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Baugh

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[54] **SUBSEA CONTROL NETWORK**

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[51] **Int. Cl.** **E21b 43/01**

[58] **Field of Search** .... 166/.5, .6; 251/14, 26, 251/130; 137/567; 61/53.58; 137/236, 606

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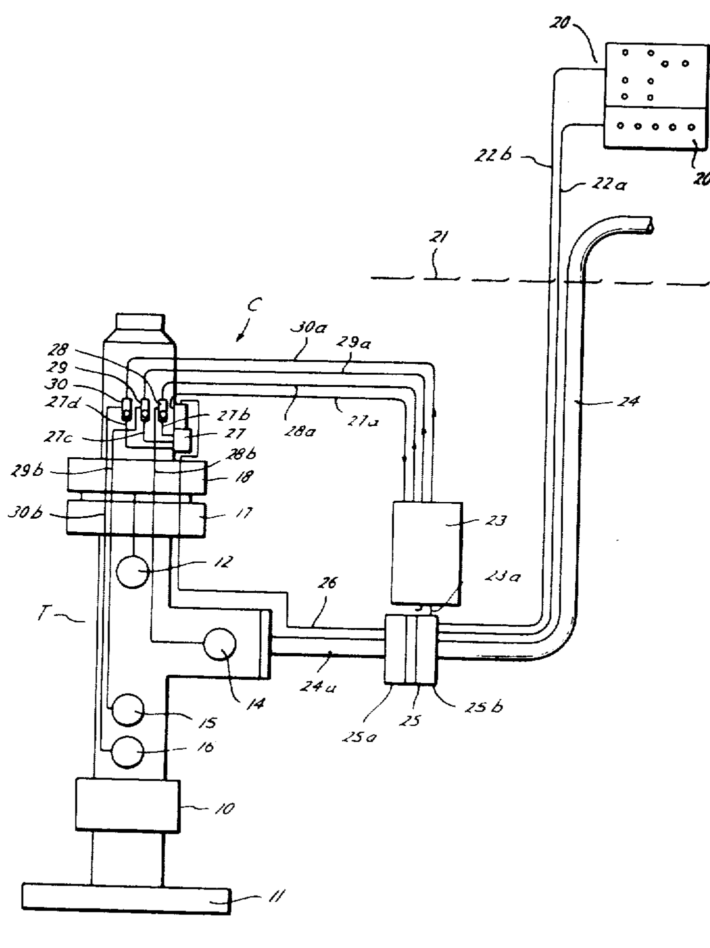
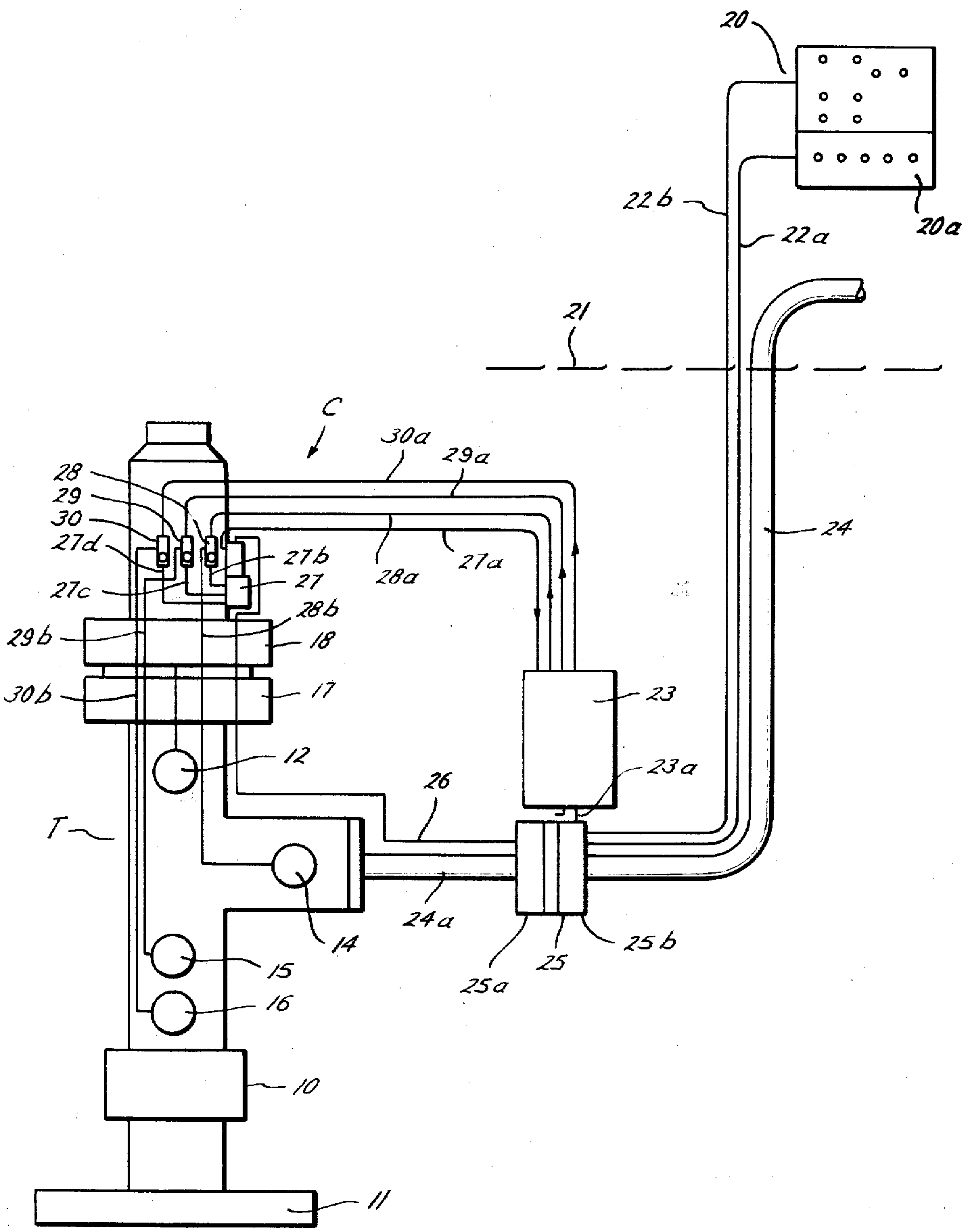
[57] **ABSTRACT**

A new and improved subsea control system which eliminates the necessity of redundant control lines extending from the water surface to an underwater wellhead installation such as a christmas tree, including a multiple pressure responsive sequence valve mounted in a single hydraulic control line for providing direct control to the valves on the underwater installation under emergency conditions.

9 Claims, 1 Drawing Figure

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SUBSEA CONTROL NETWORK

BACKGROUND OF THE INVENTION

The field of this invention is subsea control systems for controlling underwater wellhead installations such as christmas trees under both normal and emergency conditions.

It is well known to use surface controlled christmas trees mounted at the wellhead of underwater wells to control production in such wells. Such christmas trees generally include a number of specific function operating valves which control the actual flow of oil from the well through a flow-line to some type of storage facility on the surface of the water. The christmas tree valves are controlled by various types of control systems including totally hydraulic systems, electro-hydraulic systems, and electric control systems. If the christmas tree control system is hydraulic or electro-hydraulic, it is necessary to extend at least one hydraulic supply line from the surface control platform down to the christmas tree in order to provide fluid under pressure to the wellhead.

Whenever electro-hydraulic or hydraulic control systems are used to control a subsurface christmas tree, one of the most difficult problems to overcome is total failure of the control system. For example, if an electro-hydraulic control system is being used, an electro-hydraulic control pod mounted on the christmas tree is connected to an electro-hydraulic supply line which extends to the surface. If the electro-hydraulic control pod fails, then it is virtually impossible to operate the christmas tree valves. In this case, if the control pod is removable, the control pod must be removed and replaced. If the control pod is permanent, or if the damage to the control pod occurs in the part of the pod which is permanently mounted onto the christmas tree, then it may be necessary to remove the entire tree. In either event, repair of the christmas tree and/or the control pod mounted with the christmas tree is extremely expensive, both in terms of the equipment necessary to accomplish the repair and in loss of production.

Because the repair expenses are so high, various systems have been proposed to extend the life of subsurface christmas tree control systems in order to eliminate the need for repair and thus eliminate or at least postpone production interruptions. One solution for extending the operating life of a christmas tree is to provide a separate, redundant control system which is identical to the main christmas tree control system. An example of such a redundant control system may be found in the Composite Catalog of Oil Field Equipment and Services, 1972–1973, Vol. 3, 30th Revision published by World Oil, pages 4152–4161.

Another method of extending christmas tree operating life is to provide the conventional hydraulic control system, including the hydraulic control line and control pod in combination with a separate hydraulic supply line connected to some type of pressure operated valve, which valve is connected with the christmas tree valves through a shuttle valve for the purpose of operating the christmas tree valves in the event of failure of the main pod.

SUMMARY OF THE INVENTION

It is an object of this invention to provide a new and improved subsea control system for operating an un-

derwater wellhead installation such as a christmas tree or a blowout preventer stack which is capable of extending the operating life of the wellhead while eliminating the necessity of use of two separate hydraulic supply lines extending from the water surface down to the underwater installation.

In the preferred embodiment of this invention, the subsea control system includes an electro-hydraulic control pod mounted with a wellhead valve system, which wellhead valve system includes various known control valves for normally operating the well. Two-way hydraulic control valves are mounted with the wellhead valve system or installation and are hydraulically connected to the various wellhead control valves and to the hydraulic control pod. A multiple pressure responsive failsafe or sequence valve is connected with the two-way hydraulic control valves and to the control pod, the failsafe valve providing various distinct fluid output signals in response to fluid input signals of various pressures. A surface control means and a single hydraulic control line extend from the surface of the water into hydraulic connection with the failsafe valve in order to provide variably pressured input signals to the failsafe valve. And, the failsafe valve includes means for providing a normal output operating signal to the control pod for operating the control pod under normal conditions and further includes means providing separate output signals directly to the two-way valves for operating the wellhead valves under emergency conditions.

DESCRIPTION OF THE DRAWING

The FIG. is a schematic view of an underwater installation such as a christmas tree which is connected to the new and improved failsafe control system of the preferred embodiment of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The letter C generally designates in the drawing the subsea control system of the preferred embodiment of this invention for controlling an underwater installation such as the christmas tree T mounted subsea. The christmas tree T is illustrated as being mounted onto a wellhead connector **10** which in turn is mounted onto a wellhead guide structure **11.** The christmas tree T, the wellhead connector **10** and the guide structure **11** are all subsea equipment well known in the oil industry. For example, a suitable guide structure **11** is illustrated on page 4500 of the Composite Catalog of Oil Field Equipment and Services, Volume 3, page 4500, published by World Oil, 1972–1973. Further a suitable wellhead connector such as **10** is illustrated on page 4509 of the same volume. In addition, a suitable christmas tree T is illustrated on pages 4536–4537 of the same volume.

The numbers **12, 14, 15** and **16** designate valve operators for certain christmas tree vlves such as production valves, testing valves and safety valves, all of which are known in the art. The valve operators **12–16** are hydraulically operated to open and close such valves using hydraulic pressure. The christmas tree T further includes a christmas tree manifold **17** having mounted thereon a christmas tree cap **18.**

The subsea control system C includes the surface control system **20** which is schematically illustrated as a panel **20***a* mounted above the water line **21.** The surface control system **20** may be similar to the control system illustrated on page 4164 of Volume 3 of the Composite Catalog of Oil Field Equipment and Services, 1972–1973. Of course, it is understood that the control panel **20***a* is merely representative of the entire surface control system which is adapted to provide hydraulic fluid under pressure and suitable electric signals to the underwater christmas tree T for operating the valves mounted thereon controlled by valve operators such as 12–16.

The christmas tree T has mounted thereon a control pod **23** which is adapted to receive hydraulic signals and electrical signals from the surface control system **20** for the purpose of operating the valve operators such as **12–16.** The control pod **23** may be landed with the christmas tree T itself or may be landed on the christmas tree T after the christmas tree T is secured at the wellhead. The control pod **23** may be known in the art and may be a pod similar to the control pods illustrated on pages 4154–4159 in Volume 3 of the Composite Catalog of Oil Field Equipment and Services, 1972–1973. A flowline **24** extends from a surface storage facility (not shown) downwardly to a flowline connector station **25** such as described in U.S. Pat. Application, Ser. No. 386,431 now U.S. pat. No. 3866677 filed on Aug. 7, 1973 in the name of invention Benton F. Baugh who is also the inventor of the invention set forth herein. The flowline connector station **25** basically includes a christmas tree connection terminal **25***a* which connects to the christmas tree T itself through a tree flowline such as **24***a*. The flowline connector station **25** additionally includes a flowline connecting terminal **25***b* connected to the flowline **24.** The flowline connector terminal **25***b* is landed and operably connected with the christmas tree flowline connector terminal **25***a* in order to make operable connection to transfer oil from the christmas tree T to the surface.

A hydraulic supply line **22***a* and an electrical supply line **22***b* extend from the surface control system **20** downwardly to the christmas tree T along with the flowline **24.** The electrical supply line **22***b* may be connected to the control pod **23** by any suitable connection means such as that schematically illustrated at **23***a*. Hydraulic connection to the control pod **23**, however, is made utilizing the subsea control system C of the preferred embodiment of this invention. Accordingly a second hydraulic supply line **26** is connected to the christmas tree flowline terminal **25***a* and extends into hydraulic connection with a multiple pressure responsive failsafe or sequence valve **27** mounted onto the christmas tree cap **18.** The hydraulic line **26** makes up hydraulic connection with the hydraulic supply **22***a* through the flowline connector **25** in order to provide a fluid input signal to the sequence valve **27.**

The sequence valve **27** is the subject of the previously described U.S. Pat. Application, Ser. No. 464,771, filed Apr. 29, 1974 and invented by Benton F. Baugh. The function of the sequence valve is to receive an input signal through line **26,** which signal may be at various pressures, and provide separate and distinct output signals according to the pressure of the input signal. The sequence valve **27** includes four output modes or paths **27***a*, **27***b*, **27***c*, and **27***d*. The output path or line **27***a* is a hydraulic line extending from the sequence valve **27** to the control pod **23** for the purpose of providing hydraulic fluid under a particular pressure to the control pod **23.** Under normal operating conditions, hydraulic fluid under pressure is provided through the sequence valve **27** and through output line **27***a;* and, the control pod **23** is operated utilizing such hydraulic pressure in line **27***a* in combination with electrical signals sent from the control system **20** to the pod **23.**

The output path or line **27***b* is also a hydraulic line which is connected to a two-way valve or shuttle valve **28** mounted on the tree. The sequence valve output path or line **27***c* is connected to a second shuttle valve **29** and the sequence valve output path or line **27***b* is connected to a third shuttle valve **30.**

The shuttle valves **28–30** are two-way hydraulic control valves such as disclosed on page 4223 of Volume 3 of the Composite Catalog of Oil Field Equipment and Services, 1972–1973. The shuttle valve **28** includes a pod input line **28***a* and an output line **28***b* which is connected with the valve operator **14.** The shuttle valve **29** includes pod input line **29***a* and valve output line **29***b* connected to the valve operator **15**; and, the shuttle valve **30** includes pod input line **30***a* and valve output line **30***b*. The shuttle valve **28** provides an output signal through output line **28***b* to valve operator **14** in response to a fluid input signal from either the pod input line **28***a* or the sequence valve output line **27***b*. Similarly, the shuttle valve **29** provides a fluid output signal to valve operator **15** in response to a fluid input signal either from line **28***a* or from line **27***c*, which is the sequence output line connected to that shuttle valve. The shuttle valve **30** provides the fluid output signal to line **30***b* and thus to valve operator **16** in response to a fluid input signal either from pod input line **30***a* or from sequence valve output line **27***d*.

Thus the valve operators such as **14, 15** and **16** are operable based upon receipt of output signals from the shuttle valves **28–30,** respectively. And, the shuttle valves **28–30** provide output signals in response to fluid input signals from either the control pod **23** or from the sequence valve **27.**

The sequence valve **27** is capable of diverting a fluid input signal through line **26** into any of the four lines **27***a*–**27***d*, depending upon the fluid pressure level of the input signal in line **26.** Further, whenever the fluid input signal in line **26** is diverted through the sequence valve **27** into any one particular output line, for example **27***a*, fluid pressure is not provided through any of the other output lines **27***b*–**27***d*.

In operation and use of the subsea control system C of this invention, the sequence valve is run or lowered onto the christmas tree either with the christmas tree cap or the pod **23.** Upon landing on the tree, suitable hydraulic connectors known in the art connect the sequence valve to the pod **23** and to the shuttle valves **28–30.** In the preferred embodiment, fluid pressure through input line **26** is diverted into the pod input line **27***a* at a first pressure level. This first pressure level is used exclusively during normal operating conditions. Under normal conditions, the subsea control pod **23** receives the fluid pressure through line **27***a* and in cooperation with electrical signals from line **22***b*, controls the application of hydraulic fluid through lines **28***a*, **29***a*, and **30***a* in order to direct fluid into the shuttle valves **28–30** respectively, and thus control the operation of valve operators **14–16.**

If the control pod **23** should fail, the application of fluid pressure at the first pressure level through the line **27***a* to the control pod **23** is of little or no use to actually operate the valve operators **14–16.** When such an emergency condition occurs, the sequence valve **27** may be shifted to a second, third or fourth pressure level in order to operate any of the valve operators **14–16**. For example, upon failure of the control pod **23**, the pressure in supply line **22***a*and hydraulic input line **26** is increased to a second pressure level (higher than the first pressure level), which shifts the sequence valve **27** to a second position wherein the fluid in line **26** is diverted into sequence output line **27***b*. The fluid in sequence output line **27***b* is directed into the shuttle valve **28** and then outwardly through the shuttle output line **28***b*into the valve operator **14** in order to operate the valve connected therewith.

Increasing the fluid pressure level in the supply line **22**a and thus into the input line **26** to a third higher pressure level will cause the sequence valve to shift and divert the fluid at the third pressure level into the shuttle valve **29** through sequence valve output line **27***c*. The fluid diverted into the shuttle valve **29** is then passed through shuttle valve output line **29***b* to valve operator **15** in order to operate the valve connected therewith. In a similar manner, the valve operator **16** can be actuated by increasing the fluid pressure level in lines **22***a* and **26** to a fourth pressure level higher than the three previous pressure levels thereby causing the sequence valve **27** to shift and deliver the fluid under pressure through line **27***d* into shuttle valve **30.** As has been previously explained, each of the shuttle valves such as **28** acts to provide an output fluid signal through output line such as **28***b* in response to a fluid signal through either of the input lines such as **28***a* or **27***b*. In this manner, the sequence valve **27** may be utilized to override the subsea control valve pod **23** whenever necessary.

The sequence valve **27** may also be connected to the control pod **23** such that, under normal operating conditions, fluid pressure in lines **22***a* and **26** is diverted into the pod input line **28***a* when the fluid pressure is at a fourth, highest pressure level. Under these circumstances, the sequence valve is utilized to deliver hydraulic fluid under pressure to any of the three shuttle valves **28–30** whenever the fluid pressure in lines **22***a* and **26** is reduced to a third, second or first pressure level, all of which are consecutively lower than the fourth, highest pressure level. This mode of operation is particularly advantageous when the control pod **27** may fail due to a pressure leak which might cause difficulties in increasing the pressure in the sequence valves sufficiently to a second, higher pressure level to move it out of its first position.

In the preferred embodiment of this invention as stated herein, the subsea control system C has been described in terms of controlling the valves on a christmas tree T. It should be understood, that the same principles apply to any remote, underwater wellhead installation including a blowout preventer stack mounted at the wellhead during drilling operations. It is noted that the mounting of the sequence valve on the christmas tree cap **18** allows the control pod **23** to be removed and repaired while the sequence valve is used to operate the tree T.

The foregoing disclosure and description of the invention are illustrative and explanatory thereof, and various changes in the size, shape, and materials as well as in the details of the illustrated construction may be made without departing from the spirit of the invention. For example, it should be understood that the sequence valve **27** can be run or lowered onto the christmas tree T with the pod **23**, itself instead of with the tree cap **18.** In either event, the sequence is removable and retractable from the tree T. Also, the signal output lines such as **27***b* for the sequence valve **27** can be connected to more than one valve operator if desired.

I claim:

1. A new and improved subsea control system for operating a wellhead valve system at a subsea wellhead installation, comprising:

a wellhead valve system having various valve operators mounted therewith for normally operating and controlling flow through said wellhead valve system, said wellhead valve system including an electro-hydraulic control pod for normally operating said various valve operators;

two-way hydraulic control valves mounted with said wellhead valve system;

said control pod being hydraulically connected to said various valve operators through said two-way valves;

a multiple pressure responsive failsafe valve connected to said two-way hydraulic control valves and to said control pod, said multiple pressure responsive valve providing various distinct fluid output signals in response to a change in pressure of a single fluid input signal;

a surface control means and a single hydraulic control line extending into hydraulic connected with said multiple pressure responsive valve in order to deliver a variable fluid input signal from said surface control means to said multiple pressure responsive valve; and

said multiple pressure responsive valve including means providing an output operating signal to said hydraulic control pod under normal operating conditions and further, providing output signals directly to said two-way valves for operating said valve operators under emergency conditions.

2. The structure set forth in claim **1**, including:

ssaid surface control means and said single hydraulic control line including means for delivering a first fluid input signal to said multiple pressure responsive valve which delivers a first fluid output signal to said control pod, said control pod utilizing such first fluid output signal for delivering valve operating signals to said two-way valves for operating said valve operators under normal conditions.

3. The structure set forth in claim **2**, including:

said surface control means and said hydraulic control line providing a second fluid input signal to said multiple pressure responsive valve, which includes means for delivering said second input signal to at least one of said two-way valves for directly operating at least one of said valve operators.

4. The structure set forth in claim **3**, including:

said multiple pressure responsive valve including means for closing off the delivery of said fluid to said control pod in conjunction with said delivery of fluid to one of said two-way valves.

5. The structure set forth in claim **3**, wherein:

said first fluid input signal is at a higher pressure than said second fluid input signal.

6. The structure set forth in claim **3**, wherein

said second fluid input signal is at a higher pressure than said first fluid input signal.

7. The structure set forth in claim **1**, including:

said two-way valves delivering fluid pressure signals from either said pod or from said multiple pressure responsive valve to said valve operators.

8. The structure set forth in claim 1, including:

said multiple pressure responsive valve being landed with said control pod onto said christmas tree.

9. The structure set forth in claim 1, including:

said multiple pressure responsive failsafe valve being landed separable from said pod such that said well can remain operating through said sequence valve with said pod removed.

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