NEW STEAM AGE

Steam-powered touring car.

JANUARY 1942

1200-lb. Reheat in Maritime Commission Cargo Vessel

Knox High Pressure Small Boiler

Gas Turbines

Solid Fuel for Cars

Experimental Dept.

Vol. 1 No. 1
QUARTERLY

THE MAGAZINE OF MODERN STEAM POWER

In its first few issues, NEW STEAM AGE will not accept any advertising. When its rate of growth has become stabilized, when the soundness of its reasons for existence has been month interval provides time for the careful checking and rechecking of material demanded by a new scientific magazine. With subscriptions rolling in at press-time, and expressions of reader interest already appearing, an increase in the number of pages, in illustrations, and a development of some of the departments now in a formative state, seems highly probable, demonstrated, advertising will be solicited. Meanwhile, if readers wish to be placed in touch with manufacturers of any equipment mentioned in NEW STEAM AGE, the services of the editorial department, which maintains up-to-date files on products for this purpose, are available to subscribers.

Another reason for this policy is the possibility of a change in the publishing schedule. If it appears that the service rendered by NSA can be increased thereby, more frequent publication will be considered. For the first issues, the three-

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NEW STEAM AGE

Next Issue

The editors have been gathering information on gas generators, first because they are an inexpensive method of converting any automobile for the use of a cheap fuel, and second, because the principle of the down-draft gas producer is worth exploring, for its possibilities as an automatic firing source for steam boilers. Modern European practice in automotive use of gas generators will be described.

Fundamental preliminary design of a steam automobile, from powerplant to body style, is the subject of an article by a painstaking researcher on automotive subjects. Once an executive of a well-known motor car company, and now engaged in the machine toot industry, the author has the experience and engineering knowledge to evaluate problems in as diverse fields as aerodynamics, heat-loss, and production, and apply his conclusion in an orderly manner to a specific design problems modern steam car.

Concluding the description of the Knox steam plant, (the boiler is described in this issue) a report on the design, construction, and testing of the Knox compound engine, will illustrate the "works" of this interesting uniflow engine and unique valve gear.

Our marine department has been active and successful in ferreting out some unusual installations of high-pressure propulsion machinery. And several steam vessels have been on long and eventful maiden voyages.

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Blow-off

From many conversations over a period of years, from many friendly letters, and encouraging signs in the daily press, the concept of an American magazine devoted entirely to modern steam power, has gradually taken shape in the minds of our editors and many of our "First Readers".

There have been other magazines on this subject, but the last to be published in this country expired long ago. The reasons for its passing were obvious: the steam automobile was disappearing from the highway. The Gas Age was in full swing. Automobiles had become a means of transport rather than a source of sport. The Sunday morning major overhaul in the alley, once a joy to the mechanically inclined office worker, has faded into the past-almost. The silent and graceful steam launches of our lakes and harbors had given way to the "put-puts". Steam was still useful in huge power plants, ocean liners, and locomotives, but it lost popular favor, and its days seemed numbered. Even the Turkish bath was on the skids.

Why do we, Phoenix-like, rise from these ashes? What has happened to provoke the publication of a new magazine, especially in these unsettled times? In the last two decades, steam has reached new heights of economy and ease of control. Since the Stanley Steamer ceased to be the "best performer" on the highway, the "flash" boiler has been perfected, the automatic atomizing oil burner has been installed in millions of homes, lubricating oils have been improved, and metals that retain strength and wearing qualities at high temperatures are available-with a priority order. The capabilities of steam as a light weight power plant have been demonstrated by successful flights of a steam-powered aircraft. In many vehicles, ships, and stationery plants, in great laboratories and in backwoods machine shops, steam is being re-investigated, revaluated, and "streamlined" to perform tasks that Watt would have considered miraculous.

It will be our steadfast purpose to keep abreast of these investigations, to report the greatest and the least of them with unbiased scientific zeal, to stimulate and correlate these efforts, and to promote insofar as possible a sound understanding of the merits of steam power, without failing to recognize the sometimes superior qualities of other prime movers. We shall also take a general interest in fuel conservation in transportation, in domestic heating, and other fields.

Of course, we will relax *sometimes.* The history of steam is so full of human and mechanical complexities that we will not be able to resist an occasional story on steam plants of the past. And a good piece of model engineering is not beneath notice.

-The Editors

1200-lb. Reheat Marine Plant

Benjamin Fox and Richard H. Tingey*

The following extracts from a paper presented at the annual meeting of the Society of Naval Architects and Marine Engineers describe briefly the most important features of this unusual installation, sponsored by the Maritime Commission for operation by American Export Lines. Through the cooperation of the authors, the Society, and the Maritime Commission, NEW STEAM AGE is privileged to be among the first to announce this important milestone in the history of steam power.

The S.S. *Examiner* is one of a class of eight 450-foot cargo ships, known as the C-3 design, built by the Bethlehem Steel Company. The machinery plant consists of single-screw, double reduction geared turbines of 8000 shaft horsepower. The steam conditions of seven vessels of the group are 425 lbs. and 740 F. at the throttle. The design and performance characteristics are generally in accordance with the best current practice.

When the group was about half completed, the Commission arranged with the builders and the operators to change the design of the machinery for the eighth vessel to a 1200-lb reheat installation. The complete redesign was worked out by the shipbuilder with the cooperation of the Maritime Commission and the manufacturers of the boilers, turbines, and auxiliaries. The intent was to determine, by full scale experiment, the suitability of such machinery for marine propulsion, particularly with a view to adoption of the cycle for the Commission's contemplated large high-powered passenger vessels.

The changes were confined to those inherent in the new steam conditions, and the S.S. *Examiner* therefore differs only in the turbines, boilers, and equipment intimately connected with the heat cycle. An excellent opportunity is here presented to compare the two types in the same service. Exhaustive trials are contemplated when the installation, now nearly complete, is in operation.

The characteristic features of the reheat cycle can be explained by reference to the following description of the steam path

(1) Steam is generated and superheated in conventional boiler and superheater elements. (2) The steam is then expanded through the high pressure elements of the turbine to the reheater inlet pressure. (3) It is then reheated at this reduced pressure in the reheater elements. (4) The reheated steam is finally expanded in the low-pressure elements of the turbine down to vacuum and is then condensed.

The steam leaving the high-pressure turbine may be heated by flue gases or by live steam at boiler temperature and pressure. Both of these methods have been applied in land plants; in marine practice an application was made in the Loeffler boiler in the S.S. *Conti Rosso*. The installation under discussion has separate furnaces and

(Continued on page 20)

Assistant Manager of Enginering, and Chief Engineer, respectively, of Bethlehem Steel Co., Shipbuilding Division.

Gas Generators For Automotive Use

With increasing frequency since World War I there have been waves of interest in substitute motor fuels, particularly in Europe. In the United States the abundance of petroleum has prevented any serious study of small gas producers. With possible diversion of oil supplies to military uses in view, a study of the gas generator seems appropriate.

The Dim Past

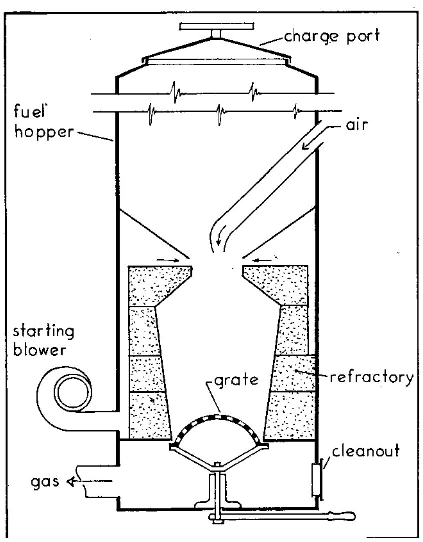
The gas producer has been in existence since the beginning of iron production in furnaces. In the first part of the 19th century it was discovered that the gas evolving from the reduction of iron with coal could be utilized for heating air, operating blowers, and other equipment around the furnace. In 1835 William Barnett, working on the earlier ideas of Lebon, inventor of illuminating gas, designed a motor for the use of producer gas. In 1861 Milton rediscovered the possibilities of harnessing the waste gas, and a year later Beau de Rochas, in a treatise now famous because of its description of the four-stroke cycle, devoted some attention to improvements in gas generators and their possible use in supplying fuel for engines.

Anticipating modern designs, Prof. Arbos de Barcelone described in 1862 an engine drawing gas directly from a generator, without storage of gas, thereby governing gas production in direct proportion to the needs of the engine.

Alfred Wilson, then Emerson Dowson, built generators using the injection of steam into the combustion chamber. It was this type of gas that operated the first Otto engines of Dentz and of the Crossley brothers of Birmingham.

Paradoxically, all of the above generators used oil as fuel, and it was only after the general use of refined spirits for internal combustion engines that charcoal and other solid fuels were applied to the portable gas generator. Little interest in the problem was shown until 1914, when the Automobile Club of Morocco held a race for five trucks and tractors equipped with gas generators. European fuel shortages during the first World War stimulated government bureaus to investigate the gas generator, for military transport as well as civilian uses. By 1936 there were a dozen generators on the market in France, and prizes, automobile club meets, and subsidies in the form of tax reductions

Figure 1. Panhard generator.



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Hero II, One-Man Steam Yacht

By Capt. A. Vapeur

During the fitting-out period, curiosity brought many amateur and professional skippers to the dock, some hoping to see an explosion, some seeking enlightenment, others just plain curious. When reports reached me that Hero was making trial runs, I lost no time in getting to the waterfront.

The stack distinguished *Hero* from other cruisers at the dock. I found the owner absorbed in some carpentry, and "Gus," the "crew," busy below putting down a fine red linoleum sink top. The engine hatch was raised for my entertainment, and Mr. York, the owner, proceeded with his carpentry. I was soon absorbed in trying to follow wires and pipes around the boiler unit, a confusing task because of the heavy insulation on all the parts, and I failed to notice that the owner's task was over. When I next looked up from the bilge, we were a dozen yards from the dock. Mr. York had cast off the lines and stepped to the bridge to open the throttle. We were moving smoothly out into the harbor, and for a moment I felt the strange exciting sensation that comes over one as a liner sails. The silence, the absence of vibration, and the mysterious changing perspective of the shore, all convinced me that I was aboard a-genuine steamer.

As the dock disappeared astern, I pulled my wits together, and went to the bridge to discover what the gages were saying, secretly hoping that Mr. York would let me take the helm. A faint purring noise below the hatch indicated that the burner was on, responding automatically to the need for more steam as speed increased. The owner asked if I would *mind* taking the wheel. Trying not to show too

Figure 1. Hero 11 at mooring. The hatch aft of the stack houses the boiler. Engine is forward, under floor.

unit. Barber's patent drawings show compressors for both air and gas mixture, and an impulse type turbine wheel on which impinged the high velocity jet of gases leaving the nozzle in one extremity of the combustion chamber. To prevent the subjection of the turbine parts to excessive temperatures, a provision for cooling the gases by water injection was also indicated.

John Dumbell, also of England, patented in 1808 a device which was a prototype of the "exploon" type of gas turbine to be described more fully later. Products of combustion traversed a turbine rotor comprising several rows of blading. The design could hardly be considered propitious, however, since it consisted entirely of rotating blading and did not include stationary or guide elements, thereby depriving it of the advantages of the present day multi-stage type of turbine.

A machine whose essential features resembled those of a turbine used in the Armengaud and Lemale experiments, to be recounted later, was patented by Bresson in Paris in 1837. A fan delivered air under pressure to a combustion chamber where it mixed with gaseous fuel, burned, and the products of combustion, cooled by excess air, directed in the form of a jet onto a wheel.

Forerunners of Present Types

Other gas turbine schemes were proposed during this period, but they, as well as those mentioned above, exhibited various features of design which rendered them impracticable. In 1872, however, a patent for a "fire turbine" was applied for by Dr. F. Stolze, of Charlottenburg. The similarity between the Stolze gas turbine and the modern combustion type is indeed striking. The unit consisted of an axial flow compressor directly coupled to a reaction turbine- Before expansion through the turbine, air discharged from the compressor was heated in an externally fired chamber. Tests on an actual unit indicated the design was unsuccessful primarily because of the inadequacy of the axial compressor. In view of the limited knowledge of aerodynamics existing at that time, such unfavorable results could be expected.

In 1884 Sir Charles Parsons obtained his original steam turbine patent, and in it reference was made to the gas turbine. It was explained that the turbine could be converted into a compressor by driving it in a reverse direction by an external means. The compressed air was discharged into a furnace where fuel was injected, and the resulting products of combustion were expanded through a turbine. Except for blade contours and angles, the compressor was similar to the axial compressor as it is known today. The patent also provided for the cooling of the turbine blades by either water or other suitable fluid.

During the years 1900-08 the Parsons Company built about 3o axial compressors, the largest having a capacity of 50,000 cfm. The highest delivery pressure of any of the units was 11.75 psi gauge. Much effort was expended with inconsequential success in improving the efficiency of the axial compressor. Primarily because of his numerous other activities but also because of the higher efficiency centrifugal compressor of Rateau, introduced commercially in 1908, Sir Charles finally abandoned further research on the axial compressor.

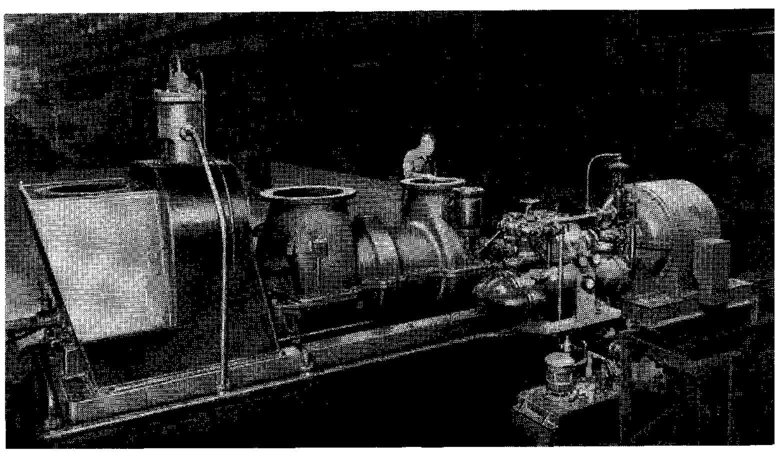
First Practical Gas Turbines

The Société des Turbo-moteurs in Paris during the years 1903 to 1906 built several experimental gas turbines operating on a cycle similar to that of the modern combustion gas turbine. The work, really the first significant attempt at building a practical gas turbine, was performed by Armengaud and Lemale. The results of the original tests obtained on a *25* hp DeLaval turbine led to the construction of a turbine of higher capacity, consisting of a two-row impulse wheel with provision for water cooling of the blades and disk.

Compressed air from a multi-stage Rateau compressor driven by the turbine was supplied to a combustion chamber in which liquid fuel was burned. The resulting combustion gases, cooled by water injection, were expanded through the turbine. A thermal efficiency of slightly less than three percent was obtained. Notwithstanding this poor performance, the experiments were significant because this was probably the first combustion gas turbine to actually produce useful work.

In 1908 Karavodine, in Paris, built a *2* hp, single stage, 10,000 rpm, impulse turbine operating on the explosion cycle with an open type combustion chamber. Four nozzles were circumferentially spaced around the rim of the 6 in. diameter wheel. Connected to each nozzle is a separate, waterjacketed combustion chamber wherein the explosion of the charge caused an increase in pressure and the gases expanded through the nozzle onto the wheel. The cycle repeated itself after the suction effect of the departing gases drew in a fresh charge. The explosions were timed to occur consecutively around the wheel periphery. The combustion chamber was referred to as the "open" type because no

Figure 1. A 40,000 cfm turbine-compressor unit.



Allis-Chalmers Electrical Review

valves were placed between the explosion region and the nozzle inlet, compression being effected by the inertia of the burning gas mixture. Although the turbine reputedly operated satisfactorily, the overall thermal efficiency amounted to less than three percent.

Holzwarth Turbines

In 1908 Dr. Hans Holzwarth began his long years of experimental work on the explosion type of gas turbine which bears his name. The continued activity and interest exhibited in this turbine by Holzwarth and others has persisted to the present day. The Holzwarth turbine operates on the explosion or Otto cycle, the expansion phase of the cycle extending to atmospheric pressure. The explosion occurs upon ignition of a charge of air and gas introduced under pressure into the combustion chamber. The pressure in the closed chamber increases until it overcomes the action of a spring-loaded valve, permitting the gases to flow to a nozzle whence they are discharged at high velocity onto a turbine wheel. The nozzle valve is specially constructed so that it remains open under oil pressure until the combustion chamber is emptied. Expansion is followed by a scavenging operation which clears the combustion chamber of residual burnt gases and also cools the turbine blades. After scavenging, a fresh charge is admitted and the cycle repeated.

Precompression of the charge was not provided in the first turbine built by Holzwarth, but later ones bad a moderate amount produced by a steam turbine-driven compressor. A waste

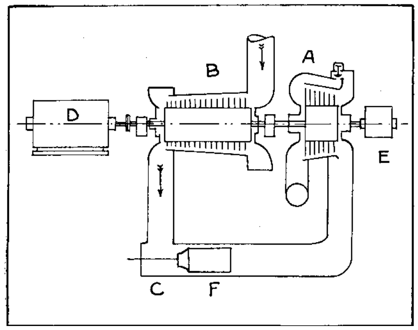


Figure 2. Diagram of modern gas turbine unit.

heat boiler located in the exhaust passage of the gas turbine supplied steam for the compressor turbine which operated condensing in order to furnish sufficient power to effect compression.

Published test results of the Holzwarth turbines appear to have unsatisfactory interpretations, but Stodola has concluded that the highest overall thermal efficiency obtained in any of the experiments performed up to 1927 is about 13 percent.

Limitations of Earlier Units

No attempt has been made in the foregoing historical review, to record all of the information available, but rather only that which had a predominant influence on gas turbine progress. A recounting of each of the thousands of patents granted pertaining to gas turbines would be prohibitive and of doubtful necessity, Therefore, only items of apparent major importance have been included.

Recapitulating, review of past practice has indicated the need of a simple, efficient, and reliable gas turbine. Associated with the few machines that actually operated were either low efficiency or complex construction-the

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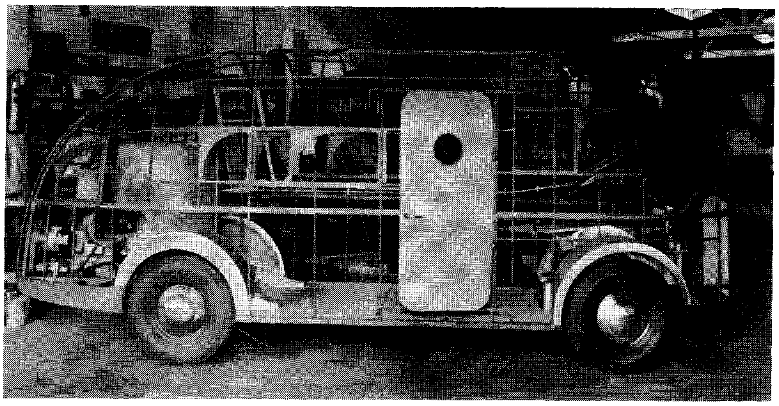


Figure 1. Welded tubular steel chassis and body.

The Hunt Steam Touring Car

Rear-Engined Vehicle with Comforts of Home

"Hats off to California" will be a frequent toast of steam car enthusiasts. They do things in a big way out there, and this land-cruiser is a big job of design, perseverance, and ingenuity.

Roy Hunt is an ace motion picture photographer. If you've seen the movie about "Wrong-way Corrigan," and "Parachute Battalions," you've seen the work of an artist and a steam enthusiast. Hunt is a busy man, but when he is on a vacation, the comforts of home follow him closely wherever he goes.

The silvery aluminum skin, giving the car the appearance of a wingless bomber on the highway, is fastened to a tubular steel frame. The design of the large body has been carried out with a good sense of proportion, and there is little attempt at fake steamlining, no messy gadgets to mar the smooth surfaces.

The difficulties of accomplishing this result may be imagined when a list of the interior facilities is examined. Up forward, but out of the way, is a small gasoline-electric plant. Interior lights, an electric range, and many other electrical conveniences make this independent plant a necessity. The "Galley," (nautical terms seem to fit this craft) with its pots and pans neatly stowed, can serve a full course dinner to visitors at the folding table. A writing desk is another convenience for the traveller.

Hot running water, shower, and a flushable toilet are provided in the bath room. Trailerites will also envy the heat that is available from a steam plant. A wide passenger seat just in front of the engine compartment becomes a lower and upper berth when a snug harbor is reached at nightfall.

Fig. 1 shows the general method of construction and the location of the steam plant. Note that the framework of the body is cut away behind the steam unit, to facilitate removal of the plant as a whole for service.

Fig. *2* indicates the excellent design and workmanship that have gone into the Hunt Steamer. Knowing the difficulties that have accompanied the dissembling of earlier steam engines, Mr. Hunt has employed the simple expedient of stay bolts joining cylinder and crankcase, a design that proved sound in the Stanley engine. The relation of the auxiliaries to the main engine is compact, with a V-belt drive running generator and circulating pump.

The use of a low-pressure turbine for driving the condenser fan, an economy achieved in the Doble car, is

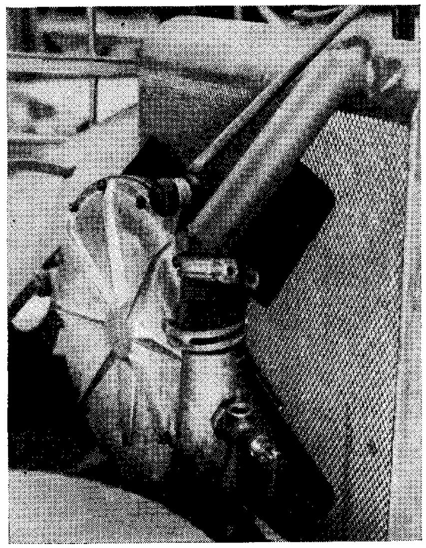
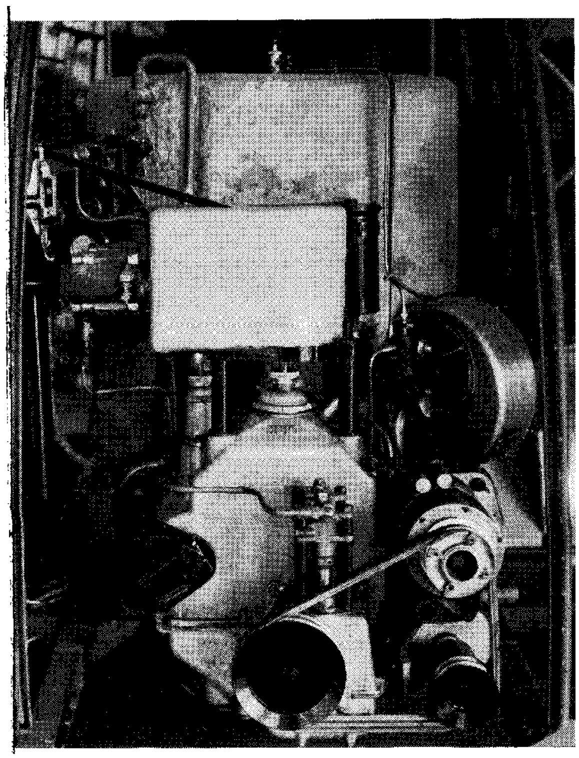


Figure 3. Turbine and fan.

Figure 2. Power plant, rear view.



again worthy of note. The condenser unit is the only part of the power plant that is not attached directly to the unit, for obvious reasons. Wide use of aluminum castings has kept the weight of the entire car down to a reasonable minimum. Steam car experimenters recognize that excessive weight is one of their chief enemies, first because it usually upsets the weight distribution calculations, and, second, because the final economy of a car is jeopardized by unnecessary deadweight.

Since this is but a preliminary report on the Hunt Steamer, details of design and technical data are few.

The boiler delivers steam at a total temperature of 750° F. The burner operates on 125 psi oil pressure, with a 7-gallon nozzle. Dimensions of the engine are 5" bore x 4." stroke, two cylinder, double-acting. Piston valves, with joy valve gear are employed. Design speed is 100 rpm, producing approximately 150 hp.

The Knox Boiler

This is the first of two articles on a compact, efficient, high-pressure steam power plant, originally designed for mobile purposes by S. L. G. Knox. The general design of the boiler will be described, and test results quoted. The second article will be devoted to the high speed compound, uniflow engine forming the "business end" of the plant. Because it could not be improved upon for clarity, brevity, and accuracy, the editors have quoted in large part the report of J. I. Yellott, M.M.E., onetime Assistant Professor of Mechanical Engineering, Stevens Institute of Technology, . and now Professor of Mechanical Engineering, Illinois Institute of Technology.

The unique feature of the Knox boiler is the principle of internal forced circulation, which is accomplished by means of an impeller located within the water space of the boiler and driven by an external motor which also drives the forced draft fan. (See U. S. Patent 2, 110,882, issued March 15, 1938, to S. L. G. Knox). To generate steam continuously in a boiler, some means must be provided whereby the feed water is caused to circulate through the tubes. In the conventional natural circulation boiler, this is brought about by the difference in weight between the relatively cool and dense water in the down-comers located in a lower temperature portion of the boiler, and the less dense mixture of steam and hot water in the risers which are located in the higher temperature portion of the furnace. In order to make this circulation sufficiently positive to prevent "dead spots" which may result in burned out tubes, and also to promote a high rate of heat transfer, such natural circulation boilers must be quite tall, and the tubes must be large to minimize friction.

Forced circulation in some form must be adopted if a small, high capacity boiler is required, for under such conditions natural circulation is inadequate. This inadequacy is more pronounced at the higher pressures, at which there is a diminishing difference in density between the water in the down-comers and the water-steam mixture in the risers. Previous solutions of this problem have been found by using the once-through, or series, principle, in which the boiler consists essentially of a single tube. Feed water is pumped into one end of the tube at high velocity, and superheated steam emerges from the other end. The Benson boiler is the best known example of this type although it has also been used by Doble and others. The principal disadvantage lies in the fact that there is no reserve of steam or feed water, and consequently automatic control must be provided which is almost instantaneous in its response as well as absolutely fool and accident proof in operation.

Another solution of the forced circulation problem is found in the use of an external circulating pump, which forces large quantities of water through the boiler tubes. The steam which is thus generated is separated from the unevaporated water in a drum, as in the LaMont boiler, or in an external separator, as in the Velox and Steamotive boilers. The disadvan tages of these boilers lie in the cost of the circulating pumps and the power required by them, as well as in control problems.

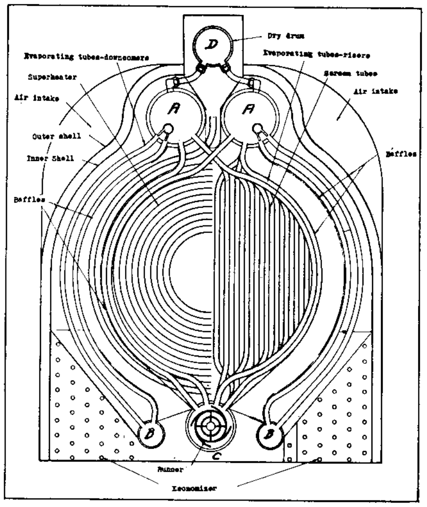


Figure 1. Cross section.

The Knox boiler uses the simple and effective system which is shown in its essential nature in the simplified diagram, Fig. I. The feed water is pumped into the two steam drums A1, A2, after passing through several economizers which will be discussed later. Leading downward from these two drums are the down-comers, which are located in the third pass of the boiler, and which connect to the two smaller lower drums, B1 and B2. The center drum at the bottom of the boiler, C, is connected to the outer drums by headers at both ends, and within this center drum is located a hollow impeller. This impeller is driven by a shaft which emerges from the header through a simple stuffing box. When the imp.-Iler is rotated, the pumping action creates a pressure which forces the water in drum C to pass upward through the risers which form the walls of the combustion chamber. The suction caused by the displacement of this water causes the water in B r and B2 to flow into the middle drum, and thus a vigorous forced circulation is established. This circulation is quite uniform along the length of the drum, as was proved by observation of the water through glass plates in the end of the drum, when the impeller was being operated with no pressure in the boiler. The velocity of this circulation is somewhat uncertain, although rough measurements indicate that it is about 4. ft. per second under ordinary circumstances. Since this pumping action is assisted by the natural circulation, it is probably still more powerful when the boiler is generating steam.

The general arrangement of the heating surface is shown in Fig. 2. The risers, through which the water is forced upward to the drum by the impeller, consist of four rows of stainless steel tubes, each being Y2 in. 0. D. by 0.43 in. 1. D., and approximateI Y 3 ft. long. The tubes are e staggered, the distance between centerlines being I 3-16 in. The combustion space is thus entirely water walled, although it was found necessary to put refractory over the first few rows of tubes near the burner to provide radiant heat for vaporizing the oil.

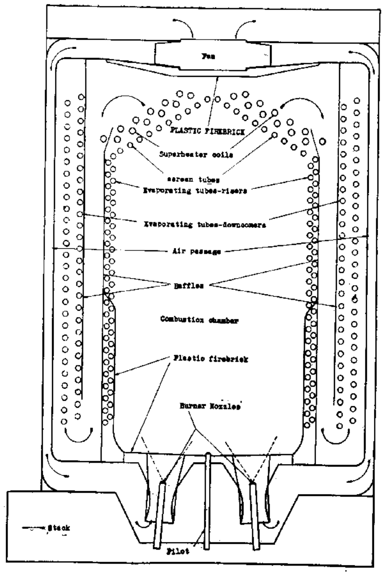
The down-comers are located in the third pass of the boiler, the radial spacing being much greater than for the risers. The heat transmission is much less intense in these tubes because they are not exposed to the radiation from the flame.

In order to supply dry steam to the superheater, a dry-drum D is provided above A1 and A2, and is connect ed to them by a number of small tubes. Perforated metal screens are also placed above the water line in A1 and A2 to prevent priming, or carrying over of large slugs of water.

The superheater is composed of a spiral coil of tubing and is located at the back of the combustion space, facing the burner, but separated from the combustion space by a single row screen of riser tubes. It was originally intended to have a second superheater around the burner, but this was found to be unnecessary. Control of the temperature of the superheated steam was accomplished by injecting feed-water into the inlet to the superheater. Steam temperatures above 800º F were obtained, although the temperature was usually kept around 750° F.

Three economizers are used, with the result that the flue gas temperature leaving the last economizer is always below 4000 F. The first two economizers are located in the last pass, in space which is available because the general shape of the boiler proper is cylindrical. The third economizer consists of coiled tubing located in the base of the stack.

Since the Knox boiler is intended to operate without the benefit of a stack to produce a natural draft, it is provided with a unique forced draft system. The entire boiler is covered with an air-tight metal casing, which is in turn partly enclosed within a removable aluminum outer jacket. (See Fig. 2). Between this outer shell and the jacket on each side of the boiler is a space through which the incoming air is drawn by the forced draft fan. The fan consists of a cast aluminum impeller, running on ball bearings, and driven by a V-belt and pulleys from the motor which also drives the im



Fiqure 2. Horizontal section.

peller. Major variations in fan capacity are accomplished by changing the driving pulley.,; and minor variations are made by restricting the air intake opening.

The air, which is sucked in through the fan after having passed over the outer shell of the boiler, is then forced through the space between the inner and outer shells, and is preheated to about 350°F before it enters the combustion chamber. The air pressure at the burner inlet is about 2 in. of water, under the usual operating conditions. As a result of this unusual arrangement of the air supply, the jacket around the upper part of the boiler is at almost the same temperature as the surrounding air, and consequently the losses due to radiation and convection are negligible.

The course of the flue gases can be

seen on Fig. 2. After passing through the coiled superheater at the rear of the combustion chamber, the gases divide and turn back through the second pass, in which it was originally intended to locate more superheater tubes. Experience showed that the one coil was enough and consequently in future boilers this empty second pass could be put to good use, or the size of the boiler could be still further reduced. Upon leaving the second pass, the gases go back through the third pass in which the down-comers are located. The gases then move down, as shown in Fig. , into the economizer space, and again come to the front of the boiler, where they enter the header which leads to the last economizer and finally to the stack.

The usefulness of the last economizer is demonstrated by the test results, which show that the flue gas temperature in the header is about 590° F at full load, while the gas temperature at the last economizer outlet is about 380° F.

During the tests the flue gases were discharged to the atmosphere through a 12 in. duct at a height of about 10 ft. above the ground. The velocity of the gases at the duct outlet was about 1200 fpm as determined by a Velometer.

The stack was entirely free from smoke during the tests, and in fact the air supply could probably have been still more reduced without causing smoke.

The principal difficulty which was encountered in the development of the Knox boiler was the smokeless and efficient combustion of fuel oil at extremely high rates in a very small chamber. The combustion equipment which was in use when the tests were run consisted of four main burners, arranged around a small pilot burner. The individual burners were located centrally in venturi-shaped openings through which the combustion air entered. The burners were standard 80° tips of the type used in domestic units, and the maximum capacity of the boiler could be varied by changing the size of the burners.

The boiler was started by electrical ignition of the pilot burner, which was located in the center of the refractory disc. After the pilot burner was operating satisfactorily, the electrical ignition was shut off. The oil supply to the burners came directly from a small motor driven gear pump which kept the pressure at about 160 psi gage. The oil supply passed through a solenoid valve which was so connected into the control system that it could be shut off by the operator, as well as by the various safety devices which will be described in the next section.

The combustion chamber was partially lined with plastic refractory, in order to give sufficient incandescent radiation surface to vaporize the oil. The amount of this refractory lining was determined by experience, and it was kept to a minimum so that the surface of the risers would be available for absorbing the radiant heat of the flame.

The furnace volume was about 5.67 cubic ft., and this proved to be adequate for the release of 1,970,000 Btu per hr. The average heat release was thus about 350,000 59,999 Btu per cu. ft. per hr. This is an extremely high figure, and it will receive further comment in a later section of this report.

The problem of control in the

Knox boiler is greatly simplified because of the presence of the two large upper drums, and the three lower drums, which give a relatively large water capacity. Should the water level in the drums rise or fall as much as two inches above or below the water line, no harm would be done. This is equivalent to more than two minutes output, about fifteen times as long as it takes the controls to act, and many times as long as would be available for the much faster controls required for the continuous tube boilers. This feature of the boiler is particularly important, because it means that the fuel and water supplies do not have to be instantaneously adjusted.

Except for the safety valve, all controls are electrically operated. The safety valve is a double, spring-loaded poppet valve, which is connected to the two upper drums by pipes of ample size. The safety valve had no occasion to function during the tests.

The pressure control consisted of a spring-loaded bellows, equipped with contacts which were connected in series with the solenoid valve in the oil line. When the pressure rose above the set valve, the contacts opened, the oil flow was shut off, the four main burners went out and the pressure immediately fell. Since there is little refractory in the boiler to provide heat storage, there is consequently very little lag in the response of the pressure controller. The boiler can operate safely at pressures up to 700 psi, but for convenience during the tests it was run at 500 and 55o psi gage.

The high and low water controls are of the thermal-expanding type, in which a brass tube alters its length in response to changes in the water level in the drum. Electrical contacts are opened when the water level falls too low, and the fuel supply is thus shut off. When the water level becomes too high, another set of contacts opens and these close a solenoid valve in the suction side of the feed water line.

Manual control of steam temperature was in use during the tests. This control was accomplished by injecting water into the inlet of the superheater, the amount of injected water being regulated by a needle valve.

It should be noted that a water level glass is provided, the connections being taken from the right top drum, A-2, in Fig. I. This is a unique feature for a -forced circulation boiler, since most of them have such wide variations in water level that a glass would be impractical.

During the test the boiler was supplied with water by a multi-cylinder motor driven reciprocating pump. The pump was kept running at constant speed, and the water delivery was regulated by the solenoid valve in the suction line. The water went from the pump through two separate circuits, each passing through two economizers, and then into one of the two upper drums.

The dimensions of the boiler are as follows

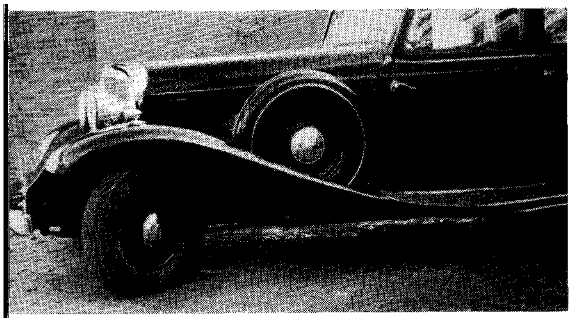
Diameter: 36"

Length: 6o"

Height, base of boiler to cover of dry drum: 38".

Total heating surface of the boiler is 154 sq. ft., including economizers. The volume of the combustion chamber is 5.67 cu. ft. At full capacity (maximum smokeless output) during the tests, the boiler generated 1186 lbs. of steam per hour with an efficiency of 81.3%. The flue gas tempera

(Continued on page 19)



A Modern Steam Car

There are a large number of former steam automobile drivers who would like to own a modern steam car. Most of them will wait some time. One of the few who have refused to wait is Leland Sprinkle, a mathematician whose logical mind has led him into the design of a steamer, and probably into no little trouble.

Utilizing available steam parts where they were adequate, Sprinkle began to assemble his steamer in November, 1939. A Stanley engine, reconstructed by the use of piston valves, was mounted under a modern chassis. Instead of the awkward, heavy steam supply pipe originally used on the engine, three small pipes were fitted,' providing a flexible and durable connection. The boiler is of the water level, water tube type, built to Sprinkle's own design. An indicator of the thermocouple type shows the water level on the dashboard. Control of water level is by a mechanically operated steam valve, controlling a steam feed water pump. The burner, of the usual gun type, is controlled by a mercury switch, according to steam pressure fluctuations. The operating range is around 750 psi. The burner operates without smoke or noise on a fuel pressure of 5o psi, and ignition is by a dual system permitting independent use of either coil and spark plug by simply turning a switch on the instrument panel. The entire 12-volt electrical system is protected by three easily accessible fuses.

A foot accelerator pedal of original design returns to a closed position of the throttle by steam pressure rather than by a spring. This, and the hydraulic braking system, provide simple and safe control of the car by any novice to steamers. A handsome modern body of aluminum gives the car a distinguished appearance.

Gas Generators

(Continued from Page 4)

had begun to take effect in creating interest amongst fleet operators. Little opportunity was ever presented for any actual military use of gas generators, so rapid were the onslaughts of modern war. Civilian employment of substitute fuels has been particularly prevalent in Scandinavia, where charcoal is the

The Recent Past

Almost all of the European generators in use were charcoal or wood fired. All were of the down-draught design, permitting loading of the magazine without extinguishing the fire.

A typical example is the Panhard generator, Fig. I, for use with charcoal. Operation may be described briefly as follows

After lighting the fire through a port in the refractory (not shown) the blower is started, and the generator is under slight pressure. Product of combustion are exhausted to the atmosphere until the fire is well start ed. A check valve on the air tube pre vents backfiring. The engine is then started on gasoline, and a two-way valve is manually changed to cut off the gasoline carburetor and cut in the gas-air mixer. The starting blower is stopped, and the generator is under slight vacuum, depending on the speed of the engine. Gas from the gen erator is mixed with air at the engine the proportion being about 1 to 1. Not shown in Fig. r are the coolers and purifiers, requiring as much space as the generator itself, and the necessary mixing valve and controls. The purifiers are of several types, usually employed in combination. Hemp, steel wool and other filtering materials are used to remove solid particles and to precipitate condensables after the gas has passed through some form of cooling and expansion tubes. Oil and water baths are used in final cleansing. Some of the products of combustion and distillation of the fuel are extremely harmful if permitted to reach the engine, particularly acetic acid when wood is burned.

The disadvantages of the use of this type of gas producer may be deducted from the above. The gas is not only explosive but poisonous, consisting mainly of carbon monoxide and hydrogen. Fortunately the system is normally under vacuum, but starting, and by-passing of gas when idling, involve certain risks. The gas plenishment of fuel must be resorted to. The major disadvantage, especially to Americans, is the loss of power resulting from the use of producer gas. This often falls to 5o percent of the output with gasoline, and with rapidly varying load conditions, the quality of the gas fluctuates.

Most of these objections have been overcome in modern practice, although the cost of equipment has of course increased. The generator itself. however. has not been

(To be continued)

Knox Boiler

(Continued front page 17)

tune was 380° F. It is estimated that the capacity given above might be greatly exceeded if the burner were permitted to smoke, and if the feed water pump could keep up with the demands for water.

Hero-11

(Continued from page 6)

the companionway, spluttering that he'd been kept out to long The owner tossed a line around a pile, touched the reverse lever, and we were safe against the dock.

As I thanked the owner for this excellent voyage, I noticed the steam gage, showing 75 lbs.

(A description of Hero's power plant will be available in the next issue)

The Gas Turbine

(Continued from page 10)

latter feature greatly jeopardizing the possibility of achieving a dependable unit.

These prefatory remarks have indicated the limitations of previous machines. The following section will be devoted to a description of the modern combustion turbine, which has been made commercially practicable only comparatively recently, and is believed to compensate adequately for the deficiencies exhibited by earlier gas turbines. Much of the pioneer development work on the gas turbine to be described has been conducted by Brown, Boveri & Co. in Switzerland.

Modern Combustion Turbine

The arrangement of a modern combustion gas turbine unit is depicted schematically in Fig. 2. Air from the atmosphere is compressed in a multistage axial flow compressor "B", driven by a reaction type gas turbine "A". Liquid or gaseous fuel injected at "C" is burned with part of the air discharged from the compressor; the remaining, and greater, part flows through the annular space "F" and, upon emerging, mixes with and cools the products of combustion to a suitable turbine inlet temperature. Expansion of this gas to atmosphere in the turbine produces more power than that required to effect compression of the air, and the excess power is supplied to a generator "D". For starting purposes a motor "E" is provided to bring the unit up to approximately 25 percent of normal running speed, beyond which the turbine is capable of driving the compressor unassisted.

(Modern commercial applications will be mentioned in the -next issue)

1200-lb Reheat

(Continued from page 3)

oil burners to provide hot gases for the reheating elements, although built integrally with the steam generating boiler. This separation is required by the special maneuvering and astern operations of marine installations.

In turbines operating at standard pressures and temperatures (425 psi, 740° F., 28.5 in. vacuum) condensation begins to take place about half way through the turbine. The particles retard the blades by impact, and erosion may take place. In the reheat cycle steam is removed from the high pressure turbine at a pressure slightly higher than that at which condensation begins, reheated to its initial temperature, and expands in the low pressure elements, condensing only in the last few stages. Reheating therefore decreases the number of stages in which moisture occurs, and the losses due to moisture.

Other gains due to reheating are found in the properties of superheated steam to produce more work in the turbine than saturated steam. With the same initial steam conditions, a reheat turbine, performing a larger portion of its work in the superheat region, will be more efficient than a nonreheat turbine.

The above gains are effective within the turbine itself. The theoretical efficiency, based on the Carnot cycle, is also increased by reheating, for the average temperature at which heat is added is increased.1

The main turbines consist of an all impulse high pressure element, a com

1 *The detailed design of reheaters for this installation, depending on marry strictly marine requirements, is omitted.*

bined impulse and reaction intermediate-pressure turbine, and an all reaction low-pressure turbine. Speeds are 8010, 5035, and 4201 rpm, respectively.

Each of the two boilers contains two separately fired furnaces. In one furnace two oil burners supply the heat for the reheater and the primary superheater; the two burners in the other furnace control the boiler pressure and supply the heat needed to raise the temperature of the steam in the secondary superheater. The reheater and the priinary and secondary superheaters function as convection units and are protected from the radiant heat of the furnaces by watercooled screen tubes. When reheat is not required, the boiler furnace alone is used.

Two main feed pumps, triplex plunger type, have variable stroke and are motor driven. The auxiliary feed pump, unusual for marine use, is a vertical 16-stage centrifugal unit, driven at 6320 rpm by a single-wheel turbine.

For the 12,000-lb ship, the fuel economy will be about 0.513 lb. compared with the average of 0.595 lb for the trials of the seven sister ships of the 425-lb design. (12.8 per cent reduction) An increase of 9 per cent in the weight of machinery is expected. No fair comparison of the costs of the two types can be made because only one high-pressure plant was installed, but it is estimated that under equal conditions, a to per cent increase cavils be expected for the 1200-th ship of this size. Pending actual experience, a comparison of reliability, maintenance requirements and operation should be reserved.

The Steam Motor Association

ESTABLISHED 1941

To foster interest in the past achievements. present potentialities, and future development of steam as a motive power. '

Framingham MASS., SEPT. 20, 1941--The Steam Motor Association was formed at an informal meeting of amateurs of the steam car, following the annual meet of the Veteran Motor Car Club. A pleasant dinner was followed by impromptu stories from the z5 ladies and gentlemen present. Through the kind invitation of Mr. and Mrs. Hyde Ballard, to hold the next meeting at their home in Merion, Pa., a date was set for October it. -rhe meeting adjourned, and some of the members climbed into their steamers (there were four Stanleys of various vintages in the driveway of the restaurant) and presumably reached home safely.

Merion, PA., Oct. 11, 1941-During the afternoon, several Stanleys brought passengers to the Ballards' house, to be greeted by the sight of the host's collection of three steamers. Everyone had a pleasant time examining these beautifully maintained veterans and riding in them, but the conversation centered on modern steam plants. A dinner and meeting were held at a nearby hotel, and the Association now has a constitution and an interesting program for future meetings. Inquiries are invited from those interested in establishing local groups in their own regions.

Byron Spence, President, Little Falls, N. Y.; G. Stevenson, Vice President, Box ¢¢, Newton, Mass.; Brooks Jones, Secretary, Glens Falls, N. Y.; Deneale Hunter, Treasurer, 20 Washington Place, Hackensack, N. J.

Regional Groups-New England: Russell J. Goodall, Vice President, Sanford, Me. Middle Atlantic: Hyde W. Ballard, Vice President, 227 Bowman Ave., Merion, Pa.