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CONTROL OF WELL FORMATION FRACTURING OPERATIONS

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2 Sheets-Sheet 1
In the hydraulic fracturing of well formations a car- 
rier, for example oil, and a propping agent, for example 
sand, are mixed together and pumped under high pres-
sure into the well head and conveyed downward through 
easing to the well formation to be fractured. The pari-
ting, 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 
bose by continued pumping. Higher effective permeab-
ility is obtained by the new flow channels created by the 
fractioning operation. The sand packs and fills the frac-
ture, 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 num-
ber of heavy-duty high-pressure pumps are assembled at 
the well site and high-capacity mixing apparatus is pro-
vided 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 individual 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 pro-
vided 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:

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

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 horse-
power being applied to the well head. This information 
furnished to the operator in charge of the entire fractur-
ing 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 show-
ing means for carrying out our improved method; and.

FIGURE 2 is a schematic diagram showing compo-
ments of the instrument panel. 

Referring to the drawings, a blender unit generally 
designated 10 may include a mixing tube 12 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 an incline screw 
conveyor 19. 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 ex-
ample oil, is delivered to the metering pump 25 from the 
storage tanks 27 by way of conduit 28, and oil is dis-
charged 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 
26 by means of the gear-shift levers 24 on the gear-re-
duction 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 open-
ing 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 plu-
arity of such pumps are ordinarily used and these pum-
ps 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 de-
ivered 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 "Densom-
ter," may be of the general type shown in patent appli-
cation Serial No. 805,772, filed April 2, 1959, and it 
serves for continuously measuring the density of the mix-
ture being transmitted through the low-pressure conduit 
34.

A small portion of the mixture being transmitted through the conduit 34 is bypassed through the Densometer 
52 and returned to the mixing tub 11 through pip-
ing 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 50 and these pulses 
are transmitted through an electric conductor 55 to the
instrument panel, generally designated 56. At the instru-
mament panel, an integrator converts these pulses to an 
analogue electrical signal. This analogue electrical sig-

nal is converted by means of a transducer 57 from an 
electrical current to air under pressure, in turn, is 

conveyed to a dial gage 58, calibrated in gallons per 
minute.

In conjunction with the flow meter 59, electrical pulses 
are fed to a digital counter 59 through a count-down cir-
cuit 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 conven-
tional 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 trans-
mision pressure, for example, 15 p.s.i. This is accom-

plished 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, cali-

brated 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 blende 10 and pumps 40. Thus, the instru-

ment panel, which furnishes a visual indication of the 
important variables in the fracturing process, may be 
placed at a location of maximum safety and conveni-
cence to personnel.

In the course of a particular well-fracturing opera-
tion, 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:

\[ \text{Hydraulic horsepower} = \text{Pressure (p.s.i.)} \times \text{flow rate (bbls/min.)} \]

This is accomplished by employing a computer 70 and 
a multiplying relay 71 to operate the hydraulic horse-
power 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 horse-
power.

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 pres-

sure, 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 gage 72 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 in-

crease in well head pressure, the operator would not 

know, without calculations, whether the high-pressure 
pumps 40 could be speeded up without stalling their prime 
movers. However, by checking the hydraulichorsepower 
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 hy-

draulic 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 con-
tinuous record of the critical variables for the complete 
well fracturing operation.

Having fully described our invention, it is to be under-
stood 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 continu-
ously 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 prod-

uct proportional to the hydraulic power input into the 

well, and means for continuously displaying an indica-

tion 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 continu-
ously 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 plu-

rality of pumps connected in parallel, each pump hav-
ing a prime mover connected to drive said pump through 
a change speed transmission, means for continuously 
multiplying together said measurements to obtain a prod-

uct 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 from said mixing device to said high pressure pumps, 
means for continuously measuring the rate of flow of said mixture; 
means for continuously measuring the pressure of said 
mixture at a location upstream from said high pressure pumps, 
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 de-

livering 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 

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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.

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