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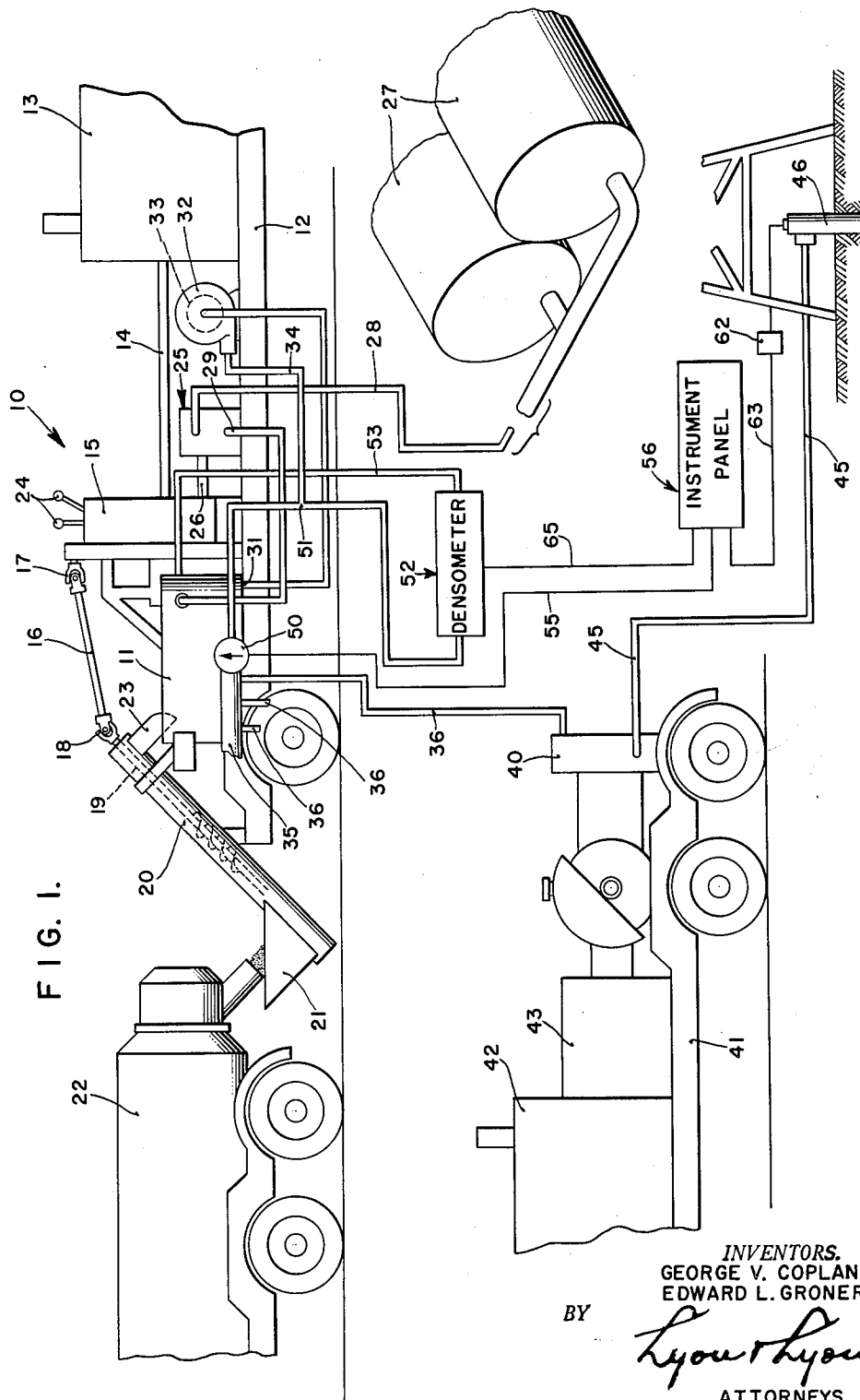
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CONTROL OF WELL FORMATION FRACTURING OPERATIONS

Filed June 6, 1960

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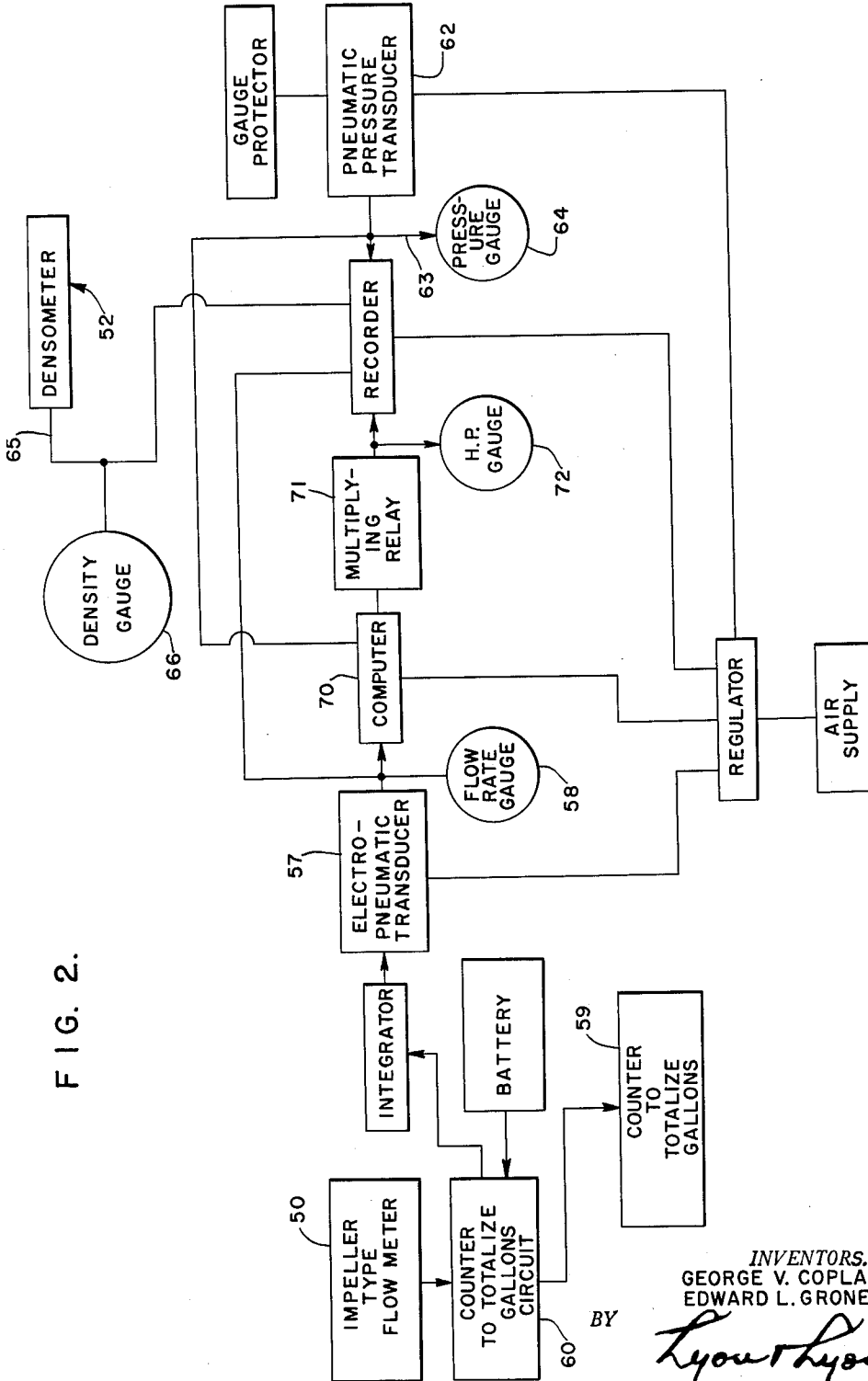
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2 Sheets-Sheet 2



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1

3,090,439

CONTROL OF WELL FORMATION FRACTURING OPERATIONS

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4 Claims. (Cl. 166—75)

In the hydraulic fracturing of well formations a carrier, for example oil, and a propping agent, for example sand, are mixed together and pumped under high pressure into the well head and conveyed downward through casing to the well formation to be fractured. The parting, or fracturing, of the desired section of formation is accomplished by the application of hydraulic pressure, and the fracture so made is extended away from the well bore by continued pumping. Higher effective permeability is obtained by the new flow channels created by the fracturing operation. The sand packs and fills the fracture, serving as a propping agent to hold the fracture open. After completion of the fracturing operation, the additional flow channels of high capacity result in greater production of oil from the well.

In a typical well formation fracturing operation, a number of heavy-duty high-pressure pumps are assembled at the well site and high-capacity mixing apparatus is provided for proportioning the carrier fluid (oil) and the propping agent (sand). Although the process requires large volumes of mixture of sand and oil to be pumped under high pressure into the well, the total time involved in the actual fracturing operation may be relatively short, for example, one-half hour.

The heavy-duty, high-pressure pumps are truck mounted for portability, and each is driven by a large internal combustion engine unit through a change-speed transmission. The change-speed transmission enables the engine unit to be operated at a speed to produce maximum horsepower output, regardless of the speed of the pump. Proper control of the individually powered pumps during the fracturing operation is very important, in order that a proper amount of oil and sand may be delivered into the well head at the desired rate of flow and at the desired pressure.

In accordance with this invention, instruments are provided to furnish a remote indication of (a) the injection rate of the mixture, (b) the well head pressure, and (c) the density of the mixture being pumped. In most if not all fracturing operations it is desired that the injection rate of the mixture and the well head pressure be so related as to produce maximum hydraulic horsepower as stated in the following formula:

Hydraulic horsepower

$$= \frac{\text{Pressure (p.s.i.)} \times \text{flow rate (bbls/min.)}}{40.81}$$

Accordingly, it is an important object of this invention to provide a method and apparatus furnishing a visual indication at a remote location of the hydraulic horsepower being applied to the well head. This information furnished to the operator in charge of the entire fracturing operation enables him quickly to make adjustments in the speed of the heavy-duty high-pressure pump units in order to achieve maximum hydraulic horsepower.

Other and more detailed objects will appear herein after.

In the drawings:

FIGURE 1 is a diagrammatic illustration of a preferred form of apparatus embodying our invention and showing means for carrying out our improved method; and

2

FIGURE 2 is a schematic diagram showing components of the instrument panel.

Referring to the drawings, a blender unit generally designated 10 may include a mixing tub 11 open at the top and mounted on a mobile frame 12. A prime mover 13 mounted on the same frame 12 has an output shaft 14 connected to drive a gear-reduction unit 15. A plurality of shafts 16 are driven from the gear-reduction unit 15 through universal joints 17. Each shaft 16 is connected through another universal joint 18 to a screw shaft 19 of an incline screw conveyor 20. These screw conveyors 20 are mounted in gang or battery fashion, and each receives material from a hopper 21 mounted at the lower end thereof. A propping agent, such as sand, is delivered into the hopper 21 by one or more sand trucks 22, and the screw conveyors lift the sand from the hopper 21 and discharge it through chutes 23 into the mixing tub 11. The speed of rotation of each of the shafts 16 may be selected by suitable positioning of a gear-shift lever 24 connected to the gear-reduction unit 15. From this description, it will be understood that power for the screw conveyors 20 is delivered by the prime mover 13 through the gear-reduction unit 15 and the shafts 16.

A metering pump, generally designated 25, is mounted on the frame 12 and has a power-input shaft 26 driven from the gear-reduction unit 15. Liquid carrier, for example oil, is delivered to the metering pump 25 from the storage tanks 27 by way of conduit 28, and oil is discharged from the metering pump 25 through conduit 29 into the mixing tub 11. The proportion of sand to oil is regulated by changing the speed of the screw conveyors 20 by means of the gear-shift levers 24 on the gear-reduction unit 15. It will be noted that variations in speed of the prime mover 13 do not affect the proportion of sand to oil, since the prime mover 13 drives both the metering pump 25 and the screw conveyors 20.

The mixing tub 11 is provided with a discharge opening 31 leading to the inlet of a centrifugal pump 32, driven by a prime mover 33. The discharge from the centrifugal pump 32 is connected by pipe 34 to a header 35, and a series of discharge pipes 36 are connected to this header. The centrifugal pump 32 serves to transfer the mixture of oil and sand from the mixing tub 11 to a series of heavy-duty high-pressure pumps 40, mounted on mobile frames 41. While only one such pump 40 is shown on the drawings, it will be understood that a plurality of such pumps are ordinarily used in order to develop sufficient volume at the desired pressure. Each pump 40 is driven from a prime mover 42 through a change-speed transmission 43. The sand-oil mixture delivered to the pump 40 through pipe 36 is discharged under high pressure through pipe 45 into the well head 46. In practice, a number of pumps 40 are employed and the same number of separate high-pressure conduits 45 extend to the well head 46.

A flow meter 50 is located in the low-pressure conduit 34 at a point downstream from the junction 51 of a sampling pickup point for the density-measuring device, generally designated 52. This device, called a "Densometer," may be of the general type shown in patent application Serial No. 803,772, filed April 2, 1959, and it serves for continuously measuring the density of the mixture being transmitted through the low-pressure conduit 34. A small portion of the sand-oil mixture passing through the conduit 34 is bypassed through the Densometer 52 and returned to the mixing tub 11 through piping 53.

The total flow of mixture entering the pump 40 passes through the impeller type flow meter 50. Electrical pulses are given off by the flow meter, and these pulses are transmitted through an electric conductor 55 to the

3

instrument panel, generally designated 56. At the instrument panel, an integrator converts these pulses to an analogue electrical signal. This analogue electrical signal is converted by means of a transducer 57 from an electrical current to air under pressure, which, in turn, is conveyed to a dial gage 58, calibrated in gallons per minute.

In conjunction with the flow meter 50, electrical pulses are fed to a digital counter 59 through a count-down circuit 60, so as to give a ratio such that each gallon of mixture is represented by a predetermined number of pulses. The counter 59 may be provided with conventional dials, serving as a totalizer for the number of gallons of sand-oil mixture transmitted.

Pressure at the well head 46 is converted pneumatically from hydraulic pressure to a standard pneumatic transmission pressure, for example, 15 p.s.i. This is accomplished in the converter 62. The pneumatic pressure is then conveyed through a small tube 63 to a pressure gage 64, calibrated in thousands of pounds per square inch.

The signal from the Densometer 52 is transmitted through a small tube 65 to a pressure gage 66, calibrated in terms of pounds per gallon, and this gage is mounted on the instrument panel, along with the flow-rate gage 58, the well head pressure gage 64, and the total-gallons indicator 59. The instrument panel is located at a point remote from the well head 46 and from the blender 10 and pumps 40. Thus, the instrument panel, which furnishes a visual indication of the important variables in the fracturing process, may be placed at a location of maximum safety and convenience to personnel.

In the course of a particular well-fracturing operation, the rate of flow of the mixture may decrease while at the same time the pressure at the well head increases. The person in charge of the entire fracturing operation may not know whether the high-pressure pumps 40 could be run faster to increase the flow rate without danger of stalling the prime movers. From experience, it is known that the magnitude of the hydraulic horsepower provides a satisfactory measure of the output of the high-pressure pumps, and this hydraulic horsepower is proportional to the product of the flow rate and well head pressure. In accordance with this invention, we provide means on the instrument panel for furnishing a visual indication of the hydraulic horsepower in accordance with the following formula:

Hydraulic horsepower

$$= \frac{\text{Pressure (p.s.i.)} \times \text{flow rate (bbls./min.)}}{40.81}$$

This is accomplished by employing a computer 70 and a multiplying relay 71 to operate the hydraulic horsepower gage 72. The computer 70 multiplies the signal received from the transducer 57 and from the converter 62, and then multiplying relay 71 applies the constant so that the gage 72 reads directly in hydraulic horsepower.

The operator is thus furnished an indication of the rate of flow of sand-oil mixture into the well head by gage 58, the visual indication of the well head pressure, in thousands of pounds per square inch by the gage 64, and, in addition, the hydraulic horsepower gage 72 furnishes a visual indication which is proportional to the product of the reading of the gages 58 and 64. When the operator observes a change in the reading of the gages 58 and 64, he determines by inspecting the hydraulic horsepower gage 72 whether the speed of the high-pressure pumps 40 should be increased or decreased by changing the setting of the change-speed transmissions 43. Thus, if the gage 58 indicates a reduction in flow rate and at the same time the gage 64 indicates an increase in well head pressure, the operator would not

4

know, without calculations, whether the high-pressure pumps 40 could be speeded up without stalling their prime movers. However, by checking the hydraulic horsepower gage, which is a measure of the power output of the high-pressure pumps 40, the operator quickly determines whether a change in speed of the pumps 40 is required.

In practice, the operator regulates the speed of the high-pressure pumps 40 to maximize the reading of the hydraulic horsepower gage 72, since this furnishes the best single indication of the power input into the well head.

Each of the gages 58, 64, 66, and 72 may be equipped with a recorder, if desired, in order to furnish a continuous record of the critical variables for the complete well fracturing operation.

Having fully described our invention, it is to be understood that we are not to be limited to the details herein set forth, but that our invention is of the full scope of the appended claims.

We claim:

1. Apparatus for performing a fracturing operation in a well formation, comprising in combination: a well head, means for pumping a mixture of a liquid carrier and a propping agent into said well head, means for continuously measuring the rate of flow of said mixture, means for continuously measuring the pressure of said flowing mixture at the well head, and means for continuously multiplying together said measurements to obtain a product proportional to the hydraulic power input into the well, and means for continuously displaying an indication of said product at a location remote from the well head.

2. Apparatus for performing a fracturing operation in a well formation, comprising in combination: a well head, means for pumping a mixture of a liquid carrier and a propping agent into said well head, means for continuously measuring the rate of flow of said mixture, means for continuously measuring the pressure of said flowing mixture at the well head, said means including a plurality of pumps connected in parallel, each pump having a prime mover connected to drive said pump through a change speed transmission, means for continuously multiplying together said measurements to obtain a product proportional to the hydraulic power input into the well, and for continuously displaying an indication of said product at a location remote from the well head, whereby said prime movers may be operated at optimum speed for maximum hydraulic horsepower input into the well.

3. Apparatus for performing a fracturing operation in a well formation, comprising in combination: a well head, a mixing device, means for delivering a liquid carrier to the mixing device, means for delivering a propping agent to the mixing device, a plurality of power driven high pressure pumps, means for delivering a mixture of liquid carrier and propping agent from said mixing device to said high pressure pumps, means for measuring the flow rate of said mixture at a location upstream from said high pressure pumps, conduit means whereby the high pressure pumps may deliver the mixture to the well head, means for measuring the pressure of the flowing mixture at the well head, and means for displaying an indication of said flow rate and an indication of said pressure at a common location remote from the well head.

4. Apparatus for performing a fracturing operation in a well formation, comprising in combination: a well head, a mixing device, means for delivering a liquid carrier to the mixing device, means for delivering a propping agent to the mixing device, a plurality of power driven high pressure pumps connected in parallel, means for delivering a mixture of liquid carrier and propping agent from said mixing device to said high pressure pumps, said means including a header connected to the inlet of

5

each of said pumps, means for measuring the flow rate of said mixture at a location upstream from said header, conduit means whereby the high pressure pumps may deliver the mixture to the well head device, means for measuring the pressure of the flowing mixture at the well head device and means for displaying indication of said flow rate and an indication of said pressure at a common location remote from the well head device.

5

6

References Cited in the file of this patent

UNITED STATES PATENTS

2,082,329	Foran et al.	June 1, 1937
2,695,671	Kingston	Nov. 30, 1954
2,758,653	Desbrow	Aug. 14, 1956
2,798,557	Sewell	July 9, 1957
2,927,638	Hall	Mar. 8, 1960
2,958,821	Webb	Nov. 1, 1960