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GREENE ON ELECTRICITY ON BOARD SHIP, [January-April 5, 1899]

PROF. Elihu Thomson: — I happened to make a trip about two or three months ago to Washington for the express purpose of convincing the department, as far as I was able to, that electricity was the only thing to use on shipboard, in place of these numerous steam plants. As I thoroughly believed that to be the case, I made the best plea I could of course. I found, however, that in one of the departments especially, there seemed to be an idea that we should move slowly; do one thing at a time and test what we had done before leaping in the dark. That might be a rational estimate of the situation coming from one who probably had not looked into the comparison between these various sources of power and electrical power. However, I am perfectly satisfied that the time is short when it must come about that an electric equipment, on account of its numerous advantages, will be adopted for practically all of this distribution of power around a ship, just as it is being adopted for the distribution about a large city. The reasons are even more cogent in the case of a ship where the coal consumption is a vital factor. One cannot look at the tables presented by Mr. Greene, without seeing the enormous coal consumption of some of those small powers, and yet I know it also as an experimental fact, that engines as small as four horse power can be made to develop a brake horse power, not indicated—on about 20 pounds of water per horse power hour; that engines probably of larger capacity can be made to go very much below this, and those engines will be simple, non-condensing engines, uncompounded. Now I make that statement advisedly because I have been experimenting for a year in that direction. Engines of this kind can be turned out in any machine shop without any particular difficulty, being as easy to make as any simple engine. I find curiously enough that after doing a considerable amount of work in this direction, M. Serpollet of Paris has recently published a statement concerning a steam engine as applied to horseless vehicle work, and I find further that his engine is about the same as mine. This goes to show that we have been thinking pretty much in the same groove. I need make no secret as to what the engine is, because M. Serpollet has published it, although of course our patents are pending. But it is so simple that it is astonishing that something of the kind has not been used or at least experimented with before. If it takes over twenty pounds per horse power—and indicated horse power as noted in that table — (referring to one of Mr. Greene's tables) in the main starboard engine, and we can do as well with a non-condensing simple engine of four horse power, we have certainly done something worthwhile.

My reasoning was this: that the gas engine is an efficient engine and that I must run my steam engine on the same principle of the gas-engine. In other words, I must imitate the cycle of the gas engine in steam, and then I would get high efficiency, with other advantages. If I represent an ordinary steam cylinder as an open-ended cylinder in Fig. 1, and put a piston P in that cylinder, well packed by rings, and either use a straight piston rod and guides in the ordinary way, or the connecting rod R jointed to the piston, we have the type of engine as it stands.

Now instead of reversing the motion of our steam as it enters back of the piston and throwing it back to the heated surfaces in exhausting, we are careful never to throw it back, but always let it go forward. We make an exhaust consisting of a number of holes uncovered by the piston at the extreme outward portion of its stroke as at E. The piston is moving slowly when it is out here near k and there is plenty of time, if the holes are made around the piston, to discharge all the steam. In order to use the steam superheated so as not to burn the valves or injure the engine, and we use somewhat superheated steam, or quite dry steam, we simply have here a poppet valve V which is raised by proper valve mechanism in time with the rotations of the crank.

The steam supply pipe from the steam generator is at s. Now let us see what we can get in this engine. In the first place let us suppose the engine cylinder has been exhausted of steam at **E** to atmospheric pressure. If we construct an indicator diagram, Fig. 2, calling base line atmospheric pressure, we reach the end of our stroke at ***e***. Instead of letting the piston go all the way up to the end of the cylinder we can allow a clearance space which represents the clearance space in a gas engine. We can thus allow a certain compression; and the compression can nearly equal the boiler pressure, or it may fall below it. This seems to make but a slight difference. We have, therefore, adiabatic compression with a slight heating during the compression line along ***e d.*** Fig. 2, because the steam left in the cylinder is being driven up towards hot surfaces, those that have been heated by the live steam. Then we have valve ***v*** opened suddenly, and pressure risen to boiler pressure ***g***. The valve ***v*** stays open but a very short time, and expansion takes place from ***g*** to ***r***. The diagram resembles a gas engine diagram. What is left in the cylinder is again driven up and compressed. Now what is the result) There is a temperature gradient from one end of the cylinder to the other. The steam always coming in hot, cools off by expansion; by the time it gets to **E**: it is ready to go out. It sweeps out all water of condensation—explodes it out or blows it out, and what steam is left in the cylinder is driven back on hot surfaces, dried, superheated; the poppet valve opens and makes as it were an explosion of steam; remains open but a small time and expansion brings the pressure down again and so on. The engine with four cylinders, 2 1/2”   in diameter, 3” stroke has given the result of 20 ½ pounds water per horse power hour.

Figures on following page.

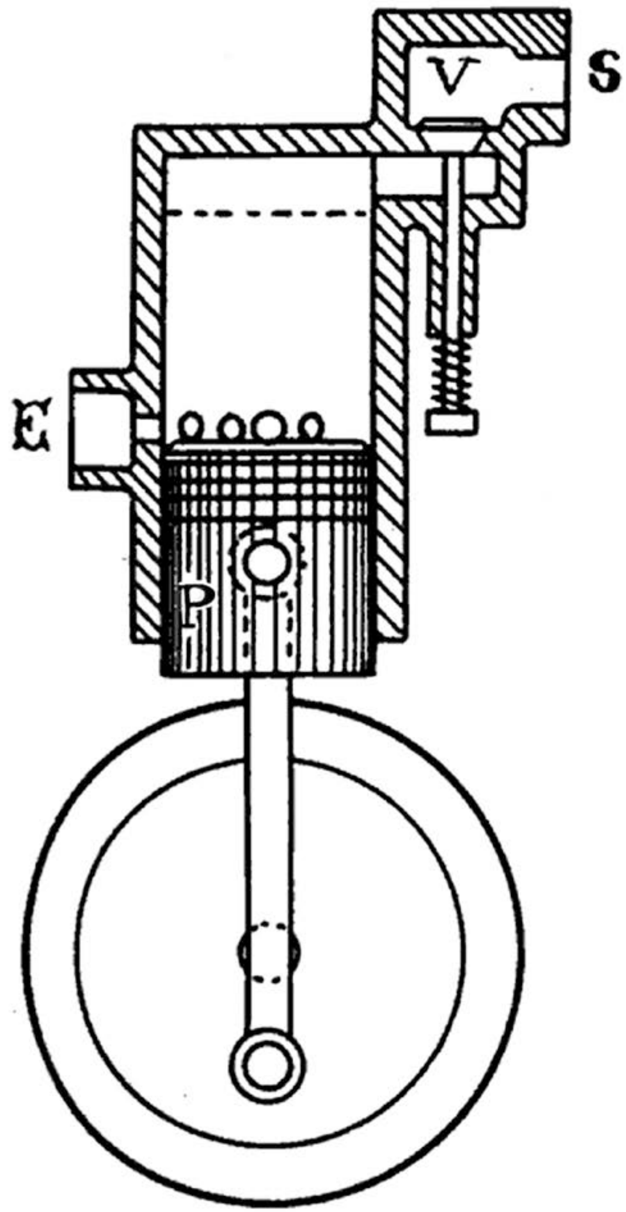

Fig. 1.

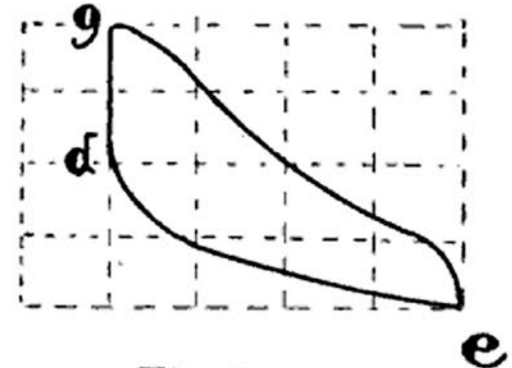

Fig. 2

Mr. Greene: —What steam pressure?

Prof. Thomson: —160 pounds, anywhere between 160 and 200 pounds. No doubt it can be made to run with higher pressures. There is no question about that. It could be run on 300 pounds easily enough. The result of it would be that if we needed engines to equip boats very rapidly in case of a war we could turn such engines out in a very short time. We need not wait to make elaborate compound condensing engines. This small engine does not condense at all; the escape is outwardly to the air. We made careful brake tests, driving a dynamo and loading the dynamo, and against the results of test is the transmission by a chain and the bearing on which the dynamo ran. That is, we really ought to allow about five per cent more, which would bring the steam down to about 19 ½ pounds per brake horsepower hour. With a large engine I see no reason why it should not go down to something like 15 or 16. Surely we ought to gain something with increase of size. But notice the conditions. The conditions are such that there is no re-traversing of passages, no re-traversing of even the cylinder portion. The steam enters, goes forward and out, and it is running steadily forward, so that we do not have any of those inter-actions that use up energy.

We have a temperature gradient from one end to the other of steam cylinder. We use superheated steam, highly superheated if we please, because the engine is like the gas engine which can use flame. We have run it at all degrees from moderate superheating up to red heat. The engine has been operated with the steam pipe red hot right up to the engine, but our tests were made when it was at a moderate superheat.

MR. Townsend Wolcott: —I would like to ask Prof. Thomson if there is anything equivalent to variable cut-off in this type of engine.

Prof. Thomson: —Yes; we have a variable cut-off, although we usually run it at full load with a very small time for feeding steam. In starting, we of course give steam during a good portion of the stroke of each of the four cylinders. In order to get continuous torque in this case, we give it for about two-thirds of the stroke.

Mr. Wolcott: —One of the chief drawbacks to the ordinary gas engine is that there is very little speed regulation, and then when running too fast a stroke is lost and it doesn’t take gas on that stroke.

Prof. Thomson: —There is no difficulty whatever in this case. We have in fact a variable cut-off arrangement whereby we can give a little more or a little less steam or run on compression alone for a few revolutions.

Lieut. Walling: — 1 have listened with much pleasure to the instructive paper read before the Institute this evening, and being here in the capacity of a listener, without expectation of taking any part in the discussion, my remarks on the subject of the lecturer's paper, a subject with which I have been intimately associated for the past two years, must be more brief than I should desire. In all the discussions which come up regarding electrical installations on board ship there are a great many things to be considered that 1 do not think are understood in commercial life, for electric appliances of all kinds have their severest tests in naval installation.

In regard to the *Minneapolis* and the use of steam and coal for auxiliaries; we have made several tests on board ships on dynamo engines for water consumption. I am not aware that it is known to the Institute but we have gone through a long series of types of engines each tending toward better efficiency and are now using the tandem compound. We are now getting an efficiency of about 21 pounds per indicated horse-power and about 30 to 32 per kilowatt hour. We started out with engines that I think must have, on original tests, given about 65 pounds per indicated horse-power, and have later come down to about 48 on the improved types. The *Minneapolis* had pistons that were not packed and wore badly. They were of rather soft material. The steam short-circuited from one side of the piston to the other. In a similar type of engine, almost the same type, used on the *Marblehead* there was 125 per cent, increase in a period of two years. You cannot get good coal economy with that kind of an engine. We repaired the Marblehead engines, packed the pistons, and have never had any like trouble since. We took the matter up then with the company which made the engines. They have since packed pistons and their engines have done very well.

The case of the *Marblehead's* engines has been repeated in a number of ships and, until I heard the data given in this paper, I was not aware that the economy of other auxiliaries had ever been effectually tested.

The installation of electrical appliances for working all auxiliaries on board ship will, I think, be very general within the next two years. There are, however, two types which we will be rather slow in changing from steam drive, namely, the anchor gear-windlass or capstan — and the steering gear. It is still a question as to the availability of motors for their use. Motors will answer for most, of the uses in commercial life; but for anchor use, when a ship is pitching badly in a heavy sea and her anchor must be weighed, the motor may or may not be reliable, and we cannot take the chance that it may not. It is mainly a question of application. With steering gear a similar condition obtains from the "kicking" of the helm in heavy weather.

page 39 **[Communicated after Adjournment by Mr. George Hill.]**

Professor Elihu Thomson's discussion of Mr. S. Dana Greene's paper "Electricity on Board Ship" presented at the meeting of January 25th, 1899, calls for a comment on certain statements made, which in the opinion of the writer are not borne out by the facts. The intimation is made that a simple single acting non-condensing steam engine can be made by a slight change from the standard design as economical as a triple-expansion condensing engine. The principle of the change is indicated by Professor Thomson in the statement that "I must imitate the cycle of the gas engine in steam, and then I would get high efficiency with other advantages." The cycle of a gas engine as ordinarily understood is as follows:

The admission of a certain amount of mixed gas and air during the forward stroke of the piston; the compression of this gas and air during the returning stroke of the piston; the explosion of this compressed mixture at the instant that the piston begins to move forward, the sweeping out of the products of this explosion on the return stroke of the piston, and the drawing in of a new charge of gas and air with the forward stroke beginning a new cycle. The cycle therefore occupies two complete revolutions, one of which may be called a working revolution and the other an idle one. Nothing in the engine described by Professor Thomson approaches this. In describing the action of the engine he says "now instead of reversing the motion of our steam as it enters back of the piston and throwing it back to the heated surfaces in exhausting, we are careful never to throw it back, but always let it go forward." Such a statement seems very curious from so eminent a source; the steam must act expansively; as a consequence the entire cylinder is filled with steam during the entire

forward stroke at a constantly decreasing pressure and consequently a decreasing temperature. When the return stroke begins, the cylinder is filled with steam at atmospheric pressure and this steam is compressed giving the compression line shown in Fig. 2. The entire cylinder being filled with steam of a given temperature at the point of release, it really makes no difference at which end of the cylinder the steam is withdrawn. As a consequence, the engine is no different in principle from the Westinghouse engine. The steam consumption
per horse-power hour seems very low, and would be remarkable, if it were ordinary steam at 160 lbs. pressure without superheat, but Professor Thomson states that superheated steam is used, without stating the number of degrees of superheat, which accounts for the low water consumption. If he had expressed the efficiency of the engine in heat units actually utilized, or in pounds of coal of a stated composition per horse-power hour, the result would have appeared very different. The available heat in steam at 160 lbs. gauge pressure, expanded to atmospheric pressure is 46 H. U. per pound, each degree of superheat adding to the available energy a considerable percentage, which percentage is greater than that due to an increase of one pound in pressure, but both require the expenditure of energy either by the consumption of coal or otherwise, and must be accounted for in stating the economy of the engine. Something too must be allowed for the fact that the engine tested was new, and probably a great deal of pains taken to eliminate all waste. In conclusion it would seem desirable to obtain much more data in regard to the engine and its operation before we flatter ourselves that any material advance has been made in steam engineering by either Professor Thomson or M. Serpollet.

NEW YORK. MARCH 28TH. 1899.

[A Reply by Prof. Elihu Thomson to Mr. Hill's comments on his discussion of Mr. S. D. Greene's paper on “Electricity on Board Ship."]

I am too busy to enter into a lengthy discussion with Mr. Hill on the points raised by him, but will venture, for the present, the following remarks:

My comments following Mr. Greene's paper were made offhand, and were not prepared in advance. They had necessarily to be brief, and nearly as possible to the point. I certainly did not intend to indicate that the best results of triple expansion engine practice were likely to be excelled by the simple form of engine which I described. But that the effects of simple engines could be made to approach more nearly the highly economical results of more complex types is evident when it is borne in mind that our simple engine of only five and a fraction horsepower, in reality composed of four simple engines of little over one H.P. each, when tested, gave results in water consumption not greatly differing from those of tests of engines of hundreds of horse-power in compound condensing types. A factor in the cost of power is interest, wear and tear and depreciation, which are manifestly the less, the simpler and cheaper the engine, other things being equal. Mr. Hill finds fault with my comparison of the cycle of the small engine with that of a gas engine, seemingly ignoring those types of single cylinder gas engine which make one explosion every revolution. He must admit, however, that in the simple engine, an action is produced every revolution which in the type of gas engine he selects for comparison is only produced for every other revolution, and that in consequence the simple steam engine described has the advantage of less friction and negative work. Besides, I was speaking only in general terms when I referred to the gas engine cycle, and merely as an assistance to the understanding of the actions in the simpler engine itself.

We have indeed to be thankful that:—"Nothing in the engine described by Prof. Thomson approaches" the *idle* revolution of the four stroke cycle of the gas engine. I am surprised at Mr. Hill's not understanding what was meant by the statement I made in the words; "throwing it back to the heated surfaces in exhausting," etc. He has totally missed the significance of the words *"in exhausting."* Does he find that the steam goes back to the hot end and out of that end *in exhausting?* It does go back (what amount is left of it) *in compressing.* This is so plainly evident as to need no discussion, and it is certainly not a bad feature. It is not a wasteful process, surely.

Does Mr. Hill really think, and can he truthfully maintain that it makes no difference at which end of the cylinder the steam is withdrawn? If one end is hot, as heated by the incoming steam at high pressure, is it economical to discharge steam, *cooled* by expansion and delivery of energy to the moving piston, at the hot end, and so allow the steam in exhausting to run away with useful heat? What a beautifully wasteful process is that which involves the admission of steam between or over surfaces which have just been bathed in cool steam (and perhaps condensed water) leaving the cylinder. I freely admit that the fact of the use of superheated steam, has perhaps something to do with the low water consumption shown by repeated tests, and preparations are being made to test a much larger engine of the same type, with steam in all degrees of humidity, dryness and superheat.

As I was testing an engine and not a *boiler,* I rather preferred to exclude the boiler from the tests, particularly as no means were at hand to do differently. Just why this was the case I cannot stop to explain now. It is true that to obtain hot, dry steam, may mean the communication of more heat units per pound of steam than in the case of wet steam or saturated vapor, but the difference is comparatively slight. The change of state involved in boiling the water is, as Mr. Hill must know, the chief factor in the case, whether the steam be produced in one condition or another.

I cannot admit that: "A great deal of pains was taken to eliminate all waste." The engine was in good condition, of course, but not exceptionally so. Its simple construction permits of relatively easy maintenance. When I made the engine I expected to realize a result of about 30 pounds of dry steam per brake horsepower hour, which in itself would have been roughly about twice as economical a result as is shown in the best tests of such very small engines, of which I was able to obtain any data. I was skeptical of the result of the first tests, and freely expressed my doubts, but by going over the work and watching it personally, while insisting that everything be done to have the errors count against the engine rather than in favor of it, I became convinced that my expectations had been greatly exceeded, and that a result of 20 pounds per horsepower hour, or slightly better than that, had been in fact, obtained, as I have indicated.

It remains to finish and test an engine of larger capacity and to do it under such varied conditions as will be likely to point out the relative values of those features which undoubtedly contribute to the still lower consumption which will probably be obtained.

The small engine tested was designed for automobile work, it being regarded as extremely desirable that but little water and fuel be carried, and but little steam escape during work. The clearance is great and the manner of exhaust and admission such that no trouble is ever experienced with condensed water in starting.

The engine is now in use upon a steam automobile, having a coil-pipe boiler heated by ordinary kerosene. It runs satisfactorily even under the very extreme condition adopted in some experiments with it, of a steam supply-pipe at a bright red heat. But this is, of course, abnormal and only indicates the wide range in character of steam which is permissible. That it is not injured by excessive heat in the steam supplied, is due, doubtless, to the poppet valve admission and the extremely early cut-off which permits the entrance of only a momentary puff of hot steam when the piston is full in.

As a matter of interest in this connection I would conclude by calling attention to the fact that Ewing in his work on "The Steam Engine, and other Heat Engines," on pages 160 and 161 gives some results of tests by Willans on a small, simple, non-condensing single-cylinder engine, in which, with 172 pounds of steam, an indicated horse-power hour was obtainable with 18 ½ lbs. of steam. This represents, as Ewing points out, an efficiency of 75 per cent, of the theoretical efficiency of an engine working under the conditions. Ewing also refers in this connection to "Min. Pro. Inst. C. E., vol. xiii., part 3, and vol. xcvi., part 2," in a foot note.

Lynn, Mass., April 5th, 1899.

Added Material:

APRIL, 1933 pages 225-228 MECHANICAL ENGINEERING

ELIHU THOMSON:

Some of His Mechanical Inventions

BY KARL T. COMPTON[1]

Two years ago this veteran inventor, engineer, and scientist was made an Honorary Member of the A.S.M.E. In celebration of his eightieth birthday, Dr. Compton interestingly recounts here a number of Professor Thomson's achievements in a field closely allied to the electrical one to which he has brought such honor and renown.

Article on next page