# LOCK MANDREL AND RUNNING TOOL ASSEMBLY FOR WELL

This invention relates to well tools and more particularly relates to a lock mandrel and running tool for releasably locking a flow control device such as a safety valve in a flow conductor of a well.

In the well art, particularly that relating to oil and gas wells, it is standard practice to complete the wells using wireline equipment and methods which provides for substantial cost reductions during future well servicing operations. Wireline completion methods and equipment are illustrated and described in substantial detail in PETROLEUM ENGINEER INTERNATIONAL for August 1981 at pages 83-89. Presently available lock mandrels for sub-surface safety valves are of the extension hanger type which may present several operational problems when used with safety valves. Extension hanger locks are set by applying force in the same downward direction required for driving the safety valve into the landing nipple in which the valve is to be locked. The friction caused by packing between the safety valve and the landing nipple may require such excessive drive-down force that the lock mandrel is prematurely set. Further, it is possible to only partly engage the lock mandrel in the recess, establish control line pressure, and remove the running tool used to set the lock mandrel without any indication of a serious problem. One remedy which has been employed is a spring isolator device which eliminates major problems but still may malfunction. The locking sleeve of the extension hanger type lock must move in the opposite direction from flow to lock a safety valve. It is possible that flow could lift the locking sleeve releasing the lock.

It is, therefore, a particularly important object of the invention to provide a new and improved well tool.

It is another particularly important object of the invention to provide a new and improved lock mandrel and running tool assembly for use in wells to releasably lock devices such as safety valves at a landing nipple along the flow conductor of the well.

It is another object of the invention to provide a lock mandrel and running tool operable with wireline equipment.

It is another object of the invention to provide a running tool and a lock mandrel which is set by a force applied in a direction opposite to the direction of force required to drive the device such as a safety valve connected with the lock mandrel into the landing nipple in which the lock mandrel is set.

It is another object of the invention to provide a running tool with a lock mandrel which may be driven downwardly with unlimited force without the possibility of pre-setting the lock.

It is a further object of the invention to provide a runnin tool with a lock mandrel having a locking sleeve which moves to lock the mandrel in the direction of flow in the well thereby preventing well flow from releasing the lock.

It is a still further object of the invention to provide a running tool and a lock mandrel which requires that the lock mandrel be properly set and the well tool activated before the running tool can be released.

It is another object of the invention that safety valve control line integrity be established before the running tool can be released from the lock mandrel.

It is another object of the invention to provide a new and improved running tool for well apparatus such as a safety valve.

It is another object of the invention to provide a well device running tool which cannot be released from the well device until the device is properly set and activated in a well bore.

According to one aspect of the present invention there is provided a lock mandrel and running tool assembly for setting and locking a well tool in a landing nipple along a well bore comprising: a lock mandrel having a body provided with side windows, a support shoulder on said body for supporting said mandrel in a no-go landing nipple, a radially movable locking dog in each of said side windows, a longitudinally movable expander sleeve in said body movable within said dogs for expanding and locking said dogs outwardly and releasing said dogs for inward movement, and means for connecting said mandrel body to said well tool; and a running tool having a head assembly for connection with an operating tool string, an upper latch key assembly slidably connected with said head assembly for releasably coupling said running tool with said lock mandrel body, a lower latch assembly operable by said head assembly for releasably coupling said running tool with and raising said lock mandrel expander sleeve, said lower latch assembly comprising a lower setting sleeve and radially movable locking lugs carried by said lower setting sleeve to engage and move said expander sleeve of said lock mandrel, said head assembly including an upper setting sleeve releasably connectible with said lower setting sleeve, said lower setting sleeve including transfer lugs

only for releasable engagement with said upper setting sleeve to form the releasable connection between the upper and lower setting sleeves, a core having a prong end coupled with said head assembly for engaging a well tool operator member to apply a force from said operator member to said upper latch key assembly to lock said key assembly with said lock mandrel body, and said head assembly and core being movable in a direction opposite to the direction of setting said assembly in said landing nipple to expand said lock mandrel locking dogs and release said running tool from said lock mandrel.

According to another aspect of the invention there is provided a running tool for setting and locking a lock mandrel in a landing nipple along a well bore comprising: a head assembly for connection of said running tool with an operating tool string; an upper latch key assembly slidably connected with said head assembly for releasably coupling said running tool with the body of said lock mandrel; a lower latch assembly operable from said head assembly for coupling with and lifting an expander sleeve in said lock mandrel; a core secured with said upper latch key assembly and slidable in said lower latch assembly said core having a lower end prong for engagement with an operating member of said well tool below said lock mandrel to apply a force from said well tool to said upper latch key assembly for holding said upper latch key assembly in locked relation with said lock mandrel body, and said core having latch assembly lock and release means movable relative to said lower latch assembly to operate said lower latch assembly in response to movement of said head assembly for moving said lock mandrel expander sleeve and releasing said running tool from said lock mandrel, and wherein said lower latch assembly includes a lower setting sleeve having means for releasably engaging the expander sleeve

in said lock mandrel, said head assembly including an upper setting sleeve releasably connectible with said lower setting sleeve at one of a plurality of longitudinal positions of said core, and radially movable locking lugs and radially movable transfer lugs are carried by said lower setting sleeve, said locking lugs being releasably engageable with said expander sleeve of said lock mandrel and said transfer lugs being releasably engageable with said upper setting sleeve to form the releasable connection between the upper and lower setting sleeves.

According to another aspect of the invention there is provided a running tool for setting and locking a lock mandrel in a landing nipple along a well bore, said lock mandrel having an expander sleeve movable upwardly for locking said mandrel at said landing nipple, said running tool comprising: a head assembly having means at an upper end thereof for connection with a wireline tool string, said head assembly including a tubular outer skirt and an upper setting sleeve disposed in concentric spaced relation within said skirt, said setting sleeve having an internal annular operating flange at the lower end thereof and an internal annular recess above said operating flange, and diametrically opposed longitudinal slots above said recess; a tubular retainer sleeve slidable within said skirt around said upper setting sleeve, said retainer sleeve having circumferentially spaced windows opening through said sleeve below said skirt; a radially removable latch key in each of said windows of said retainer sleeve for releasably locking said running tool with the body of said lock mandrel; a spring coupled with each of said latch keys biasing each of said keys radially inwardly; an elongated tubular core slidably disposed along an upper end thereof within said upper setting sleeve, said core having longitudinally

spaced external annular release recesses; a roll pin connected transversely through upper end portions of said retainer sleeve and said core passing through said longitudinal slots in said upper setting sleeve for movement of said retainer sleeve and said core as a unit; a spring within said head assembly engaging an upper end edge of said core biasing said core downwardly relative to said head assembly; a lower setting sleeve slidably disposed around said core within said retainer sleeve and having an upper end portion movable into a lower end portion of said upper setting sleeve, said lower setting sleeve having an external annular release recess alignable within said latch keys at a release position of said lower setting sleeve permitting said latch keys to move inwardly around said lower setting sleeve for release of said running tool from said lock mandrel body, said lower setting sleeve having circumferentially spaced windows along an upper end portion thereof and circumferentially spaced windows along a lower end portion thereof; radially movable transfer lugs disposed in said upper windows of said lower setting sleeve for releasably coupling said lower setting sleeve with said upper setting sleeve; locking lugs in said lower windows of said lower setting sleeve for releasably coupling said lower setting sleeve with said expander sleeve of said lock mandrel; said release recesses along said core and along said lower setting sleeve being positioned for said core holding said locking lugs in expanded lock relation within said lock mandrel expander sleeve and said transfer lugs at inward release positions when said core is at a first upper position and for holding said transfer lugs outwardly and said locking lugs outwardly at a second lower position of said core and a first lower position of said lower setting sleeve whereby said upper setting sleeve is coupled with said lower setting sleeve

for moving said lock mandrel expander sleeve upwardly to lock said lock mandrel at a landing nipple and said locking lugs are aligned with one of said release recesses around said core at a second upper position of said lower setting sleeve for release of said locking lugs from said lock mandrel expander sleeve and said release recess around said lower setting sleeve is aligned with said latch keys for release of said running tool from said lock mandrel body.

Reference is now made to the accompanying drawings, in which:-

Figures 1A and 1B taken together are a longitudinal and sectional view of an embodiment of the running tool onf the invention;

Figure 2 is a longitudinal view in section of the retainer sleeve of the running tool of Figures 1A and 1B;

Figure 3 is a view in section along the line 22-22 of Figure 2;

Figure 4 is a fragmentary view in elevation of a lower end portion of the retainer sleeve of Figure 2 showing a latch key window as viewed along the line 23-23 of Figure 2;

Figure 5 is a view in elevation of the outside surfaces of one of the latch keys of the running tool;

Figure 6 is an ~~right~~ end view in elevation of the latch key of Figure 5;

Figure 7 is an inside view in elevation of the latch key of Figures 5 and 6;

Figure 8 is a longitudinal view in section and elevation of the lower setting sleeve of the running tool of Figures 1A and 1B;

Figure 9 is a view in section along the line 28-28 of Figure 8;

Figure 10 is a view in section along the line 29-29 of Figure 8;

Figure 11 is a fragmentary view in elevation of the upper end portion of the lower setting sleeve of Figure 8;

Figure 12 is an enlarged inside view of the transfer lugs of the running tool of Figure 1A and 1B;

Figure 13 is a view in section and elevation along the line 32-32 of the transfer lug of Figure 12;

Figure 14 is a top end view in elevation of the lug of Figure 12;

Figures 15A and 15B taken together form a longitudinal view in half section of a lock mandrel and the running tool of Figures 1A and 1B in the running mode of the tools;

Figures 16A and 16B taken together form a longitudinal half section of the running tool and lock mandrel in the drive-in mode for inserting the lock mandrel into a landing nipple in a well;

Figures 17A and 17B taken together form a longitudinal half section of he running tool and lock mandrel after the lock mandrel is inserted into a landing nipple and pressure has been applied to a safety valve supported from the lock mandrel preparatory to expanding the locking keys on the lock mandrel; and

Figures 18A and 18B taken together form a longitudinal view in half section after expansion of the keys on the lock mandrel and release of the running tool from the lock mandrel.

A running tool of the invention is shown in Figures 1A and 1B through 14 which illustrate a running tool R2. Referring to Figures 1A and 1B, the running tool R2 has a top sub or head 200 provided with an externally threaded pin 201 for connecting the running tool with a tool string such as operated on a wireline for lowering the running tool and the lock mandrel secured to a well tool such as a safety valve in a well bore. Included in the

running tool supported from the top sub are an upper latch assembly 202 for releasably coupling the tool with a lock mandrel body and a lower latch assembly 203 for releasably connecting the running tool with the expander sleeve of the lock mandrel. The upper and lower latch assemblies are supported from the top sub along a core 204 which transfers an upward force from the operator tube of the well tool connected with the lock mandrel such as a safety valve to the upper latch assembly so that the upper latch assembly remains coupled with the lock mandrel body until a control line pressure opens the safety valve supported from the lock mandrel. The core also has structural features for operation of the lower latch assembly to set the lock mandrel in a landing nipple and release the running tool from the lock mandrel.

As shown in Figures 1A and 1B the top sub 200 has a tubular skirt 205 defining a bore 210 having a reduced internally threaded upper end portion 211. A plurality of bypass ports 212 are formed in the top sub opening into the upper end of the bore 210 for fluid flow through the running tool as the tool is lowered and raised in a well bore. An upper setting sleeve 213 is secured in concentric spaced relation within the top sub connected by an externally threaded upper end section into the threaded portion 211 of the top sub bore. The upper setting sleeve has an enlarged lower end section 214 provided with an internal annular locking recess 215. The upper end edge of the sleeve enlarged portion 214 defines an external annular stop shoulder 220 around the upper setting sleeve. The upper setting sleeve is provided with two longitudinal slots 221 aligned along opposite sides of the sleeve for sliding longitudinal movement of a roll pin 222 the purpose of which is described hereinafter. The upper latch assembly 202 includes a retainer sleeve

223 slidably telescoped between the skirt 205 and the upper setting sleeve 213. The retainer sleeve has a head portion 224 provided with an internal annular shoulder 225 which is engageable by the shoulder 220 on the upper setting sleeve 213. The upper end portion of the core 204 is telescoped into the upper setting sleeve and pinned to the retainer sleeve by the roll pin 222 so that the core, roll pin, and retainer sleeve move as a unit. As shown in Figure 2 the retainer sleeve has diametrically positioned holes 230 for the roll pin 222. The lower end portion of the retainer sleeve 223 is provided with four circumferentially spaced latch key windows 231 which communicate at the lower ends with longitudinal slots 232 extending along the surface of the retainer sleeve below each of the windows 231 opening at the upper end into the window and having a longitudinal axis coincident with the longitudinal axis of the window. The bottom of the lower end portion of each of the slots 232 is provided with a circular recess 233. An external annular recess 234 is formed around the retainer sleeve intersecting the longitudinal slots 232 between the circular recesses 233 and the central portion of the slots 232. As shown in Figure 1B a latch key 235 is positioned in each of the windows 231 baised radially inwardly by a flat leaf spring 240. A retainer band 241 in the annular recess 234 holds the leaf springs in positon. The configuration of each of the keys 235 is shown in Figures 5, 6, and 7. As evident in Figures 5 and 6 the outer locking end portion, the lower end portion of Figure 1B, of each of the keys is provided with two laterally aligned locking bosses 242 spaced on opposite sides of a spring recess 243. The longitudinal side edges of the keys 235 are each provided with spaced retainer lips 244 which hold the keys in the windows 231. The inside surfaces of each of the keys 235 as illustrated in Figures 6 and 7 are

defined by cylindrical concave surfaces which fit around the portion of the lower setting sleeve 203 within the keys. As seen in Figure 1B showing a side longitudinal edge of one of the springs 241, each of the springs lies along a central flat portion in a slot 232 below the window 231 of the retainer sleeve with an upper end portion of the spring resting in the recess 243 of the key 235 in the window 231 while a lower end portion of the spring bent at 90° to the flat body portion of the spring engages the round recess 233 opening into slot 232. The retainer band 241 around the flat portion of the springs holds the springs in the slots 232 with end portions of the springs each resting in one of the slots 243 of the adjacent key 235 biasing the lower ends of the keys inwardly against the outer surface of the lower setting sleeve within the keys. The keys 235 function to couple the running tool R2 with the body of the lock mandrel M2 as shown in Figures 15A - 15B. The keys 235 as shown in Figure 1B are in the outward lock positions at which the mandrel M2 is locked on the running tool.

Referring to Figures 1B, and 8 - 10, the lower setting sleeve 203 telescopes in sliding relation into the upper latch assembly 202 performing a duel function in the operation of the running tool including release of the latch keys 235 as well as operating the lock mandrel M2. The lower setting sleeve has a reduced upper end portion 250 which slides on a reduced upper end portion 251 of the core 204 above an external annular stop shoulder 252 on the core. The upper end portion 250 of the lower setting sleeve 203 has circumferentially spaced windows 253 each sized and shaped to receive a transfer lug 254 which serve release and coupling functions between the lower setting sleeve 203 and the upper setting sleeve 213. At radially inward release positions the transfer lugs 254 move along inward portions into an

external annular release recess 255 formed around the core 204 above the shoulder 252 on the core. Further details of the windows 253 on the upper end portion of the lower setting sleeve 203 and the transfer lugs 254 are shown in Figures 9 and 11 - 14. The lugs shown in Figures 12 - 14 are substantially enlarged in size compared with the scale of the setting sleeve as shown in Figures 8 - 11. Each of the lugs is a circular segment having outer latching bosses 254a and end flanges 254b as shown in Figure 14 for holding the lugs within the windows 253. The depth of each of the lugs is substantially greater than the wall thickness of the sleeve portion 250 at the windows so that the bosses 254a of the lugs may extend outwardly beyond the outer surface of the sleeve portion 250 when the lugs are at fully expanded positions. At inward positions of the lugs as shown in Figure 1B the outer surfaces of the bosses 254a are in alignment with the outer surface of the sleeve portion 250 and thus are at release positions.

As seen in Figures 1B and 8, the lower setting sleeve 203 has an external annular upper latch key release recess 255 which permits inward movement of the upper latch keys 235 when the recess 255 is aligned within the keys. The lower end portion of the lower setting sleeve 203 is provided with circumferentially spaced windows 260 each of which receives a locking lug 261 for releasably locking the lower setting sleeve with the locking sleeve of the lock mandrel M2 when supported on the running tool. The locking lugs 261 have the same shape as the lugs 254 shown in Figures 11 - 14 including end flanges for holding the lugs within the windows 260 while permitting the lugs to expand outwardly sufficiently to releasably engage the lock mandrel setting sleeve when the setting sleeve is disposed around the lower setting sleeve 203 of the running tool. The

lower setting sleeve 203 is also provided with circumferentially spaced upwardly extending integral collet fingers 262 which are radially flexible and provided with external unlocking shoulders 263 and internal operating bosses 264. The unlocking lips or shoulders 263 on the collets 262 are engageable with the end edge of the locking mandrel locking sleeve for unlocking the mandrel with the running tool in the event that it is necessary to retrieve the mandrel with the running tool. The internal bosses 264 on the collets 262 are engageable with the outer surface of the core which provides a metal backup to securely the collet fingers outwardly at the unlocking positions.

Referring to Figures 1A and 1B, the core 204 is slidably disposed within the lower setting sleeve 203 and the upper setting sleeve 213. The core is secured at the upper end with the upper end of the retainer sleeve 223 by the roll pin 222 which passes through the diametrically opposed slots 221 in the upper setting sleeve so that the core and the retainer sleeve move together as a unit. A coil spring 265 is confined between the upper end edge of the core within the bore of the upper setting sleeve and a downwardly facing surface at the end of the head assembly bore biasing the core downwardly. The core is provided with longitudinally spaced external annular release recesses 270 and 271 positioned to receive the internal bosses 264 on the collet fingers 262 and the locking lugs 261, respectively, at the release position of the core relative to the lower locking sleeve 203. A running prong 272 is threaded on the lower end of the core below the lower end of the lower setting sleeve 203. The upper end edge 273 of the prong engages the lower end edge 274 of the setting sleeve 203 in the relative positions of the running tool parts shown in Figures 1A and 1B. The

lower end of the prong is provided with an inwardly tapered annular surface 275 for engagement of the prong with an operator tube of a well tool below the running tool such as a safety valve.

Referring to Figure 15B, the running tool R2 is operable with the lock mandrel M2 for setting the lock mandrel in a landing nipple to support a well tool such as a safety valve in a well bore below the landing nipple. Mandrel M2, Figure 15B, is functionally identical to the lock mandrel M of Figure 1 of our U.K. Patent Specification 2119426A differing only in minor structural features. The lock mandrel M2 has a tubular mandrel body including a main section 280 provided with circumferentially spaced windows 281 and a lower portion 282 threaded into the lower end of the section 280. The section 280 has an external annular stop shoulder 283 which stops at and seats on a seat surface in a landing nipple, not shown, similar to the landing of the mandrel M in the landing nipple 160 at the shoulder 162 as shown in Figure 18B of our U.K. Patent Specification 2119426A. A radially expandible locking dog 284 is disposed in each of the windows 281 of the mandrel body section 280. An expander sleeve 285 is slidably disposed within the mandrel body sections within the locking dogs 284 for movement between a lower end position at which the dogs are retracted as shown in Figure 15B and an upper end position at which the dogs 284 are expanded as illustrated in Figure 18B. The body mandrel 290 of a safety valve, not shown, is secured at the upper end thereof into the lower end of the body section 282 of the mandrel M2 for supporting the safety valve from the mandrel. The safety valve has an operating tube 291 having a downwardly and inwardly convergent upper end edge 292 which is engageable with the lower end surface 275 on the running prong of the running tool R2 for

holding the running prong and core of the running tool at an upper end positon when the running prong on the core engages the safety valve operating tube during the running, and landing of the mandrel M2 prior to pumping the safety valve fully open with operating fluid from the surface. When using the lock mandrel M2, an annular seal such as a seal 34 shown in Figure 1 of our U.K. Patent Specification 2119426A is located on the safety valve body rather than on the mandrel body. The body section 280 of the mandrel M2 has an internal annular locking recess 293 for the retainer dogs or latch keys 235 on the running tool R2.

To run and set the mandrel M2 at a landing nipple in a well bore with a safety valve supported from the mandrel, the mandrel and running tool R2 are assembled at the surface by inserting the running tool prong 272 and core 204 and the retainer sleeve 223 with the retainer dogs 235 into the mandrel body and locking sleeve as shown in Figures 15A and 15B. The running tool may be coupled with the lock mandrel using the following procedure. The lock mandrel is made up to the safety valve and the entire assembly is placed in a vice with the lock mandrel in a locked condition at which the locking keys 284 are fully expanded. The running tool is then inverted with the top sub 200 down and the prong 272 extending upwardly. The prong is pulled upwardly and the lower setting sleeve 203 should drop freely so that the latch keys 235 may retract and the locking lugs 261 are free to retract. The safety valve, not shown, is then pumped open with a hand pump. The running tool is inserted into the lock mandrel until the latch keys 235 are within the locking recess 293 of the lock mandrel body section 280. The unlocking collets 262 on the lower setting sleeve snap into place with the unlocking shoulders 263 engaging the end edge of the lock mandrel

expander sleeve 285 and the locking lugs 261 are aligned with and engaging the expander sleeve operating shoulder 295 in the general relationship shown in Figures 16A and 16B except that the locking sleeve of the lock mandrel M2 is at the position of Figures 18A and 18B. A set of wireline type jars and a short section of stem are then attached to the threaded end 201 of the top sub 200. With the safety valve still pumped open, the running tool is jarred toward the lock mandrel M2 until the expander sleeve 285 of the lock mandrel is driven toward the safety valve to the unlocked position of Figures 15A and 15B. This also shifts the lower setting sleeve 203 to the position of Figures 15A and 15B at which the latch keys 235 are held outwardly in locking positions within the recess 293 of the lock mandrel body section 280. The pressure is then released on the safety valve permitting the spring in the safety valve, not shown, to urge the operating tube 291 of the safety valve against the end edge 275 of the running prong 272. The force of the safety valve operating tube against the running prong holds the running prong at an upper position as shown in Figures 15A and 15B at which the recess 255 is aligned with the transfer lugs 254 so that the lugs are free to move inwardly into the recess and cannot be engaged by the upper setting sleeve 213. The running tool is then checked by first pulling the top sub 200 of the running tool outwardly away from the lock mendrel M2 to a position of full extension as essentially shown in Figures 15A and 15B and pushing the top sub toward the lock mandrel to essentially the position of Figures 16A and 16B to insure that the top sub will move through the full length of travel without engaging the transfer lugs. At this stage the running tool, lock mandrel, and safety valve assembly are ready to run into a well bore.

The running tool R2 with the lock mandrel M2 and

safety valve are assembled in a wireline tool string and lowered in a well bore into a landing nipple such as represented in Figure 18B of our U.K. Patent Specification 2119426A. The lock mandrel enters the nipple and is jarred downwardly until the stop shoulder 283 on the lock mandrel body is seated against the no-go shoulder such as the shoulder 162 in the landing nipple represented in Figure 18B of U.K. Patent Specification 2119426A. The running tool and mandrel with the safety valve are lowered as represented in Figures 15A and 15B. During the lowering of the tool assembly the top sub with the skirt 205 and the upper setting sleeve 213 remain telescoped to the upper end position illustrated at which the shoulder 225 of the retainer sleeve hangs on the shoulder 220 of the upper setting sleeve. As the lock mandrel enters the landing nipple and is jarred downwardly the top sub is telescoped downwardly over the retainer sleeve and upper end portion of the core to the position shown in Figures 16A and 16B at which the lower end edge of the top sub skirt 205 engages the upper end edge of the lock mandrel body section 280 for driving the lock mandrel into the landing nipple against the no-go shoulder. After the lock mandrel is against the no-go shoulder the relative positions of the parts of the running tool and lock mandrel as seen in Figures 16A and 16B. The control line pressure to the safety valve is then increased to the level required to fully open the valve which moves the operating tube 291 of the safety valve downwardly to the position shown in Figures 17A and 17B thereby removing the upward force from the running tool core 204. With the core no longer forced upwardly by the safety valve operating tube, the spring 265 in the top sub expands shifting the core 204 downwardly moving the release recess 255 below the transfer lugs 254 so that the surface of the core above the release recess

expands the lugs into the recess 215 of the upper setting sleeve 213 as illustrated in Figures 17A and 17B. The increase of the control line pressure opening the safety valve must be done at the time that the top sub of the running tool is still at the lwoer end position and thus before an upward pull is applied to the top sub so that the upper setting sleeve 213 will be telescoped downwardly around the transfer lugs as illustrated. An upward force is then applied to the top sub telescoping the top sub including the skirt 205 and the upper setting sleeve 213 upwardly relative to the retainer sleeve 223 and the core 204. When the upper setting sleeve is pulled upwardly to the position of Figures 18A and 18B the transfer lugs within the recess 215 of the upper setting sleeve are lifted raising the lower setting sleeve 203 for expanding the locking keys 284 of the lock mandrel M2 and releasing the latch keys 235 of the running tool from the lock mandrel body section 280. This sequence of operation will be better understood by reference to both sets of Figures 17A and 17B and 18A and 18B. As the upward force is applied to the lower setting sleeve the lugs 261 are pulled upwardly against the shoulder 295 within the lock mandrel locking sleeve 285 forcing the sleeve upwardly within the locking keys 284 expanding the keys to the positions shown in Figures 18A and 18B which lock the mandrel M2 in the landing nipple. By the time that the locking sleeve 285 is lifted to the locking position, the lugs 261 are aligned with the release recess 271 in the running tool core 204 so that the lugs 261 are cammed inwardly to release positions into the recess 271 thereby releasing the lugs from the locking shoulder of the locking sleeve. Simultaneously the unlocking collets 262 on the lower setting sleeve are cammed inwardly into the release recess 270 of the core 204. Also simultaneously the upward movement of the

lower setting sleeve aligns the release recess 255 of the lower setting sleeve with the latch keys 235 which are squeezed inwardly by the springs 240 releasing the keys from the locking recess 293 in the body section 280 of the lock mandrel M2. These release positions of the lugs 261, the unlocking collets 262, and the latch keys 235 are illustrated in Figures 18A and 18B. With the running tool released from both the body of the lock mandrel M2 and the locking sleeve of the lock mandrel, the running tool is telescoped upwardly out of the lock mandrel and pulled back to the surface by the wireline leaving the lock mandrel M2 with the safety valve locked at the landing nipple in the well bore.

If an operational problem prevents the control line pressure from fully opening the safety valve and thereby removing the upward force of the safety valve operating tube from the prong and core of the running tool, it will be apparent that the core will remain in the positions of Figures 15A and 15B and will not be shifted upwardly to the position of Figures 17A and 17B. Thus if the control line presure does not fully open the safety valve, upward jarring on the running tool will not lock the lock mandrel M2 in the landing nipple but rather will extract the lock mandrel M2 and the safety valve from the landing nipple because the relationship of the top sub will be as shown in Figures 15A ans 15B the parts being at positions at which the transfer lugs 254 cannot be engaged by the upper setting sleeve and thus the lock mandrel M2 cannot be locked in the landing nipple but rather will be pulled from the nipple by the running tool. This of course is one of the principle procedures of the invention which precludes leaving the lock mandrel and safety valve in the well bore if the safety valve is manfunctioning.

If after the tool operator has extracted the running tool R2 from the lock mandrel M2 some condition develops

which indicates that the lock mandrel and safety valve should be retrieved, the running tool may be used as a pulling tool. It is required however when so using the running tool that the safety valve be operational because the safety valve must be pumped fully open with the operator tube 291 of the safety valve at the lower position represented in Figures 17A and 17B and 18A and 18B. In such event the running tool is lowered and telescoped back into the lock mandrel entering the lock mandrel in the condition represented in Figures 18A and 18B so that the latch keys 235 may enter the body section 280 of the lock mandrel and the lugs 261 as well as the unlocking collets 262 are at inward positions for entering the lock mandrel. When the unlocking collet heads approach the locking sleeve 285 of the mandrel M2 in essentially the position of Figures 18A and 18B, the unlocking collets expand outwardly until the shoulders 263 on the collet heads engage the end edge of the locking sleeve 285 so that further downward force on the running tool top sub drives the lower setting sleeve 203 with the unlocking collets downwardly moving the locking sleeve 285 downwardly to the release position represented in Figures 17A and 17B. The downward movement of the lower setting sleeve also moves the release recess 255 around the sleeve below the latch keys 235 shifting the full diameter surface of the lower setting sleeve behind the dogs which are expanded back into the recess 293 of the lock mandrel body section 280. After the control line pressure on the valve has been decreased and the operating member 291 of the safety valve moves up, an upward force on the top sub will pull the running tool and lock mandrel with the safety valve back upwardly out of the landing nipple.

CLAIMS

1. A lock mandrel and running tool assembly for setting and locking a well tool in a landing nipple along a well bore comprising: a lock mandrel having a body provided with side windows, a support shoulder on said body for supporting said mandrel in a no-go landing nipple, a radially movable locking dog in each of said side windows, a longitudinally movable expander sleeve in said body movable within said dogs for expanding and locking said dogs outwardly and releasing said dogs for inward movement, and means for connecting said mandrel body to said well tool; and a running tool having a head assembly for connection with an operating tool string, an upper latch key assembly slidably connected with said head assembly for releasably coupling said running tool with said lock mandrel body, a lower latch assembly operable by said head assembly for releasably coupling said running tool with and raising said lock mandrel expander sleeve, said lower latch assembly comprising a lower setting sleeve and radially movable locking lugs carried by said lower setting sleeve to engage and move said expander sleeve of said lock mandrel, said head assembly including an upper setting sleeve releasably connectible with said lower setting sleeve, said lower setting sleeve including transfer lugs only for releasable engagement with said upper setting sleeve to form the releasable connection between the upper and lower setting sleeves, a core having a prong end coupled with said head assembly for engaging a well tool operator member to apply a force from said operator member to said upper latch key assembly to lock said key assembly with said lock mandrel body, and said head assembly and core being movable in a direction opposite to the direction of setting said assembly in said landing nipple to expand said lock mandrel locking dogs and release said running tool from

* C L N S *

said lock mandrel.

2. An assembly acocrding to Claim 1, wherein the transfer lugs are carried by said lower setting sleeve so as to be radially movable.

3. An assembly according to Claim 1 or 2, wherein said lower setting sleeve includes a release collet for engaging said expander sleeve to release said lock mandrel locking dogs.

4. An assembly acording to Claim 3, wherein said core has spaced external annular recesses for coacting with said locking lugs and collet on said lower setting sleeve.

5. An assembly according to any preceding claim, wherein said lock mandrel body has an internal annular recess for engagement of said upper latch assembly and said expander sleeve has an internal annular recess for engagement by said lower latch assembly.

6. An assembly according to Claim 5, including latch means for releasably latching said expander sleeve at a position at which said locking dogs are expanded.

7. An assembly according to Claim 6, wherein said latch means comprises a latch flange around said expander sleeve, and a latch flange within said mandrel body.

8. An assembly according to Claim 7, wherein said support shoulder on said mandrel body comprises an annular no-go ring.

9. A lock mandrel and running tool assembly according to Claim 8, wherein said locking dogs are each provided with internal cam surfaces for expanding said dogs and said expander sleeve is provided with external cam surfaces for engaging said locking dog cam surfaces.

10. A running tool for setting and locking a lock mandrel in a landing nipple along a well bore comprising: a head assembly for connection of said running tool with an operating tool string; an upper latch key assembly

slidably connected with said head assembly for releasably coupling said running tool with the body of said lock mandrel; a lower latch assembly operable from said head assembly for coupling with and lifting an expander sleeve in said lock mandrel; a core secured with said upper latch key assembly and slidable in said lower latch assembly said core having a lower end prong for engagement with an operating member of said well tool below said lock mandrel to apply a force from said well tool to said upper latch key assembly for holding said upper latch key assembly in locked relation with said lock mandrel body, and said core having latch assembly lock and release means movable relative to said lower latch assembly to operate said lower latch assembly in response to movement of said head assembly for moving said lock mandrel expander sleeve and releasing said running tool from said lock mandrel, and wherein said lower latch assembly includes a lower setting sleeve having means for releasably engaging the expander sleeve in said lock mandrel, said head assembly including an upper setting sleeve releasably connectible with said lower setting sleeve at one of a plurality of longitudinal positions of said core, and radially movable locking lugs and radially movable transfer lugs are carried by said lower setting sleeve, said locking lugs being releasably engageable with said expander sleeve of said lock mandrel and said transfer lugs being releasably engageable with said upper setting sleeve to form the releasable connection between the upper and lower setting sleeves.

11. A running tool according to Claim 10, wherein said upper latch key assembly includes a key retainer sleeve having windows therein and a plurality of radially movable latch keys in said windows, pin means between said key retainer sleeve and said core for holding said

retainer sleeve and said core together as a unit when said head assembly is moved to shift said expanded sleeve in said lock mandrel for expanding locking dogs of said lock mandrel and thereafter for releasing said running tool from said lock mandrel.

12. A running tool according to Claim 10 or 11, wherein said lower setting sleeve includes release collet fingers for engaging said lock mandrel expander sleeve to release said lock mandrel from a landing nipple.

13. A running tool according to Claim 12, wherein said core has longitudinally spaced external annular release recesses for receiving said locking lugs, said transfer lugs, and said release collet fingers.

14. A running tool according to Claim 13, wherein a first release recess in said core is aligned within said transfer lugs at a first upper end position of said core and second and third release recesses on said core are aligned with said locking lugs and said release collet finger and said first release recess is misaligned from said transfer lugs at a second lower position of said core.

15. A running tool according to Claim 14, including a spring between said head assembly and said core biasing said core toward said second lower position.

16. A running tool for setting and locking a lock mandrel in a landing nipple along a well bore, said lock mandrel having an expander sleeve movable upwardly for locking said mandrel at said landing nipple, said running tool comprising: a head assembly having means at an upper end thereof for connection with a wireline tool string, said head assembly including a tubular outer skirt and an upper setting sleeve disposed in concentric spaced relation within said skirt, said setting sleeve having an internal annular operating flange at the lower end thereof and an internal annular recess above said

operating flange, and diametrically opposed longitudinal slots above said recess; a tubular retainer sleeve slidable within said skirt around said upper setting sleeve, said retainer sleeve having circumferentially spaced windows opening through said sleeve below said skirt; a radially removable latch key in each of said windows of said retainer sleeve for releasably locking said running tool with the body of said lock mandrel; a spring coupled with each of said latch keys biasing each of said keys radially inwardly; an elongated tubular core slidably disposed along an upper end thereof within said upper setting sleeve, said core having longitudinally spaced external annular release recesses; a roll pin connected transversely through upper end portions of said retainer sleeve and said core passing through said longitudinal slots in said upper setting sleeve for movement of said retainer sleeve and said core as a unit; a spring within said head assembly engaging an upper end edge of said core biasing said core downwardly relative to said head assembly; a lower setting sleeve slidably disposed around said core within said retainer sleeve and having an upper end portion movable into a lower end portion of said upper setting sleeve, said lower setting sleeve having an external annular release recess alignable within said latch keys at a release position of said lower setting sleeve permitting said latch keys to move inwardly around said lower setting sleeve for release of said running tool from said lock mandrel body, said lower setting sleeve having circumferentially spaced windows along an upper end portion thereof and circumferentially spaced windows along a lower end portion thereof; radially movable transfer lugs disposed in said upper windows of said lower setting sleeve for releasably coupling said lower setting sleeve with said upper setting sleeve; locking lugs in said lower windows

of said lower setting sleeve for releasably coupling said lower setting sleeve with said expander sleeve of said lock mandrel; said release recesses along said core and along said lower setting sleeve being positioned for said core holding said locking lugs in expanded lock relation within said lock mandrel expander sleeve and said transfer lugs at inward release positions when said core is at a first upper position and for holding said transfer lugs outwardly and said locking lugs outwardly at a second lower position of said core and a first lower position of said lower setting sleeve whereby said upper setting sleeve is coupled with said lower setting sleeve for moving said lock mandrel expander sleeve upwardly to lock said lock mandrel at a landing nipple and said locking lugs are aligned with one of said release recesses around said core at a second upper position of said lower setting sleeve for release of said locking lugs from said lock mandrel expander sleeve and said release recess around said lower setting sleeve is aligned with said latch keys for release of said running tool from said lock mandrel body.

17. A running tool according to Claim 16, including integral release collet fingers in said lower setting sleeve for engaging said expander sleeve of said lock mandrel to return said expander sleeve downwardly to a release position, said unlocking collet fingers being movable into one of said release recesses of said core when said running tool is released from said lock mandrel.

18. A lock mandrel and running tool assembly substantially as described with reference to, or as shown in Figures 1 to 18 of the drawings.