Sept. 20, 1971 L. K. EDWARDS 3,605,629

HIGH SPEED GROUND TRANSPORTATION SYSTEM

Filed Sept. 5, 1969 3 Sheets-Sheet 1

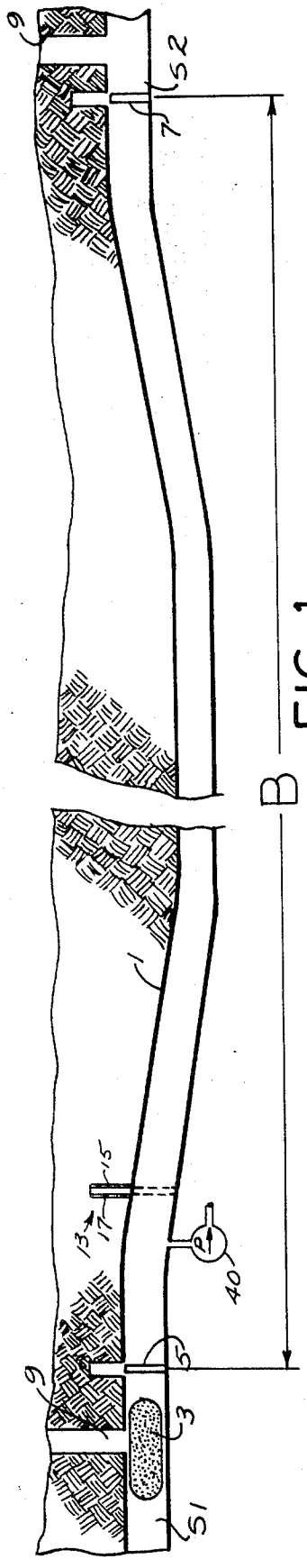


FIG. 1

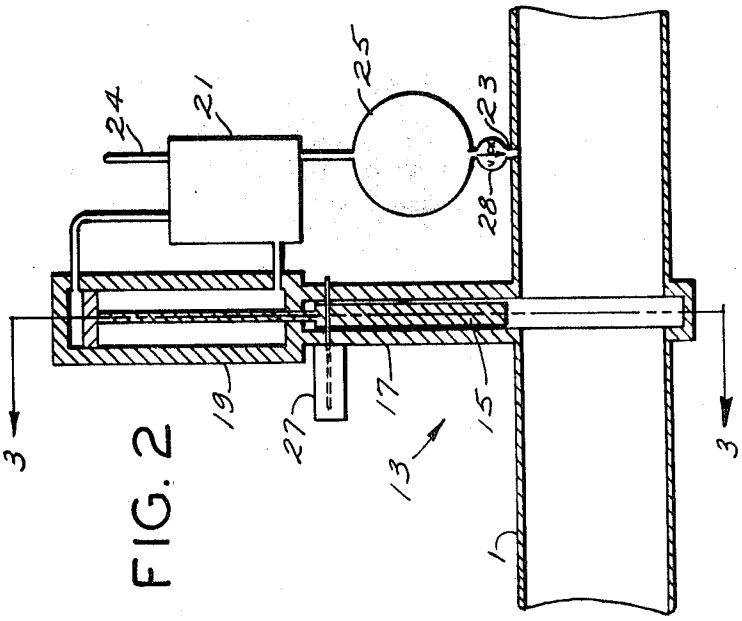


FIG. 2

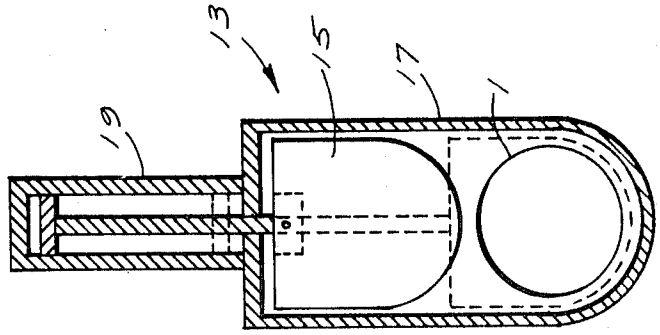


FIG. 3

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HIGH SPEED GROUND TRANSPORTATION SYSTEM

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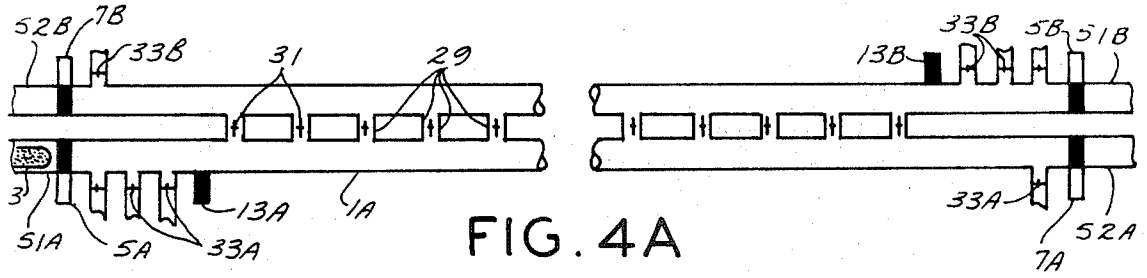


FIG. 4A

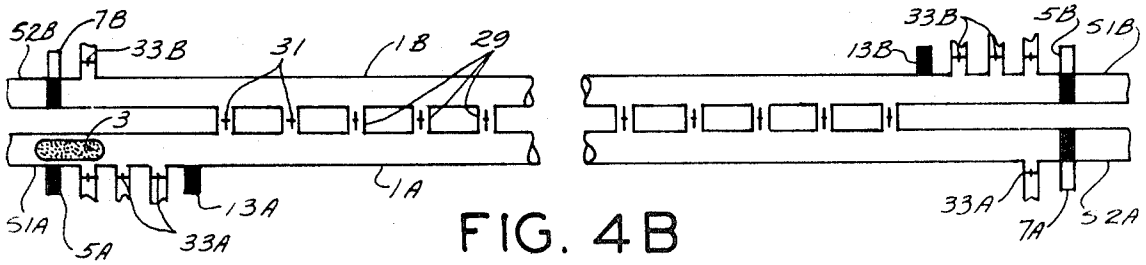


FIG. 4B

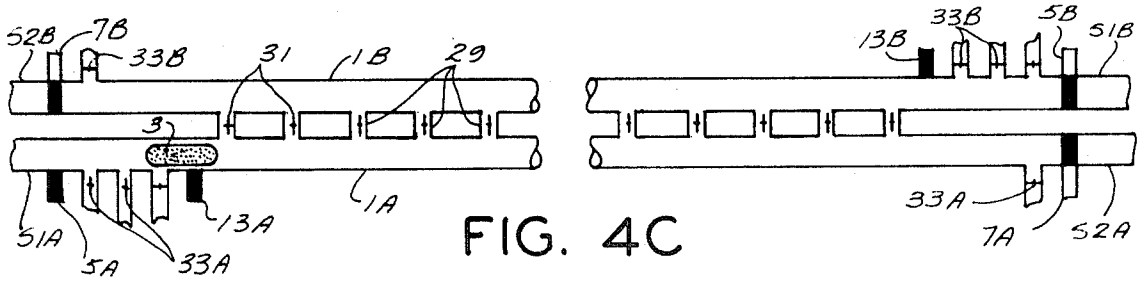


FIG. 4C

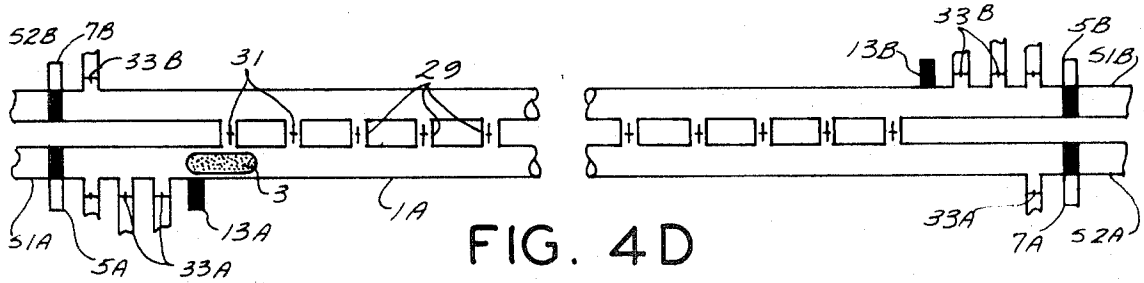


FIG. 4D

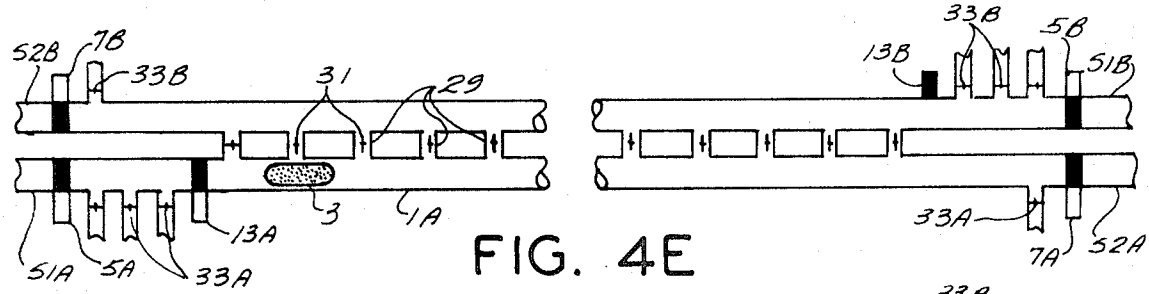


FIG. 4E

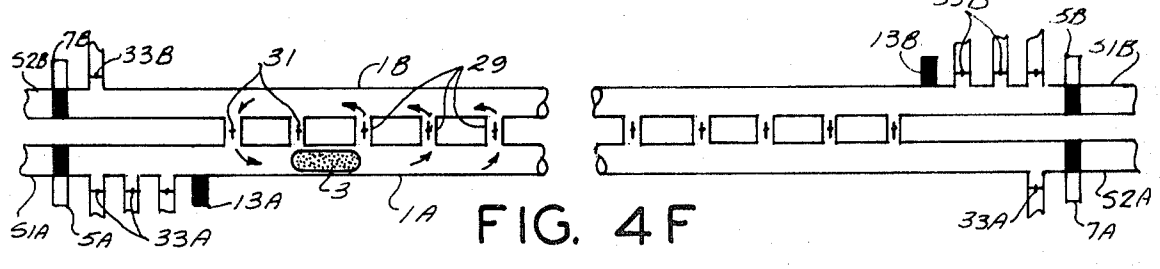


FIG. 4F

HIGH SPEED GROUND TRANSPORTATION SYSTEM

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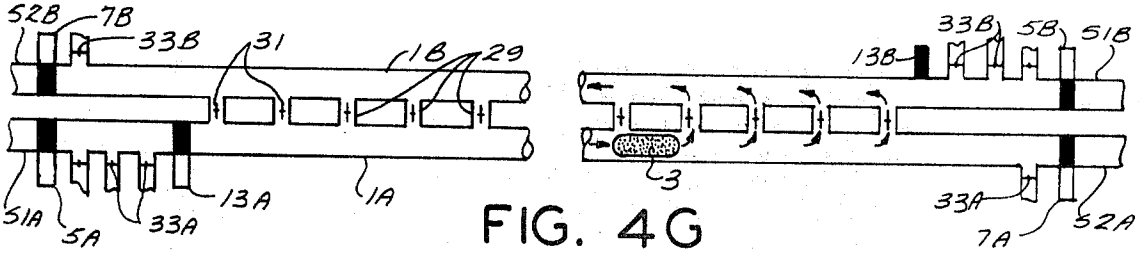


FIG. 4G

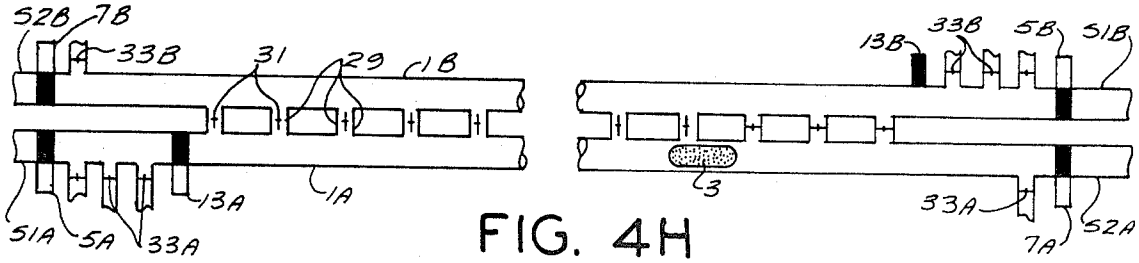


FIG. 4H

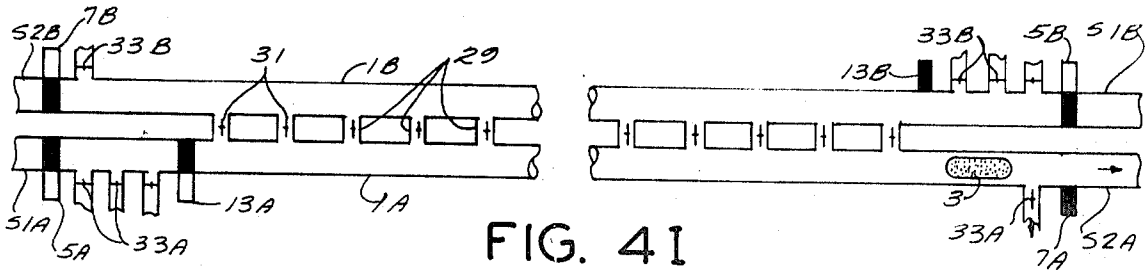


FIG. 4I

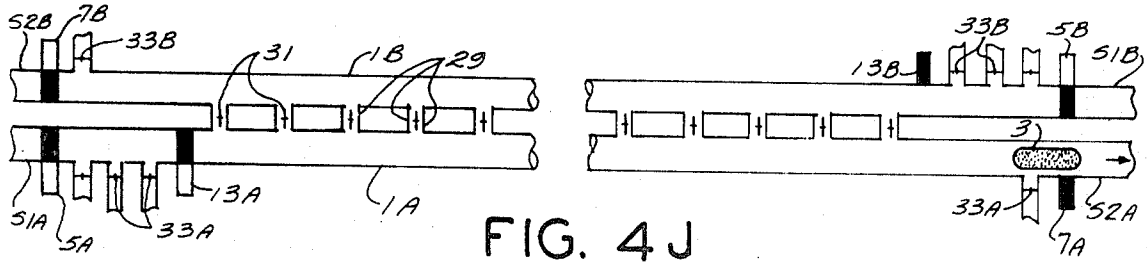


FIG. 4J

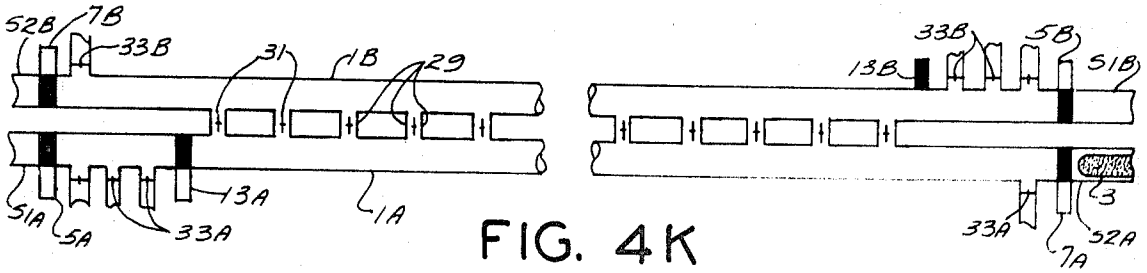


FIG. 4K

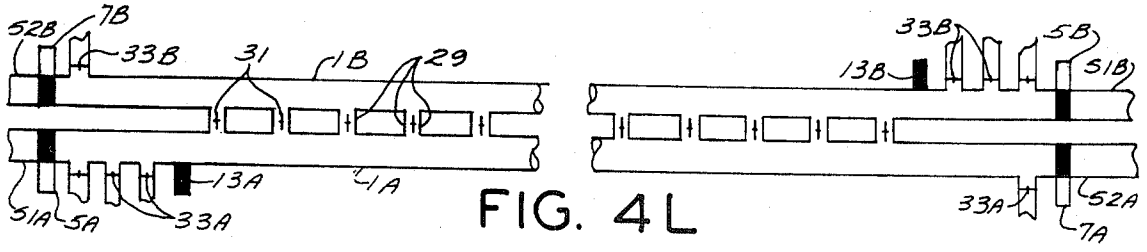


FIG. 4L

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3,605,629

HIGH SPEED GROUND TRANSPORTATION SYSTEM

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Int. Cl. B61b 13/10; B65g 51/04
U.S. Cl. 104—138 21 Claims

ABSTRACT OF THE DISCLOSURE

A high-speed ground transportation system comprises a duct through which a vehicle is adapted for propulsion as a free piston. Entrance and exit valves are provided adjacent the ends of the duct and the section of the duct between the valves is preevacuated. On opening the entrance valve, air pressure forces the vehicle into the section and after the vehicle has passed the entrance valve and a predetermined amount of propulsive air has entered the duct behind the vehicle, the valve is closed. A cut-off valve is provided in the duct downstream from the entrance valve for preventing the propulsive air admitted behind the vehicle from entering the main body of the duct. The exit valve opens when the pressure ahead of the vehicle reaches a predetermined pressure.

BACKGROUND OF THE INVENTION

The invention is particularly concerned with improvements in high-speed ground transportation systems of the type in which a vehicle is propelled as a free piston through a tube or duct by differential air pressure between the front and rear of the vehicle, such as are disclosed in copending United States patent application Ser. No. 720,408, filed Apr. 10, 1968 and United States Pat. No. 3,404,638, each entitled High-Speed Ground Transportation System.

In said United States patent application Ser. No. 720,408, there is shown a high-speed ground transportation system comprising a duct, a vehicle adapted for propulsion as a free piston through the duct by differential air pressure on the rearward and forward ends of the vehicle, a valve for the duct adjacent one end of the duct and a valve for the duct adjacent the other end of the duct, these valves being adapted when closed to block off a section of the duct from valve to valve. This section is evacuated prior to entry of a vehicle therein. The duct has end portions outward of the valves constituting air locks or stations which are open to the atmosphere. In operation, starting with the vehicle in a first station, the corresponding valve (serving as an entrance valve) is opened for propulsion of the vehicle therethrough propelled by atmospheric pressure acting on the rear of the vehicle. The entrance valve is closed after the rearward end of the vehicle has passed thereby, so as to trap a slug of atmospheric air in the duct. This slug of air expands to continue to propel the vehicle through the duct until the pressure of air rearward and ahead of the vehicle is equalized. The vehicle then coasts forward under the kinetic energy built up therein, compressing air ahead of the vehicle, and opening the other valve (serving as an exit valve) when the pressure of air ahead of the vehicle generally equals atmospheric pressure for exit of the vehicle from said section, the vehicle passing into and being stopped in the second station and the exit valve closing behind the vehicle. There is also shown a system in which a second duct extends parallel to the first duct for travel of vehicles in opposite directions on the same route. The two ducts are provided with cross-connections or cross-ducts for circulation of air around the vehicle as it traverses one of the ducts, and with auxiliary valves (indicated at 25 in

said application Ser. No. 720,408). This system is used for long stages, ten miles or longer, for example. Recent analysis indicates that the combined pneumatics and gravity can accelerate the vehicle rapidly to high speed. As the vehicle reaches a high speed, e.g., of the order of four hundred miles per hour, the flow losses in the air column behind the vehicle become so large that the pressure immediately behind the vehicle drops to near vacuum even though the entrance valve and auxiliary valves are still open. Thus the air behind the vehicle is no longer capable of imparting energy to the vehicle and it would be fruitless to admit more air or to expand the air already in the duct. To this end, the entrance valve and auxiliary valves are closed. In addition, the open cross-ducts serve to equalize pressure around the train or vehicle. Recent analysis indicates that there may be a rise of the order of 2 p.s.i. in the ambient duct pressure if the several-mile-long accelerating air slug is permitted to expand and diffuse via the cross-ducts throughout the pair of ducts. A second vehicle, being propelled through the opposite duct at the same time would cause still higher pressure rise and consequent higher losses.

SUMMARY OF THE INVENTION

Among the several objects of this invention may be noted the provision of an improved high-speed ground transportation system of the class above described and method of operation thereof in which the propulsive air admitted behind the vehicle is prevented from expanding throughout the duct, thereby permitting lower pressures to be maintained during the coast phase of the trip with the result of lower losses and higher overall efficiency of the system; the provision of such a system in which relatively low-power pumping equipment may be used; and the provision of an improved system as above described and method of operation thereof which reduce to a minimum the effect of a vehicle traveling in one direction in one of the ducts on a vehicle traveling in the other direction in the other duct.

In general, a high-speed ground transportation system of this invention comprises a duct adapted for propulsion of a vehicle therethrough as a free piston by differential air pressure on the ends of the vehicle. Entrance and exit valves are provided for the duct. The entrance valve is adapted to close a suitable time after the rearward end of the vehicle has passed and a predetermined amount of propulsive air has entered behind the vehicle in the duct, thus controlling the energy input to the vehicle. A cut-off valve is provided for the duct downstream from the entrance valve adapted to close after the rearward end of the vehicle has passed thereby to trap the propulsive air between it and the entrance valve, thereby preventing the accelerating air slug from expanding throughout the duct. This decreases the duct pressure for the coast phase of the trip. If the duct is interconnected with another duct for passage of a vehicle in the opposite direction, this also avoids an undesirable rise in forces resisting free passage of a vehicle through the opposite duct. In the operation of the system, starting with the vehicle in the duct outward of the entrance valve, the entrance and exit valves closed, the section of the duct between these valves evacuated, and the cut-off valve open, the entrance valve is opened for entrance of the vehicle into the duct and propulsion of the vehicle therethrough. The entrance valve is closed after the rearward end of the vehicle has passed and a predetermined amount of propulsive air has entered the duct behind the vehicle, and the cut-off valve is closed after the rearward end of the vehicle has passed thereby to trap the propulsive air between the cut-off valve and the entrance valve. Other

objects and features will be in part apparent and in part pointed out hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic view in section of a high-speed ground transportation system of this invention;

FIG. 2 is a section showing a cut-off valve of this invention;

FIG. 3 is a section on line 3—3 of FIG. 2; and

FIGS. 4A–4L are views illustrating a trip of a vehicle in a double-duct system of this invention.

Corresponding reference characters indicate corresponding parts throughout the several views of the drawings.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1 of the drawings, there is indicated at **1** a subterranean tube or duct extending from a station S1 to a station S2 along the route of a transportation system and continuing on from station S2. At **3** is indicated a vehicle adapted for propulsion as a free piston through the duct by differential pressure of air between the rear and the front of the vehicle. Entrance of the vehicle from station S1 to the duct is via an entrance valve **5** at the entrance end of the duct. Exit of the vehicle from the duct to station S2 is via an exit valve **7** at the exit end of the duct. The valves **5** and **7** may be of the type shown in application Ser. No. 710,582, filed Mar. 5, 1968, by Lawrence K. Edwards and Bruce E. Skov, entitled High-Speed Ground Transportation System.

Valves **5** and **7**, when closed, block off a section B of the duct from valve to valve between stations S1 and S2. Provision is made for evacuating this section of the duct down to low pressure (of the order of one p.s.i., or even one-fifth p.s.i., for example), as by means of an evacuating pump **40**. Each station is adapted for entry of atmospheric air (for pressurizing the rear of a departing vehicle or discharge of air ahead of an arriving vehicle) via a shaft **9**.

It is feasible to utilize an additional propulsive power source, namely, gravity, by sloping the duct downward from the stations as shown in FIG. 1. That is, the duct descends to a greater depth between stations than at the stations in an arc of predetermined contour or profile. It may descend to a depth of up to 3,500 feet, for example. With this arrangement, gravity is utilized to increase the acceleration of the vehicle leaving station S1 and to increase the deceleration of the vehicle approaching station S2, interchanging potential and kinetic energy with the same high efficiency as a pendulum. Thus, as the vehicle traverses the downward slope of the arc it is accelerated both by gravity and by the differential air pressure on its front and rear. Similarly, as the vehicle traverses the upward slope of the arc it is decelerated by gravity and compression of air ahead of it, with the loss in speed due to gravity being equal to the gain in speed attained from gravity in the down slope.

In accordance with this invention, a cut-off valve **13** is provided in the duct downstream from the entrance valve **5**. The cut-off valve **13** is adapted to close after the rearward end of the vehicle has passed thereby to trap the propulsive air between it and the entrance valve to prevent this slug of air from expanding throughout the duct, thereby avoiding an increase in the pressure in the duct for the coast phase of the trip between stations S1 and S2. This increases the overall efficiency of the system, particularly in a double-duct system, as will appear. As shown in FIGS. 2 and 3, the cut-off valve **13** may comprise a gate **15** slidable in a housing **17** for movement between an open or retracted position out of the duct and a closed position extending across the duct (shown in phantom in FIGS. 1 and 3). The piston rod of a double-acting pneumatic actuator or air cylinder **19** is secured to the gate for moving it into and out of the duct in response to operation of a control valve **21**. Pneumatic energy for actuating the cylinder **19** is readily drawn from the near vacuum normally existing in the adjacent duct, as indicated at **23**, and through a port **24** open to atmosphere. A reservoir **25** is provided to store energy for periods when conditions other than vacuum exist in the duct, and a safety latch **27** locks the gate **15** in its retracted position. A check valve **28** is provided between the duct and the reservoir. Control valve **21** is adapted to be set in a first position for drawing a vacuum in the upper end of cylinder **19** and supplying air under atmospheric pressure to the lower end of the cylinder **19** for retracting the gate, and in a second position for drawing a vacuum in the lower end of cylinder **19** and supplying air under atmospheric pressure to the upper end of the cylinder **19** for closing the gate.

FIGS. 4A–4L illustrate a double-duct system of this invention which comprises a pair of ducts, designated **1A** and **1B**, located side-by-side for travel of vehicles in opposite directions on the same route. The two ducts are cross-connected at suitably spaced intervals along their length by cross-ducts **29**, each of which may have a control valve therein as indicated at **31**. The valves **31** are not always necessary for the practice of the instant invention and the system may preferably be operated without them or with them open at all times. There are air locks or stations S1A and S2A at the ends of duct **1A** and stations S1B and S2B at the ends of the duct **1B** (corresponding to stations S1 and S2 of duct **1** of FIG. 1). There are entrance and exit valves **5A** and **7A** adjacent the ends of duct **1A** and entrance and exit valves **5B** and **7B** adjacent the ends of duct **1B** (corresponding to the valves **5** and **7** adjacent the ends of the duct **1** of FIG. 1). Each duct **1A** and **1B** may also have a series of auxiliary valves designated **33A** and **33B** spaced at intervals along the length of the duct immediately inward of each entrance and exit valve at both ends of the duct. Each of these valves **33** is in communication with the ambient atmosphere and is adapted, when opened, to admit atmospheric air to the respective end of the section B of the respective duct. These valves are not always necessary and the system may preferably be operated according to the instant invention without them or with them closed at all times. Additionally, each duct **1A** and **1B** has a cut-off valve **13A** and **13B** between the last auxiliary valve **33**, if provided, and in any event between the entrance valve **5** at the entrance end of the duct and the first cross-duct **29**. The valves **13A** and **13B**, when closed, form a pressure barrier between the portions of the duct to either side of the valve and, when open, permit passage of a vehicle.

The mode of operation of the FIG. 4A double-duct system for travel of vehicle **3** through duct **1A** from station S1A to S2A will now be described, and it will be apparent from this how the system is operated for travel of a vehicle in the opposite direction through duct **1B**. As shown in FIG. 4A, the vehicle **3** is at rest in station S1A at the left end of duct **1A**. Initially, main valves **5A**, **7A**, **5B** and **7B** are closed. Auxiliary valves **33A** and **33B**, if provided, are closed and cut-off valves **13A** and **13B** and cross-duct valves **31**, if provided, are open. Section B of each of ducts **1A** and **1B** has been evacuated down to low pressure (of the order of one p.s.i., or even one-fifth p.s.i., for example). The trip of the vehicle through duct **1A** is initiated by opening valve **5A**.

As a result of opening valve **5A**, and with near-vacuum ahead and atmospheric pressure behind, the vehicle **3** is propelled through station S1A and into section B of the duct, as indicated in FIG. 4B. As the vehicle progresses further into the duct, the entrance valve **5A** remains open and, if desired, although usually not necessary, the auxiliary valves **33A** at the left end of the duct are opened in succession as the rearward end of the vehicle passes thereby, thus admitting additional at-

mospheric air into the duct behind the vehicle. Although the pressure on the rear of the vehicle drops somewhat due to flow losses in the tube, the vehicle continues to accelerate due to greater pressure behind than ahead and the downward slope of the duct as shown in FIG. 4C.

When a predetermined amount of pneumatic energy has been imparted to the vehicle, the entrance valve **5A** and the auxiliary valves **33A** at the left end of the duct (if any had been opened) are closed, as shown in FIG. 4D, trapping a slug of accelerating air between the valve **5A** and the rear end of the vehicle. This slug of air in the duct behind the vehicle expands causing the pressure to drop and propelling the vehicle forward, with the vehicle continuing to accelerate, though at a diminishing rate, as the slug of air expands. The pressure immediately behind the vehicle drops faster than the average pressure in the duct behind the vehicle because of airflow losses in the duct.

As the vehicle passes through the cut-off valve **13A**, it is nearing cruise speed. Soon after the vehicle has passed, the valve **13A** is closed trapping the accelerating air slug between it and the entrance valve **5A**. The small amount of air trapped between the valve **13A** and the vehicle rapidly expands to a low pressure. After the vehicle passes the first cross-duct the vehicle coasts circulating the thin air as indicated in FIG. 4F. If, as the vehicle passes each cross-duct, the air between the rear of the vehicle and valve **13A** has not expanded down to the ambient pressure existing in tube **1B**, and if valves are provided in the cross-duct, the cross-duct valve **31** may be closed as the vehicle passes as shown in FIG. 4E and then reopened once the pressure behind the vehicle equalizes with that in tube **1B**. The thin air will then circulate as indicated above and as shown in FIG. 4F.

The vehicle continues to coast with some loss of speed through duct **1A**, air ahead of the vehicle passing from duct **1A** via the cross-connections **29** ahead of the vehicle (the valves **31** of which, if provided, are open) to duct **1B** and thence via duct **1B** and the cross-connections **29** rearward of the vehicle (the valves **31** of which, if provided, are open) back to duct **1A** behind the vehicle, as shown in FIG. 4G. At a predetermined time (dependent on vehicle weight, velocity and other system parameters), the remaining cross-duct valves **31**, if any, ahead of the vehicle are closed, as shown in FIG. 4H, and the vehicle begins to compress the thin air ahead, thereby increasing the pressure of air ahead and retarding the vehicle. As each cross-duct valve **31**, if any, is passed, it is again opened. In any event, as it passes the last cross-duct it will compress the thin air ahead with the results as indicated supra.

The vehicle continues to decelerate at an increasing rate as it climbs the slope to station **S2A** and compresses the air ahead. The compression of the air ahead of the vehicle continues as the vehicle travels forward until the pressure of the air reaches essentially atmospheric pressure. At this point the exit valve **7A** and auxiliary valves **33A**, if any, at the right end of the duct are opened, as shown in FIG. 4I, and the air ahead of the vehicle is forced out of the duct while remaining at near atmospheric pressure. Normally, auxiliary valve(s) **33A** will not be needed, but it can be used to provide an additional escape path for the air and thereby reduce losses and associated pressure rise on the front of the vehicle. With near-vacuum behind and atmospheric pressure ahead, the vehicle decelerates rapidly. The auxiliary valve **33A**, if provided, is closed when the vehicle passes thereby, as indicated in FIG. 4J. The vehicle continues to decelerate and comes to a stop in station **S2A** and the exit valve **7A** is closed behind the vehicle as shown in FIG. 4K.

Vacuum pumps **40** are connected to each duct. These pumps may be configured to operate more or less continuously, exhausting air from the ducts. When the cut-off valve **13A** is closed, the pump exhausts air from the region between the valve **13A** and the entrance valve **5A** thus removing the accelerating air slug after the vehicle passes. Once the air slug is removed and the pressure across the cut-off valve is equalized, the cut-off valve is opened and the system is ready for another trip, as shown in FIG. 4L.

Propulsion of a vehicle in the opposite direction through duct **1B** is effected in a similar manner. It will be observed that, as regards travel of the vehicle through duct **1A**, duct **1B** serves as an auxiliary duct, in conjunction with the cross-connections **29**, for passage of air from ahead of the vehicle to behind the vehicle during the intermediate coasting phase of the trip. The addition of valves **33** may be advantageous for more rapidly and efficiently admitting air to the duct behind the vehicle at the start of a trip for accelerating the vehicle and for more rapidly and efficiently pushing air out of the duct ahead of the vehicle at the conclusion of a trip when the pressure in the duct ahead of the vehicle has reached atmospheric pressure. However, the use of such valves is not always necessary for the practice of the instant invention. Valves may also be placed in the cross-ducts so that a single tube can be repressurized in an emergency.

Neglecting losses due to air circulation, heat transfer, drag and rolling friction, the momentum of the vehicle is sufficient to eject the same amount of air in the last phase of the operation as was taken in during the initial phase of the operation, and each succeeding trip of the vehicle, apart from these losses, is a relatively free trip, i.e., it requires no additional power except that which may be needed to make up for said losses.

From the above, it will appear that the cut-off valve **13A** (as to duct **1A**) and the cut-off valve **13B** (as to duct **1B**) advantageously captures the accelerating air slug so that the latter is not allowed to disperse throughout the double-duct system. Thus, a lower pressure can be maintained for the coast phase of the trip with the result of lower losses. It should be noted that it may be necessary to allow a portion of the accelerating air slug to disperse throughout the system, so that there is sufficient air in the ducts for the compression phase as the vehicle approaches the end of a trip. Careful sizing of the pump may avoid this problem.

The fact that the accelerating air slug is not allowed to disperse throughout the double-duct system reduces to a minimum the effect of vehicles traveling in opposite directions in the ducts. Since a single vehicle (in one duct) does not appreciably alter the ambient conditions in the cross-vented section of the double-duct system, a vehicle in the other duct will not be affected by the presence of the first vehicle except for a small change in air circulation losses as the vehicles pass. Thus, operation of the vehicle in one tube is essentially independent of the presence of a vehicle in the other tube.

It will be understood that the principles of the double-duct system with the valved cross-connections and the entrance and exit valves at the ends of the ducts may be utilized in a single-duct system, as to which the place of the second vehicle duct would be taken by a second or auxiliary duct cross-connected to a single vehicle duct.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As various changes could be made in the above constructions and methods without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A high-speed ground transportation system comprising a duct adapted for propulsion of a vehicle therethrough as a free piston by differential air pressure on the ends of the vehicle, said duct having an entrance end and an exit end each in communication with the earth's atmosphere, an entrance valve for the duct downstream

from and adjacent its entrance end, an exit valve for the duct adjacent its exit end, the entrance valve being adapted to close after the rearward end of the vehicle has passed and a predetermined amount of propulsive air has entered behind the vehicle in the duct, a cut-off valve for the duct downstream from the entrance valve adapted to close after the rearward end of the vehicle has passed thereby to trap the propulsive air between the cut-off valve and the entrance valve, and an auxiliary valve inward of the entrance valve for admission of additional propulsive air, said auxiliary valve being located between the entrance valve and the cut-off valve.

2. A high-speed ground transportation system as set forth in claim 1 having a series of auxiliary valves inward of the entrance valve for admission of additional propulsive air, said auxiliary valves being located between the entrance valve and the cut-off valve.

3. A high-speed ground transportation system as set forth in claim 1 wherein said cut-off valve comprises a gate movable between a retracted position clear of the duct and a closed position blocking the duct.

4. A high-speed ground transportation system as set forth in claim 2 and including a pneumatic actuator for the gate, and a control valve for the actuator interconnected with the duct and having a port in communication with the atmosphere.

5. A high-speed ground transportation system as set forth in claim 4 further having a vacuum reservoir in the interconnection between the control valve and the duct.

6. A high-speed ground transportation system as set forth in claim 1 having a second duct paralleling said first-mentioned duct, and cross-ducts between said ducts.

7. The system of claim 6 wherein each cross-duct has a control valve therein.

8. A high-speed ground transportation system as set forth in claim 6 wherein the second duct is a vehicle duct having an entrance valve and an exit valve and adapted for propulsion of a vehicle therethrough as a free piston by differential air pressure on the ends of the vehicle, the entrance valve for the second duct being adapted to close after the rearward end of the vehicle in the second duct has passed and a predetermined amount of propulsive air has entered behind the vehicle in the second duct, and a cut-off valve for the second duct downstream from the entrance valve for the second duct adapted to close after the rearward end of the vehicle has passed thereby to trap the propulsive air in the second duct between the cut-off valve and the entrance valve of the second duct.

9. A high-speed ground transportation system as set forth in claim 8 wherein the cut-off valve for each duct is located between the entrance valve and the first cross-duct for the respective duct.

10. A high-speed ground transportation system as set forth in claim 9 wherein each duct has an auxiliary valve inward of its entrance valve for admission of additional propulsive air, each cut-off valve being located between the auxiliary valve and the first cross-duct for the respective duct.

11. A high-speed ground transportation system as set forth in claim 9 wherein each duct has a series of auxiliary valves inward of its entrance valve for admission of additional propulsive air, each cut-off valve being located between the innermost auxiliary valve and the first cross-duct for the respective duct.

12. A high-speed ground transportation system as set forth in claim 8 wherein each cut-off valve comprises a gate movable between a retracted position clear of the respective duct and a closed position blocking the respective duct, a pneumatic actuator for the gate, and a control valve for the actuator interconnected with the respective duct and having a port in communication with the atmosphere.

13. A high-speed ground transportation system as set forth in claim 12 further having a vacuum reservoir in the interconnection between each control valve and the respective duct.

14. The method of operating a high-speed ground transportation system in which a vehicle is propelled as a free piston through a duct, the duct having an entrance valve and an exit valve adjacent its ends adapted when closed to block off a section of the duct from valve to valve, and a cut-off valve downstream from the entrance valve, comprising starting with the vehicle in the duct outward of the entrance valve, the entrance and exit valves closed, the cut-off valve open, and said section of the duct between the entrance and exit valves evacuated, opening the entrance valve for entrance of the vehicle into the duct and propulsion of the vehicle therethrough, closing the entrance valve after the rearward end of the vehicle has passed and a predetermined amount of propulsive air has entered the duct behind the vehicle, closing the cut-off valve after the rearward end of the vehicle has passed thereby to trap the propulsive air between the cut-off valve and the entrance valve, and opening the exit valve as the vehicle approaches the latter, the vehicle passing into and being stopped in the other end of the duct and the exit valve closing behind the vehicle.

15. The method of claim 14 wherein the duct has an auxiliary valve inward of the entrance valve communicating with the atmosphere, the cut-off valve being located inward of the auxiliary valve, and wherein, at the start, the auxiliary valve is closed and is opened as the vehicle passes thereby, the entrance valve and the auxiliary valve being closed afer a predetermined amount of air has been admitted behind the vehicle.

16. The method of claim 14 wherein the duct has a series of auxiliary valves inward of the entrance valve communicating with the atmosphere, the cut-off valve being located inward of the innermost auxiliary valve, and wherein, at the start, the auxiliary valves are closed and are successively opened as the vehicle passes thereby, the entrance valve and the auxiliary valves being closed after a predetermined amount of air has been admitted behind the vehicle.

17. The method of operating a high-speed ground transportation system in which a vehicle is propelled as a free piston through a first duct, said first duct having an entrance valve and an exit valve adjacent its ends adapted when closed to block off a section of the first duct from valve to valve, and a cut-off valve downstream from the first valve, there being a second duct alongside the first duct and cross-ducts between the ducts spaced at intervals therealong, the cut-off valve in the first duct being located between the entrance valve for the first duct and the first cross-duct, comprising starting with the vehicle in the first duct outward of the entrance valve for the first duct closed, the cut-off valve for the first duct open, and the ducts evacuated, opening the entrance valve for the first duct for entrance of the vehicle into the first duct and propulsion of the vehicle therethrough, closing the entrance valve for the first duct after the rearward end of the vehicle has passed and a predetermined amount of propulsive air has entered the first duct behind the vehicle, closing the cut-off valve for the first duct after the rearward end of the vehicle has passed thereby to trap the propulsive air between the cut-off valve and the entrance valve for the first duct, and opening the exit valve for the first duct as the vehicle approaches the latter, the vehicle passing into and being stopped in the other end of the first duct and the exit valve closing behind the vehicle.

18. The method of claim 17 wherein each cross-duct has a control valve therein and as the vehicle passes through the duct the control valves in the cross-ducts are closed as the vehicle passes and is subsequently reopened.

19. The method of claim 18 wherein the control valve in the first cross-duct is closed as the vehicle passes thereby, and is subsequently reopened.

20. The method of claim 17 wherein the first duct has an auxiliary valve inward of its entrance valve communicating with the atmosphere, the cut-off valve being located inward of the auxiliary valve, and wherein, at the start, the auxiliary valve is closed and is opened as the vehicle passes thereby, the entrance valve and the auxiliary valve being closed after a predetermined amount of air has been admitted behind the vehicle.

21. The method of claim 17 wherein the first duct has a series of auxiliary valves inward of its entrance valve communicating with the atmosphere, the cut-off valve being located inward of the innermost auxiliary valve, and

wherein, at the start, the auxiliary valves are closed and are successively opened as the vehicle passes thereby, the entrance valve and the auxiliary valve being closed after a predetermined amount of air has been admitted behind the vehicle.

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