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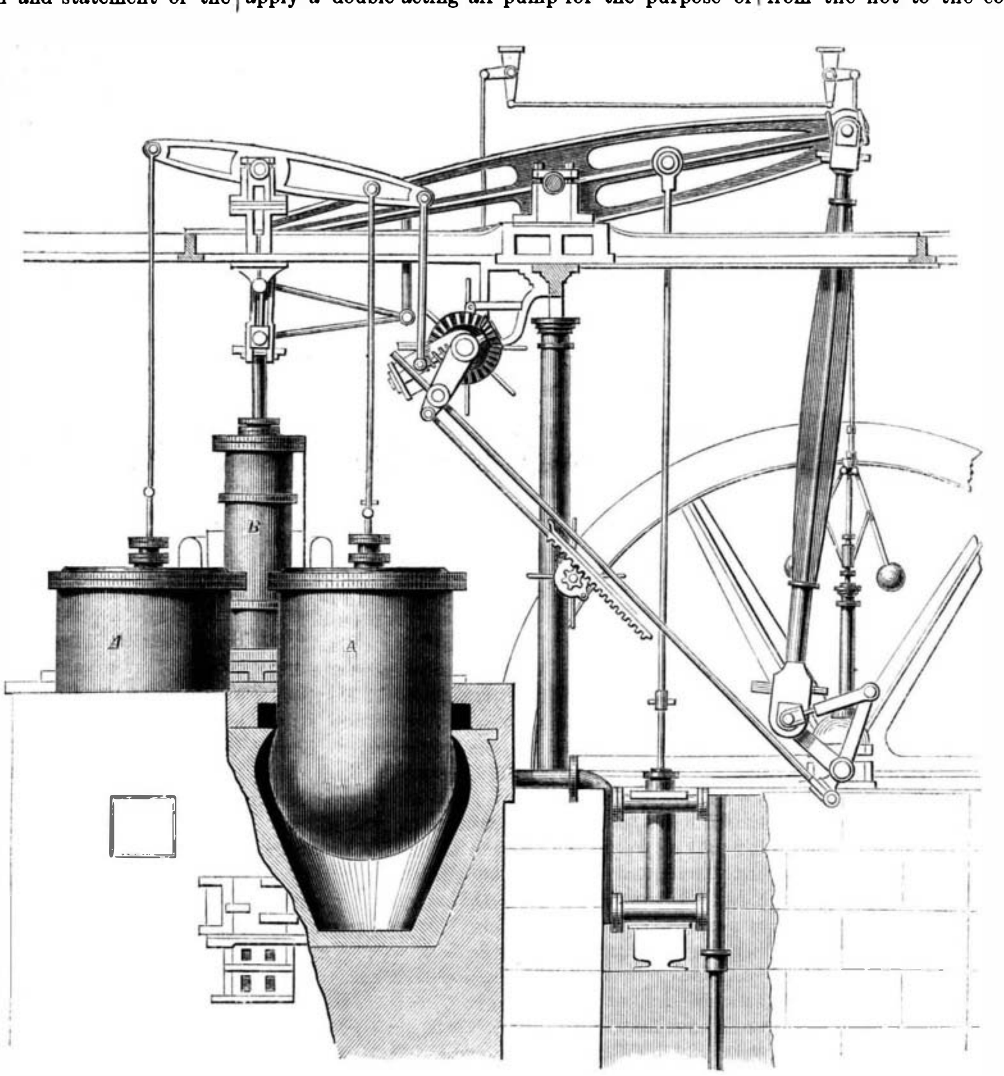
Important Discussion on the Air Engine.

At the third meeting of the session of the Institution of Engineers in Scotland, held in the Philosophical Society's Hall, in Glasgow, on Wednesday, 26th December, 1860, the President in the chair, the following paper was read by Mr. Patrick Stirling :—

The subject of this paper may require some apology for being introduced at this time ; but at a recent meeting of this institution there was one of Mr. Ericsson's air engines exhibited and explained, without any account of its performance as to power, consumption of fuel, &c., being given ; and it has been considered that a description and statement of the performance of Stirling's air engine might be interesting to members of the institution. The engine forming the subject of this paper was constructed by Mr. James Stirling, at the Dundee Foundry, in 1842, for the purpose of driving the machinery there, and was erected in room of the steam engine, by removing the boiler, cylinder, air pump and condenser, and making use of as many of the parts of the steam engine as could be made available, which will account for the apparent want of arrangement of the different parts of the engine. In this engine, which is represented in the engraving, there were two strong air-tight vessels, A A, connected by passages with the opposite ends of the working cylinder, B, in which last was a piston of the ordinary construction used in the steam engine. The lower ends of the air vessels were kept at a high temperature by a furnace which was common to both, and the upper ends of the vessels were kept from accumulating heat by a series of water pipes, through which there was a constant flow of water. In each of these vessels there was an air-tight vessel or plunger filled with a non-conducting substance, such as pounded bricks, to prevent the radiation of heat. These plungers were slung to the opposite ends of a lever, and were capable of being moved up and down in the interior of the air vessels, and their use was to shift a body of air from the hot ends of the vessels to the cold ends alternately, and in such a manner that the quantity in one would be at the hot end whilst that in the other was at the cold end.

If we consider, then, that the movements of the air engine depend upon the well-known principle in pneumatics that air has its bulk or pressure increased when it is heated and decreased when it is cooled, there will not be much difficulty in understanding that the movement of the plungers up and down will cause a pressure to be exerted on the opposite sides of the piston alternately ; and upon the difference of pressure obtained on the opposite sides of the piston depends the power of the engine. It may be mentioned that the plungers were moved by an eccentric or crank on the crankshaft of the engine, in the same way as the slide valve of a steam engine, and at nearly the same angle to the crank.

This engine was made to work on the high pressure principle, as it was found that engines working at the simple atmospheric pressure gave so little power in proportion to their size as to render them unfit for practical use. It was found necessary, therefore, to apply a double-acting air-pump for the purpose of increasing the density of the air in the air vessels, and the usual minimum pressure was ten atmospheres, which, on being thrown to the hot end of the air vessels, was converted into a pressure of fifteen and a half atmospheres by the addition of heat. The difference, then, in the pressure of the air when hot and cold constituted the disposable pressure upon the piston for the purpose of producing power. When the pump had got up the full working pressure in the engine, the air, instead of being blown off, was allowed to pass into an air-tight magazine, where a sufficient quantity was kept over night to fill the engine up to full pressure at starting in the morning, and this done, the suction valves of the pump were nearly closed together, the leakage of the engine being so small that scarcely any addition of air was necessary.



STIRLING'S AIR ENGINE.

Having explained in a general way the principles of the air engine, and by what means power was obtained from two opposing volumes of air, it will be necessary to consider the means by which economy in fuel was effected, as it must be evident to the most casual observer that, were the whole heat that was necessary in making one stroke taken from the hot end of the air vessel and thrown away at the cold end, the power produced by its expansion and contraction would be more expensive than that which is gained by the use of steam. To obviate this waste of heat, Dr. Robert Stirling discovered that the air could be divested of its heat to a great extent, on its passage from the hot to the cold end of the air vessels, by dividing the air into a multitude of thin films by means of strips of thin sheet iron kept apart from each other, and presenting a great metallic surface for receiving the heat. Now, as everybody, by contact, will give out heat to one that is colder than itself, the air, when it enters the narrow passages, must give out a portion of its heat even at the hottest end of the passages, and must continue to give out more and more heat in its progress upward, as the temperatures of the passages diminish, until it ultimately escapes into the cold end of the vessel, where there is only a small portion of heat to be extracted to reduce it to the required temperature. Thus, the temperature of the air at the hot end may be 600°, and when it arrives at the cold end it may be down to 150°, so that the whole heat constituting the difference of these two temperatures must have been left in the sheets of iron forming the narrow passages ; and this being the case, there is no room to doubt that the cold air, when again made to enter the narrow passages for the purpose of being heated, immediately comes in contact with metal that is hotter than itself, and consequently has its temperature increased by so many degrees every inch it travels downward, until, on its arrival at the hot end, it requires but a comparatively small addition to its temperature to complete the necessary pressure to move the piston. The thin sheets radiate from the center of the air vessel, and fill up the space between it and the plunger. In this may be said to lie the grand principle of the air engine, and when it was applied to highly compressed air it produced a large amount of work for the fuel consumed.

The engine under consideration had a working cylinder of 16 inches diameter, with a stroke of 4 feet, and when tested with a friction brake, it was found capable of sustaining a weight of 1,250,000 lbs. raised 1 foot per minute ; or 37 horses' power for a whole day, on a consumption of 1,000 lbs. of Scotch Chew coal, including the quantity necessary to get up the heat in the morning. This gives a consumption of 2.7 lbs. per horse-power per hour; but when the engine was not fully burdened, the consumption was considerably under 2.5 per horse-power per hour. This was considered a very fair result to be obtained eighteen years ago; and it is not unreasonable to suppose that, had the construction of engines of this kind been persevered in, still greater economy in fuel would have resulted. The engine drove the works at the Dundee Foundry for several years at a very small cost for maintenance.

The whole interior of the machine being entirely free from dust and moisture, there was little or no tear and wear of the different parts, and the piston, and piston and plunger-rods, did not consume a gill of oil in a week.

The principal cause of the failure of the air engine was the difficulty experienced in getting heat to pass through the lower ends of the air vessels with sufficient rapidity to supply the place of the heat that was carried away by the water pipes or refrigerator at each stroke; and in order to compensate for the slowness of the conducting power of the metal, which was necessarily pretty thick, it was necessary to keep the outside of the vessel at a very high temperature, which induced irregular expansion and contraction and incipient decay, resulting in the cracking of the metal and consequent destruction of the vessels. Notwithstanding this hitherto unsurmounted defect, the writer is of opinion that small engines upon this principle could be constructed and used with economy, in situations where the use of steam is impracticable from want of room to erect steam boilers, or from other causes. There would be less smoke emitted from the chimney; there would be no noise as with a steam boiler blowing off, or a high pressure engine exhausting; and accidents from explosion would be entirely avoided, as, when the air vessels did give way, a very small opening made its appearance, which allowed the air to escape in a few seconds without doing the slightest injury.

In answer to various questions from different members, Mr. Stirling said that as long as the plunger was moving up the pressure kept up well, but of course it did not continue as great as at the commencement of the stroke. The plunger was over the center before the engine piston. When the plungers were placed at half stroke the whole was in equilibrio, and the engine was set in motion by moving one plunger up and the other down. The heating vessels were four feet internally in diameter, and on every side there were minute air passages formed by metal plates, arranged not quite 1-32d of an inch apart. The plungers fitted as closely as they could make them, but there was no packing except about the piston and plunger rods. The packing of the plunger rods was peculiar. There was a copper tube filled with a solution of pitch and oil, fixed to the top of the plunger, and into this there dipped a pipe attached to the stuffing box, whilst a leather collar above encircles the rod, so that by no amount of pressure could any air get through. He had not heard of any air engine since this one was made which had been so successful as it. This engine could be made to work at 10, 15, or even 20 horses' power, with every satisfaction. For such powers the air vessels were not so large, but that they could make their bottoms comparatively thin. If these vessels were efficiently constructed, and with their bottoms thin—for example, not thicker than the upper part of the vessel's sides—the success of the engine would be complete. There was no practical difficulty, except in getting air vessels to withstand the heat. So far as the piston and cylinder were concerned, he had never seen better working machinery. The piston has worked for years without alteration, and it was observed that the sides of the cylinder were polished like mirrors. The piston packing was a pair of common cast iron rings, such as in ordinary steam engines, and made self-springing. The piston rod was packed with a leather like that of the heating vessel, and exactly like the plunger of a Bramah press. These leathers would work for three or four months. The temperature of the cylinder varied between 120° and 150°. He could not say exactly what was the highest temperature of the air vessels, but the bottoms were kept red hot. The temperature in the cylinder was almost constant, and also in the tops of the air vessels, where it never rose above 150°, but it was not so easily measured at the bottom. It had been assumed, however, that it was 600°. In the practical working of the engine the plates in the side passages of the air vessel took up heat from any body hotter than itself, passing over it, which heat it gave out again in the reverse process. The air entered at 150°, got heated during its descent by coming in contact with gradually hotter portions of the plate, and so, by the time it got near the bottom of the vessel, it had become heated to nearly 600°. The great difference between this engine and Mr. Ericsson's was this:—The engine of Mr. Ericsson on board the steamer which attracted so much attention, was a low pressure one, and it took in fresh air at every stroke, and as quickly threw it away. The blowing of the air through a wire gauze was the first thing tried by his father to obtain economy, and for which a patent was taken out in 1816. He might state that, in 1827, when his father was taking out his second patent, he met Mr. Ericsson, who asked him if he confined the air before using it; to which he answered that he did. Then Mr. Ericsson said their plans were quite different, and he would not require to oppose my father's patent. The air vessel no doubt might be made of copper, but it would not be so strong; and there was another objection, if it became red hot it might stretch or get out of shape. No doubt platinum would be the best metal to make it of. He could not arrive at the first cost of an air engine as compared with that of a steam engine; but of course there were no boilers nor slide valves required in the air engine. Diagrams of the engine had been taken, but they could not be depended upon as absolutely perfect, from the fact that there was a great deal of friction with the indicator piston, which required to be very tight on account of the great pressure. They never got a very truthful figure on account of the friction, but the diagram was a good one so far as it went. He had not one of the diagrams now in his possession.

Mr. Milne said he had seen this air engine working, and had never seen any description of engine work more smoothly.

Mr. Stirling, in answer to an inquiry, said that he was not aware of any engine of this kind being now in operation. The engine described had worked for four years, and in that time they had to renew the air vessels once. It took very little water to keep the top part of the engine cool. They allowed it to run down into a cistern, where it cooled, and was then used over again. The temperature of the water rose to 150° or 160° on passing through the refrigerating coils.

Mr. Brownlee thought that, in some cases, one difficulty in connection with this engine would be, that it required more water than a high pressure steam engine. He considered that it would not require a very high temperature to get a pressure of five atmospheres in this engine; for, the lowest temperature of the air being 150°, with a pressure of ten atmospheres, it would only require a temperature of 455° to get an additional pressure of five atmospheres.

Mr. Stirling did not admit that more water was required in the air engine than in high pressure steam engines, as they always got back the water, and so could use it again and again. With regard to the pressure obtained in this engine, he remarked that there was always a pressure of about six atmospheres at the starting, but after working a little it generally went back half an atmosphere, and at that it worked steadily. One great matter to be attended to in the construction of air engines was to have as little vacant space as possible, anywhere about it, into which the air could be compressed. Of course, great attention was paid to have all the passages in the air vessels as small and all the parts as close fitting as possible, so that the air was pumped out very completely every time the plunger came down.

The President remarked that still there would be a large quantity of air that would never leave the lower parts of the air vessels. The thin plates referred to as inserted in the sides of the vessel presented great surfaces for communicating heat. They did not, he supposed, assist in the economy of heating the air directly, but they were a means by which the heat applied through the bottom of the vessel was more rapidly distributed to the air. They took up the heat and gave it back again to the air when returning to the lower parts of the air vessels.

Mr. Stirling said that economy was undoubtedly the reason for the use of the plates, as they offered a large surface for picking up heat from the air when it was wanted to cool it, and which heat was given back again to the air when it was wanted to heat it, so that very little extra heat was required to raise the pressure to its maximum. These plates received their heat from the air, and not directly from the fire. They received heat in the same way as Dr. Jeffery's respirator did. There were only about eight or nine cubic feet of air in the vessels altogether. If this process of abstracting and giving up heat by the plates were absolutely perfect they would throw away no heat. They had only to make up for loss of heat by radiation.

Mr. Brownlee did not quite agree with that; for they knew that when air was compressed it gave out heat, so that, when the piston returned and the plunger partly returned, the consequent compression of the air must raise its temperature. If they could utilize all the heat of the fuel it would require only about a quarter of a pound of coal per horse-power per hour. He believed that this engine might be made to work with one pound of coal per horse-power per hour.

Mr. Lawrie asked what was the cause of the total failure of Ericsson's engine. He thought it was very extraordinary, seeing the high success of Mr. Stirling's engine.

Mr. Stirling replied that he could not say, as no data had been published. All that they could get were newspaper notices.

Mr. D. Rowan said if the economy of this engine was so great why did they not continue to work it?

Mr. Stirling answered, because they could not get the vessels to stand any length of time. The thickness of the vessels was about four inches. Possibly thinner metal would have stood, and they would have lost less heat from the outside. The vessel was the one difficulty of the engine.

The President drew attention to the principle of a new furnace, whereby fire-brick was used to save the wrought iron vessel from being burnt. He thought an air vessel might be got to stand, made on that principle.

Mr. Downie asked if, in Stirling's engine, any means of protecting the bottoms of the air vessels by fire-clay or other refractory material had been tried.

Mr. Stirling said the fire did not act directly on the vessels. The furnace was in a central space, from which the fire gases entered the two heating chambers containing the heating vessels, which chambers, with their fire-brick lining, were converted into a red hot bath. There were slips of fire-bricks between the furnace and the chambers, so that no part of the vessels were directly exposed to the fire; all the heat was got at second hand.

Mr. Downie said it occurred to him that if the bottom of the air vessel had been concave, and with fire-bricks built close up to it, it would have given better results.

Mr. Stirling said they had tried a number of bottoms, and amongst them one having a bottle shape, which gave good results, but the hemispherical one was found to stand best.

One Hundred Years Ago.—In the last part of the eighteenth century appeared, nearly at the same time, the edicts of Turgot for the enfranchisement of labor, and the book of Adam Smith on the nature and the causes of wealth. At nearly the same epoch, Lavoisier laid the foundation of the discoveries which were to transform chemistry; Watt took his first patent for his perfections of the steam engine, and Arkwright obtained a patent for spinning by rolls. These events contain the germ of the principles and of the means adopted by modern industry. Modern chemistry gave birth to numerous industrial processes; the perfected steam engine furnished a motive force applicable to the most varied mechanism; mechanical spinning and weaving replaced the ancient mode of manufacturing tissues and multiplied the productions of manual labor; finally, the ideas until that time dominant gave place to notions more just and more exact on the nature of wealth and on the means of developing it.

Homogeneous metal, so called, is made by melting Swedish wrought iron, cut into scraps, along with about one per cent of powdered charcoal; six oz. of the latter being allotted to a charge of 40 lbs. of iron.