

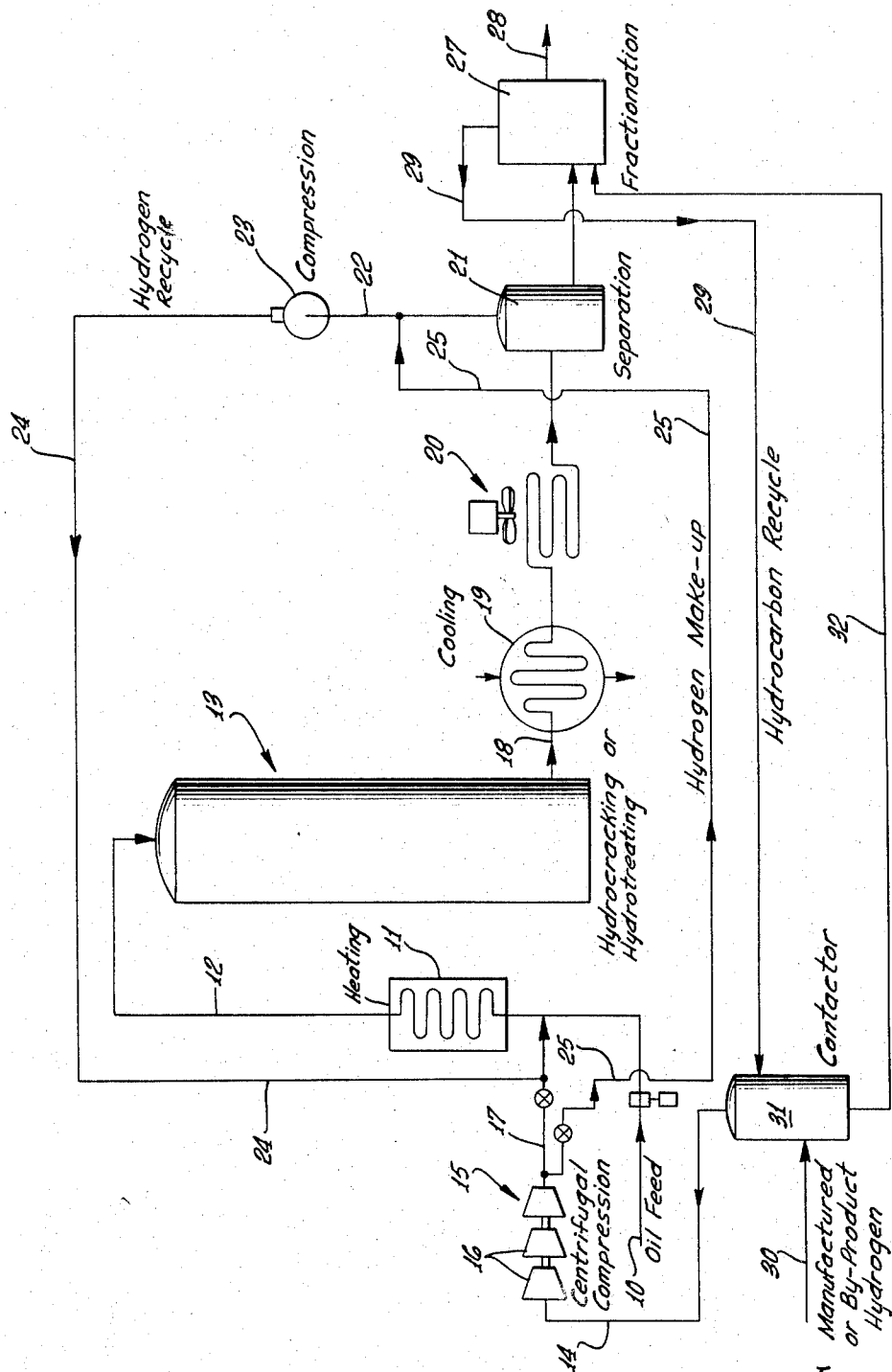
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S. B. JACKSON

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HYDROGEN COMPRESSION BY CENTRIFUGAL COMPRESSORS

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INVENTOR.

STEVEN B. JACKSON

By White & Haefliger

ATTORNEYS.

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HYDROGEN COMPRESSION BY CENTRIFUGAL COMPRESSORS

Steven B. Jackson, Fullerton, Calif., assignor to The Fluor Corporation, Ltd., Los Angeles, Calif., a corporation of California

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ABSTRACT OF THE DISCLOSURE

The invention is predicated upon utilization of multi-stage centrifugal compressors for elevating an essentially hydrogen stream to high pressures required for such known oil refining or conversion processes as hydrocracking or hydrotreating, and the employment of a method for reducing the number of required compressor stages by introduction to the hydrogen stream in advance of compression, butane or its molecular equivalent in the 30 to 80 molecular weight range, so that the hydrocarbon content of the stream will be in the 1% to 12% range and sufficiently high to materially increase the effective pressure to which the hydrogen is elevated by the compression, the added hydrocarbon being derivable from an essentially C₄ fraction of the hydrogen-hydrocarbon reactor output.

This invention relates generally to the compression of gaseous hydrogen or predominately hydrogen streams by multi-stage centrifugal compressors of the (e.g. Clark, Elliot or Ingersoll Rand) types commonly used for field, refinery, or chemical plant gas compression. These are multi-stage in employing a succession of pressure increasing impellers, as well as in accommodating impeller series in each of successive case sections of the compressors. The successive case stages are customarily connected in tandem to a common drive shaft which is connected to a common driver and gear speed changer if required. It is the operation of multiple case stage centrifugal compressors with which the invention is primarily concerned.

In certain types of processes involving hydrogen reactive conversion of hydrocarbons, or in other types which can tolerate a low percentage of hydrocarbons in the hydrogen, it becomes necessary to compress the hydrogen to elevated pressures, e.g., in the 500 to 4,000 pounds per square inch gage range. For reasons unnecessary to explain, it is found most advantageous to employ for such compression, centrifugal compressors of the types named, instead of reciprocating or piston type compressors. However, serious economic considerations arise in the requirements for a centrifugal compressor capable of raising the hydrogen pressures to the high levels indicated. The major considerations are the greater number of compressor stages required and corresponding high initial compressor costs, as well as the expense of mechanical maintenances that may result from a greater number of stages, and the loss of reliability in dependence on increased complexity of the rotating equipment.

One of my major objectives is to achieve hydrogen compression employing a lesser number of compressor stages, to a high level beyond the normal capability of such stages and thus to eliminate the necessity for costly extra stages. This objective is achieved by providing for the presence in the hydrogen undergoing compression of a relatively small mole or volume percentage, about 1% to 12% of hydrocarbon in the 30 to 80 molecular weight range, preferably butane or mixed hydrocarbons of about the molecular weight equivalent of butane.

Thus supplemented, the hydrogen will undergo compression to consequentially higher pressure by a given compressor, and therefore it becomes possible to employ a reduced number of compressor stages and correspond-

ingly reduced compressor cost, to achieve high level hydrogen compression. To illustrate, whereas in a given instance high compression of substantially pure hydrogen might require five or six case compressor stages, butane or equivalent addition to the hydrogen may permit its corresponding compression using only three compressor stages. It is considered that the equipment economics justify the butane occasioned increase in the volume of gas to be compressed.

The invention has further objects in reference to its particular applicability to hydrocarbon-hydrogen reaction or hydrogen treating processes, well known as hydrocracking or hydrotreating, wherein hydrogen is contacted at high pressures for reactive conversion of selected oil stocks or fractions. Such processes adapt to the purposes of the present invention in requiring recovery and recirculation of hydrogen which normally is required to be present in the reactor in excess of actual reaction requirements, as well as being productive of low boiling hydrocarbons useable as supplement for the hydrogen compression.

All the various features and objects of the invention as well as the salient characteristics of an illustrative embodiment will be more fully understood from the following detailed description of the accompanying flow sheet.

In reference to the flow sheet, an oil feed appropriate for hydrocracking, such as virgin or catalytically cracked gas oil, or for hydrotreating, e.g. gas oil in the boiling range of diesel oil needing reduction in sulfur content or increase in cetane number to meet product specifications, is introduced to the system through line 10 and pumped through heating facility 11 and thence by way of line 12 to a hydrocracking or hydrotreating unit which may include one or more reactors 13 wherein the oil feed undergoes conversion at high pressure that may range between about 500 and 4,000 pounds per square inch, and at temperatures in the order of about 500° F. to 900° F., depending upon the more specific conditions to be maintained in hydrocracking or hydrotreating processes, with which the invention is not concerned other than with respect to the high pressures employed. The unit 13 may serve to contact the heated oil feed with catalyst appropriate to the type of conversion, as is generally known in the art of hydrogen conversion processes.

A predominately hydrogen gas stream, e.g. about 90% hydrogen, is supplied through line 14 to a centrifugal compressor generally indicated at 15, which as previously indicated, comprises a series of case stages 16 individually containing their respective impeller series. In passing through the compressor the hydrogen feed is progressively increased in pressure to the level required for the oil feed conversion in unit 13, the compressor discharge being taken through line 17 to be combined with the line 10 oil feed going to heater 11. The normally liquid and gaseous, or entirely gaseous mixture resulting from the conversion in unit 13 is discharged therefrom through line 18 and subjected to cooling as by passage through exchanger 19 and air cooler 20 beyond which the cooled and partially condensed mixture enters separator 21. Hydrogen supplied to the unit 13 in excess of the amount required for the oil conversion, is released from separator 21 through line 22 together with a relatively low percentage of light hydrocarbons, and the released gas is returned by compressor 23 through line 24 to line 17, and at a pressure as high as the pressure therein, as hydrogen recycle which may be required or desired to supplement hydrogen feed to unit 13. In general, the discharge from compressor 15, may enter the system at any suitable location retentive of the recycle. Thus for example, the discharge from compressor 15, may be routed instead through line 25 and introduced elsewhere into the system "loop," as to the suction side of compressor 23. The most

advantageous point for introduction of hydrogen makeup from compressor 15 into the system "loop" is subject to calculation for a given case in hand.

The effluent from separator 21 containing the liquefied butane equivalent compression supplement as well as reaction products is shown to be taken through line 26 for fractionation by suitable or conventional equipment diagrammatically indicated at 27 and which is productive of a fraction having average molecular weight in the 30 to 80 range, or desirably a fraction which is largely butane. Residual or product hydrocarbon leaves the fractionation stage through line 28. Separated butane or equivalent is taken through line 29 as supplement to manufactured or by-product hydrogen being fed to the system through line 30. In order to insure production of a uniform mixture of the butane recycle with the line 30 feed, the streams may be introduced to a contactor 31 from which a gaseous butane and hydrogen mixture is taken as the line 14 feed to the compressor 15. Unvaporized material from separator 31 may be returned to the fractionation section through line 32. The use of an impure hydrocarbon supplement of average molecular weight near butane, rather than pure butane can now be made apparent. Such a material achieves the objective of the invention, but may be available at an earlier stage in the fractionation train, and thus the expense of fractionation to produce nearly pure butane may be avoided. The proportion of butane or equivalent thus added to the hydrogen feed is so controlled as not to consequentially exceed the quantity of hydrocarbon required for the desired elevation of the hydrogen compression by compressor 15. In practice the butane supplement will be so controlled as to constitute between about 1 and 12%, and most often in the range of about 5 to 10% by volume of the feed to the compressor, the quantity added being dependent primarily on the purity and average molecular weight of the manufactured and/or byproduct hydrogen feed introduced in line 30. The byproduct hydrogen feed may be most commonly a byproduct of catalytic reforming operations. This byproduct hydrogen normally contains hydrocarbon impurities (methane through butane). These impurities are variable depending on operations and catalyst condition in the reformer. Another objective of the invention thus becomes apparent, i.e. to control the quantity of butane supplement so that the desired elevation of hydrogen compression is constant regardless of variation in hydrogen feed purity.

One of the major criteria for selecting the butane equivalent supplement hydrocarbon is that it should condense essentially into the liquid phase in separator 21. The quality of recycle passing through line 24 and 24, thence back to unit 13 is judged primarily by its hydrogen content. If the supplemental material can be essentially liquefied in separator 21, this material will not build up in concentration in the vapor phase and therefore will influence the hydrogen content of the recycle only to a very limited extent.

Ordinarily, as where essentially pure hydrogen is to be compressed to within the high level pressure range previously indicated, the number of compressor stages 16 required may be such as to involve excessively high compressor cost in proportion to the number of required stages. For example, for hydrogen compression to around 1,600 pounds per square inch, six case stages normally could be required. By reason of butane or equivalent addition to the line 14 feed, the resulting increased density of the gaseous mixture permits corresponding or equivalent hydrogen compression, e.g. to 1,600 pounds, by a

lesser number of compressor stages, which in the example given may reduce to three and with corresponding reduction in the cost of the compressor installation.

I claim:

1. In a method wherein a predominantly hydrogen gaseous feed stream is compressed to high pressure by passage through a multiple case stage centrifugal compressor and the thus compressed feed stream is then contacted at said high pressure for recative conversion of oil stocks or fractions, the improvement which comprises adding to the hydrogen feed stream, before it is compressed, hydrocarbon in the 30 to 80 molecular weight range so that the feed stream contains about 1% to 12% of such added hydrocarbon, whereby the effective hydrogen compression by said compressor is substantially increased above the level otherwise attainable under the same operating conditions but in the absence of the added hydrocarbon.

2. The method of claim 1, in which said hydrocarbon molecular weight corresponds substantially to that of butane.

3. The method of claim 1, in which the added hydrocarbon is separated from residual hydrogen by condensation following the compression.

4. The method of claim 3, in which the added hydrocarbon is separated from residual hydrogen following the compression and is returned to said stream.

5. The method of claim 1, in which the predominately hydrogen gaseous feed stream varies in purity and hence in average molecular weight, and the added hydrocarbon is controlled so that the effective hydrogen compression by said compressor is constant regardless of variations in said feed stream purity.

6. The method of claim 1, including also the steps of contacting the compressed gas with relatively high boiling hydrocarbons for conversion by hydrogen reaction therewith to produce a mixture of lighter hydrocarbons, higher boiling liquid hydrocarbons and residual unreacted hydrogen, separating the unreacted hydrogen from said mixture by partial condensation and fractionating the resultant predominately hydrocarbon mixture to separate said lighter hydrocarbons, and returning the separated lighter hydrocarbons to said feed stream as said hydrocarbon added thereto.

7. The method of claim 6, in which said separated unreacted hydrogen is recycled and combined with the first mentioned hydrogen stream for said reaction with higher boiling hydrocarbons.

8. The method of claim 7, in which the first mentioned hydrocarbon corresponds substantially to butane in molecular weight.

9. The method of claim 8, in which said hydrocarbon constitutes about 5% to 10% of the gas stream undergoing compression.

10. The method of claim 6, in which the predominately hydrogen gaseous feed stream varies in purity and hence in average molecular weight, and the added hydrocarbon is controlled so that the effective hydrogen compression by said compressor is constant regardless of variations in said feed stream purity.

References Cited

UNITED STATES PATENTS

3,008,895	11/1961	Hansford et al.	208—68
3,141,748	7/1964	Hoke et al.	208—95

DELBERT E. GANTZ, *Primary Examiner.*

A. RIMENS, *Assistant Examiner.*