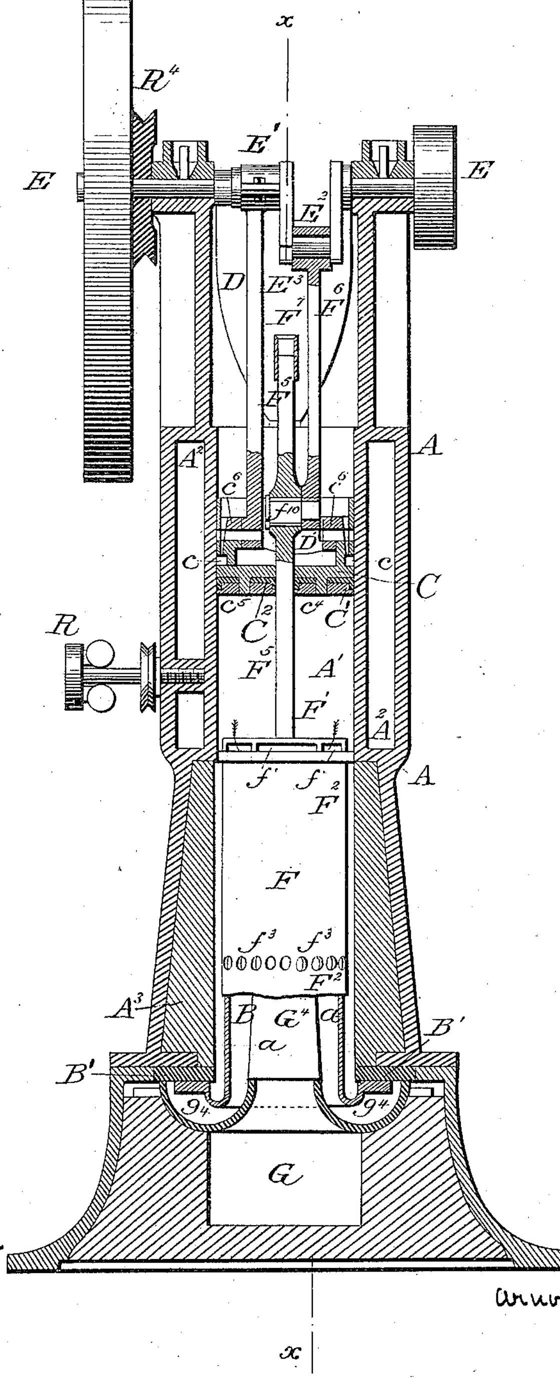
(No Model.) 2 Sheets—Sheet 1.

A. E. & H. ROBINSON.

HOT AIR ENGINE.

No. 309,163. Patented Dec. 9, 1884.

Fig. 1.



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(No Model.) 2 Sheets—Sheet 2.

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HOT AIR ENGINE.

No. 309,163. Patented Dec. 9, 1884.

Fig. 2.

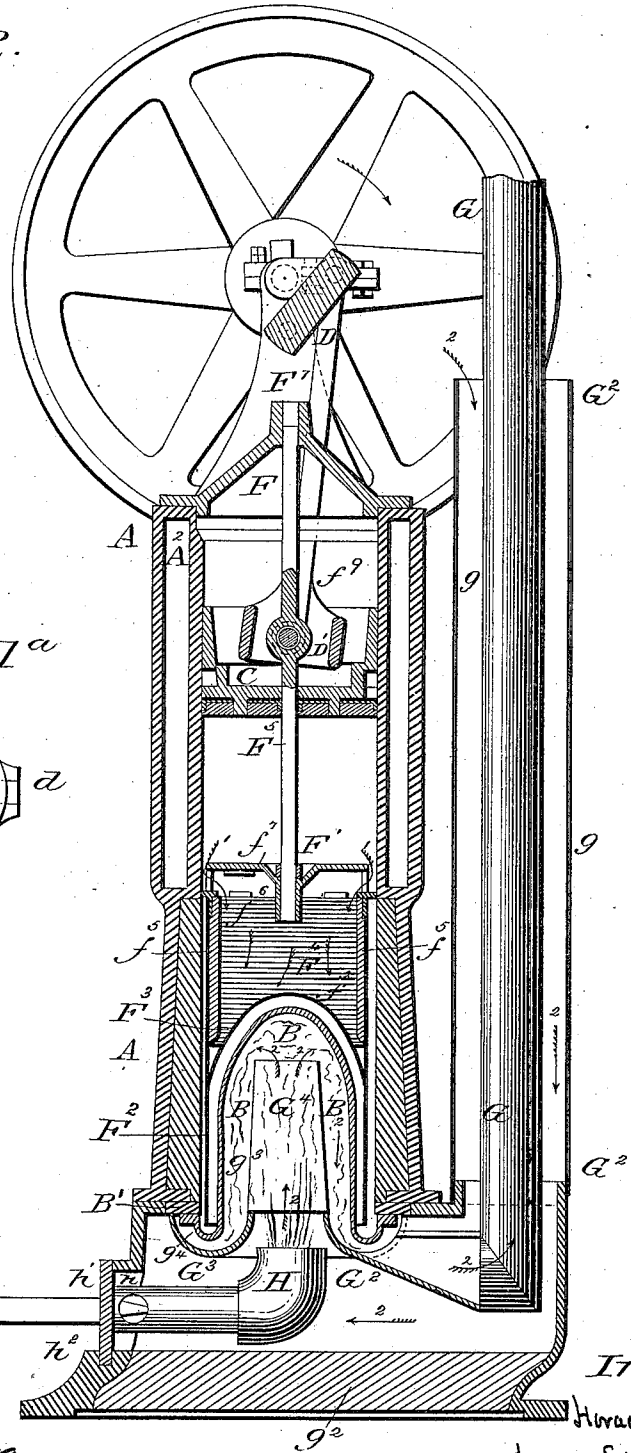
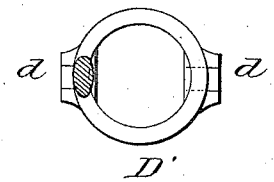


Fig. 1ª



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UNITED STATES PATENT OFFICE.

ARNOLD EDMUND ROBINSON AND HORACE ROBINSON, OF MANCHESTER, COUNTY OF LANCASTER, ENGLAND, ASSIGNORS, BY MESNE ASSIGNMENTS, TO THE VICTOR CALORIC ENGINE COMPANY, OF JERSEY CITY, N. J.

HOT-AIR ENGINE.

SPECIFICATION forming part of Letters Patent No. 309,163, dated December 9, 1884.

Application filed June 24, 1884. (No model.) Patented in England November 18, 1881, No. 5,056.

To all whom it may concern:

Be it known that we, ARNOLD EDMUND ROBINSON and HORACE ROBINSON, subjects of the Queen of Great Britain, and residents of Manchester, county of Lancaster, England, have invented certain new and useful Improvements in Hot-Air Engines, of which the following is a specification.

Our invention relates to that class of air-engines in which the air is alternately heated and cooled, and the consequent expansion and contraction and variation of pressure is utilized to produce motive power.

We construct our engine with a vessel or cylinder open at one end, and formed of suitable metal, such as iron. The part nearer the open end is cooled, preferably, by means of a water jacket or tank surrounding it, while the part nearer the closed end is made of a larger internal diameter, and is lined internally with fire-clay, plumbago, or other material being a good non-conductor of heat. The internal diameter of the said lining is equal to or slightly larger than the internal diameter of the cooled part of the cylinder, thus forming a continuation of it. The lined portion of the cylinder or vessel is closed by an end or heater, preferably of an egg-ended form, or of a partly-hollow cylindrical form with an egg end, which extends into the lined part of the cylinder, but leaving a space between the heater and the said lining. This space constitutes part of the heating-chamber. The heater is formed separately, and is bolted to the chamber or cylinder, with a ring of asbestus or other good non-conductor of heat interposed. The aforesaid enlarged lined portion of the chamber or cylinder may be formed separately and attached to the cooled portion of the cylinder. The object of the aforesaid lining of non-conductor is to more effectually confine the heat within the heating-chamber, and so that heat shall not readily be transferred to the metal cylinder. The position of the non-conductor also better separates the heater from the cooled end of the cylinder. The heater is heated by means of a flame or fire within it, in the manner described hereinafter, and the heat is transmitted through it to the air within the lined portion of the cylinder or chamber. The heater being of the form already described, the pressure within the cylinder subjects the material of the heater to compression. The heater may with safety be made thinner than if it were subject to strains of tension. Thus heat is easily conducted into the heating-chamber. Another advantage of this form of heater is that it can be carried into the heating-chamber within the internal diameter of the aforesaid lining of non-conductor. The working-piston operates within the aforesaid cooled end of the cylinder or vessel, and a displacing-piston, combined with a moving regenerator, also works partially within the cooled end of said cylinder and partially within the beforementioned lined portion of the cylinder or chamber, in the manner described hereinafter. The working-piston is constructed of metal, and is made preferably of considerable length. On the external diameter may be formed a groove, within which is placed sponge or cotton wick or other suitable material for taking up and distributing the oil on the sides of the cylinder. At the inner end of the piston a junk-ring is fitted for the purpose of adjusting the main cup-leather, (turned inward,) which leather works against the sides of the cylinder. A second junk-ring of smaller diameter is fitted to the piston to adjust a small cup-leather in the working-piston, through which works the displacer-rod; or a gland may be substituted. Within the hollow portion of the working-piston are formed two bosses projecting inward. The piston is connected to the crank-shaft by means of a connecting-rod, the end of which, connected to the piston, is formed as a ring with two bosses thereon, which bosses fit between the aforesaid two bosses in the piston. The said connecting-rod is continued from one side of the ring. A pin on each side is fitted through each of the said bosses on the piston into each of the bosses on the ring of the connecting-rod, so that the connecting-rod is free to oscillate. The other end of the connecting-rod is connected to one crank of a two-throw crank-shaft.

The mode of attaching the working-piston connecting-rod to the working-piston by means of the ring in the connecting-rod and bosses on the piston is for the purpose of relieving the working-piston from undue side strain,

and also to allow the displacer-rod and displacer connecting-rod to be connected to the crank-shaft conveniently. The said crank-shaft is made preferably with two cranks set at an angle of ninety degrees, and as it is desirable to have the crank-pins as close to one another as possible they are connected together by a single sheaf or link. The displacer-rod, which is brought through the small cup-leather or gland in the working-piston, is connected to the other crank-pin by means of the displacer connecting-rod. The displacer-rod is formed with an enlargement or boss upon it outside or beyond the cup-leather, and the rod is carried up through the guide. A pin is fixed tightly to the small end of the displacer connecting-rod, and is free to work in the boss in the displacer-rod. The displacer-rod and the small end of the displacer connecting-rod can work through the ring end of the working-piston connecting-rod. The object of this arrangement of connecting-gear is to get a compact and as direct a connection as possible without imposing undue side strain.

The combined displacer and regenerator is constructed preferably in the following manner: A metal cap or piston is made to form the end of the said displacer farthest away from the heater. The displacer-rod is attached thereto. This cap or piston works within the working-cylinder. The outer part of the said cap or piston is of smaller diameter than the cylinder, and has holes formed through its sides in such a manner that the air passing out through them from the regenerator shall be projected against the cool sides of the cylinder. The said cap or piston is enlarged near its inner end to fit the working-cylinder, and a groove may be turned upon it, within which is placed sponge or wick, or suitable material to take up and distribute the oil on the sides of the cylinder. A cylinder, preferably of thin sheet metal, is attached to the aforesaid cap, and is of such a diameter that it works near to the non-conducting lining of the heating-chamber aforesaid, but leaves a space between the aforesaid lining and the sides of the said cylinder of thin metal. This cylinder of thin metal is carried to such a length that when the said combined displacer and regenerator is at the extremity of its inward stroke the thin sheet metal shall be interposed between the non-conducting lining of the heated chamber or cylinder and the heater, leaving an annular-shaped passage on either side of the said thin metal. A cap of cast-iron or other suitable material is attached within the said thin-metal cylinder in such a position that when the displacer is at the end of its inward stroke the said cup shall nearly touch the egg-ended part of the heater. Holes are formed in the thin-metal cylinder of the displacer near to the part where the said cap is attached. These holes are for the purpose of allowing the air to pass from the regenerator to the outside of the said thin-metal cylinder. The aforesaid cap is formed so that it follows the lines or form of the egg-shaped end of the heater. Webs are cast on the cap, which support an annular or hollow shaped piece of material, being a good non-conductor of heat, within the said thin-metal cylinder. This non-conducting material extends to or nearly to the outer cap or piston, already described. Within the inner diameter of the said non-conductor is placed the regenerator, of wire-gauze or other suitable material, presenting a large surface. At the end of the said non-conductor farthest away from the heater is placed a ring, and at the same end of the regenerator is placed another ring. These rings are just within the outer cap or piston of the displacer, and several screws are placed in the said outer cap, bearing on each of the said rings, for the purpose of adjusting the said non-conductor and regenerator, the aforesaid non-conductor bearing against the said wings or projections of the inner cap, with a metal ring interposed, and the regenerator bearing against the inner cap.

The heating apparatus is constructed preferably in the following manner: Round the chimney which carries away the products of combustion of the flame or fire is placed a tube or casing of larger diameter or size than the chimney. This space or passage leads to a chamber or fire-box beneath the heater, which chamber may be lined with a material which is a good non-conductor of heat, such as fire-clay or cement. The top of the said chamber or fire-box consists of a diaphragm formed with a tubular extension or uptake upon or attached to it. This tube or uptake extends toward the apex of the heater, and being of smaller diameter or size than the heater, a space is left between it and the heater. This space leads to an annular space opening into the chimney.

When gas is used to heat the apparatus, we prefer to use a Bunsen burner within the closed chamber or fire-box. In the side of the chamber is formed an opening through which the burner can be withdrawn from the chamber for lighting and inspection, and replaced. A cover or lid for the opening is formed upon or attached to the pipe or burner. This lid or cover is larger than the hole or opening in the chamber. When the burner is in its proper position for use, the lid or cover at its lower side drops in between a stop and the lip of the opening, and the weight of the burner within the chamber causes the upper part of lid to bear against the lip or opening, thus closing it.

We do not confine ourselves to gas for heating the apparatus, as liquid or solid fuel may be used. When liquid fuel is used—such as petroleum or other hydrocarbon—the flame of the lamp is used in the chamber or fire-box in place of the Bunsen burner. When coal or other solid fuel is used, the chamber or fire-box is made deeper, and fire-bars are provided within it. The heated air from the space

around the chimney is in this case brought into that part of the chamber below the fire-bars, which part of the chamber acts as an ash-box; or air may be brought direct from the atmosphere into this part of the chamber without being drawn down the space around the chimney.

The action of the engine is as follows: The heater is heated by means of the gas-flame or fire in the chamber or fire-box. The flame being supplied with air heated by being drawn through the space formed around the chimney, as already described, the flame or heated products of combustion pass through the tube or uptake before mentioned and come into contact with the heater, and are carried or drawn down the sides of the heater to the annular space leading to the chimney, up which they escape. The air within the heated chamber is heated and the expansion drives the working-piston outward. This actuates the crank-shaft, and rather before the working-piston has reached the outer extremity of its stroke the crank-shaft causes the combined displacer and regenerator to commence its travel from the cool portion of the cylinder to the heated chamber. The air from the heated end of the chamber passes between the sides of the heater and the inner sides of the lower portion of the thin-metal cylinder forming part of the displacer, then passes up part way along between the outer side of said thin-metal cylinder and the inner side of the non-conductor of the heated chamber, then through the holes or openings through the thin-metal cylinder, near to the inner cap of the displacer, to the regenerator, of wire-gauze or other suitable material, contained within the displacer. The air then passes through the said regenerator, giving up a portion of its heat to the regenerator, and passes out considerably cooled through the holes or openings in the outer cap of the displacer. The air rushes through said holes against the cooled sides of the working-cylinder, and is further cooled. The consequent contraction reduces the pressure in the cylinder and allows the working-piston to descend, continuing the motion of the crank-shaft, and, rather before the working-piston has reached the extremity of its inward stroke, causes the displacer to commence its outward stroke. This causes the cool air to rush through the holes in the outer cap of the combined displacer and regenerator into and through the regenerator. Part of the heat previously left in the regenerator is now taken up by the air in its passage, and the air which is thus partially heated passes over the inner cap, and is further heated, then passes out through the holes or openings in the thin-metal cylinder of the displacer, and flows between the outer sides of the thin-metal cylinder and non-conductor of the heated chamber. The air then passes between the inner sides of the thin-metal cylindrical portion of the displacer and the heater, and is thus heated, the consequent expansion of the air forcing the working-piston outward. Motive power is thus obtained. The crank actuating the displacer is set so as to move the displacer in advance of the working-piston.

In place of the double crank with one intermediate sheaf or link and connection, as described, we may connect the working-piston by an ordinary connecting-rod to one crank or disk. A pin attached to another disk or crank or to the fly-wheel actuates the combined displacer and regenerator through the following connections: A rocking arm or lever is provided, which oscillates or works within the aforesaid chamber or cylinder and a recess formed in the side of the said chamber or cylinder. The combined displacer and regenerator is suitably connected to the end of this arm or lever, and the other end of said arm or lever is attached to a rocking shaft, which rocking shaft is carried out through a cup-leather or suitable packing. Another arm or lever is attached outside to the said rocking shaft, and this arm or lever is connected by a rod to the aforesaid crank or disk pin, or pin in the fly-wheel; and in order that our invention may be fully understood and readily carried into effect, we will describe the accompanying sheets of drawings, reference being had to the figures and letters marked thereon.

Figure 1 is a vertical section of a hot-air engine, taken in line with the crank-shaft. Fig. 2 is a vertical section on *x x*, Fig. 1.

A is the vessel or cylinder, open at one end, surrounded at its cooled or working end A' by a water jacket or tank, A^2, and at its heated end having a lining, A^3, of fire-clay, cement, plumbago, asbestus, or other material being a good non-conductor of heat. The lined portion of the cylinder may be formed separately and attached to the cooled portion of the cylinder.

B is the heater, of an egg-ended form, or partly of a hollow cylindrical form with an egg end. This heater extends into the lining A^3 of the cylinder or vessel, but leaves a space, *a*, between the heater B and the lining A^3. The space *a* constitutes part of the heating-chamber. The object of the lining A^3 is to more effectually confine the heat within the heating-chamber *a*, and so that heat shall not readily be transferred to the metal cylinder or vessel. The position of the non-conductor lining A^3 also better separates the heater B from the cooled part of cylinder or vessel. The heater B is preferably formed separately, and is attached or bolted to the cylinder or vessel A, with a ring, B′, of asbestus or other good non-conductor of heat, interposed. The heater B being of the form described, the pressure within the cylinder subjects the material or part of the material of the heater to compression, and the heater may with safety be made thinner than if it were subject to strains of tension. Thus heat is more readily conducted into the heating-chamber. Another advantage of this form of heater is that it can

be carried into the heating-chamber within the lining A^3.

C is the working-piston, which works within the cooled end of the cylinder A′. A groove, *c*, may be formed on the piston, within which may be placed sponge or cotton wick or other suitable material for taking up and distributing the oil on the sides of the cylinder.

C′ is a cup-leather turned inward. C^2 is a smaller cup-leather.

C^4 is a junk-ring for adjusting the cup-leather C^2.

C^5 is a junk-ring for adjusting cup-leather C′.

C^6 C^6 are two bosses formed within the working-piston, and project inward.

The crank-shaft E is made with two cranks, E′ E^2, set at about an angle of ninety degrees, and as it is desirable to have the crank-pins E′ E^2 as close to one another as possible, they are connected together by a single sheaf or link, E^3.

F is the combined displacer and regenerator, and is constructed in the following manner:

F′ is a metal cap or piston forming the end of the displacer and regenerator F. This cap or piston F′ works within the cylinder A′. The outer portion, *f*, of cap F′ is of smaller diameter than the cylinder A, and has holes or openings *f′ f′ f′* formed through its sides. The enlarged end of the cap F′ fits the cylinder A′.

F^2 is a hollow cylinder or hood, preferably of sheet metal, which is attached to the cap F′, and is of such a diameter that it works within the lining A^3, but leaves a space between itself and the lining A^3. This cylinder or hood F^2 is of such a length that when the combined displacer and regenerator F is at the extremity of its inward stroke part of the thin metal F^2 shall be interposed between the lining A^3 of the heater B, leaving an annular-shaped passage on either side of F^2.

F^3 is a cap, preferably of metal, attached within F^2 in such a position that when the combined displacer and regenerator is at the end of its stroke, as shown in Fig. 1, the said cap F^3 shall be close to the egg-ended part of the heater B. Holes f^3 f^3 f^3 are formed in the thin-metal cylinder F^2 near to the part where the cap F^3 is attached. These holes f^3 f^3 f^3 are for the purpose of allowing the air to pass from the regenerator to the outside of the hood or cylinder F^2. The cap F^3 is so formed that it follows the lines or form of the egg end of the heater B. Webs may be formed on the cap. These webs support an annular or hollow shaped piece of material, f^5—such as asbestus or fire-clay—being a good non-conductor of heat. This material f^5 extends toward the outer cap, F′.

F^4 is the regenerator, of wire-gauze or other suitable material, presenting a large surface.

At the end of the non-conductor f^5 farthest away from the heater may be placed a ring, f^6, and at the same end of the regenerator F^4 is placed another ring, f^7. These rings are within the cap F′, and several screws may be placed in the cap F′, bearing on each of the said rings f^6 f^7, for the purpose of adjusting the aforesaid non-conductor f^5.

D is the connecting-rod for connecting the piston C to the crank-shaft E. The end of the connecting-rod D which is attached to the piston is formed as a ring, D′, (shown more clearly in Fig. 1ª,) with two bosses, *d d*, thereon. These bosses fit between the bosses C^6 C^6. A pin on each side is fitted through each of the said bosses C^6 C^6 into each of the said bosses *d d*, so that the connecting-rod D is free to oscillate. The other end of the connecting-rod D is connected to a crank, E′, of the crank-shaft E.

F^5 is the displacer-rod, brought through the cup-leather C^2, or gland in the working-piston C. This rod F^5 is connected to the crank-pin E^2 by means of a connecting-rod, F^6, and works through the guide F^7. The displacer-rod F^5 is formed with an enlargement or boss, f^9, upon it, outside or beyond the cup-leather C^2. A pin, f^{10}, is fixed tightly to the small end of the connecting-rod F^6, and is free to work in the boss f^9 on the rod F^5. The rod F^5 and a small end of displacer connecting-rod F^6 can work through the ring end D′ of the piston connecting-rod D. The object of this arrangement of connecting-gear is to get a direct connection between the crank-shaft and the reciprocating parts.

R is a governor.

G is a chimney to carry away the products of combustion of the flame or fire.

G′ is a casing around the chimney G, but leaving a space, *g*, between the chimney G and the casing G′. This space or passage *g* leads to a chamber or fire-box, G^2. This chamber may have a lining, g^2, of a material which is a good non-conductor of heat.

G^3 is a diaphragm formed with a tubular extension or uptake, G^4, upon or attached to it. This uptake G^4 extends toward the heater B, and being of smaller diameter or size than the heater B a space, g^3, is left between G^4 and B. This space g^3 leads to an annular space, g^4, opening into the chimney G.

H is a Bunsen gas-burner within the chamber G^2.

In the side of the chamber G^2 is formed an opening, *h*, through which the burner can be withdrawn from the chamber for lighting and inspection, and can be replaced. A cover or lid, *h′*, for the opening *h* is formed upon or attached to the pipe or burner H. The lid *h′* is larger than the hole or opening *h*. When the burner H is in its proper position for use, as shown, the lid *h′* at its lower side drops in between a stop, h^2, and the lip of the opening *h*, and the weight of the burner H within the chamber causes the uppermost part of the lid *h′* to bear against the lip of the opening, thus closing it. When liquid fuel—such as petroleum or other hydrocarbon—is used instead of gas, the flame of the lamp is used in the chamber G^2 in place of the Bunsen burner H.

The action of the engine, as shown at Figs. 1 and 2, is as follows: The heater B is heated

by the flame of the Bunsen burner H or fire, the flame being supplied with air heated by being drawn through the space *g*, formed around the chimney G, as already described. The flame or heated products of combustion pass through the tube or uptake G^4, and come in contact with the heater B, and are carried along the sides of the heater, as shown by the arrows 1 1, Fig. 2, to the annular space g^4, leading to the chimney G, up which they escape. The air or part of the air within the cylinder or vessel A is caused to flow from the cooled to the heated part and from the heated to the cooled part alternately by the action of the combined displacer and regenerator F on the "Sterling" hot-air engine. The regenerator is actuated by the crank E^2, which is in advance of the crank E'. The combined displacer and regenerator F is moved from the heated to the cooled part. The air or part of the air passes in the direction of the arrows 1 1, Fig. 2, from the cooled part through the holes *f' f'* into and through the regenerator F^4, taking up some of the heat left in the regenerator by the previous instroke. The air then passes through the holes f^3 f^3, then between the lining A^3 and the hood F^2, and round between the hood F^2 and the heater B. The air is thus heated, and the consequent expansion drives the piston C outward. When the combined displacer and regenerator is moved from the cooled to the heated part of the cylinder or vessel A, the air or part of the air passes in the opposite direction to that shown by the arrows 1 1, Fig. 2, and the air passing through the regenerator F^4 gives up a portion of its heat to the regenerator and passes out into the cooled part of cylinder or vessel, and is further cooled, and the consequent contraction allows the piston C to perform its inward stroke.

We have shown and described in the accompanying specification and drawings an improvement in governors which we consider as new, but do not claim herein, but reserve for a future separate application.

Having stated the nature of our invention and described the manner of performing the same, we declare that we claim—

1. In a hot-air engine, the combination of a double crank-shaft, E, with the connecting-rod D from the crank-pin, connected to the piston C, as shown, so as to allow, without causing undue side strain, the rod F^5 to work through the cup-leather C^2 or gland in the piston, and the other crank-pin being connected to the rod F^5 by connecting-rod F^6, as hereinbefore described, and illustrated in Figs. 1, 1^a, and 2 of the accompanying drawings.

2. In a hot-air engine, a casing or hood or cylinder of thin metal, F^2, with openings f^3 f^3 f^3, the said casing containing a regenerator, F^4, and cap F^3, the hood F^2 being arranged so that air shall pass through the holes *f' f' f'* and f^3 f^3 f^3 and over the heater B, as hereinbefore described, and illustrated in the accompanying drawings.

3. In a hot-air engine, the lining A^3 within the cylinder or vessel for more effectually confining the heat, the said lining A^3 surrounding the heater B, a space being left between the heater B and lining A^3, in which space the hood F^2 works, as hereinbefore described, and illustrated in the accompanying drawings.

In testimony that we claim the foregoing as our invention we have signed our names, in presence of two witnesses, this 14th day of May, 1884.

ARNOLD EDMUND ROBINSON.
HORACE ROBINSON.

Witnesses:
ARTHUR C. HALL,
ALBERT E. HALL,
U. S. Consulate, Manchester.