under treatment ascertained by titration test of a sample 100 C.C. before treating the bulk.

This is very necessary, specially in using the astringent, otherwise coagulation will follow if much chondrine is present, but for the purpose of purifying gelatine this property can be utilised and the astringent added until the whole of the chondrine is precipitated.

If desired the alumina can be wholly extracted from the liquor by means of ammonia or any of the fixed alkalies after the above or any operation. But this is not necessary.

On glue size from bones the degree of clarification by this method is very marked, the colour attainable thereby being a rich sherry, instead of the dark muddy brown, as now produced.

A permanganate of potash solution will be found invaluable as a deodorant and disinfectant for floors, etc., also for judicious sprinkling of hides, skins, fleshings, bones, refuse, etc., to prevent the development of eremecautical putrefaction.

Special attention is now being given to the more careful separation of various parts of the animal for the purpose of manufacturing table jelly, meat extract, etc., as good prices are obtainable. This is a rapidly developing industry.

Fresh bullock heads and feet, also the cartilage joints, are found the most suitable for this purpose.

The heads are generally smashed, and the whole thoroughly washed with a brine of 5 per cent. strength, *i.e.*, 1 cwt. salt to the ton, until the liquor comes away quite clear, using air as the agitator.

Great care is necessary in macerating, to extract the whole of the bloody matter before applying any heat, except in winter, when the temperature can be raised, but should not exceed 80° F.

Sufficient clean water is then added, and the temperature raised and retained from 150° to 160° F., but not higher, air still being used as an agitator until the operation is completed. Periodical stops are made to enable the fatty matter which accumulates on the surface to be removed.

The length of time requisite for complete extraction of the gelatinous matter is difficult to gauge, as the quantity treated and various other conditions affect any exact approximation. It must therefore depend at first on the skill of the operator, who, however, should be able, after one or two batches, to definitely fix and control same. The specific gravity of the liquor will prove of great service in its determination.

When finished the liquor is strained off and evaporated with dry air, at a temperature of 170° to 180° F., until the desired consistency is obtained, or it may be dessicated in the usual way.

The bones, etc., are then separated from the meat, and the latter dried or pressed and sold for the manufacture of dog biscuits, etc., the combined operation thereby yielding a very remunerative return.

The degelatinising of bones is also very rapidly performed by the combined application of steam and air, and the maximum percentage of glutinous matter is obtained therefrom.

The passing of a current of dry air through the bones before their removal from the copper or pan after the liquor has been withdrawn would help their drying considerably, and decrease to a minimum the smell that arises therefrom when stored as they now are in the wet condition.

In doing this, keep the bottom draw-off tap open, so that the separated moisture, driven out of the bones by the air, may drain away. Hot or cold air, the latter being most preferable on account of its cooling power, may be used at discretion, which will be found to speedily accomplish the drying of the bones, and at the same time tend to sweeten them very materially.

Hitherto the evil of stacking bones in the wet condition, charged with gelatinous matter, has been a very vexed question and a sore point with the sanitary authorities, on account of the rapidity with which putrefaction invariably takes place, in consequence of the great heat generated.

The expense to the manufacturer in the endeavour to overcome this evil has been very great, and the cause of much perturbation and annoyance in the past, as nothing tangible has been successfully introduced for its alleviation.

The only remedy is to remove the cause of the evil, which is achieved by the adoption of the method above described.

In the final treatment of rough stuff, scutch fat or dregs, use when boiling 1 or 2 lb. permanganate potash dissolved in hot water to each ton, which will be found very effective in the removal of smell, also in aiding the general disintegration of the mass, without injury in any way to the fatty matter.

Horse slaughterers will find this very beneficial to use when boiling their meat, as it imparts thereto a sweet, wholesome smell, 4 oz. for each pan being about the quantity required.

Bones contain from 35 to 44 per cent. animal and gelatinous matter, the former consisting of fat, etc., and the latter chondrine and osseine.

Gelatine proper is made principally from the skin and cellular membranes, but is also procurable in the form of osseine from bones.

Chondrine is obtained from the cartilaginous tissues.

Glue and size are, however, generally made therefrom, but there is no reason why the whole or a greater portion thereof should not be converted into gelatine by the use of air as an oxidiser, with increased profit to the manufacturer.

Average composition of the gelatinous group :—

	Gelatine.	*Chondrine.*	*Osseine.*
Carbon . . .	50·5	50·0	50·5
Hydrogen . .	6·6	6·6	6·5
Nitrogen . .	18·3	14·6	16·9
Oxygen . . .	24·6	28·5	26·1
Sulphur . .	—	0·3	—

Bones are rapidly bleached by treatment with air, which renders those which are suitable for manufacture more valuable, whilst those for manurial use are quicker and easier worked.

The fats also obtained thereby are considerably improved.

The vast improvements obtainable by the utilisation of the methods herein described, carefully and scientifically performed, should be of sufficient importance to merit their immediate adoption, as the outlay is small, whilst the value of the products derivable therefrom is materially increased, and the rapidity of manufacture greatly facilitated.

The intrinsic value in the adoption of the latest improvements has been clearly demonstrated and verified by the superiority of the articles treated thereby, so that in every way the benefits to be derived are of great monetary value, and therefore claim prompt consideration.

The importance of this class of business has been too long ignored and neglected.

CHAPTER VI.

OZONISED AIR IN THE BLEACHING AND DEODORISING OF FATS, GLUES, ETC.

The presence of ozone in the atmosphere is essential to health.

Ozone exists in the air of woods and fields, particularly in the neighbourhood of pine trees, and wherever there is active vegetation, the percentage may range to from 3 to 5 per cent.

In large towns, on the contrary, and in houses or wherever numbers of men or animals are collected, ozone disappears, or at least diminishes considerably.

It is considered by some authorities that the disappearance of ozone is one of the causes of epidemics, its absence permitting the growth and accumulation of miasmata.

Whether such hypotheses are correct is at present undetermined, but its corrosive powers and property for destroying organic substances are known to be most remarkable.

In a concentrated form its bleaching properties are superior to chlorine.

It destroys sulphuretted hydrogen (SH_2) and rapidly bleaches vegetable colours, fats, oils, etc.

It is also a powerful oxidiser, converting indigo into isatin, black sulphide of lead into white sulphate of lead, and yellow ferrocyanide into red ferricyanide of potassium. It also transforms many of the lower oxides into peroxides.

Nitrites can be changed thereby into nitrates.

It deoxidises peroxide hydrogen and barium, which become water and baryta respectively.

The following metals are also oxidised by ozone :—

Arsenic,	Antimony,
Iron,	Manganese,
Zinc,	Tin,
Lead,	Bismuth,
Silver,	Mercury.

Ozone is insoluble in acids and alkalies.

The utilisation of ozone in the manufacture of paints and colours, also the bleaching and deodorising of oils, fats, glue, size, etc., is therefore a valuable adjunct.

Manufacturers, however, for reasons which are obvious, are handicapped in obtaining it in sufficient quantities from the atmosphere, and are therefore compelled to resort to artificial means for its production.

A simple method for its manufacture will be hereinafter given, also the appliances described for its application upon the various articles enumerated, but before so doing a few moments spent in the examination of its composition will be found serviceable and beneficial.

What is ozone?

Various definitions are given it by different authorities, viz.:—

Electrified	oxygen.
Allotropic	,,
Active	,,
Excited	,,

That of allotropic or modified oxygen seems, however, to define most accurately its constitution, as it is found that 3 volumes of oxygen condense to form 2 volumes of ozone. Ozone is $1\frac{1}{2}$ times as heavy as oxygen. Ozone possesses a peculiar odour, which is observed when electrical machines are in motion, also after a thunderstorm.

To detect the presence of ozone a piece of paper steeped in a solution of iodide of potassium containing starch is used, the iodine is set free, coming in contact with the starch, the paper assumes a blue tint.

As other bodies give the same reaction, it is preferable to use reddened litmus paper dipped into a very dilute solution of iodide of potassium; ozone decomposes this salt and forms oxide of potassium: this, on contact with moisture, makes the litmus blue, which is a most reliable test.

A precaution should be taken, however, to

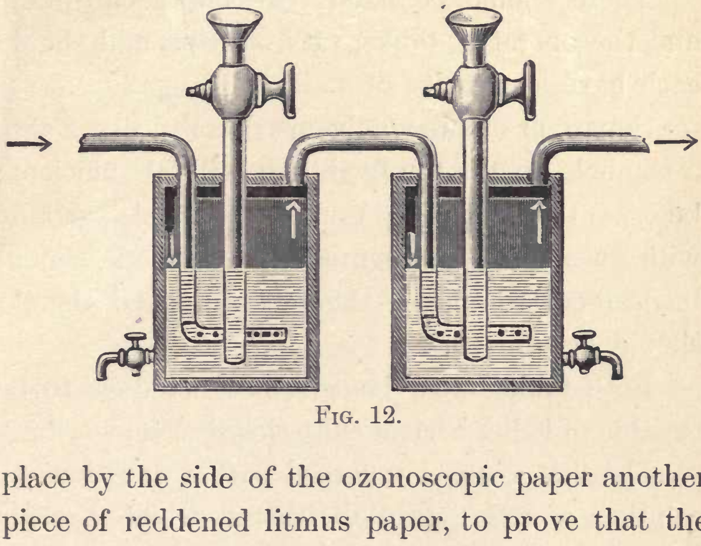

FIG. 12.

place by the side of the ozonoscopic paper another piece of reddened litmus paper, to prove that the blue colour is really due to ozone, and not to the accidental presence of a small quantity of ammonia.

Ozone, or to be more strictly correct, ozonised air can be produced by both chemical and electrical means. The former method requires the simplest and least costly appliances, but the latter yields it the most certain and economical. The plant required to use ozone is not at all complicated and is readily fitted up.

The plant required for the generation of ozone consists of two closed tanks of sufficient size and capacity, according to the quantity necessary to be made for the work in hand, as shown in Fig. 12.

These should be fixed between the air-pump and the operating tanks, vats or pans, and should each have a capacity of at least 100 gallons.

Square or circular galvanised tanks, fitted with a manhole on the top for filling, will be sufficient; but, as the ozonising tank is charged partially with an acid, it is essential that this one should be lead-coated inside, the pipes inserted therein should be of lead.

Both tanks must be so constructed as to be capable of being hermetically closed when working.

The first vessel is charged with a caustic soda solution of 22° Twaddle, through which the air from the pump is passed for the purpose of purification.

By such operation any carbon dioxide that may be present is absorbed by the soda, such extraction being most essential in any operation where rapid bleaching and oxidation are desired.

Into the second vessel a solution of 1 lb. permanganate potash to 8 gallons of hot water is placed.

In neither vessel should the liquor used occupy more than *half* the total capacity.

Each vessel requires to be fitted with a straight pipe, entering at the top centre-end nearest to the air-pump extending therefrom to the bottom and then diverted by means of an elbow or otherwise to the opposite side, the end of which is plugged, this lower portion being perforated with holes along the top, of sufficient size to collectively equal the bore of pipe utilised, so as to prevent any check on the air admitted thereto. There is also a pipe on the opposite side of the cover just passing into the cover of the vessel. The two vessels are then connected by the short pipe on the cover of the first tank, connecting with the down pipe in the ozonising tank, the outlet pipe therefrom going direct to the vessel which contains the oil or other substance to be operated on. To the down pipe of the first tank which contains the caustic soda is connected the air pump to blow air through the apparatus.

To complete the second vessel an additional down pipe is required, reaching nearly to the bottom of tank, which should extend through the cover and terminate funnel-shape for the purpose of adding the requisite acid to effect the preliminary decomposition of the permanganate.

This pipe is automatically sealed by its continuous immersion in the liquor, and acts also as a safety-valve.

Should, however, the pressure of the substance upon which the air is operating be sufficient at any time to break the seal, an additional length of pipe added thereto from the outside will remedy the evil.

The acid used for decomposition is 1·840 sulphuric, the quantity required being 1 gallon for every pound of permanganate potash used.

When charging this vessel, have the whole plant ready for operation, with a batch of whatever substance is to be treated in the respective tank, vat or pan, so that when the acid is poured into the permanganate solution the liberated ozone generated will pass thereto.

The air-pump can then be started, or, if desired, steam and air by means of an X L ejector, such as previously described. If, however, air alone is preferred, it should be heated to a temperature of 160° to 170° F. before passing through the ozonising liquor, either in the way demonstrated in a previous chapter, or by other available means. A very cheap and simple way where gas is available is to heat the pipe by means of a bunsen flame, the pipe so heated being imbedded in sand or salt, which retains the heat and also prevents oxidation. The temperature can also be regulated as desired, or can be generated cold throughout if necessary.

By the wet method the steam pressure should not be under 60 lb., otherwise water will accumulate in the purifier and ozoniser and weaken their action. The former plan is therefore safer and more economical, as water can be added direct to the substance under treatment with equal effect.

In this way ozonised air is procured in a very cheap and advantageous manner, the respective tanks requiring very seldom recharging, especially in the case of the ozoniser, the recuperative power of which is most remarkable. The purifying liquor also lasts for a considerable time before it gets wholly carbonated, such being easily ascertained by titration by the usual method, and the other by the ozone test already given.

Production of Ozone from Electricity.

When a discharge of electricity is sent through oxygen gas or atmospheric air, the great bulk of the oxygen is converted into ozone.

In generating ozone from air, however, it requires to be carefully dried and likewise freed from carbonic acid before it is brought in contact with the electric current—which should be continuous—and thereby becomes ozonised, and is accomplished by passing same through caustic lime.

It will be found advantageous to cool the air before drying and sending it through the ozoniser, as heat has a considerable influence in the effective generation of ozone by this method.

Naturally the discharge of electricity in the apparatus produces some small degree of heating, the temperature usually reaching about 100° F., at which point, however, the efficiency of the apparatus is but feebly affected ; but if run continuously this limit is liable to be exceeded, therefore it is advisable to adopt precautionary measures to keep the temperature as low as possible.

The quantity of oxygen contained in atmospheric air is about 21 per cent. of the volume, therefore the maximum ratio of ozone attainable, if the whole is converted, is some 14 per cent. In actual working, however, this quantity is never produced, but with an efficient apparatus it is possible to produce 10 per cent. ozone, but even if only half of this quantity were made, the ozonised air would still possess powerful properties.

No bleaching agent for oils or fats is so good as ozonised air.

The temperatures at which the best results are obtained range as under :—

Lubricating oils and fats . . .	140° to 160° F.
Siccative oils	180° to 220° F.

India-rubber tubing or joints must be avoided, as ozone has a most rapid destructive action thereon.

Iron, tin, lead or zinc may be used for lining purposes, or coils, but not copper, as ozone has a strong corrosive action on the latter metal.

Bleaching Textile Fibres.

It is well known that all modern as well as the old air processes of bleaching ultimately resolve themselves into the destroying effect of oxygen on the colour of the unbleached fibre. Ozone ought to be much more effective, especially in the bleaching of wool and silk, and should prove a strong competitor of the articles now utilised in the bleaching of all kinds of textile fibres, as its application is very simple.

The fabric to be bleached is hung in a closed chamber, and a current of ozone forced therein until the action of the gas has performed its allotted task.

No deleterious substances are formed during the process, which successfully completes the bleaching operation without rendering any further treatment necessary.

The benefits derivable from the usage of ozonised air for bleaching, purifying, deodorising, etc., must become a most important feature to manufacturers of glue, size, grease, tallow and oils, as it thereby enables them to manufacture without the necessity of having to resort to the direct use of mineral acids, which tend at all times to deteriorate rather than improve such articles.

The rapidity of action, combined with cheapness, accomplishable is also of material importance, and enhances their respective market value considerably.

The powerful oxidising properties, etc., of ozone must also render its use profitable to paint, colour and varnish manufacturers.

Bone grease, melted stuff and scutch grease, when acted upon by ozonised air, are sweetened, bleached and purified in a most beneficial way.

Edible cotton oils bleach rapidly under its influence, and are rendered practically tasteless.

Tallows and fats are rendered very sweet, and lose rapidly any rancidity or mustiness which they may contain.

Oxidation of oils, especially linseed, is most rapid and effective, the colour and extreme sweetness in every case being most pleasing.

The low cost of erecting such a plant and its simplicity, combined with cheapness and rapidity of action, should stimulate every manufacturer to its immediate adoption, and will repay for the outlay a hundredfold.

APPENDIX

OF

GENERAL INFORMATION.

Air and Gases.

Absolute zero by the different standard thermometrical scales :—

Fahrenheit – 459·4°, Centigrade – 273°, Raumer – 218·4°.

The volume occupied by the same weight of a perfect gas varies directly as its absolute temperature ; in other words, the product of the pressure and volume is proportional to the absolute temperature, *i.e.*, it is always equal to the absolute temperature multiplied by a coefficient for each respective gas according to its density.

The following coefficients have been determined for 1 lb. gas :—

Gases.	Volume of 1 lb. Gas at 32° Fahr. under one atmosphere.	Coefficient when the pressure varies from 14·7 lb. per sq. inch.	Coefficient when the pressure is constant, *i.e.*, 14·7 lb. per sq. inch.
Hydrogen	178·83	5·33200	·362721
Gaseous steam	19·913	·59372	·040389
Nitrogen	12·723	·37937	·025807
Oxygen	11·205	·33406	·022725
Air	12·387	·36935	·025126

The coefficients are used as follows :—

To find the pressure of one pound of air of any volume and at any temperature :—

$$P = \frac{(T + 459{\cdot}4) \times {\cdot}36935}{V}.$$

To find the volume of one pound of air at any pressure and any temperature :—

$$V = \frac{(T + 459{\cdot}4) \times {\cdot}36935}{P}.$$

To find the volume of one pound of air at any temperature when the pressure is constant, *i.e.*, 14·7 lb. :—

$$V = (T + 459{\cdot}4) \times {\cdot}025126.$$

To find the temperature of one pound of air of any volume and pressure :—

$$T = \left(\frac{VP}{{\cdot}36935}\right) - 459{\cdot}4.$$

To find the weight in pounds per cubic foot of air at a given temperature and pressure :—

$$W = \frac{P}{(T + 459{\cdot}4) \times {\cdot}36935}.$$

One cubic foot of air at atmospheric pressure and at 62° F. weighs ·076097 lb. or 34·51704 grammes.

The volume of one pound of air under atmospheric pressure and 62° F. is 13·141 cubic feet.

The atmosphere is the gaseous envelope encircling the earth, the constant uniform pressure of which is 14·7 lb. per sq. inch, and is taken as unity, *i.e.*, one atmosphere, all increased pressure being a multiple thereof, and expressed in whole or part atmospheres.

Pressure of Air at Various Temperatures.

Temp. in Fahr. Degrees.	Pressure of a Given Weight of Air having a Constant Volume.		Temp. in Fahr. Degrees.	Pressure of a Given Weight of Air having a Constant Volume.	
	Pounds per sq. in.	Comparative Pressure.		Pounds per sq. in.	Comparative Pressure.
0	12·96	·881	95	15·63	1·063
5	13·10	·891	100	·77	·073
10	·24	·901	110	16·05	·092
15	·38	·910	120	·33	·111
20	·52	·920	130	·61	·130
25	·66	·929	140	·89	·149
30	·80	·939	150	17·17	·168
32	·86	·943	160	·46	·187
35	·94	·948	170	·74	·207
40	14·08	·958	180	18·02	·226
45	·22	·967	190	·30	·245
50	·36	·977	200	·58	·264
55	·50	·986	210	·86	·283
60	·64	·996	212	·92	·287
62	·70	1·000	220	19·14	·302
65	·78	·005	230	·42	·321
70	·92	·015	240	·70	·340
75	15·07	·025	250	·98	·359
80	·21	·034	260	20·27	·379
85	·35	·044	270	·55	·398
90	·49	·054	280	·83	·417

VOLUME AND WEIGHT OF AIR AT VARIOUS TEMPERATURES.

Temp. in Fahr. Degrees.	Volume of 1 lb. at a Constant Atmospheric Pressure of 14·7 lb. per sq. inch.		Weight of one cubic ft. at 14·7 lb. Pressure per sq. inch.	Temp. in Fahr. Degrees.	Volume of 1 lb. at a Constant Atmospheric Pressure of 14·7 lb. per sq. inch.		Weight of one cubic ft. at 14·7 lb. Pressure per sq. inch.
	Volume cu. feet.	Comparative Volume.			Volume cu. feet.	Comparative Volume.	
0	11·583	·881	·086331	90	·845	·054	·072230
5	·709	·891	·085402	95	·970	·063	·071580
10	·834	·901	·084500	100	14·096	·073	·070942
15	·960	·910	·083608	110	·346	·092	·069698
20	12·085	·920	·082745	120	·598	·111	·068500
25	·211	·929	·081894	130	·849	·130	·067342
30	·337	·939	·081055	140	15·100	·149	·066221
32	·387	·943	·080728	150	·352	·168	·065140
35	·462	·948	·080233	160	·603	·187	·064088
40	·588	·958	·079439	170	·854	·207	·063072
45	·714	·967	·078658	180	16·106	·226	·062090
50	·840	·977	·077884	190	·357	·245	·061134
55	·964	·987	·077133	200	·606	·264	·060210
60	13·090	·996	·076400	210	·860	·283	·059313
62	·141	1·000	·076097	212	·910	·287	·059135
65	·216	·006	·075667	220	17·111	·302	·058442
70	·342	·015	·074950	230	·362	·321	·057596
75	·467	·025	·074260	240	·612	·340	·056774
80	·593	·034	·073565	250	·865	·359	·055975
85	·718	·044	·072894	260	18·116	·379	·055200

FUEL.

The value of any fuel is measured by the number of heat units which its combustion will generate, a unit of heat being the amount required to heat 1 lb. of water 1° F. The fuel used in generating steam is composed of carbon and hydrogen, and ash, with sometimes small quantities of other substances not materially affecting its value.

Average evaporative power :—

1 lb. coke evaporates 9 lb. water.
1 lb. coal ,, 9 lb. ,,
1 ton coal ,, 2,000 gallons.

"Combustible" is that portion which will burn; the ash or residue varying from 2 to 36 per cent. in different fuels.

TABLE OF COMBUSTIBLES.

KIND OF COMBUSTIBLE.	Air Required.	Temperature of Combustion.			
	In Pounds per pound of Combustible.	With Theoretical Supply of Air.	With 1½ Times the Theoretical Supply of Air.	With Twice the Theoretical Supply of Air.	With Three Times the Theoretical Supply of Air.
Hydrogen	36·00	5750	3860	2860	1940
Petroleum	15·43	5050	3515	2710	1850
Carbon { Charcoal, Coke, Anthracite Coal }	12·13	4580	3215	2440	1650
Coal—Cumberland . .	12·06	4900	3360	2550	1730
,, Coking Bituminous	11·73	5140	3520	2680	1810
,, Cannel . . .	11·80	4850	3330	2540	1720
,, Lignite . . .	9·30	4600	3210	2490	1670
Peat—Kiln dried . .	7·68	4470	3140	2420	1660
,, Air dried 25 per cent. water .	5·76	4000	2820	2240	1550
Wood—Kiln dried . .	6·00	4080	2910	2260	1530
,, Air dried 20 per cent. water .	4·80	3700	2607	2100	1490

SAVING OF FUEL BY HEATING FEED-WATER. (IN PER CENT. STEAM AT SIXTY POUNDS.)

Initial Tem. of Water.	Final Temperature of Feed-Water.						
	120°	140°	160°	180°	200°	250°	300°
32°	7·50	9·20	10·90	12·36	14·30	19·03	22·90
35	7·25	8·96	10·66	12·09	14·09	18·34	22·60
40	6·85	8·57	10·28	12·00	13·71	17·99	22·27
45	6·45	8·17	9·90	11·61	13·34	17·64	21·94
50	6·05	7·71	9·50	11·23	13·00	17·28	21·61
55	5·64	7·37	9·06	10·85	13·60	16·93	21·27
60	5·23	6·97	8·72	10·46	12·20	16·58	20·92
65	4·82	6·56	8·32	10·07	11·82	16·20	20·58
70	4·40	6·15	7·91	9·68	11·43	15·83	20·23
75	3·98	5·74	7·50	9·28	11·04	15·46	19·88
80	3·55	5·32	7·09	8·87	10·65	15·08	19·52
85	3·12	4·90	6·63	8·46	10·25	14·70	19·17
90	2·68	4·47	6·26	8·06	9·85	14·32	18·81
95	2·24	4·04	5·84	7·65	9·44	13·94	18·44
100	1·80	3·61	5·42	7·23	9·03	13·55	18·07
110	·90	2·73	4·55	6·38	8·20	12·76	17·28
120	0	1·84	3·67	5·52	7·36	11·95	16·49
130		·92	2·77	4·64	6·99	11·14	15·24
140		0	1·87	3·75	5·62	10·31	14·99
150			·94	2·83	4·72	9·46	14·18
160			0	1·91	3·82	8·59	13·37
170				·96	2·89	7·71	12·54
180				0	1·96	6·81	11·70
200					0	4·85	9·93

COAL.

The rate of combustion of coal in steam boilers per square foot of fire-grate per hour may be taken on the following basis :—

Portable engine boilers . . .	9 to 15 lb.
Vertical boilers	6 to 13 ,,
Cornish boilers	12 to 16 ,,
Lancashire boilers	14 to 28 ,,

Water at Different Temperatures.

There are four notable temperatures for pure water, *viz.* :—

1. Freezing point at sea level . . . 32° F.
2. Point of maximum density . . . 39·1° F.
3. British standard for specific gravity . 62° F.
4. Boiling point at sea level . . . 212° F.

32° F.	Weight per cub. ft. 62·418 lb. ;	per cub. in.,	·03612 lb.
39·1° F.	,, ,, ,, 62·425	,, ,, ,,	·036125 ,,
62° F.	,, ,, ,, 62·355	,, ,, ,,	·03608 ,,
212° F.	,, ,, ,, 59·760	,, ,, ,,	·03458 ,,

A British Imperial gallon holds 277·274 cubic inches and 10 lb. water at 62° F., which is equivalent to 0·16045 cubic feet.

Sea water (average) has a specific gravity of 1·028 boils at 213·2° F., and weighs 64 lb. per cubic foot at 62° F.

A pressure of 1 lb. per sq. in. is exerted by a column of water 2·3093 ft., or 27·71 in. high, at 62° F.

In solvent power water has a greater range than any other liquid. For common salt this is nearly constant at all temperatures, while it increases with increase of temperature for others, magnesium and sodium sulphates, for instance.

Where water contains carbonic acid it dissolves some minerals quite readily, but a boiling temperature causes the disengagement of the carbonic acid in gaseous form and the deposition of a large part of the minerals thus held in solution.

Lime salts are more soluble in cold than in hot water, and most of them are deposited at 320°, or less. When frozen into ice, or evaporated into steam, water parts with nearly all substances held in solution.

TABLE OF SOLUBILITIES OF SCALE-MAKING MINERALS.

SUBSTANCE.	Soluble in parts of pure water at 32° F.	Soluble in parts carbonic acid water, cold.	Soluble in parts of pure water at 212°.	Insoluble in water at
Carbonate of Lime .	62,500	150	62,500	302° F.
Sulphate of Lime .	500	...	460	302 ,,
Carbonate of Magnesia .	5,500	150	9,600	...
Phosphate of Lime .	...	1,333	...	212 ,,
Oxide of Iron . .	...	...	...	212 ,,
Silica	...	Und't'd	...	212 ,,

Water has a greater specific heat, or heat-absorbing capacity, than any other known substance (bromine and hydrogen excepted), and is the unit of comparison employed for all measurements of the capacities for heat of all substances whatever. The specific heat of water is not constant, but rises in an increasing ratio with the temperature, so that it requires slightly more heat, the higher the temperature, to raise a given quantity of water from one temperature to another. The specific heat of ice and steam are, respectively, ·504 and ·475, or practically about half that of water.

A British Thermal Unit (or heat unit) is that quantity of heat which will raise 1 lb. of water at or about freezing point, 1° F. A French "Calorie" is the heat required to raise one kilogramme of water 1° C., and is equal to 3·96832 British thermal units.

The following table gives the number of British thermal units in a pound of water at different temperatures. They are reckoned above 32° F., for, strictly speaking, *water* does not exist below 32°, and ice follows another law.

Water between 32° and 212° F.

Temperature Fahr.	Heat Units per lb.	Weight, lb. per cub. ft.	Temperature Fahr.	Heat Units per lb.	Weight, lb. per cub. ft.
32°	0·00	62·42	110°	78·00	61·89
35	3·02	62·42	112	8[illegible]·00	61·86
40	8·06	62·42	113	81·01	61·84
45	13·08	62·42	114	82·02	61·83
50	18·10	62·41	115	83·02	61·82
52	20·11	62·40	116	84·03	61·80
54	22·11	62·40	117	85·04	61·78
56	24·11	62·39	118	86·05	61·77
58	26·12	62·38	119	87·06	61·75
60	28·12	62·37	120	88·06	61·74
62	30·12	62·36	121	89·07	61·72
64	32·12	62·35	122	90 08	61·70
66	34·12	62·34	123	91·09	61·68
68	36·12	62·33	124	92·10	61·67
70	38·11	62·31	125	93·10	61·65
72	40·11	62·30	126	94·11	61·63
74	42·11	62·28	127	95·12	61·61
76	44·11	62·27	128	96·13	61·60
78	46·10	62·25	129	97·14	61·58
80	48·09	62·23	130	98·14	61·56
82	50·08	62·21	131	99·15	61·54
84	52·07	62·19	132	100·16	61·52
86	54·06	62·17	133	101·17	61·51
88	56·05	62·15	134	102·18	61·49
90	58·04	62·13	135	103·18	61·47
92	60·03	62·11	136	104·19	61·45
94	62·02	62·09	137	105·20	61·43
96	64·01	62·07	138	106·21	61·41
98	66·01	62·05	139	107·22	61·39
100	68·01	62·02	140	108·22	61·37
102	70·00	62·00	141	109·23	61·36
104	72·00	61·97	142	110·24	61·34
106	74·00	61·95	143	111·25	61·32
108	76·00	61·92	144	112·26	61·30

WATER BETWEEN 32° AND 212° F.—*continued.*

Temperature Fahr.	Heat Units per lb.	Weight, lb. per cub. ft.	Temperature Fahr.	Heat Units per lb.	Weight, lb. per cub. ft.
145°	113·26	61·28	179°	147·54	60·57
146	114·27	61·26	180	148·54	60·55
147	115·28	61·24	181	149·55	60·53
148	116·29	61·22	182	150·56	60·50
149	117·30	61·20	183	151·57	60·48
150	118·30	61·18	184	152·58	60·46
151	119·31	61·16	185	153·58	60·44
152	120·32	61·14	186	154·59	60·41
153	121·33	61·12	187	155·60	60·39
154	122·34	61·10	188	156·61	60·37
155	123·34	61·08	189	157·62	60·34
156	124·35	61·06	190	158·62	60·32
157	125·36	61·04	191	159·63	60·29
158	126·37	61·02	192	160·63	60·27
159	127·38	61·00	193	161·64	60·25
160	128·38	60·98	194	162·65	60·22
161	129·39	60·96	195	163·66	60·20
162	130·40	60·94	196	164·66	60·17
163	131·41	60·92	197	165·67	60·15
164	132·42	60·90	198	166·68	60·12
165	133·42	60·87	199	167·69	60·10
166	134·43	60·85	200	168·70	60·07
167	135·44	60·83	201	169·70	60·05
168	136·45	60·81	202	170·71	60·02
169	137·46	60·79	203	171·72	60·00
170	138·46	60·77	204	172·73	59·97
171	139·47	60·75	205	173·74	59·95
172	140·48	60·73	206	174·74	59·92
173	141·49	60·70	207	175·75	59·89
174	142·50	60·68	208	176·76	59·87
175	143·50	60·66	209	177·77	59·84
176	144·51	60·64	210	178·78	59·82
177	145·52	60·62	211	179·78	59·79
178	146·53	60·59	212	180·79	59·76

Head of Water and Equivalent Pressure in Pounds per Square Inch.

Head in Feet.	Pressure.	Head in Feet.	Pressure.	Head in Feet.	Pressure.	Head in Feet.	Pressure.
1	0·43	21	9·09	41	·75	61	26·42
2	0·86	22	·53	42	18·19	62	·85
3	1·30	23	·96	43	·62	63	27·29
4	·73	24	10·39	44	19·05	64	·72
5	2·16	25	·82	45	·49	65	28·15
6	·59	26	11·26	46	·92	66	·58
7	3·03	27	·69	47	20·35	67	29·02
8	·46	28	12·12	48	·79	68	·45
9	·89	29	·55	49	21·22	69	·88
10	4·33	30	·99	50	·65	70	30·32
1	·76	31	13·42	51	22·09	71	·75
2	5·20	32	·86	52	·52	72	31·18
3	·63	33	14·29	53	·95	73	·62
4	6·06	34	·72	54	23·39	74	32·05
5	·49	35	15·16	55	·82	75	·48
6	·93	36	·59	56	24·26	76	·92
7	7·36	37	16·02	57	·69	77	33·35
8	·79	38	·45	58	25·12	78	·78
9	8·22	39	·89	59	·55	79	34·21
20	·66	40	17·32	60	·99	80	·65

Properties of Saturated Steam.

Total Pressure per square inch, lb.	Temp. of Steam and Water in Fahr. Degrees.	Number of Thermal Units contained in one pound calculated from Fahr.			Weight of one cubic foot.		Volume of one pound of Steam, cu. feet.	Cubic feet of Steam from one cubic foot of Water at 62° F.
		Number contained in the Water.	Number required for Evaporation, i.e., Latent Heat.	Total Number contained in the Steam.	Steam, lb.	Water, lb.		
15	213·1	214·1	964·3	1178·4	·0387	59·722	25·85	1611
6	216·3	217·3	962·1	1179·4	·0411	·639	24·32	1516
7	219·6	220·5	959·8	1180·3	·0435	·550	22·96	1432
8	222·4	223·5	957·7	1181·2	·0459	·476	21·78	1357
9	225·3	226·4	955·7	1182·1	·0483	·397	20·70	1290
20	228·0	230·1	952·8	·9	·0507	·325	19·72	1229
1	230·6	232·4	951·3	1183·7	·0531	·253	18·84	1174
2	233·1	234·6	949·9	1184·5	·0555	·186	·03	1123
3	235·5	236·7	948·5	1185·2	·0580	·119	17·26	1075
4	237·8	239·0	946·9	·9	·0601	·054	16·64	1036
5	240·1	241·3	945·3	1186·6	·0625	58·990	15·99	996
6	242·3	243·6	943·7	1187·3	·0650	·928	·38	958
7	244·4	245·6	942·2	·8	·0673	·870	14·86	926
8	246·4	247·6	940·8	1188·4	·0696	·814	·37	895
9	248·4	249·7	939·4	1189·1	·0719	·757	13·90	866
30	250·4	250·9	937·9	·8	·0743	·699	·46	838
1	252·2	253·7	936·7	1190·4	·0766	·647	·05	813
2	254·1	255·6	935·3	·9	·0789	·592	12·67	789
3	255·9	257·5	934·0	1191·5	·0812	·540	·31	767
4	257·6	259·2	932·8	1192·0	·0835	·491	11·97	746
5	259·3	260·9	931·6	·5	·0858	·441	·65	726
6	260·9	262·5	930·5	1193·0	·0881	·395	·34	707
7	262·6	264·2	929·3	·5	·0905	·346	·04	688
8	264·2	265·8	928·2	1194·0	·0929	·299	10·76	671
9	265·8	267·4	927·1	·5	·0952	·253	·51	655
40	267·3	268·9	926·0	·9	·0974	·207	·27	640
1	268·7	270·5	924·9	1195·4	·0996	·166	·03	625
2	270·2	271·9	923·9	·8	·1020	·121	9·81	611
3	271·6	273·3	922·9	1196·2	·1042	·079	·59	598
4	273·0	274·7	921·9	·6	·1065	·037	·39	585
5	274·4	276·2	920·9	1197·1	·1089	57·995	·18	572
6	275·8	277·6	919·9	·5	·1111	·953	·00	561

PROPERTIES OF SATURATED STEAM—*continued.*

Total Pressure per square inch, lb.	Temp. of Steam and Water in Fahr. Degrees.	Number of Thermal Units contained in one pound calculated from Fahr.			Weight of one cubic foot.		Volume of one pound of Steam, cu. feet.	Cubic feet of Steam from one cubic foot of Water at 62° F.
		Number contained in the Water.	Number required for Evaporation, *i.e.*, Latent Heat.	Total Number contained in the Steam.	Steam, lb.	Water, lb.		
47	277·1	278·9	919·0	·9	·1133	·914	8·82	550
8	278·4	280·2	918·1	1198·3	·1156	·875	·65	539
9	279·7	281·5	917·2	·7	·1179	·836	·48	529
50	281·0	282·8	916·3	1199·1	·1202	·797	·31	518
1	282·3	284·1	915·4	·5	·1224	·758	·17	509
2	283·5	285·4	914·5	·9	·1246	·722	·04	500
3	284·7	286·7	913·6	1200·3	·1269	·686	7·88	491
4	285·9	287·8	912·8	·6	·1291	·650	·74	482
5	287·1	289·0	912·0	1201·0	·1314	·613	·61	474
6	288·2	290·1	911·2	·3	·1336	·579	·48	466
7	289·3	291·3	910·4	·7	·1364	·545	·36	458
8	290·4	292·4	909·6	1202·0	·1380	·511	·24	451
9	291·6	293·6	908·8	·4	·1403	·473	·12	444
60	292·7	294·7	908·0	·7	·1425	·439	·01	437
1	293·8	295·9	907·2	1203·1	·1447	·405	6·90	430
2	294·8	297·0	906·4	·4	·1469	·374	·81	424
3	295·9	298·1	905·6	·7	·1493	·340	·70	417
4	296·9	299·1	904·9	1204·0	·1516	·309	·60	411
5	298·0	300·1	904·2	·3	·1538	·275	·49	405
6	299·0	301·1	903·5	·6	·1560	·244	·41	399
7	300·0	302·1	902·8	·9	·1583	·213	·32	393
8	300·9	303·1	902·1	1205·2	·1605	·185	·23	388
9	301·9	304·1	901·4	·5	·1627	·154	·15	383
70	302·9	305·0	900·8	·8	·1648	·123	·09	378
1	303·9	305·8	900·3	1206·1	·1670	·092	5·99	373
2	304·8	306·7	899·6	·3	·1692	·064	·91	368
3	305·7	307·7	898·9	·6	·1714	·036	·83	363
4	306·6	308·7	898·2	·9	·1736	·008	·76	358
5	307·5	309·7	897·5	1207·2	·1759	56·980	·68	353
6	308·4	310·6	896·8	·4	·1782	·953	·61	349
7	309·3	311·6	896·1	·7	·1804	·925	·54	345
8	310·2	312·5	895·5	1208·0	·1826	·897	·48	341

Properties of Saturated Steam—*continued.*

Total Pressure per square inch, lb.	Temp. of Steam and Water in Fahr. Degrees.	Number of Thermal Units contained in one pound calculated from Fahr.			Weight of one cubic foot.		Volume of one pound of Steam, cu. feet.	Cubic feet of Steam from one cubic foot of Water at 62° F.
		Number contained in the Water.	Number required for Evaporation, *i.e.*, Latent Heat.	Total Number contained in the Steam.	Steam, lb.	Water, lb.		
79	311·1	313·4	894·9	·3	·1848	·868	·41	337
80	312·0	314·2	894·3	·5	·1869	·839	·35	333
1	312·8	315·1	893·7	·8	·1891	·813	·29	329
2	313·6	316·0	893·1	1209·1	·1913	·788	·23	325
3	314·5	316·9	892·5	·4	·1935	·759	·17	321
4	315·3	317·6	892·0	·6	·1957	·733	·11	318
5	316·1	318·5	891·4	·9	·1980	·708	·05	314
6	316·9	319·3	890·8	1210·1	·2002	·682	·00	311
7	317·8	320·2	890·2	·4	·2024	·653	4·94	308
8	318·6	321·0	889·6	·6	·2044	·628	·89	305
9	319·4	321·9	889·0	·9	·2067	·602	·84	301
90	320·2	322·6	888·5	1211·1	·2089	·577	·79	298
1	321·0	323·4	887·9	·3	·2111	·551	·74	295
2	321·7	324·2	887·3	·5	·2133	·529	·69	292
3	322·5	325·0	886·8	·8	·2155	·503	·64	289
4	323·3	325·7	886·3	1212·0	·2176	·477	·60	286
5	324·1	326·5	885·8	·3	·2198	·452	·55	283
6	324·8	327·3	885·2	·5	·2219	·430	·51	281
7	325·6	328·2	884·6	·8	·2241	·404	·46	278
8	326·3	328·9	884·1	1213·0	·2263	·381	·42	275
9	327·1	329·6	883·6	·2	·2285	·356	·37	272
100	327·9	330·3	883·1	·4	·2307	·330	·33	270

VOLUME OF THE FLOW OF STEAM INTO THE ATMOSPHERE.

Pressure, lb. per sq. inch.	Velocity per second, feet.	Velocity per minute, feet.	Pressure lb. per sq. inch.	Velocity per second, feet.	Velocity per minute, feet.
1	482	28920	30	1643	97580
5	973	58380	50	1791	107460
10	1241	74460	70	1877	112620
20	1504	90240	100	1957	117420

For each nominal horse-power a boiler requires :—

1 cubic foot of water per hour.
1 square yard of heating surface.
1 square foot of fire-grate surface.
1 cube yard capacity.

To Heat Rooms.—One square foot of steam pipe surface is required for 80 cubic feet of space ; 1 cubic foot of boiler is required for 1500 cubic feet of space ; 1 horse-power boiler is sufficient for 40,000 cubic feet of space.

To find the Area of a Circle when the Radius is known.—Square the radius, multiply by 22 and divide the result by 7.

To find the Circumference.—Multiply the diameter by 22 and divide by 7.

To find the Radius when the Circumference is known. — Multiply the circumference by 7 and divide by 44.

Rules for finding the horse-power nominal of boilers :—

1. *Plain Cylindrical Boilers.* — Multiply the length by the diameter and divide by 6.

2. *Single Flue Boilers.*—Add the diameter of shell and flue, multiply by the length, and divide the result by 7.

3. *Double Flue Boilers.*—Add the three diameters of shell and flue tubes, multiply by the length, and divide the result by 8.

A horse-power in a steam-engine or other prime mover, is 50 lb. raised 1 ft. per second, or 33,000 lb. 1 ft. per minute.

Temperature of steam :—

PRESSURE IN LB. PER SQUARE INCH (INCLUDING ATMOSPHERE).

15 lb.	212° F.
20 ,,	228°
25 ,,	240°
30 ,,	250°
40 ,,	267°
50 ,,	274°
60 ,,	293°
70 ,,	303°
80 ,,	312°
90 ,,	320°
100 ,,	327°
120 ,,	341°
140 ,,	353°
160 ,,	363°
180 ,,	373°
200 ,,	382°

One cubic foot water makes 283 cubic feet of steam at 80° and 1642 at O. lb. pressure.

Decimal approximations for facilitating calculations in mensuration :—

Lineal feet	multiplied by	·00019	= miles.
„ yards	„	·000568	= „
Square inches	„	·007	= square feet.
„ yards	„	·0002067	= acres.
Circular inches	„	·00546	= square feet.
Cylindrical inches	„	·0004546	= cubic feet.
„ feet	„	·02909	= cubic yards.
Cubic inches	„	·00058	= cubic feet.
„ feet	„	·03704	= „ yards.
„ „	„	6·242	= imperial gallons
„ inches	„	·003607	„
Cylindrical feet	„	4·895	„
„ inches	„	·002832	„
Avoirdupois lb.	„	·09	= cwts.
„ lb.	„	·00045	= tons.

Bones.—The temperature required for the degelatinising process by steam is 300° F., being equivalent to 65 lb. to 70 lb. steam pressure.

Glue.—The yield of glue from skin, etc., is about 50 per cent. The strongest quality glue is obtained from skins. Temperature of drying-room, 71° to 72° F. Melting-point of glue 144° to 145° F.

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