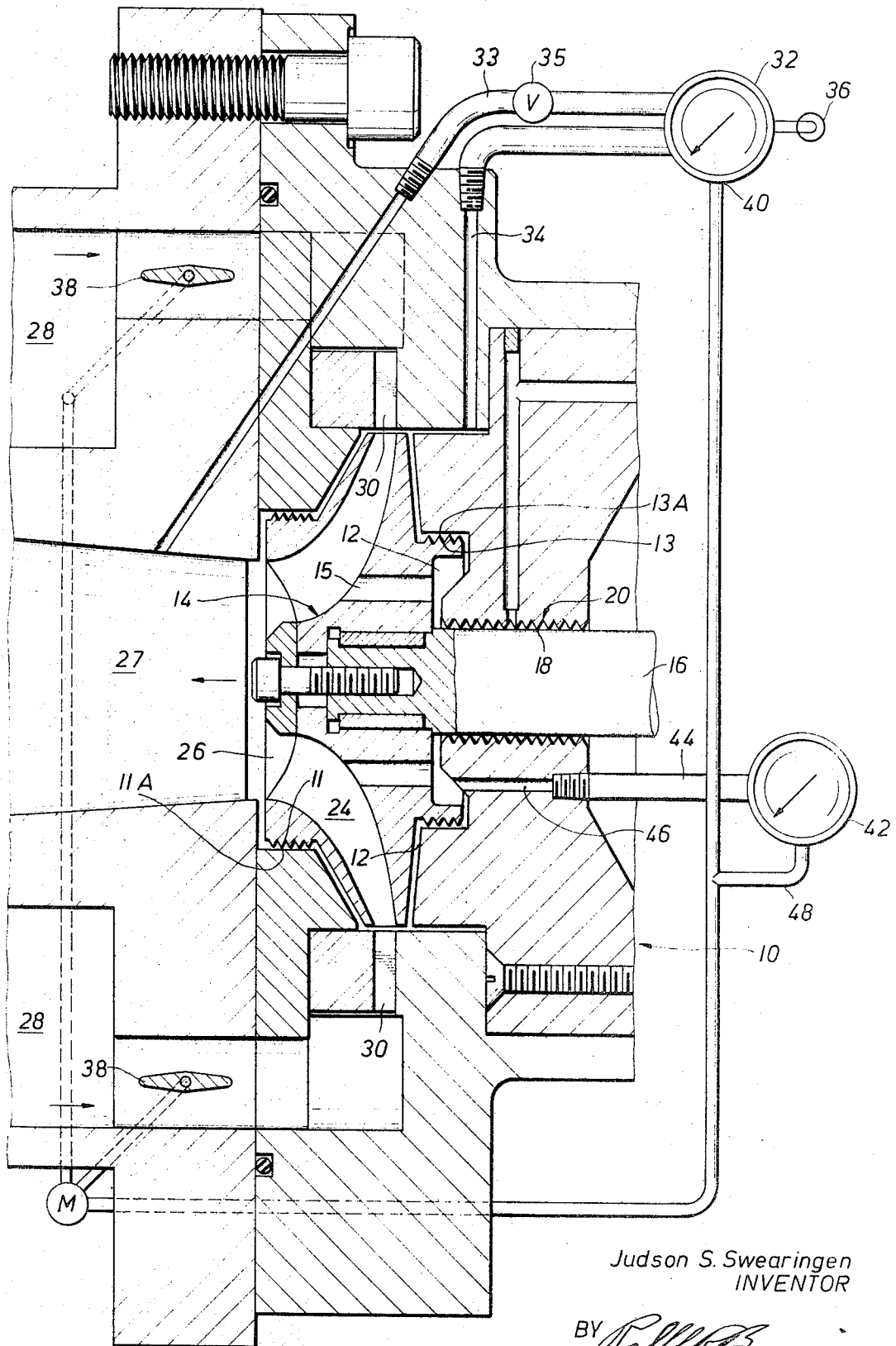


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METHOD OF AND APPARATUS FOR DETECTING
DEPOSITION IN TURBOEXPANDER
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METHOD OF AND APPARATUS FOR DETECTING DEPOSITION IN TURBOEXPANDER

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11 Claims

ABSTRACT OF THE DISCLOSURE

A gas expansion turbine has a seal between the turbine wheel and the housing exteriorly of the wheel and between the inlet and outlet openings of the wheel so as to provide a space in communication with the inlet openings of the wheel which, by comparison with the pressure downstream from the outlet openings of the wheel will indicate the pressure drop through the wheel. This pressure drop is detected by means of pressure detection devices connected through passageways through the housing to communicate with the compartment upstream of the seals mentioned and the space downstream from the wheel outlets, thereby to detect the accumulation of a substance such as Dry Ice in the passages through the wheel. Means are also provided for giving an audible signal and for automatically shutting down the turbine by closing the inlet when too great a pressure drop through the wheel is indicated.

This application is a continuation-in-part of my co-pending application Ser. No. 597,420, filed Nov. 28, 1966, for Method of and Apparatus for Detecting Carbon Dioxide Deposition in Turboexpander, and now abandoned.

The invention relates to a novel method of and apparatus for the detection of deposition in turboexpanders. Carbon dioxide or Dry Ice is referred to hereinafter as the deposit, but this is for example only as other deposits of frozen gaseous materials may likewise be detected.

During the processing of natural gas, it has been found efficient to use turboexpanders to expand the processed gas during one or more stages. If there is carbon dioxide in the natural gas being processed, conditions frequently are such that carbon dioxide in the form of Dry Ice will be deposited in the turbine wheel. Such deposition is very undesirable. For example, the deposition may not be uniform, resulting in an unbalance of the turbine wheel. Further, if the turboexpander is of such construction that the turbine wheel is in sealed relation with the housing, there will be a buildup of pressure behind the turbine wheel causing excessive load on the thrust bearings. Accordingly, it is most desirable that any deposition of carbon dioxide be detected as soon as possible so that remedial steps may immediately be taken to eliminate the formation of the Dry Ice, thereby preventing serious damage to the turboexpander.

It has been found that one method of detecting carbon dioxide deposition in a turboexpander is to provide such close fits at selected locations as to seal the turbine wheel relative to its housing sufficiently to maintain a desired pressure drop through the turbine wheel. In such event, there is provided a sealed compartment in the turbine housing downstream of the turbine nozzles and upstream of the turbine wheel. Such compartment will be referred to hereinafter as a "sealed compartment" but it will be understood that this is a relative term and that the seal required is such as to maintain a practical pressure drop through the turbine wheel. If carbon dioxide is deposited in the form of Dry Ice in the passages of the turbine

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wheel, there will be an increase in pressure drop through the turbine wheel and an increase in pressure in the sealed compartment. By sensing the pressure in the sealed compartment and monitoring it, it is possible to immediately detect any buildup in pressure. The pressure increase indicates a buildup of carbon dioxide deposit in the turbine wheel. The monitoring may be accomplished by visual inspection of the pressure sensing device, or by having some type of alarm incorporated with the pressure sensing device which will provide a declaratory signal upon the pressure reaching a predetermined level. Also, it is possible to automate the controls of such turboexpander so that upon the pressure in the sealed compartment reaching a predetermined level a control is automatically actuated which shuts down the turboexpander.

It is an object of the present invention to provide an improved method of detecting deposit of carbon dioxide in a turbine wheel.

It is another object to provide a turboexpander used in the processing of natural gas with means whereby any deposit of carbon dioxide in the wheel of the turboexpander may immediately be detected.

It is still another object to provide a turboexpander with means which seals the turbine wheel relative to the housing sufficiently so that a desired pressure drop is maintained through the turbine wheel and a compartment which is sealed for practical purposes and which may be monitored to changes in pressures is formed downstream of the nozzles and upstream of the turbine wheel. Changes in pressure in the sealed compartment will indicate deposition of carbon dioxide in the turbine wheel.

It is a further object to provide a turboexpander having such a sealed compartment downstream of the nozzles and upstream of the turbine wheel reflecting changes in the pressures with a pressure sensing device providing visual indication of pressure changes so that deposition of carbon dioxide may be immediately detected.

It is still a further object to provide a turboexpander having such a sealed compartment downstream of the nozzles and upstream of the turbine wheel reflecting pressure changes and a pressure sensing device in communication with said compartment to indicate such changes with means which will provide a declaratory signal upon the pressure in the sealed compartment reaching a predetermined value.

It is still a further object to provide a turboexpander having such a sealed compartment downstream of the nozzles and upstream of the turbine wheel reflecting pressure changes and a pressure sensing device in communication with said compartment to indicate such changes with means which will automatically terminate operation of the turboexpander upon the pressure in the sealed compartment reaching a predetermined value.

It is a further object to provide a turboexpander of the character described above in which there are interconnecting passageways between the opposite end faces of the rotor providing intercommunication therebetween so that comparable areas on the two opposite end faces of the rotor will be subjected to substantially the same low pressures, and to provide means for monitoring the pressure on that end face of the rotor opposite the discharge of the rotor so as to detect any buildup of pressure on said opposite end face such as might create destructive thrust forces on the rotor.

Other objects and advantages of this invention will become apparent from the following description taken in connection with the accompanying drawing, wherein is set forth by way of illustration and example only, and not by way of limitation, one embodiment of this invention.

In the drawing:

The single figure shows a cross section through a turbo-expander constructed in accordance with this invention, the section being taken along the axis of the turbo-expander.

In general, liquefaction of natural gas is carried out either by staged mechanical refrigeration or by a combination of mechanical refrigeration plus the use of turboexpanders. Turboexpanders have been found useful in taking energy out of a cold stream of pressurized liquid. However, natural gas often has some carbon dioxide entrained in it and the conditions existing in the turboexpander stage of the liquefaction process are often such that carbon dioxide in the form of Dry Ice may be deposited in the passages of the turbine wheel. Such deposit is very undesirable. For instance, the deposit may not be uniform causing an unbalance of the turbine wheel. Accordingly, it is very desirable that any deposit of carbon dioxide be immediately detected so that corrective measures may be taken to eliminate the deposit before there is damage to the turboexpander. While the preferred embodiment is particularly advantageous in the detection of carbon dioxide during the processing of natural gas, it can be utilized in other operations of a turbo-expander to detect the deposit of deleterious material in the turbine wheel.

Referring now to the drawing, there is illustrated a turboexpander which can be utilized to expand gases during several stages in the liquefaction of natural gases. The turboexpander has a housing 10 having a turbine wheel compartment in which is mounted turbine wheel 14. Turbine wheel 14 is mounted on a shaft 16 which extends through an opening 18 in the housing 10. A labyrinth-type gas seal 20, or other type of seal known to those skilled in the art, is used to seal the turbine compartment from the remainder of the turboexpander. Accordingly, there is no significant flow of gas along the shaft 16.

The turbine wheel 14 is provided with a plurality of radially-axial extending passages 24 which are designed to receive gas and direct it through the turbine wheel for discharge through axial outlet nozzles 26 on the wheel into the discharge end 27 of the turboexpander. The housing 10 is provided with an inlet passage 28 and a plurality of nozzles 30 which direct the incoming gas tangentially and radially onto the turbine wheel 14, and through the passages 24 of the turbine wheel. The gas flows through the radial-axial passages 24 to the axial outlet nozzles 26 and is discharged through the discharge end 27 of the turboexpander. The outlet nozzles 26 are in the discharge section of the turbine wheel and are reaction passages in that they direct the gas being discharged so as to nullify rotary motion that it has as it passes through the turbine wheel.

Extending circumferentially around the discharge portion of the turbine wheel 14 is a labyrinth-type seal member 11 which cooperates with an adjacent circumferential member 11A on the housing 10. The seal member 11 taken with the close clearance on the opposite side of the wheel provided by the labyrinth-type seal 13 on the wheel and the cooperating surface 13A on the housing, makes the outer part of the turbine wheel compartment 12 into a practically closed space downstream of the stationary nozzles 30 and upstream of the turbine wheel 14. The space on both end faces of the turbine wheel radially outwardly of the seals 11 and 13 form part of such closed space. Circumferentially spaced passages 15 connect the space radially inwardly from seal 13 with the passages 24 near their discharge or low pressure ends so that the opposite end faces of the wheel near the axis will be subjected to similar pressure to avoid damaging endwise thrusts thereon.

In operation, the incoming gas expands partially in the nozzles 30 and then flows into the turbine wheel 14. The remainder of the pressure energy in the gas is spent

partly in overcoming the centrifugal force field in the turbine wheel 14 and partly in the reaction section to accelerate itself in the discharge nozzles 26 of the wheel. There is also a small frictional loss as the gas flows through the radial-axial passages 24 in the turbine wheel. The intermediate pressure at the discharge of the primary nozzles 30 reflects a drop from the inlet pressure of the order of 60% of the drop in pressure energy level between the inlet and the discharge of the turbine.

If there is carbon dioxide in the gas being expanded, and if the temperature and pressure of the turboexpander are such as to be below the frost point of carbon dioxide, there will be deposited in the passages 24 of the turbine wheel 14 carbon dioxide in the form of Dry Ice. This deposit reduces the cross section of the passages 24 in the turbine wheel 14, and, therefore, increases the pressure drop through the turbine wheel 14. As a result, pressure in the sealed compartment 12 will be correspondingly increased in relation to the pressure downstream of the turbine wheel. This increase in pressure in the sealed compartment 12 reflects the deposit of carbon dioxide in the turbine wheel 14. Accordingly, if a pressure sensing device 32 is placed in communication with the sealed compartment 12 by a passage 34 any increase in pressure in the sealed compartment 12 indicating a deposit in passages 24 may be immediately detected. Corrective steps may then be taken to eliminate the deposit prior to the turboexpander being damaged.

If the turbine wheel discharge pressure is not relatively constant, a differential pressure gage may be used at 32 to measure the difference between compartments 12 and 27. In such case it would be necessary to have also a communicating connection 33 from the compartment 27 to the gage 32. The connection 33 may be provided with a valve 35 which may be closed when differential pressure is not desired.

Accordingly, it has been found that if a turboexpander being used in the processing of natural gas is provided with a sealed compartment 12 downstream of the nozzles of the turbine and upstream of the turbine wheel itself, such a sealed compartment will reflect any change in pressure drop through the turbine wheel and by sensing and monitoring the pressure in the sealed compartment 12 the deposit of carbon dioxide on the turbine wheel can immediately be detected.

In order to eliminate the constant monitoring of the pressure sensing device 32, a signal light 36 or other type of declaratory signal may be connected to the pressure sensing device 32 in such a manner that the declaratory signaling device 36 will be energized upon the pressure in the sealed compartment 12 reaching a predetermined value.

Also, it has been found that, if desired, the process may be fully automated by providing motor-driven valves 38 in the inlets 28 to the turbine. A control device 40 is attached to the pressure sensing device 32 and set to operate at a predetermined value. Actuation of the control device 40 operates the motor controlling valves 38 to close down the flow of gas into the turboexpander and thereby terminate its operation.

It has also been found that on occasions deposits of solid carbon dioxide may form and block of partially block the passages 15 through the turbine wheel. Thereupon pressure leaking past the seal 13 from the sealed compartment 12 will build up pressure radially inwardly from the seal 13, thereby unbalancing the end thrust on the turbine wheel with such unbalance potentially increasing quite rapidly and quickly damaging the turbine wheel, bearings and the like unless quick action is taken to remedy this situation.

In order to deal with this possible eventually a second pressure indicator 42 may be provided and connected by means of a line 44 and a passageway 46 through the turbine housing to communicate with the space radially inwardly from the seal 13 on that side of the turbine wheel opposite the outlet nozzles 26. Such indicator 42

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would quickly indicate any tendency toward increase of pressure in such space urging the turbine wheel 14 toward the left as seen in the drawing, whereupon corrective action could be taken promptly. As a matter of practice it is contemplated that the indication of such increase in pressure by the indicator 42 would be transmitted through a connection 48 to actuate the motor controlling the valves 38 in the same fashion as heretofore described for such motor control by the indicator 32.

Accordingly, it can be seen from the foregoing, providing a radial turbine with a seal about the outlet forms a sealed compartment downstream of the inlet nozzles and upstream of the turbine wheel. Any deposition of carbon dioxide or other material in the passages of the turbine wheel will result in an increase in pressure drop through the turbine. The sealed compartment will reflect any change in pressure drop. Therefore, by the pressure sensing device placed in communication with the sealed compartment the change in pressure drop can be immediately ascertained and corrective measures taken before damage results. In order that the pressure sensing devices does not have to be constantly monitored a declaratory signal can be connected to the pressure sensing device to provide a signal upon the pressure exceeding a predetermined value. Also, the system can be fully automated so that when the pressure exceeds a predetermined value the turboexpander is automatically shut down.

Furthermore, in order to guard against large differentials of pressure acting on opposite end faces of the turbine wheel inwardly of the seals which provide the sealed compartment, caused by the interconnecting passageways which interconnect the opposite faces of the turbine wheel adjacent the axis becoming clogged with deposits, the space inwardly of the seal on the opposite face of the turbine wheel from the outlet openings may be monitored by a pressure sensing and indicating device to detect increase in pressure therein. The corrective action in such instance also may be accomplished manually or may be automated by connection from the pressure indicator and sensor to the controls by which the turbine may be shut down.

From the foregoing it will be seen that this invention is one well adapted to attain all of the ends and objects hereinabove set forth, together with other advantages which are obvious and which are inherent to the apparatus.

The invention having been described what is claimed is:

1. A turboexpander comprising a housing, a turbine wheel rotatably mounted in said housing and having passageways therethrough from entrances adjacent its periphery to discharges adjacent its axis, and a discharge opening from said housing in said direction, sealing means providing annular substantially sealing relation between the exterior of said wheel on opposite endwise faces thereof and the adjacent interior surface of said housing, and means for detecting buildups of deposits in certain of said passageways during operation comprising means for monitoring the pressure variations in a space within said housing where pressure would be affected by such buildups.

2. A turboexpander as set forth in claim 1 in which the passageways through said wheel are gas expansion passageways and the means for monitoring pressure comprises an externally located pressure indicator and means providing pressure communication between said indicator and the space within said housing adjacent the periphery of said wheel.

3. A turboexpander as set forth in claim 2 in which there is also means providing pressure communication between the pressure indicating means and the space within said housing adjacent but exteriorly of the discharge ends of the passageways through said wheel, and said pressure indicator is a differential pressure indicator for indicating the differential of pressures between said spaces.

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4. A turboexpander as set forth in claim 1 in which there are also passageways means interconnecting the spaces between the opposite end faces of said wheel and the housing radially inwardly from said sealing means, and the means for monitoring the pressure variations are in communication with the space between the end face of said wheel and the housing opposite from the discharge of the expansion passages to said wheel and inwardly of the sealing means, for detecting buildups of deposits in said last-mentioned passageways.

5. A turboexpander as set forth in claim 1 in which there is also valve means for controlling the admission of gas to be expanded into the housing about the periphery of said wheel, and control means interconnecting the means for monitoring pressure with said valve means whereby upon detection by said means for monitoring pressure of a pressure condition indicating a buildup of deposits in a passageway beyond a predetermined point, said control means will cause closing of said valve means.

6. A turboexpander for use in the expanding of a gas which may contain some entrained constituents capable of being deposited in the turbine, said turbine comprising: a housing having a turbine wheel compartment, said compartment having an inlet passage and a discharge passage; an opening in the housing in communication with said turbine wheel compartment; a turbine wheel shaft extending through said opening; seal means forming a seal between said opening and said shaft; a turbine wheel mounted on the shaft in said compartment; a seal about the turbine wheel and discharge passage forming a sealed compartment downstream of the inlet passage and communicating with the entrance of the turbine wheel whereby any pressure drop through the turbine wheel is reflected by an increase in pressure in the sealed compartment; a passage in the turbine housing in communication with the sealed compartment; a pressure sensing device connected to the passage; means attached to the pressure sensing device which will provide a declaratory signal upon the pressure in the compartment reaching a predetermined value.

7. The turboexpander specified in claim 6 characterized in that the turboexpander is provided with a motor controlled valve means which controls the flow of gas to the turbine, and the means attached to the pressure sensing device is a control means for said valve means whereby upon the pressure reaching a predetermined value the valve means is actuated to close the inlet.

8. The method of detecting carbon dioxide or like deposits during the processing of natural gas through a turbine having a housing with a wheel therein comprising: injecting natural gas into a turbine housing to the entrance of the wheel; forming a seal to the housing about the exterior of the turbine wheel between the inlet and outlet thereof, whereby the gas flow is directed through the turbine wheel and a sealed space is formed between the housing and the turbine wheel in communication with the entrance to the turbine wheel, with pressure variation therein indicating any increase in pressure drop through the turbine wheel; and monitoring the pressure in the sealed space to detect any build up in pressure which indicates the presence of a deposit such as carbon dioxide on the turbine wheel.

9. The method set forth in claim 8 characterized in that when the monitored pressure exceeds a predetermined level a visual indication is provided to signify the increased pressure buildup.

10. The method specified in claim 8 characterized in that when the monitored pressure exceeds a predetermined limit the inlet of the turboexpander is closed to terminate the flow of gas to the turboexpander.

11. A turboexpander for use in the expanding of a gas which may contain some entrained constituents capable of being deposited in the turbine, said turbine comprising: a housing having a turbine wheel compartment, said compartment having an inlet passage and a discharge passage; an opening in the housing in communication with said

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turbine wheel compartment; a turbine wheel shaft extending through said opening; seal means forming a seal between said opening and said shaft; a turbine wheel mounted on the shaft in said compartment; a seal about the turbine wheel and discharge passage forming a sealed compartment downstream of the inlet passage and upstream of the turbine wheel whereby any pressure drop through the turbine wheel is reflected by an increase in pressure in the sealed compartment; a passage in the turbine housing in communication with the sealed compartment; a passage from the discharge passage; and a differential pressure sensing device in communication with the passage from the sealed compartment and the passage from the discharge passage.

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Disclaimer and Dedication

3,547,606.—*Judson S. Swearingen*, Los Angeles, Calif. METHOD OF AND APPARATUS FOR DETECTING DEPOSITION IN TURBOEXPANDER. Patent dated Dec. 15, 1970. Disclaimer and Dedication filed Oct. 28, 1980, by the inventor.

Hereby disclaims and dedicates to the Public the entire remaining term of said patent.

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