Jan. 7, 1947. W. DENNIS 2,413,751

EXPANSION ENGINE

Filed June 10, 1944 2 Sheets-Sheet 1

Fig. 1.

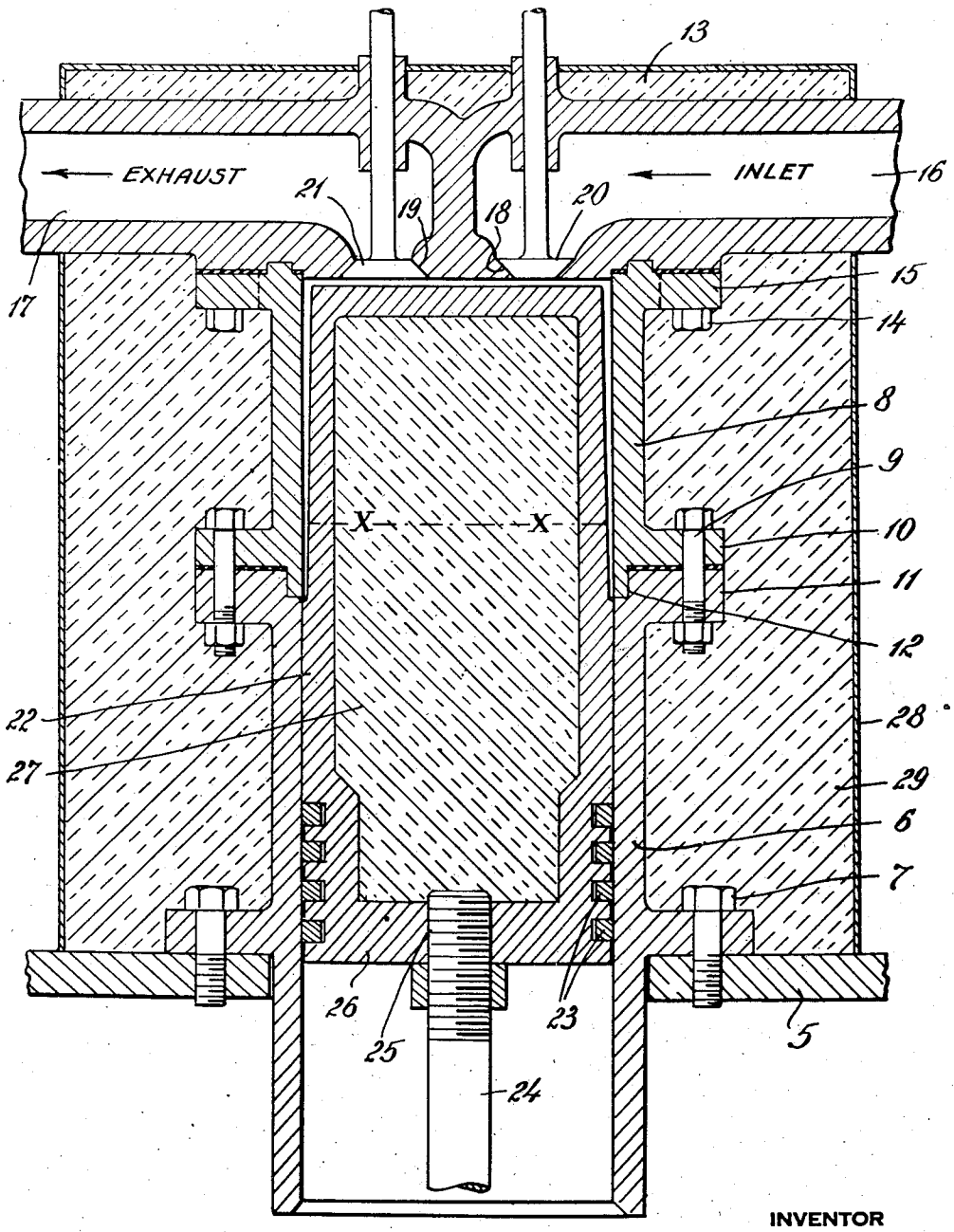

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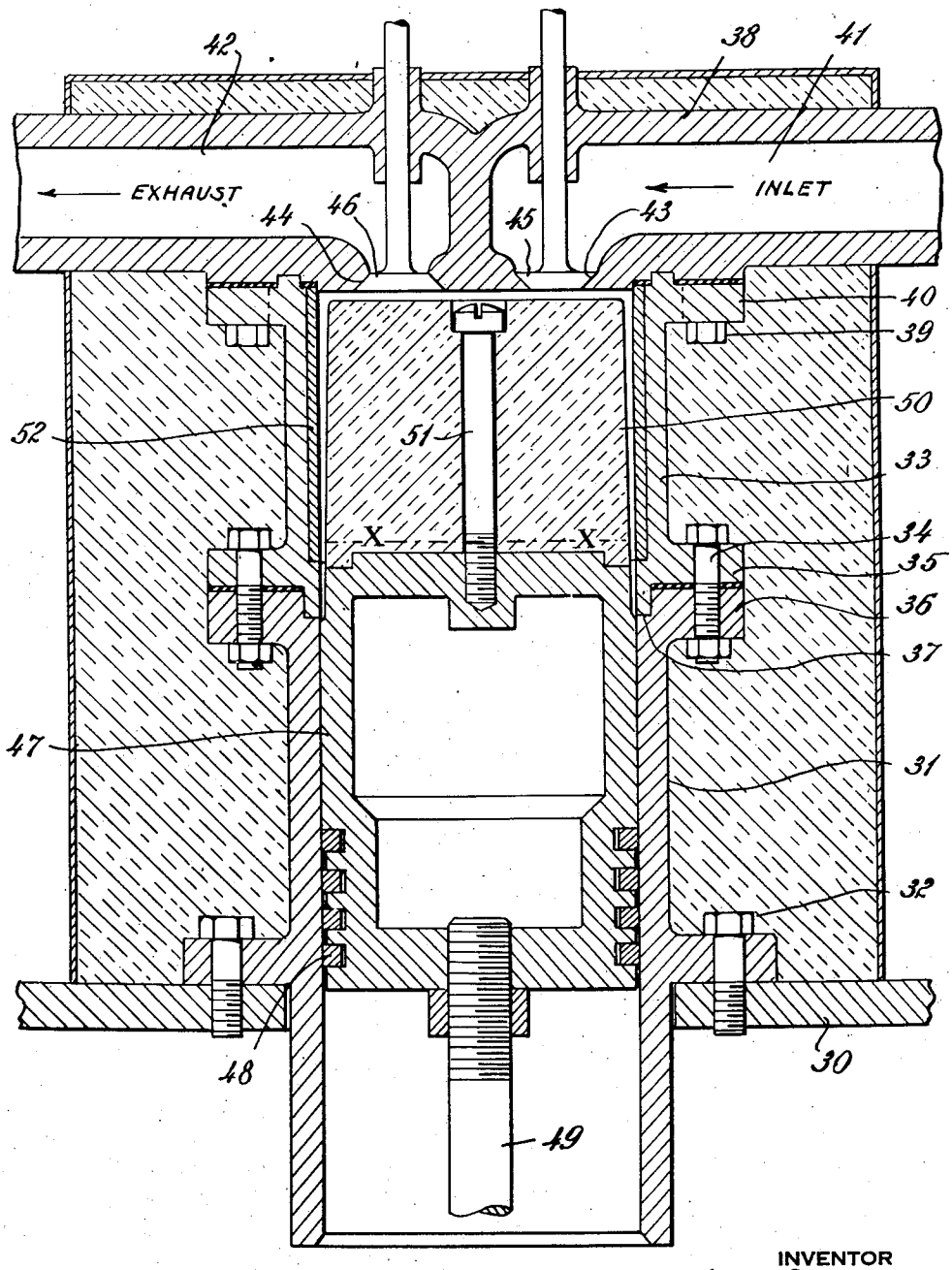
Fig. 2



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EXPANSION ENGINE

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3 Claims. (Cl. 121—1)

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This invention relates to expansion engines for liquefaction systems and particularly to improvements affording high efficiency in the operation of expansion engines at low temperatures.

In the liquefaction of gases by compression and subsequent expansion as for example in the well known Claude system, a part of the compressed and cooled gas is expanded in an engine with external work. Although engines have been employed in such systems for many years, little improvement has been effected with respect to the efficiency of operation. It has been assumed that certain undesirable losses in the operation of the engine were unavoidable.

It is the object of the present invention to provide an engine adapted to afford a higher heat drop efficiency than has been possible in engines heretofore available for expansion of gases at low temperatures.

Another object of the invention is to minimize the losses due to the introduction of heat through friction between the moving parts.

Another object of the invention is to provide for the maintenance of a temperature differential between the cold portion of the cylinder and the lubricated portion, by the action of the air or gas used to drive the engine.

A further object of the invention is the provision of a structure in which parts subject to wear can be replaced readily and economically so that the engine can be maintained at its original high efficiency and at relatively low cost.

Other objects and advantages of the invention will be apparent as it is better understood by reference to the following specification and the accompanying drawings, in which

Fig. 1 is a vertical section illustrating one form of the invention; and

Fig. 2 is a similar view illustrating a modification of the engine.

Referring to the drawings, 5 indicates a suitable frame upon which a cylinder 6 is supported by bolts 7. The cylinder is in two sections, the upper section 8 being secured to the lower section 6 by bolts 9 extending through the flanges 10 and 11. A rabbeted joint 12 is provided between the sections 6 and 8 of the cylinder to prevent escape of gas therethrough, and to insure accurate line-up of the two sections. The construction of the cylinder in the form indicated permits the removal of the lower section 6 which is subjected to wear and the replacement thereof at intervals so that the engine can be maintained at its maximum efficiency.

A head 13 is secured to the upper end of the

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cylinder 8 by bolts 14 extending through flanges 15. The head provides inlet and exhaust passages 16 and 17 terminating in valve seats 18 and 19 at the upper end of section 8 of the cylinder. Valves 20 and 21 are mounted to co-operate with the valve seats and may be actuated by any suitable mechanism (not shown) to open and close the valves. Such mechanism will provide well known means to regulate the lead and cut off of the valves in order that gas under pressure introduced through the inlet 16 may be expanded in the cylinder and discharged through the exhaust passage 17. The details of such mechanisms are well known in the art and require no further description.

Within the cylinder 6 a piston 22 is supported and provided with piston rings 23 bearing against the internal surface of the cylinder 6 to prevent the escape of gas. A piston rod 24 is connected in any suitable manner, for example threadedly, as indicated at 25, to a block 26 secured at the end of the piston 22. The piston rod 24 may be connected also to a conventional crosshead, crank, and crankshaft (not shown) adapted to translate movement of the piston. Preferably the piston is filled with insulating material 27. A casing 28 is disposed about the cylinder sections 6 and 8 and the head 13 and is filled with insulating material 29 to reduce flow of heat from the external atmosphere through the walls of the cylinder.

As indicated in the drawing, the lower end of the piston 22 has a diameter affording a relatively close fit with the cylinder 6. The upper end of the piston has a reduced diameter affording a substantial clearance between the piston and the upper section 8 of the cylinder. The clearance space is preferably tapered and extends beyond the limit of the stroke of the piston indicated by the line x—x. The amount of radial clearance between the upper end of the piston and the section 8 of the cylinder may vary. Preferably the radial clearance at the top of the piston is approximately .010 inch and at the bottom of the reduced portion the radial clearance is approximately .005 inch. However, the radial clearance may vary from approximately .020 inch at the top of the piston to .002 inch at the bottom of the reduced section.

The provision of an unusually large clearance space between the upper portion of the piston and the cylinder walls which are normally in contact with the cold expanded gases, serves two useful purposes. First, all possibility of physical contact and the generation of heat by friction in this portion of the cylinder is eliminated and

second, a heating effect is obtained in the lower part of this space by the action of the gas being used to operate the engine without in any way interfering with the attainment of high efficiency. This heating effect results when gas is admitted to the cylinder at the beginning of the working stroke with a resulting compression of the residual gas in the clearance space into the lower end of this space. In being compressed this gas becomes heated and transfers part of its heat of compression to the cylinder and piston walls near the bottom end of the clearance space. On expansion the gas in the clearance space cools but the cooling effect on the walls at the bottom of the space is much less than the previously noted heating effect because the mass of gas in contact with the previously heated walls is greatly reduced by the expansion process.

This heating effect has been repeatedly observed in the connecting piping between engine cylinders and indicator apparatus, and in engine parts having a single outlet connected to the cylinder and subject to fluctuating pressure. It is here utilized for the purpose of establishing a large temperature gradient between the cold parts of the cylinder and the working parts which it is desirable to lubricate without difficulties due to freezing of oil or condensation of moisture. It is important of course that the cylinder section **8** be made of such material and of such thickness as to minimize heat conduction to the lower cylinder section **6** in order to realize the most benefit from the heating effect. It is also desirable to extend the clearance space downward so that when the piston is in its upper position the space extends some distance below the lower limit of the piston travel. With this construction, the major portion of heat generated by compression of residual gas in the clearance space is transmitted to the cylinder walls below the line x—x.

The use of a tapered piston permits the use of a larger clearance space at the top for a given clearance volume and reduces the possibility of contact between piston and cylinder at the top edge of the piston where contact is most apt to occur.

Referring to Fig. 2, the frame **30** supports the lower section **31** of the cylinder through bolts **32**. The upper section **33** of the cylinder is secured to the lower section **31** by bolts **34** extending through flanges **35** and **36**. A rabbeted joint **37** is provided as in the previous embodiment of the invention. A head **38** is secured by bolts **39** to a flange **40** at the upper end of the section **33** of the cylinder and provides inlet and exhaust passages **41** and **42** terminating in valve seats **43** and **44**. Valves **45** and **46** are actuated by mechanism, as in the preceding embodiment of the invention, to control the flow of gas under pressure from the inlet passage **41** and withdrawal of the expanded gas through the exhaust passage **42**.

A piston **47** is supported in the cylinder and provided with piston rings **48** to afford a gas-tight fit. The piston is connected in the manner previously described to a piston rod **49** which in turn is connected to a conventional crosshead, crank and crankshaft to translate movement of the piston. The lower end of the piston has a substantially tight fit in the section **31** of the cylinder. The upper end of the piston consists of a block **50** of heat insulating material secured to the lower portion by a bolt **51**. A liner **52** of heat insulating material is disposed within the upper section **33** of the cylinder.

As in the preceding embodiment of the invention, the upper section of the piston is of reduced diameter, affording clearance preferably though not necessarily tapered, extending beyond the line x—x representing the limit of travel of the piston. The radial clearance between the piston and the cylinder wall should be within the limits hereinbefore specified. The same advantages are attained in this modification, and further advantages resulting from the elimination of heat flow from the warm end of the cylinder to the cold end as the result of use of the insulating material at the upper end of the piston and in the wall of the upper section **33** of the cylinder.

It has been demonstrated that an engine constructed in accordance with the principles set forth has a heat drop efficiency of 88% under operating conditions such as exist in its application to a Claude cycle.

Various changes may be made in the construction and arrangement of the apparatus within the scope of the appended claims, without departing from the invention or sacrificing the advantages thereof.

I claim:

1. An expansion engine for gases at relatively low temperatures comprising a cylinder, a cylinder head associated therewith including inlet and exhaust passages and valves controlling the delivery of gases to and from the cylinder, and a piston movable in the cylinder and having a bearing surface closely fitting the internal surface of the cylinder at the end remote from the cylinder head, the other end of the piston having a reduced diameter affording a relatively narrow tapered radial clearance between the piston and cylinder walls, the maximum clearance being at the cylinder-head end of the piston, the length of that portion of the piston with reduced diameter being greater than the stroke of the piston.

2. An expansion engine for gases at relatively low temperatures comprising a cylinder, a cylinder head associated therewith including inlet and exhaust passages and valves controlling the delivery of gases to and from the cylinder, and a piston movable in the cylinder and having a bearing surface closely fitting the internal surface of the cylinder at the end remote from the cylinder head, the other end of the piston having a reduced diameter affording tapered radial clearance between the piston and cylinder walls, said clearance progressively decreasing from a maximum of .020 inch at the cylinder-head end of the piston to a minimum of .002 inch, the length of that portion of the piston with reduced diameter being greater than the stroke of the piston.

3. An expansion engine for gases at relatively low temperatures comprising a cylinder, a cylinder head associated therewith including inlet and exhaust passages and valves controlling the delivery of gases to and from the cylinder, and a piston movable in the cylinder and having a bearing surface closely fitting the internal surface of the cylinder at the end remote from the cylinder head, the other end of the piston having a reduced diameter affording tapered radial clearance between the piston and cylinder walls, said clearance progressively decreasing from a maximum of .010 inch at the cylinder-head end of the piston to a minimum of .005 inch, the length of that portion of the piston with reduced diameter being greater than the stroke of the piston.

WOLCOTT DENNIS.