April 23, 1963 C. B. CHITWOOD 3,086,593

RETRIEVABLE PILOT OPERATED GAS LIFT VALVE

Filed Oct. 2, 1961 2 Sheets-Sheet 1

Fig. 1

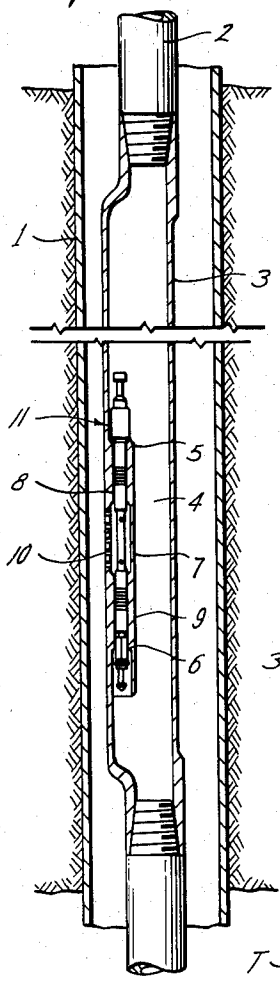


Fig. 2A

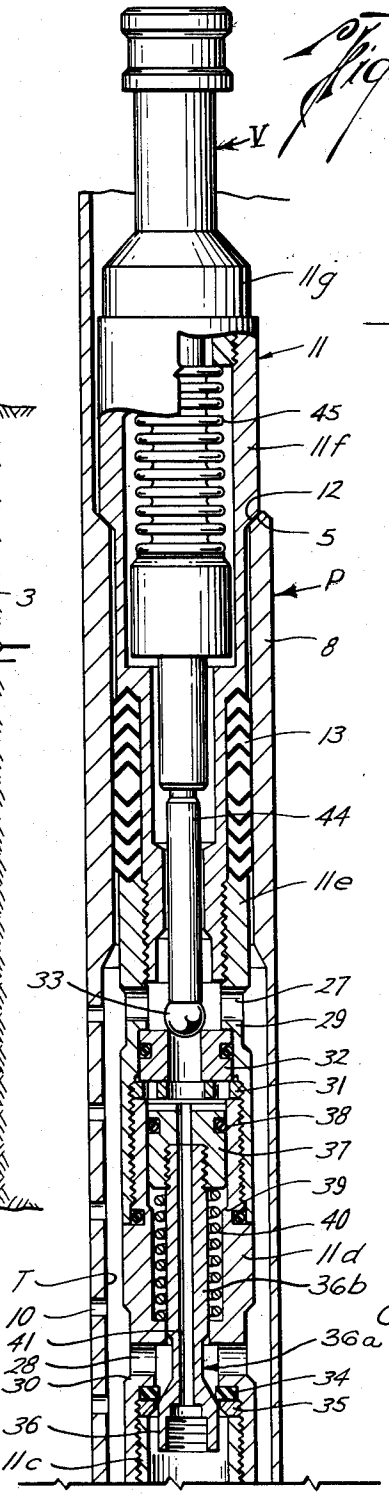
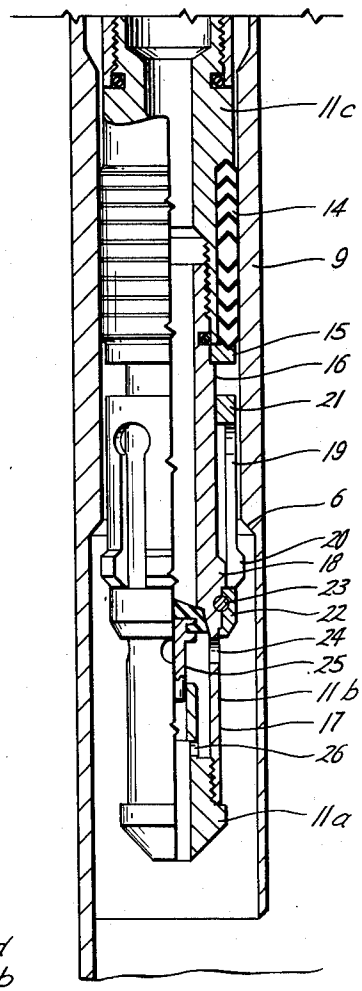


Fig. 2B



C. B. Chitwood
INVENTOR.

BY G C Helwig
ATTORNEY

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Fig. 3

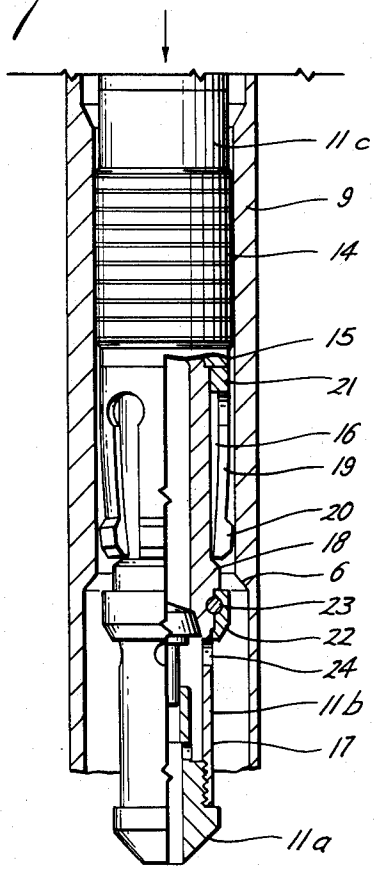


Fig. 4

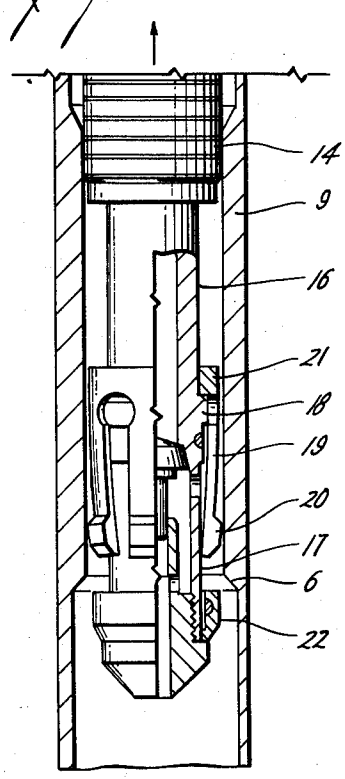
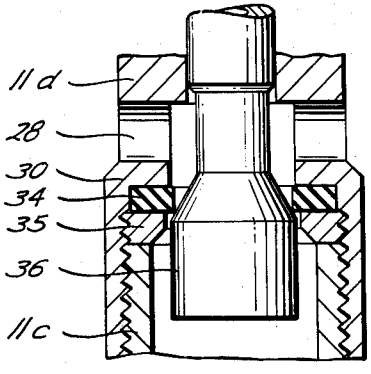


Fig. 5



C. B. Chitwood
INVENTOR.

BY G C Helming

ATTORNEY

United States Patent Office 3,086,593
Patented Apr. 23, 1963

3,086,593

RETRIEVABLE PILOT OPERATED GAS LIFT VALVE

Charles B. Chitwood, Houston, Tex., assignor to Camco, Incorporated, Houston, Tex., a corporation of Texas

Filed Oct. 2, 1961, Ser. No. 142,318
5 Claims. (Cl. 166—224)

This invention relates to gas lift systems for producing well fluids and more particularly to an improved valving structure inclusive of a compact pressure responsive valve assembly especially adapted for retrievable mounting within a relatively small receiver pocket and through which pressure air or natural gas is introduced at selected depth into a well production tubing string.

An object of the invention is to provide a retrievable gas lift valve assembly having a longitudinal succession of operating components of minimal transverse dimensions housed within an elongated narrow chambered body with internal locating shoulders and co-operating securements for retainers by which replaceable main valve and pilot valve seating rings are clamped in place and with external landing and releasable latching formations for abutment with mating formations of a valve positioning pocket in the tubing string.

A further object of the invention is to provide an improved valve assembly for installation and removal from a tubing string section by wire line suspension equipment and provided with a self-actuated latch to effect positive anchorage in a valve receiver upon installation and an unlatching response to a pulling removal operation.

Another object is to provide a valve assembly of improved design to fit narrow tubing space and to enable more economical manufacture and reliable operation with dependence on controlled lift gas pressures to cycle main valve operation and quick action without the likelihood of flutter and seat pounding in response to gas pressure imposed on the main valve through a direct acting pilot valve.

Other objects and advantages will appear from the following specification and the accompanying drawings in which FIG. 1 is a vertical sectional view of a fragment of a well installation showing a gas lift valve in an operative position in a well tubing string; FIGS. 2A and 2B are companion views partly in elevation and partly in vertical section of the improved valve structure anchored in its receiving pocket; FIGS. 3 and 4 are vertical sectional views of the lower portion of the structure shown in FIG. 2B with latching dogs retracted and in the case of FIG. 3, near the end of the running-in operation, and in the case of FIG. 4, just after the start of a pulling operation, and FIG. 5 is a fragmentary vertical section showing a portion of the main valve on a scale somewhat larger than that of FIG. 2A.

Referring to the drawing, the usual well bore lining or casing **1** has extended through it a production tubing string **2** for the flow of well fluids from a producing formation to the wellhead. The tubing string includes one or more sections or special mandrels, such as shown at **3**, for the mounting of pressure responsive valving by which lift gas is admitted into the tubing string from the annular space within the casing **1**.

Opposite ends of the tubing section **3** are secured to adjacent ends of other tubing sections and an open passageway **4** joins the opposite ends in vertical alignment with the tubing string axis and is for the unobstructed passage of operating tools through the valve carrying mandrel **3**. Between its opposite ends, the mandrel **3** is enlarged in a direction laterally offset from the main passageway **4** and encloses a tool receiving tubular pocket P which is longitudinally elongated and is located in a

region near the lower portion of the tubing section **3**. Above this laterally offset pocket, the clearance spacing internally of the tubing section **3** accommodates manipulation of a kick-over wire line suspended device for the selective placement and removal of retrievable control devices into and from the offset pocket. This tubular pocket has its bore opening at top and bottom into the interior of the tubing section **3**. At its upper end, the tubular pocket preferably has a downwardly tapered seat or landing shoulder **5** for a self centering action on an inserted tool, such as a gas lift valve assembly V, having a similarly tapered external shoulder. Near its lower end, the pocket has a downwardly facing and upwardly tapered seating shoulder **6** to provide a latch keeper. Adjacent the end shoulders **5** and **6** and above and below an intermediate laterally relieved portion **7**, the bore of the pocket at **8** and **9** is carefully machined to provide internal sealing and bearing surfaces for co-operation with mating sealing and bearing surfaces formed peripherally on an elongated valve body or other tool so that, except for the passage internally of the tool, the opposite ends of the pocket are sealed from the intermediate relieved portion **7** against the flow of gas admitted internally of the pocket from the casing annulus and through one or more side entry ports **10** extending through the exterior wall of the intermediate portion of the pocket.

For use in controlling the admission of lift gas where space conditions confine the size of a tool receiving pocket to a diameter of about one inch, transverse compactness has been designed into a longitudinal succession of operating components. The resulting relatively narrow housing enclosure or valve body **11** is constituted by a vertical succession of tubular sections **11*a***, **11*b***, **11*c***, **11*d***, **11*e***, and **11*f*** and a top closure plug **11*g*** terminating in an attachment head for connection with conventional wire line running and pulling devices. For convenience of manufacture and assembly, as well as later inspection and parts replacement, these several body sections are preformed separately and in selected succession are screw threaded together in end to end relation.

The upper tubular body section **11*f*** is formed with an external downwardly facing seat or shoulder **12** for stop abutment with the internal landing seat **5** of the tool receiving pocket. Peripherally surrounding an inwardly relieved lower portion of the body section **11*f*** and clamped between the shoulder thereon and the upper end of the body section **11*e*** is a stack of V-shaped packing rings **13** for bearing sealing engagement with the internal sealing surface **8** of the tool pocket. A similar stack of sealing rings **14** surrounds a lower relieved end of the body section **11*c*** and is clamped in place by a ring **15** carried on a locating shoulder near the upper end of the body section **11*b***. The packing rings **14** are for seal bearing engagement with the internal sealing surfaces of the pocket portion **9**.

Below the clamp ring **15**, the body section **11*b*** has a peripheral twin spool formation with a pair of longitudinally extending annular relieved portions **16** and **17** spaced or separated at adjacent ends from one another by an annular head or expander boss **18** whose top shoulder is tapered upwardly for guiding and outward camming co-operation with the bottom internal corner of one or more spring fingers or legs **19** each having a terminal outwardly projected latching lug or dog **20** for co-operation with the latch keeper abutment **6** of the tool receiving pocket. As seen in FIG. 2B, the upper end of each laterally projecting dog **20** provides an upwardly facing abutment latch surface engageable with the downwardly facing shoulder or keeper abutment **6**. By reason of such engagement, the dogs on the free ends of the

spring legs constitute latching elements. Preferably, the spring legs are designed to be straight longitudinally of the tool when the legs are unstressed and hence they are yieldingly resistant to inward deflection at their free ends so that the latching dog terminal formations are outwardly biased in relation to the center line of the tool. As is best shown in FIGS. 2B and 3, the spring legs **19** are dependent longitudinally from and are integral with a retainer collar or ring **21** in sliding embracement with the upper relieved portion **16** and the length of the portion **16** provides an over-all range of longitudinal slide collar travel between limits established by the underside of the clamp ring **15** and the upper face of the expander boss **18**. Initially, such range of travel is restricted to a region immediately adjacent the ring **15** so that the inside faces of the spring fingers adjacent the latching lugs **20** can move above the expander boss **18** for their lateral retraction into the relieved portion **16** and can move downwardly into laterally overlapping relation with the periphery of the expander boss **18** and which precludes retraction and maintains the latching lugs **20** outwardly expanded. Such initial lower limit is established by abutting engagement of the bottom edges of the spring legs **19** with a slide ring **22** releasably secured to the body section **11***b* by means of a shear pin or frangible connection **23**. When the frangible connection is ineffective, the abutment ring **22** is free to drop downwardly to the bottom of the relieved portion **17** and into stop abutment with the underlying terminal head of the body section **11***a*. This last mentioned relationship is illustrated in FIG. 4, which also shows the retaining ring **21** dropped to its lower limit in abutment with the expander boss **18** and with the bottom latching lugs **20** on the spring fingers depressed inwardly into the bottom relieved portion **17**.

Near the upper end of this lower relieved portion **11***b* are one or more outlet ports **24** leading from the chambered body to the bottom opening of the tool receiving pocket. To prevent backflow into the valve chamber when tubing pressure exceeds casing pressure, a valve seat is formed internally of the body section **11***b* above the outlet port **24** and with which co-operates an upwardly seating check valve **25** whose dependent guide stem is fitted within an upwardly extending skirt on the lowermost body section **11***a*. This upstanding skirt is radially spaced from the adjacent portion of the body section **11***b* and is provided with a drain opening **26** at the lower end of the clearance and spaced some distance below the outlet ports **24**. This arrangement tends to maintain the outlet ports **24** clear and free from the collection of debris.

For open communication to the interior of the valved body **11** from the annularly relieved portion **7** in the tool receiving pocket and from its inlet ports **10**, there are provided a pair of longitudinally spaced apart sets of side inlet ports **27** and **28** leading respectively through the wall of the body section **11***e* to a pilot valve chamber and through the wall of the body section **11***d* to a main flow valve chamber. Immediately below these inlet ports **27** and **28** are a downwardly facing shoulder **29** machined in the bore of the body section **11***e* and a downwardly facing shoulder **30** machined in the bore of the body section **11***d*. Located upwardly by the internal shoulder **29** and detachably held in place by a gland nut **31** screw threaded in the body section **11***e* is a replaceable annular valve seat or ring **32** for downward seating engagement by the head **33** of a pilot valve assembly. Similarly, the internal shoulder **30** locates an annular valve seating ring **34** preferably of a somewhat pliable elastic deformable material and which is replaceably clamped in place by an apertured retainer ring **35** screw threadedly received within the bore of the body section **11***d*. As best seen in FIG. 5, the bottom internal corner of the seating ring **34** is for line contact with an upwardly seated and tapered valve seat surface of the bottom head **36** of a substantially spool-shaped main valve element **36***a*.

Extending upwardly from the lower valve head **36** is a reduced diameter stem portion **36***b* having terminal screw threaded connection with the upper head **37** of the spool valve which head has a sliding guide fit within the counterbored cylindrical upper end of the body section **11***d*. The slide bearing surfaces are sealed as by an O-ring **38** or the like carried by one or the other of one of the relatively slidable parts so fluid pressures active on top and bottom surfaces of the head **37** are confined. The shoulder **39** at the bottom of the cylindrical counterbore provides a stop abutment for the bottom of the head **37** to limit the main valve movement in the opening direction and against the upward bias of a coil spring **40** surrounding the stem and bearing at opposite ends on the head **37** and an internal shoulder on the body section **11***b*.

With the main valve closed against the seat ring **34**, the radially grooved top face of the upper head **37** will be positioned with clearance above the head, with its entire area exposed to the central passages through the retainer ring **31** and valve seat ring **32**. So long as the pilot valve **33** remains seated, fluid pressure above and below the spool valve will be equalized by way of a vertical passage **41** extending longitudinally through the main valve. While the main injection valve is seated under bias of the spring **40**, casing pressure supplied at the entry port **28** can act on the upwardly facing areas of the main valve as defined by the internal diameter of the seating ring **34** and on the downwardly facing areas of the main valve as defined by the diameter of the cylinder in which the head **37** slides as decreased in each instance by the effective size of the head connecting stem. When these opposing surfaces are approximately in balance, casing pressure thereon has no substantial effect on the action of the main valve. For some installations, these opposing surfaces may be made to present differential areas favorable for closing tendency in supplementing the elastic force of the coil spring **40** although, in any event, the coil spring will furnish the dominant closing force.

The downwardly biased pilot valve head **33** has its valve stem **44** joined to the free end of a flexible bellows seal **45** whose opposite or upper end is mounted on the body section **11***g*. Confined within the interior of the bellows is a gas under pressure for furnishing an elastic downward biasing force. The downwardly facing areas on the stem exteriorly of the bellows seal are exposed to casing pressure and control the opening and closing of the pilot valve. Bellows internal pressure is selected to maintain the pilot valve closed until casing pressure reaches a predetermined value. Unless that casing pressure is reached and exceeded, both valves remain seated. Until casing pressure has lifted the pilot valve **33** away from its seat to a degree that the pilot valve opening passes pressure fluid in an amount greater than can be vented through the main valve internal passage **41**, the force of the main valve spring **40** plus any upwardly acting lift gas on differential areas exposed thereto on the main valve, holds the main valve closed. Additional opening of the pilot valve as casing pressure increases for a greater free passage of the pressure gas through the relatively large openings in the rings **31** and **32** results in pressure action directly against the upper face of the top head **37** of the main spool valve and the response will be a fairly rapid depression of and a firm hold-open action on the main valve for large volume free flow of lift gas past the valve head **36**. Elevation of production fluid through the tubing string will continue until casing pressure decreases below the bellows closing point, which reseats the pilot valve **33**, whereupon a quick bleed-off of pressure through passage **41** from above the upper head **37** allows upwardly biased closure of the main valve.

As seen in FIG. 2A, the lower valve head **36** has a screw threaded counterbored portion forming a continuation of the central passageway **41**. This enables selective

fitment of a suitable device either to plug the central bore **41** or to choke the passage to any extent as determined by particular operating conditions.

In operative position, the valve assembly will be securely pocketed within the receiver, downwardly by reason of the external shoulder **12** and upwardly by reason of the expanded latching lugs **20**. Upon downward insertion of a tool body within the receiver pocket, the lugs **20** will first come into engagement with the landing seat **5** and will be stopped while the body continues downward and carries with it the expander boss **18** below the bottom of the momentarily arrested latching lugs. In the further body downward movement, the retainer ring **15** will abut the mounting collar **21** and transfer the downward movement to the latch lugs **20** which ride inwardly on and are cammed by the shoulder or landing seat **5** into retracted relation within the upper body relieved portion **16** as accommodated by inward deflection of the flexible spring legs **19**. With such retraction, the lugs can pass through the restricted pocket portion **8** and then spring out into the annularly relieved intermediate portion **7** of the pocket. They will again be similarly stopped and then retracted for passage through the pocket region **9**, as illustrated in FIG. 3. Coincident with engagement with the landing seat **5** by the external body shoulder **12**, the latching lugs **20** will have passed just below the keeper shoulder **6** and will have sprung back and dropped down into abutment with the locating ring **22** and with their insides engaged and in outwardly backed projected relation with the external annular surface of the expander boss **18**. A downward jarring force will then release the running tool from connection with the top body section **11***g* for running tool removal.

For later removal of the retrievable unit, a wire line pulling tool will be caused to pick up the body by engagement with the top body portion **11***g*, whereupon an upward pull or jar transmitted to the body and resisted by latch engagement with the downwardly facing keeper shoulder **6** will effect breakage of the shearable pin connection **23**. Thereupon the stop ring **22** will drop out of blocking relation to the latching lugs **20** and elevation of the valve body will permit descent of the spring leg collar **21** to its lower limit, wherein the spring legs **19** position the terminal latching lugs opposite the lower relieved body portion **17** for their retraction and inward bending of the legs in clearance relation to the keeper shoulder **6** and the reduced diameter bores of the pocket portions **9** and **8**.

The foregoing description has dealt with the detail structure of the improved retrievable tool and lift gas control valving and is representative of the preferred but not necessarily the only embodiment and it is to be understood that such modifications can be made as come within the scope of the appended claims.

What is claimed is:

1. In combination, a well tubing string section having a passageway therethrough and a longitudinally extended tubular receiver offset laterally from and open at opposite ends into said passageway and provided with a gas lift entry port in the wall thereof and intermediate said ends, sealing surfaces formed internally of the receiver above and below said inlet port and adapted for co-operation with mating sealing surfaces on a well tool, an upwardly facing tool engageable seat on said receiver adjacent its upper end, a downwardly facing latch engageable seat on said receiver adjacent its lower end and a well tool for latched reception within said receiver and including a body, a downwardly facing locating shoulder on the body adjacent its upper end for engagment with the upwardly facing seat of the receiver, a laterally biased latch carried by the body adjacent its lower end and provided with an upwardly facing abutment to engage with said downwardly facing latch engageable seat, longitudinally spaced apart sealing surfaces peripherally carried by the body for bearing sealing engagement with the internal sealing surfaces of said receiver, a pair of longitudinally spaced apart annular valve seats positioned by the body internally thereof with the upper valve seat facing upwardly and the lower valve seat facing downwardly, flow outlet means in the body below said lower valve seat, means in the wall of the body communicating said lift gas entry port with the interior of the body above each of said valve seats, a spool-shaped main valve member housed by the body with the upper head end of the member slidably bearing on the body wall below said upper valve seat and with the lower head end of the member arranged for upward closing engagement with the lower and downwardly facing valve seat, spring means active on said member to bias the same upwardly, said member having a longitudinal flow passage therethrough of lesser flow area than the flow area of the upper valve seat and a normally downwardly biased pilot valve housed by the body to seat on said upper seat and being responsive to given lift gas pressure above said upper seat to open for pressure gas action on the upper side of said upper head end of the spool-shaped member.

2. In combination, a well tubing string section having a longitudinally extending partition wall internally thereof affording a through passageway for well fluids and a tubular pocket for removable reception of a retrievable well tool, said pocket being open at both ends into the passageway and having a lift gas entry port intermediate said ends, internal bearing surfaces within said pocket and above and below the entry port for close seal fitment therewith of a well tool, a tool landing shoulder and a tool latch keeper on the pocket and a latchable gas lift valve unit receivable in said pocket through the upper open end thereof and including a chambered body closed at its upper end and provided with a flow outlet at its lower end and with lift gas inlet means leading into longitudinally spaced apart portions of the chambered body and from the exterior of the body at an intermediate portion thereof adjacent said gas entry port, longitudinally spaced apart peripheral bearing surfaces on the body above and below said intermediate portion of the body for mating sealing co-operation with the internal bearing surfaces of said pocket, a seating ring within the chambered body between said longitudinally spaced apart portions thereof, a pilot valve engageable with said ring, means biasing the valve toward ring engagement and responsive to the pressure of lift gas to open said pilot valve pass pressure gas thereby, a valve seating ring below both of said longitudinally spaced portions of the chambered body, a longitudinally shiftable spool valve within the chambered body having its upper head end in peripheral sliding seal bearing with the body and its top face exposed to pilot valve passed pressure gas and having its lower head end positioned for movement into and out of seating engagement with the last mentioned valve seating ring as influenced by pressure gas action on said upper headed end, spring means between the body and the spool valve normally maintaining the spool valve and its lower head in seating engagement with the last mentioned valve seating ring, a longitudinal passage through the spool valve, a body carried portion having a pair of longitudinally spaced apart peripheral grooves separated by an intermediate enlargement, a collar slidably fitted in one of the grooves and having a longitudinally extended spring leg with a lateral latching lug spaced from the collar for reception by said latch keeper, means defining opposite limits of collar movement in one of which said spring leg is depressible into one of said grooves and in another of which said leg is depressible into the other groove and means including a shearable connection on the body and precluding collar movement to one of said opposite limits and restricting collar movement with a range adjacent the upper limit and to and from the intermediate position in which said spring leg bears inwardly against said inter-

mediate enlargement and is located thereby against depression.

3. In combination, a well tubing string section having a tool locating pocket with a lift gas entry port in the side of the pocket intermediate its top and bottom ends, internal cylindrical bearing surfaces in the pocket above and below said gas entry port, a tool landing shoulder on the pocket, a tool latch keeper on the pocket spaced longitudinally from the shoulder, a retrievable gas lift valve removably positionable in said pocket and comprised of a body enclosing a valve chamber and having medially of its length a side opening for communication of said entry port with the valve chamber, a pressure responsive valve in the chamber controlling flow of lift gas, a pair of peripheral seals on the body on opposite sides of said side opening and engageable with said bearing surfaces in the pocket, a locating seat on the body for bottoming abutment with the landing shoulder, a keeper engageable latch dog mounted on the body for longitudinal and lateral shifting movement relative thereto, said body in the region intermediate the range of longitudinal dog movement having a dog expander boss engageable by the dog for maintaining the same against lateral retraction from its latching position and also having portions above and below said boss which are inwardly relieved relative to the boss and accommodate lateral retraction of the dog upon its longitudinal movement out of engagement with the boss and frangible stop means carried by the body below the dog engaging boss surface for engagement by the bottom of the dog and initially restricting dog longitudinal movement downwardly from the boss and into the relieved portion below said boss.

4. A retrievable well tool for removable reception within a tubing string pocket, including a body having a downwardly facing stop abutment and an upwardly facing stop abutment assembly which is self-latchable upon downward tool movement into a tubing string pocket and is releasable in response to upward jarring force applied to the tool, said assembly comprised of a spool formation on the body having a pair of longitudinally spaced apart peripherally relieved portions and an expander boss between said relieved portions, a longitudinally shiftable latching element having a retainer collar embracing the uppermost relieved portion and a dependent flexible leg having inward bearing abutment with said expander boss at an intermediate position of movement of the shiftable element and being inwardly retractable into said relieved portions at opposite limits of movement of said shiftable element, an outwardly projected latching dog carried by the flexible leg and a stop including an abutment portion and frangible positioning means therefor securing the abutment portion to the body in the downward path of said leg and engageable therewith to preclude movement of the leg into the lowermost relieved portion so long as said frangible positioning means is effective.

5. A retrievable gas lift valve assembly for removable reception within a tubing string pocket, including a chambered body, a downwardly facing locating shoulder external of the body, a latch mounting formation on the body comprising a pair of longitudinally spaced peripherally relieved portions and an expander boss separating the relieved portions, a self-acting latch comprising a retainer collar slidably sleeved on the upper relieved portion and provided with a downwardly extended spring leg carrying an upwardly facing latch lug on a portion of the leg spaced below said collar and retractable into said relieved portions at opposite limits of collar slide travel and engaged with said boss against retraction at a collar position intermediate said opposite limits, body carried releasable means including a shearable connection and an abutment portion positioned by the shearable means on the body below said boss and engageable by the bottom of the spring leg as a stop against downward movement into the lower relieved portion, a spool-shaped main valve slidably mounted within the chambered body with an upper head in slide guide bearing on the body and with a lower head tapered upwardly to constitute a valve seating surface, an internal downwardly facing shoulder on said body immediately above the tapered seating surface, a pliable seating ring bearing on said shoulder and engageable by said tapered seating surface for closing the chambered body against lift gas flow, a retainer ring removably secured in the body in clamping engagement with said seating ring, spring means between the body and the main valve normally maintaining said main valve closed, a longitudinal passage through the main valve, a normally seated pilot valve contained within the chambered body above the main valve and responsive to lift gas pressure in directing the same against the top of said upper head to depress the main valve, a downwardly facing shoulder internally of the body above said upper head, a pilot valve seating ring located upwardly by the last mentioned shoulder and a retainer ring removably mounted in the body in pilot valve seating ring clamping relation with the last mentioned shoulder.

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