SURFACE CONDITION RESPONSIVE SUBSURFACE SAFETY VALVE SYSTEM

Filed Aug. 12, 1965

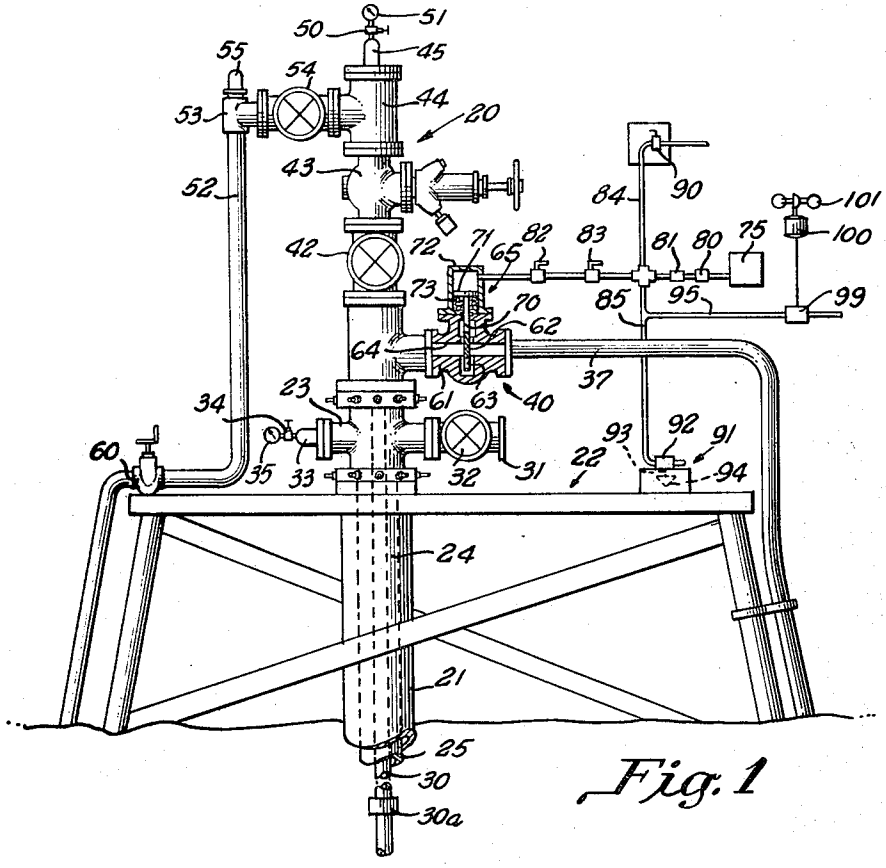


Fig. 1

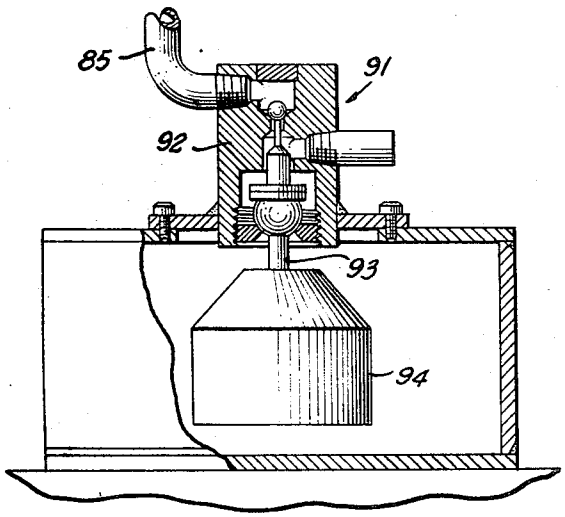


Fig. 2

INVENTORS
Phillip S. Sizer
Larry K. Spencer

United States Patent Office 3,419,076 Patented Dec. 31, 1968

3,419,076

SURFACE CONDITION RESPONSIVE SUB-SURFACE SAFETY VALVE SYSTEM

Phillip S. Sizer and Larry K. Spencer, Dallas, Tex., assignors to Otis Engineering Corporation, Dallas, Tex., a corporation of Delaware

Filed Aug. 12, 1965, Ser. No. 479,170
9 Claims. (Cl. 166—53)

ABSTRACT OF THE DISCLOSURE

A surface reactive valve system for increasing flow of fluids from well flow passages to activate a subsurface safety valve in said well and to reduce pressure in the flow conductor of the well, and means is provided responsive to pressure temperature, attitude, fluid flow and other physical conditions for opening a pressure releasing valve in a relief line for reducing the pressure in the flow conductor upstream of said safety valve. The reduction in pressure increases the flow rate through the well flow passage, and the safety valve closes in response to the increased flow.

This invention relates to fluid flow control devices and more particularly relates to a system for controlling fluid flow from a well bore.

It is a particularly important object of this invention to provide a new and improved system for reducing the fluid pressure within a flow passage of a well bore.

It is another object of the invention to provide in a well equipped with a tubing string having a subsurface safety valve a system for increasing the flow through the tubing string to a rate sufficient to close the safety valve in response to a predetermined state of one or more operating conditions such as the temperature in the vicinity of the wellhead, the wind velocity at the well, and the physical attitude of the well support structure, such as an offshore platform supporting the wellhead.

It is a further object of the invention to provide a relief valve equipped flow line connected into a tubing string of a well provided with a subsurface safety valve to increase fluid flow through the tubing responsive to a predetermined state of one or more monitored operating conditions to provide sufficient flow through the tubing string to close the subsurface safety valve for preventing wellhead damage and loss of well fluids under such conditions as may be encountered with fires in the vicinity of the wellhead or when the well is exposed to inclement weather which might damage the wellhead to the extent of rupturing the flow lines connected therewith.

It is another object of the invention to provide fire protection at a wellhead by preventing fluid flow from the well bore into the wellhead under conditions where the wellhead is either burning or sufficiently close to fire to raise the temperature in the vicinity of the wellhead to a predetermined value.

It is another object of the invention to prevent a chain reaction among several wellheads on a platform where one of the wellheads catches fire and the fire would normally spread to other nearby wellheads.

The invention is directed to a fluid flow control system for reducing fluid pressure within a flow passage of a well bore upstream of a flow control means at the upper end of the well flow passage. A relief fluid flow passage is connected to the well flow passage upstream of the flow control means communicating with the well flow passage and having relief valve means connected in said relief flow passages for controlling the flow through said relief flow passage. The relief valve has fluid pressure responsive means operable to open the relief valve to permit fluid flow from the flow passage of the well through the relief

flow passage to reduce the fluid pressure within the flow passage in the well bore controlled by control means operable in response to a predetermined change in one or more physical conditions monitored by the control means connected with the pressure responsive means of the relief valve for actuating said pressure responsive means to open the valve upon the occurrence of a predetermined change of one or more of said physical conditions monitored by the control means. The physical conditions monitored include pressure, temperature, heat, wind, vibration, and the like.

Additional objects and advantages of the invention will be readily apparent from the reading of the following description of a device constructed in accordance with the invention, and reference to the accompanying drawings thereof, wherein:

FIGURE 1 is a schematic view in elevation and section of a fluid flow control system for increasing fluid flow through the tubing of a well to effect closing of a subsurface safety valve connected in the well tubing; and,

FIGURE 2 is an enlarged sectional view of the attitude control valve assembly.

Referring to FIGURE 1, a wellhead **20** is supported at the upper end of a surface pipe or casing **21** on the platform **22** which may be located on land or water. The surface pipe may extend several hundred feet into the earth and is the first string of pipe set in the drilling of a well. Connected on the upper end of the surface pipe is a casing head **23** which provides communication into the annular space **24** between the well casing **25** and tubing string **30** which is equipped with a subsurface safety valve **30***a* such as illustrated and described at pages 3703–3705 of the Composite Catalog of Oil Field Equipment and Services, 1964–65 edition, published by World Oil, Houston, Tex. One lateral opening into the casing head is closed by the blind flange **31** on the wing valve **32** secured over the opening. A bull plug **33**, a needle valve **34**, and a pressure gauge **35** are secured to the other lateral opening to permit pressure readings to be made of the fluid pressure within the casing annulus **24**. The string of tubing **30** is suspended from a suitable tubing hanger in the wellhead, not shown, to support the tubing and seal between the tubing and the well casing **25**.

A tubing relief line **37** is connected to a tubing relief valve **40** secured to the T-connection **41** attached on the upper end of the casing head. A master valve **42** and a surface safety valve **43** are connected to the T-connection **41**. The surface safety valve is a suitable commercially available type valve such as the Type X Otis Surface Safety Valve illustrated at pages 3692–3693 of the Composite Catalog of Oil Field Equipment and Services, supra. Connected on the safety valve is a pipe T-connection **44** upon which are mounted a bull plug **45**, a needle valve **50**, and a pressure gauge **51** permitting a ready determination of the pressure of the fluids within the wellhead from the tubing string. A flow line **52** is connected into the T-connection **44** through the surface choke unit **53** and the tubing wing valve **54**. The surface choke unit is fitted with a bull plug **55** which is readily removable to permit servicing or replacement of the choke in the unit. A valve **60** is connected in the flow line **52** downstream from the choke. The flow line leads to separators, tanks, and other conventional fluid handling equipment, not shown, utilized in treating and storing the fluids flowing from the well.

The tubing relief line **37** extends to separators or a vent or blowoff line, not shown, independent of the fluid handling equipment connected to the flow line **52**. The relief line when open permits additional well fluids to flow from the tubing string upstream from the choke unit **53**, which restricts fluid flow by providing a restricted orifice

between the flow line **52** and the tubing valve **54**, and thus increases the flow from the tubing string to a sufficient rate that the subsurface safety valve **30***a* connected in the tubing string **33** closes to prevent flow of well fluids from the well through the tubing string. There is no choke unit between the relief flow line and the tubing string to restrict flow to the relief flow line. Flow through the relief line is controlled by the normally closed relief valve **40**, which preferably is a fluid actuated gate valve such as the Type U Otis Surface Safety Valve illustrated diagrammatically at page 3694 of the Composite Catalog of Oil Field Equipment and Services, supra. Briefly, the control valve **40** includes a valve body **61**, a gate **62** having a port **63** movable relative to the flow passage **64** to open and close the valve, and the fluid responsive operator assembly **65**. The operator assembly comprises the valve stem **70** secured to the piston **71** which is slidable within the cylinder **72** and biased upwardly by the spring **73** and movable downwardly by fluid pressure within the cylinder. The valve **40** differs from the valve illustrated in the reference only in the position of the port **63** through the gate. The port **63** in the valve **40** is at a lower position in the gate so that when the piston, stem and gate are held at a lower position by control fluid pressure within the cylinder **72** above the piston **71**, the valve is closed to prevent flow through the relief line. When the control fluid pressure is lowered the spring lifts the piston and gate to align the ports **63** with the passage **64** through the valve body allowing flow through the valve and the relief line.

Control fluid is supplied by a pressure source **75** to the cylinder **72** of the tubing relief valve through the line **74**. The pressure source may be any suitable fluid pressure unit adequate to supply and control fluid to the control valve such as an Otis Surface Control Manifold as illustrated and described at page 3710 of the Composite Catalog of Oil Field Equipment and Services, supra. Connected in the line **74** between the pressure source and the control valve are a check valve **80**, a choke **81**, and fusible plugs **82** and **83** which are a form of plug type relief valve having a plate adapted to rupture responsive to a predetermined temperature to relieve the pressure within the line **74**. The lines **84** and **85** are connected from the control line **74** to the manually operated valve **90** and the platform attitude control valve assembly **91**, respectively. Both the lines **84** and **85** are open at their outer ends to the atmosphere so that the pressure from the cylinder **72** and in the line **74** may be bled down through either of these lines. The attitude control valve assembly **91** (FIGURE 2) includes a suitable toggle valve **92** connected through an operator lever **93** to a weight **94** so that a shift in the position of the platform **22** causing it to lean beyond a predetermined degree from the horizontal will open the valve **92** since the pendulum-like weight **94** will hold the operator **93** vertical as the valve leans with the platform. Another bleed line **95** extends from the line **85** to a suitable electrically operated valve **99** such as a solenoid valve actuated by the electric current generated by a suitable electric generator **100** driven by an anemometer **101**. The voltage of the electric current varies in accordance with the speed of rotation of the anemometer and increases to the value at which the electric current moves the solenoid valve to its open position when the wind velocity exceeds a predetermined rate at which the wind might cause sufficient damage to the platform to rupture the wellhead causing loss of well fluids and a probable fire hazard unless the down hole safety valve is closed.

When the system illustrated in FIGURE 1 is operating under normal conditions, well fluids flow upwardly into the wellhead through the tubing string **30** passing through the T-connection **41**, the open master valve **42**, the safety valve **43**, and then through the T-connection **44** and the tubing wing valve **54** into the surface choke unit **53**. The choke reduces the fluid flow into the flow line **52** to a desired rate. The fluids flow through the flow line **52** to separator and storage facilities, not shown. So long as fluid flows through the tubing string at the rate determined by the choke unit **53**, the subsurface safety valve remains open to permit fluid flow from the well. An increase in the flow rate above that rate at which the subsurface safety valve is adapted to close will cause closure of the valve preventing fluid flow from the well into the wellhead. If, for example, the wellhead should be damaged or even knocked off so that leakage may occur from it in excess of the predetermined rate at which the subsurface safety valve is set to close, the safety valve **30***a* will close to protect the well against further loss of product and feeding a fire with the fluids, if one exists. On the other hand, however, the wellhead may leak because of damage or other malfunction to an extent sufficient to provide fuel for a damaging fire but yet not at a rate high enough to close the subsurface safety valve. The relief line **37** provides sufficient additional or supplementary flow capacity in excess of that allowed by the choke in the unit **53** to reduce the wellhead pressure sufficiently to actuate the subsurface safety valve.

During normal operation the tubing relief valve **40** in the line **37** which controls flow through the relief line is held in the closed position by control fluid provided from the source **75** through the line **74** into the cylinder **72** above the piston **71**. The relief valve remains closed so long as the operating conditions being monitored remain within normal limits and thus do not cause the control fluid to be bled from the relief valve cylinder. When a predetermined change occurs in any one of the monitored operating conditions, the pressure within the cylinder **72** is bled down through the line **74** to a level sufficiently low that the spring **73** around the valve stem **70** lifts the piston, valve stem and gate upwardly to align the port **63** through the gate with the flow passage **64** allowing well fluids to flow from the wellhead through the relief line **37** and the relief valve and thus supplementing the fluid flow through the choke unit **53** to the extent that the subsurface safety valve in the tubing string **30** closes to shut off the flow of well fluids to the wellhead. A fire in the vicinity of the wellhead which subjects either or both of the fusible plugs **82** and **83** to a sufficiently high temperature will cause the plugs to release the fluid pressure within the line **74** bleeding the line and the cylinder **72** down to a low enough level to allow the control valve to close. The probability that the well will catch fire is thus minimized since the well will be shut-in by the closing of the subsurface safety valve prior to the wellhead being subjected to a sufficiently high temperature to damage the head as by burning the packing from one or more of the various valves might allow leakage to provide fuel for a fire. Similarly, a high wind or damage to the platform by a blow from a floating barge or ship may shut in the well preliminary to surface damage which would rupture members of the wellhead. When the wind velocity in the vicinity of the platform reaches a predetermined rate the generator driven by the anemometer will generate sufficient power to open the electrically operated relief valve **99** allowing the control fluid pressure to bleed down from the cylinder of the control valve through the lines **74**, **85** and **95**. If the platform is subjected to a damaging force sufficient to change its attitude beyond a predetermined amount, the pendulum or weight **94** opens the valve **92** to bleed the pressure from the cylinder **72** through the lines **74** and **85** to open the relief valve causing the subsurface safety valve to close. The well fluids bled from the wellhead through the relief line **37** pass either to separators independent of those connected with the flow line **52** to prevent damage to the regular separators or the fluids are vented to the atmosphere at a location remote from the wellhead. If desired, the control valve may be opened by manual operation of the valve **90** which will bleed down the pressure from the cylinder **72** through the lines **74** and **84**. By this means,

personnel on the platform may quickly shut in the well in anticipation of dangerous conditions.

When conditions at the wellhead return to normal, the pressure within the control fluid system is re-established so that the valve **40** is moved by the piston **71** and stem **70** back to the closed position thus shutting off fluid flow through the relief line from the wellhead. The subsurface safety valve is then opened to permit normal flow from the well.

The connection of the relief line into the wellhead is upstream of the master valve **42** so that the subsurface safety valve will be closed by the system of the invention even when the well is shut in by the master valve. The relief line is sized to handle a sufficient volume to actuate the subsurface safety valve even when the regular flow line is not functioning.

It will be seen that a new and improved system has been described and illustrated for controlling fluid flow from a well.

It will be seen that the flow control system includes a subsurface safety valve which is actuated by increasing the fluid flow through the tubing string in which the safety valve is connected by means of reducing the pressure within the wellhead upstream of the flow tube choke allowing flow into the relief line.

It will be seen that the relief ilne includes a pressure actuated control valve adapted to function responsive to monitored operating conditions, such as the temperature in the vicinity of the wellhead, the wind velocity in the vicinity of the wellhead, the attitude of the platform supporting the wellhead, and other operating conditions to shut in the well.

It will be further seen that the detector systems connected with the relief valve in the relief line anticipate damage to the wellhead which may cause leakage from it and thus actuate the subsurface safety valve prior to such damage.

It will be further seen that the fire hazard frequently created around a well by leaking well fluids is minimized by shutting the well in anticipatory to such damage to the wellhead as might be calculated to cause such leakage.

It will be further seen that the relief line is connected into the wellhead upstream of the master valve so that the well even when shut in by closure of the master valve is protected so that a change in the monitored conditions will open the control valve to allow sufficient flow to shut the subsurface safety valve.

It will therefore be seen that the well is protected against potential damage whether or not well fluids are flowing through the wellhead.

While a particular type of relief valve has been illustrated and described in connection with both the tubing and casing pressure relief systems, it will be recognized that other forms of pressure actuated valves may be employed in the systems, such, for example, as a type K Otis Flow Line Safety Valve illustrated and described at page 3691 of the Composite Catalog of Oil Field Equipment and Services, supra. It will be further evident that additional monitoring systems may be incorporated in the tubing relief system of FIGURE 1 such, for example, as a system operative responsive to the presence to salt water which may be deposited on a detector by tremendous wave action which might endanger the platform and wellhead so that the well is shut in by the system anticipatory of damage which might break the wellhead connections to allow the well to leak.

The foregoing descripion of the invention is explanatory only, and changes in the details of the construction illustrated may be made by those skilled in the art, within the scope of the appended claims, without departing from the spirit of the invention.

What is claimed and desired to be secured by Letters Patent is:

1. A fluid flow control system for a tubing string of a well comprising: a subsurface safety valve connected in said tubing string, said safety valve having means responsive to a predetermined maximum flow rate condition of fluid flowing through said safety valve for closing said safety valve; a flow control choke in said tubing string downstream of said safety valve for controlling the flow rate through said tubing string; a relief flow line connected into said tubing string between said flow control choke and said subsurface safety valve to provide means for increasing fluid flow through said tubing string and said safety valve; a relief valve connected in said relief line for controlling fluid flow from said tubing string through said relief line; and control means connected with said relief valve operable in response to a predetermined change in one or more physical conditions monitored by said control means to open said relief valve for increasing fluid flow through said tubing string to a rate sufficient to close said subsurface safety valve.

2. A fluid flow control system for a tubing string of a well having a flow controlling choke connected therein for controlling flow through the tubing string, comprising: a subsurface safety valve connected in said tubing string and having means responsive to a predetermined maximum fluid flow rate through said safety valve for closing said safety valve; a relief flow line connected into said tubing string between said choke and said subsurface safety valve, said relief flow line having sufficient flow conducting capacity to increase the fluid flow rate through said safety valve in said tubing string to a rate sufficient to effect closing of said safety valve; a relief valve connected in said relief line, said relief valve being adapted to be held closed by fluid pressure from a pressure source independent of the fluid pressure within said tubing string; a fluid pressure source independent of the fluid pressure in said tubing string connected with said relief valve to provide fluid pressure for holding said relief valve closed; and monitoring pressure reducing means operatively associated with said fluid pressure source for reducing the fluid pressure applied to said relief valve and operable in response to a change in a physical condition monitored by said pressure reducing means to open said relief valve responsive to a predetermined change in such physical condition to increase flow of fluids through said tubing string and said safety valve to cause said safety valve to close.

3. A fluid flow control system for a well tubing string comprising: subsurface safety valve connected in said tubing string and having means responsive to a predetermined maximum rate of flow through said safety valve for closing of said subsurface safety valve; a flow control choke connected to the upper end of said tubing string to control flow through said tubing string; a relief flow line connected into said tubing string between said choke and said subsurface safety valve, said relief flow line having sufficient fluid conducting capacity to conduct fluid at a sufficient rate to effect closing of said subsurface safety valve; a relief valve connected in said relief line, said relief valve having a gate actuatable in one direction to open said relief valve by resilient means and actuatable in the other direction to hold said relief valve closed responsive to fluid pressure in a cylinder enclosing a piston connected with said gate; a fluid pressure source connected with said cylinder to provide a source of fluid pressure independent of the fluid pressure within said tubing string to hold said gate in a closed position; and pressure reducing means operatively connected with said source of fluid pressure and operable in response to a predetermined change in a physical condition monitored by said pressure reducing means for reducing the pressure within said cylinder of said relief valve to permit said resilient means to open said relief valve responsive to such predetermined change in such physical condition monitored by said pressure reducing means to increase the rate of flow through said safety valve to close said safety valve.

4. A fluid flow control system for a well tubing string comprising: a subsurface safety valve connected in said tubing string and having means responsive to a maximum flow rate through said safety valve for closing of said safety valve, said well having a well head at the upper end of said tubing string including a choke to control the fluid flow rate through said tubing string and a master valve for shutting off flow through said tubing string upstream of said choke; a fluid relief flow line connected into said tubing string between said master valve and said subsurface safety valve, said relief flow line having sufficient flow conducting capacity to conduct fluid at a sufficient flow rate to effect closing of said subsurface safety valve in the absence of fluid flow from said tubing string through said choke; a tubing relief valve connected in said relief flow line, said tubing relief valve being biased toward an open position and being holdable at a closed position responsive to fluid pressure; a fluid pressure source connected with said tubing relief valve to provide a source of fluid pressure independent of the fluid pressure within said tubing string into said relief valve to hold said relief valve closed; and pressure reducing means operatively connected with said fluid pressure source for reducing the fluid pressure supplied to said relief valve responsive to a predetermined change in an operating condition monitored by said pressure reducing means to permit said relief valve to open to increase the flow rate through said tubing string to a rate sufficient to effect closing of said subsurface safety valve.

5. A fluid flow control system in accordance with claim 4 wherein said pressure reducing means comprises a temperature responsive valve adapted to reduce the fluid pressure supplied to said tubing relief valve responsive to a predetermined maximum temperature at said temperature responsive valve.

6. A fluid flow control system as defined in claim 4 wherein said pressure reducing means comprises an attitude responsive valve for reducing the fluid pressure supply to said tubing relief valve responsive to a change of attitude of said attitude responsive valve beyond a predetermined degree.

7. A fluid flow control system as defined in claim 4 wherein said pressure reducing means comprises a wind velocity responsive assembly adapted to reduce the pressure of the fluid supplied to said tubing relief valve in response to a predetermined maximum wind velocity at said well head.

8. A fluid flow control system for reducing pressure within the flow passage of a well bore having a safety valve disposed therein operable responsive to a predetermined maximum flow rate condition of fluid flowing through said flow passage for closing said safety valve, said control system comprising: flow control means at the upper end of said flow passage of said well for controlling flow through said flow passage of said well bore; means connected with said flow passage upstream of said flow control means providing a relief fluid flow passage in communication with said flow passage of said well bore; relief valve means connected in said relief fluid flow passage for controlling fluid flow through said relief flow passage, said relief valve means having operating means operable to open said relief valve to permit fluid in said flow passage of said well bore to flow through said relief flow passage to reduce the fluid pressure within said flow passage and to increase the rate of flow of fluids within said flow passage of said well bore; and control means operable in response to a predetermined change in one or more physical conditions monitored by said control means connected with said operating means for actuating said relief valve means responsive to a predetermined change in one or more of said physical conditions monitored by said control means to open said relief flow passage to increase the flow rate through the safety valve in said well for closing said safety valve.

9. A fluid flow control system in accordance with claim 8 wherein said relief valve means is a gate valve biased in one direction by resilient means and actuatable in the other direction responsive to fluid pressure controlled by said control means.

References Cited

UNITED STATES PATENTS

267,796	11/1882	McKee	166—95 X
1,099,170	6/1914	Dunn	166—224
1,369,049	2/1921	Quick	166—45 X
1,671,511	5/1928	Carson	251—62 X
1,893,462	1/1933	Wait	251—28 X
2,587,212	2/1952	Placette	251—28 X
2,742,967	4/1956	Carpenter	166—45 X
2,831,539	4/1958	En Dean et al.	166—73
3,065,794	11/1962	Page	166—72 X
3,092,135	6/1963	Brown et al.	251—62 X
3,156,300	11/1964	Page et al.	166—72 X
3,157,233	11/1964	Sizer et al.	166—224
3,198,207	8/1965	Willis et al.	137—492.5 X
3,228,472	1/1966	Rhoads	166—75 X
3,244,399	12/1962	Jones et al.	251—337 X
3,313,350	4/1967	Page	166—72 X

CHARLES E. O'CONNELL, *Primary Examiner.*

IAN A. CALVERT, *Assistant Examiner.*

U.S. Cl. X.R.

166—72; 139—45; 166—95, 224