those which are found in greatest numbers in Itajahy (*Acræa Thalia* only perhaps equalling or even surpassing them in number), the frequent occurrence of orange-coloured or scarlet flowers in that country is probably less an adaptation to humming-birds than to this fondness of Callidryas. The red Salvia, Canna, the orange-coloured species of Lantana, *Epidendron cinnabarinum*, &c., are assiduously visited by Callidryas.

Lippstadt, May 13 HERMANN MÜLLER

LOAN COLLECTION OF SCIENTIFIC APPARATUS

SECTION—MECHANICS

PRIME MOVERS [1]

WE now come to Newcomen, who I think may fairly be looked upon as the father of the steam-engine in its present form. No. 1,942 is a model of his engine, which is further illustrated by a rare engraving (of 1712), the property of Mr. Bennet Woodcroft.

Here we have the steam boiler, the cylinder, the piston and rod, the beam working the pumps in the pit, the injection into the cylinder and the self-acting gear, making altogether a powerful and an automatic prime mover.

That conscientious writer, Belidor, to whom I have already frequently referred, says, that he hears of one of these machines having been set up in the water-works on the banks of the Thames at York Buildings. I may say to those who are not aware of it, that those works were situated where the Charing Cross Station now stands. On a Newcomen engine being erected in France at a colliery at Fresnes, near Condé, Belidor paid several visits to it in order that he might understand its construction thoroughly, and be thereby enabled to explain it to his readers. He has done so with a minuteness and faithfulness of detail, in description and in drawings, that would enable one to repeat the engine. This engine had a 30-inch cylinder with a 6-feet stroke of the piston and of the pumps. The boiler was 9 feet in diameter and $3\frac{1}{2}$ feet deep in the body; it had a dome which was covered with masonry 2 feet 6 inches thick to hold it down against the pressure of the steam. It had a safety valve (the Papin valve) which Belidor calls a "Ventouse," and says that its object was to give air to the boiler when the vapour was too strong. It had double vertical gauge cocks the function of which Belidor explains; it made fifteen strokes in a minute; and he says that being once started it required no attention beyond keeping up the fire, that it worked continuously for forty-eight hours, and in the forty-eight hours unwatered the mine for the week, whereas previously to the erection of the engine the mine was drained by a horse-power machine, working day and night throughout the whole week and demanding the labour of fifty horses and the attendance of twenty men to keep the water down. I should have said that the pumps worked by the steam-engine were 7 inches bore and were placed 24 feet apart vertically in the pit which was 276 feet deep, and that each pump delivered into a leaden cistern from which the pump above it drew.

After having given a most accurate description of the engine, Belidor breaks out into a rhapsody and says (I will give you a free translation) "It must be acknowledged that here we have the most marvellous of all machines, and that there is none other of which the mechanism has so close a relation to that of animals. Heat is the principal of its movements; in its various tubes a circulation like that of the blood in the veins is set up; there are valves which open and shut; it feeds itself, and it performs all other functions which are necessary to enable it to exist."

Smeaton employed himself in perfecting and in properly proportioning the Newcomen engine, but it was not until James Watt that the next great step was made; that step was as we all know the doing away with condensation in the cylinder, the effecting it in a separate vessel and the exclusion of the atmosphere from the cylinder. These alterations made a most important improvement in the efficiency of the engine in relation to the fuel consumed; but they were so simple that I doubt not if examiners into the merits of patents had existed in those days Mr. Watt would have had his application for a patent rejected as being "frivolous." We have here from case No. 1,928, a model made by Watt which appears to be that of the separate condenser and air-pump; we have also 8B which is a wooden model made by Watt of a single acting inverted engine, having the top side of the cylinder always open to the condenser, and a pair of valves by which the bottom side of the piston can be put into alternate connection with the boiler and with the condenser, the contents of which are withdrawn by the air-pump. 3B from the same case is a model of a direct acting inverted pumping engine, made in accordance with the diagram 8B. 1B is a model of Watt's single acting beam pumping engine, while 2B is a model of Watt's double acting beam rotary engine. 10B from the same case is Watt's model of a surface condenser. To Watt we owe, condensation in a separate vessel, exclusion of the air from the cylinder, making the engine double acting, employment of the steam jacket, and employment of the steam expansively, the parallel motion, the governor, and in fact all which made Newcomen's single acting reciprocating pumping engine into that machine of universal utility that the steam-engine now is, and not only so, but Watt invented the steam-engine indicator which enables us to ascertain that which is taking place within the cylinder and to see whether or not the steam is being economically employed. I have on the table before me a very excellent model of German manufacture, No. 2,137, illustrating an inverted direct acting pumping engine in its complete form, and I have also a model of French manufacture, the cylinder and other working parts of which are in glass; this shows a form of Watt rotary beam condensing engine at one time in common use.

I do not say, however, that Watt was the first to make the suggestion of attaining rotary motion from the power of steam. Leaving out of consideration Hero's toy, Papin, as I have remarked, hoped to get rotary movement second-hand by working a water wheel with the water that had been raised by his steam-engine; moreover, as early as 1737, Jonathan Hulls proposed to obtain rotary motion from a Newcomen engine and to employ that motion in turning a paddle-wheel, to propel a tug-boat which should tow ships out of harbour, or even against an adverse wind. I have before me one of the prints of his pamphlet and in order that you may better appreciate his invention I have put an enlarged diagram upon the wall, and I think I may take this as the starting-point for saying a few words about the steam-engine as a prime mover in steam vessels.

We have in the collection, No. 2,150, Symington's engine tried upon the Lake at Dalswinton in 1788. Here a pair of single acting vertical cylinders give, by the up and down motion of their pistons, reciprocating movement to an overhead wheel; this wheel gives a similar motion to an endless chain which chain is led away so as to pass round two pairs of ratchet wheels loose upon two paddle shafts. By the use of a pair of ratchets the reciprocations of the chain are converted into rotary motion in one direction only, and that the driving direction of the two paddle wheels placed one behind the other. Symington's arrangement for obtaining the rotary motion always in one direction of his two paddle-wheels is very similar to that proposed by Jonathan Hulls for his single stern-wheel. Want of time forbids me to do more than just to allude to the names of Hornblower and Wolff in connection with double cylinder engines, engines wherein the expansion of steam is commenced in one cylinder and continued in another and a larger one.

I wish to say a few words which will bring before you the changes that have been made within a very few years in the construction of the marine engines. I may observe that when I was an apprentice the ordinary working pressure of steam, except in the double cylinder engine, was only 3 lbs. above atmosphere, and that there was in a marine boiler more pressure on its bottom when the steam was down, due to the mere head of water in the boiler, than there was pressure in the top when the steam was up, due to the force of the steam; whereas now condensing marine engines work commonly at 70 lbs., and there is a boat under trial where the steam is, I believe, as high as 400 lbs.

To those who are curious on the subject, I would recommend a perusal of two blue books, one being the evidence taken before a Parliamentary Commission in 1817, and the other before a Parliamentary Committee in 1839; they will find there the weight of evidence to be that the only use of high pressure steam is to dispense with condensing water, and that as a steamboat must always have plenty of condensing water in its neighbourhood, no engineer knowing his business, would suggest high pressure for a marine engine.

I have before me a model of a pair of engines which, although

[1] Address delivered by F. J. Bramwell, C.E., F.R.S., one of the vice-presidents of the Section, May 25. Continued from p. 161.

they were made not so very long ago (for I saw them put into the ship), have nevertheless an historical interest. This model shows Maudslay's engines of the *Great Western*, the first steamer built for the purpose of crossing the Atlantic. I think I am right in saying that 7 lbs. steam was the pressure employed in that vessel, and in order to extract the brine from the boiler it was necessary to use pumps as the pressure of the steam was not sufficient to expel the brine and to deliver it against the pressure of the sea.

Time does not permit of my touching upon the various improvements in boilers, condensers, expansive arrangements, and other matters which have gradually been introduced into our best engines for land and for ocean purposes. I have hung upon the wall a rough diagram showing a pair of oscillating engines as applied to driving a paddle steamer, and another showing a pair of inverted compound cylinder engines to drive a screw propeller; a model of such a pair of engines with surface condensers and all modern appliances (being Messrs. Rennie's engines for the P. and O. Company's S.S. *Pera*, by which I have had the pleasure of travelling) is now before me.

I will conclude this part of the subject by saying that to the combination of science and sound practice is due the fact of the consumption of coal having been reduced from 5 lbs. per gross indicated horse-power per hour to an average of 2¼ lbs. and, in exceptional instances, to as small a quantity as 1½ lbs. per horse per hour.

Let us now devote a little of the time that is left to the consideration of the locomotive on the common road as well as on the railway. I have before me No. 2,145, a model of the actual engine of Cugnot, in the Conservatoire des Arts et Métiers, which, in 1769, journeyed—slowly, it is true, but did journey and did carry passengers—along the roads in Paris.

It is a most ingenious machine; it has three wheels, and the motive power is applied to the front, the castor, or steering wheel, so that engine and boiler turn with the wheel precisely as, within the last few years, Mr. Perkins has caused the engine and boiler to turn with the steering-wheel of his three-wheeled common road locomotive. The steam causes the pistons in a pair of inverted single acting cylinders to reciprocate, and their rods, by means of ratchet wheels, give rotary motion to the castor wheel, and thus propel the carriage. I think there is no doubt but that we must look upon this engine of Cugnot as the father of steam locomotion, as we must regard Symington's engine as the parent of marine propulsion. I have before me No. 1,926, Trevethick's engine of 1802; I have also before me a Blenkinsop rail, one that has been in actual use for many years, provided, as you will see, with teeth, into which a cogged flange on the side of the driving-wheel is geared to insure that tractive force should be obtained. This plan has been revived, within the last few years, to enable the steam locomotive to climb the Righi. A sketch of the Righi engine and rail is on the wall. It will be seen that the teeth instead of projecting from the side of the rail, are ranged between two parallel bars like the rungs of a ladder.

On the ground-floor of the exhibition we have the veritable "Puffing Billy," an engine which began work in 1813, and got along without the aid of cogs by mere adhesion upon plain rails; it is a rude-looking machine, but it laboured up till the date of the last Exhibition, doing its work for forty-nine years on the railway belonging to the Wylams Colliery, and, as tradition says, interesting George Stephenson, who, as a boy, saw it in daily operation.

On the ground-floor, also, we have 1,954, the "Rocket," with which seventeen years after the starting of "Puffing Billy" George Stephenson carried off the prize in the Manchester and Liverpool Railway competition. The leading particulars of this engine are as follows:—A pair of 7½ inch cylinders 1′ 5″ stroke, placed at a slight inclination driving 4′ 6″ wheels, the boiler, multi-tubular, having twenty-four three and a half-inch tubes, while the fire is urged by the waste blast. Before alluding to this I ought to have mentioned that in one of the Blue Books to which I have called your attention—that which gives the evidence before the Commission in the year 1817—there is a statement by a witness that in those parts there are machines called locomotives, &c.

Once more I am compelled to say that time will not admit of my entering into any detail in respect of the modern locomotive, except to remark that by the aid of excellent boilers, of high-pressure steam (140 lbs. to the inch) of considerable, although rather imperfect expansion effected by the link motion, there is provided for the use of our railways a machine which in the "passenger" form is competent to travel with ease and safety sixty miles an hour, and in the "goods" form is competent to draw a load of 800 to 1,000 tons, and to attain these results with a very commendable economy in fuel. I have put on the wall two diagrams of locomotives of the convenient form for local traffic that we call tank engines, and I have before me No. 1,957*a*, a most beautifully made sectional working model of a Russian six-wheeled "goods" engine.

Within the last twenty years another description of steam-engine has acquired a prominent and important place among our prime movers; I allude to the portable engine, or to the portable engine in its more complete form of a self-propelling or traction engine. The general construction of these machines borders closely upon that of the locomotive. Very great attention has been paid to all their details, and the Royal Agricultural Society of England, by their excellent arrangements for periodical trials, have stimulated engineers to devote their best energies to the subject. No. 1,942 is a model of one of Aveling and Porter's common road traction engines, capable also of acting as a source of power for driving farm-yard machinery or for effecting steam-ploughing. Upon the wall I have placed rough diagrams of another kind of traction engine—a kind wherein india-rubber tires are used; this is manufactured by Messrs. Ransome, Sims, and Head, and I have also placed there diagrams of the ordinary portable engine and of another most useful kind of portable engine, viz., the steam fire-engine. I have there likewise a sketch of Hancock's common road steam coach, which for so many months regularly plied for hire from the Bank to Paddington in opposition to the ordinary horse omnibus. Hancock's carriage was a vehicle which, in my judgment, has never since been surpassed, and I am sorry to say never to my knowledge equalled as regards the various points which should be attended to in making a steam carriage to circulate safely among horse-traffic.

There is another way in which steam may be employed as a prime mover. We saw that water in the form of the "Trombe d'eau" could be caused to induce a current in air and thereby to blow a forge fire, and that a rapid stream induces a current in other water, and thus drains marshy lands. Similarly steam can be caused to induce a current in water and thereby impel the water so as to raise it to a height or to force it as feed-water into a boiler against a heavy pressure. When used for a mere pumping apparatus, such a mode of employing steam is very wasteful, because the steam is condensed by the water in large quantities and the water is needlessly heated at the expense of the steam; but when used in feeding a boiler into which, thus, the whole of the heat is taken, this objection does not apply. By means of that most elegant and scientific apparatus, the Giffard injector, it is possible, by a jet of steam, to economically induce a current in surrounding water, powerful enough to take the condensed steam itself and the water into the boiler from which the steam had previously issued. No. 1,976, which I have before me, is a sectional model of a Giffard injector.

I believe it was I who first gave a popular explanation of the principle of action of the Giffard injector, and although a scientific congress is probably not the place for a popular explanation, I will venture to repeat it. The principle may be summed up in one word, "concentration." The steam that issues from an orifice of an area of 1, when condensed, has a sectional area (according to the original pressure of the steam) of only $\frac{1}{200}$th or $\frac{1}{400}$th or $\frac{1}{800}$th as the case may be, thus the velocity remaining the same and the weight the same, the energy of the steam issuing from an area of 1, is concentrated 200, 400, or 800 times upon the area due to the smaller transverse section of the liquid stream.

This concentration of energy is far more than sufficient to enable the fluid stream to re-enter the boiler from which the vaporous stream started, and so much more than sufficient, that it may be diluted by taking with it a certain quantity of water, which was employed in the condensation of the steam, and is required for the feeding of the boiler.

With a view to obtaining economy in fuel many attempts have been made to employ some other agent than steam as the means of developing the power latent in fuel, but it is imperative that I should dismiss these with a mere enumeration. A very interesting engine of this kind (because, excluding Hero's toy and smoke jacks, it is so far as I know the first proposition for obtaining rotatory motion by the aid of heat), was the fire wheel of M. Amonton, of which an account is to be found in the first volume of the "French Academy of Sciences," for the year 1699. On referring to that volume I do not see that it is stated in terms, the machine was ever put to work, although it is said that M. Amonton made many experiments to convince the Academy of the practicability of his invention. M. Amonton proposed to have a metallic wheel revolving on a horizontal axis; the outer rim of the wheel was to be divided into a number of separate air cells, each of which had a channel so as to communicate with other cells, water-cells, arranged round the wheel nearer to the centre than the air-cells; the air-cells as they passed over a fire were to be heated, and the air was to drive this water up to one side of the wheel, so as to keep that side always loaded, and thus give the wheel a tendency to revolve. The cells after leaving the neighbourhood of the fire were to be cooled by passing through water to re-contract the air ready for the next operation.

No. 1,940, which is before me, is a model of Stirling's hot-air engine, but time does not remain to describe it.

Besides hot-air engines, we have had engines working by the explosion of gunpowder, and others working by the explosion of gases. No. 1,945 is Langen and Crossley's gas engine, from which I believe extremely excellent results have been obtained.

I will now ask you to look at a tabular statement which shews the consumption of fuel in some agricultural engines, when under trial, expressed in pounds per horse-power per hour, and also in millions of pounds raised one foot high by the consumption of 1cwt. of coals. I told you how excellent were the results at which our agricultural engineers had arrived; you will see that one of those machines, working with 80lbs. steam, and of course without condensation, has developed, not a gross indicated horse-power, but an actual dynamometrical horse-power, for 2·79lbs. of coal per horse per hour, giving a duty of as much as 79½ millions. This high result was obtained by the excellence of the boiler and of the combustion, as well as by that of the engine. If you look at the column of evaporation you will find that as much as 11·83lbs. of water were converted from the temperature of the boiling point into steam by the combustion of 1lb. of coal; this was due, not to the merits of the boiler alone, but to the extraordinary ability of the stoker, and to the care and labour bestowed, a care and labour far too expensive to be employed in practice. But should not we engineers endeavour to ascertain whether we cannot by mechanical means, practically, with certainty and cheapness, procure an accuracy of combustion as great, or even greater than that which can be got by the almost superhuman attention of a highly-trained man, who at the end of four hours of such work is utterly exhausted? Many forms of fire-feeders have been attempted and used with more or less success, but I cannot help thinking that in order to obtain the accurate proportioning of air and fuel, by which alone we can get efficient and economical combustion, we shall have to turn our attention in the direction of dealing with the fuel in a comminuted state, either by converting it into gas, as is done by our president, Dr. Siemens, by availing ourselves of liquid fuel, or by employing the process of Mr. Crampton, and making the fuel into an impalpable powder, that may be driven into the furnace by the air which is there to consume it.

By these, and by other means, we may hope to improve combustion. By strict attention to the proportioning of the parts of the boiler we may hope to make the best use of this improved combustion. By higher initial pressure, by greater expansion, and by the general employment of condensation, wherever practicable (and by the use of the evaporative condenser there are very few cases in which it is not practicable), we may trust that the steam-engine, even on its present principle, will be rendered more economical than it has ever yet been, and may give us more than that one-eighth or one-ninth of the total force residing in the fuel which now alone we get under the very best and most exceptional conditions. A large loss, however, must with steam-engines, as we now know them, always be incurred. We cannot hope to deal with initial pressures and temperatures corresponding with steam of a density equal to that of water, nor to carry expansion down to the point where ice would be formed in the condenser. But wonderful as the steam-engine is, worthy as it was and is of Belidor's eulogium (which I read to you), we know it is not the only heat motor, and we are aware that there are other forms of such motors which, theoretically at all events, promise higher results.

By improvements in the existing steam-engine, by the invention and development of other heat motors, by the employment of the power of water and of wind, either as principal motors or as auxiliaries, we may look to further progress in the machines—the subject of my address—"Prime Movers."

I have brought before you, of necessity hastily, and therefore (and also on account of my own incapacity for the task) imperfectly, the leading improvements which have been made in prime movers from the date of the water-wheels of Vitruvius to the best-devised steam-engines of our own day. These improvements have been effected by men like Papin, Savery, Newcomen, Watt, Symington, Stephenson, and others, who were not mere makers of engines, but were men full of an ardent love of their noble profession, who followed it because of the irresistible attraction it possessed for them; followed it from their boyhood to their grave, and in that very following found their great reward. These men undoubtedly possessed that combination of science and practice, which combination, Dr. Tyndall has told us, is necessary if either science or practice is to continue to live; for, to use his expressive language, without this combination they both die—die of atrophy; the one becomes a ghost, the other a corpse.

We have every reason to believe that this combination will rapidly become even more fully developed, not only in the engineers of the present day, but in those of the next and of succeeding generations, and to such men as these we may trustfully leave the continued improvements of prime movers, resting content with the knowledge that a more general application of these machines must of necessity follow such improvements, and that the day will soon dawn when in no civilised country will there continue to be the temptation to employ intelligent humanity in the brutal labour of the turnspit, or of the criminal on the treadwheel.

OCEAN CIRCULATION[1]

THE present theories with regard to ocean circulation do not appear to account for many of the phenomena with which we are acquainted; and my object in this paper is to state very briefly my own opinions, with a view to provoking discussion, and, in this way, to forward the knowledge of a very difficult but interesting subject. I believe that there are at the present moment two rival doctrines, viz.:—

1. One which attributes all currents to the influence of the winds.
2. Another which attributes all ocean currents to gravitation.

I entirely disagree with the first doctrine, and shall address my remarks to the second. I quite think that ocean circulation is the result of gravitation, but, contrary to what I believe to be the present opinion, I hold that the cold feeding streams flow in a wave from the surface of the Polar oceans, and not from the bottom.

The points that I wish particularly to suggest for consideration are as follows:—

1. That all ocean currents run from a higher to a lower level.

2.[2] That the upward pressure produced in the equatorial regions by the constant inflow, at the bottom, of water from the Polar regions owing its high specific gravity to its contraction from cold; and, *vice versâ*, the constant inflow at the bottom of the Polar regions, of water flowing from the equatorial regions and owing its high specific gravity to its salinity, must, these streams flowing from a higher to a lower level, tend to elevate the lighter surface-water and drift it down a slightly inclined plane as a surface-current.

3. That the primary cause of the origin of all ocean currents is the change in the specific gravity of sea-water from one of the following causes, viz.:

(*a*) Evaporation; the vapour arising from the surface being fresh, and leaving its saline constituents behind it.

(*b*) The excess of precipitation over evaporation, particularly in the Polar seas, which by admixture with the surface-water increases its freshness.

(*c*) The expansion of surface-water through heat.

(*d*) The contraction of sea-water through cold.

It is generally admitted that currents of both air and water flowing from the equator to the poles having an excess of easterly momentum due to the velocity of rotation of the earth's surface in low latitudes as compared with the lesser velocity in high latitudes,[3] must outstrip the earth's motion, and consequently

[1] More particularly with reference to the North Atlantic Ocean, being an abstract of a paper read to the Caterham Literary Society in March last.

[2] I hold it to be impossible that you can have any such thing as an ocean level unless the different strata or layers of water from the equator to the poles are not only isometrical and isothermal, but are also of equal specific gravity; whereas the known ranges of variation of both temperature, salinity, and depth of different strata of sea-water vary much in different places and in different oceans. There is a constant disturbance of equilibrium, and the constant effort to restore and equalise it produces the currents.

[3] The rotatory velocity of the earth's surface being about 1,440 feet per second at the equator, 720 feet per second in 60° of latitude, and decreasing to zero at the poles.