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METHOD OF LOGGING WELLS

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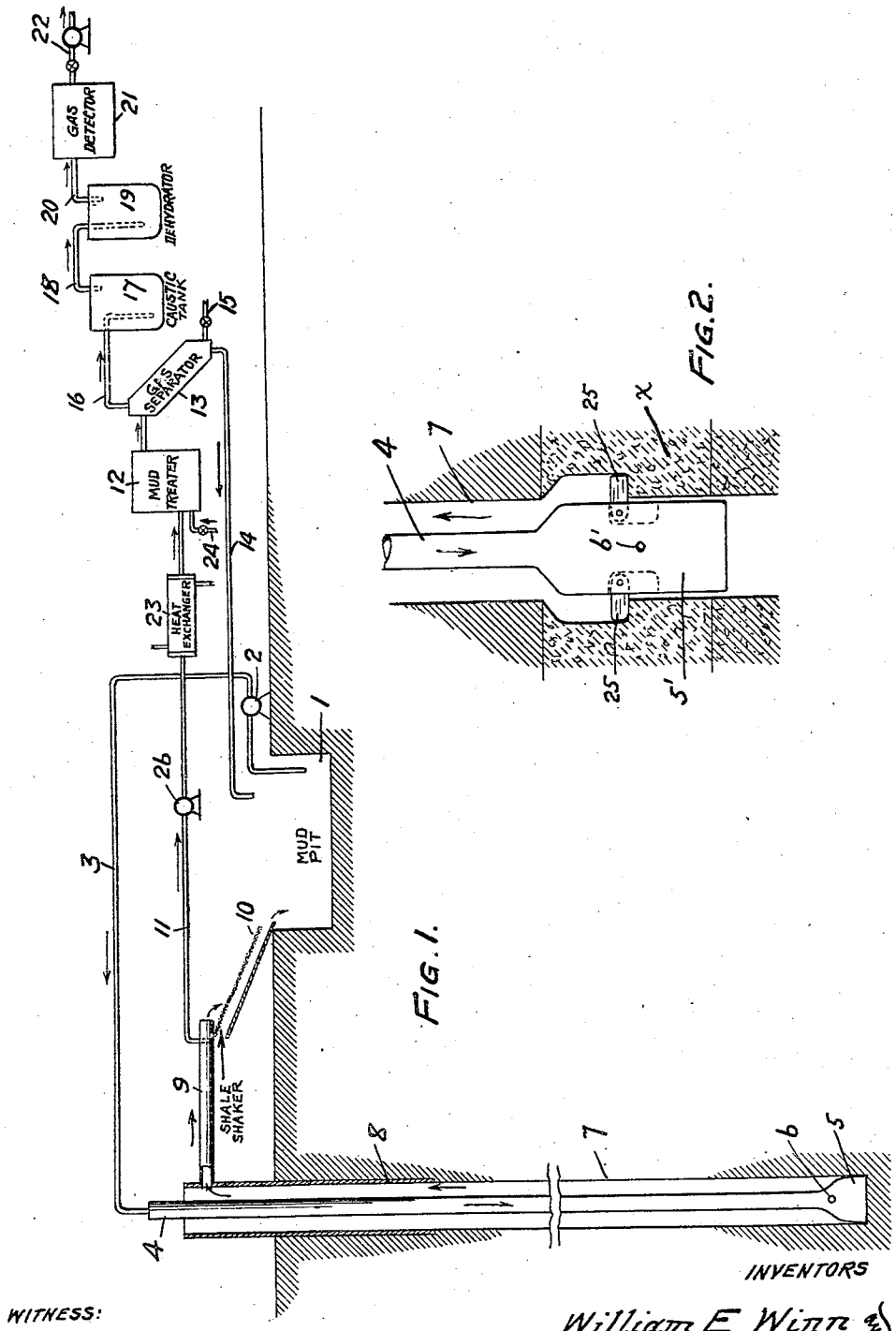


FIG. 1.

FIG. 2.

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METHOD OF LOGGING WELLS

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3 Claims. (Cl. 23—232)

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The present invention relates to a method of drilling oil and gas wells and is particularly directed to a method of detecting the presence of hydrocarbons in the strata traversed by a drill while a well is being drilled.

It has long been the practice in drilling to inspect and examine the mud fluid returns from a well in order to determine the nature of the strata being traversed by the drill and also the character of the fluid contents, if any, of such strata. The present invention is directed to an improvement in the method of detecting and determining the amount of hydrocarbons present in the mud fluid returned from the well and also the presence and amount of such hydrocarbons in the strata traversed by the drill, and is particularly directed to a method of detecting the presence of low molecular weight hydrocarbons in the strata traversed by the drill.

In the drilling of oil and gas wells by the rotary method it is customary to circulate a mud laden fluid down through the drill pipe, out through openings, generally called eyes, in the drill where the mud laden fluid exerts cooling and lubricating action on the drill and also picks up and suspends cuttings formed by the action of the drill, the mud with the cuttings suspended therein then returning to the surface through the annular space between the drill pipe and the wall of the bore hole or casing if casing has been set. At the surface the stream of mud fluid is passed over a shale shaker, which is merely a vibrating screen, in order to separate the coarser cuttings from the drill fluid. The fluid passes through the shale shaker, flows to a mud pit where it is picked up by the pumps, and is again forced down the drill pipe.

Since it is the common practice to maintain the drilling fluid at a specific gravity such that the hydrostatic head of drilling fluid at the bottom of the hole will be greater than any fluid pressure apt to be encountered in the formations traversed by the drill there is very little, if any inflow of fluids from the formations into the drilling fluid. Consequently the amounts of gases or other hydrocarbons mixed with the drilling fluid from the formations traversed by the drill are usually small, and their detection at the surface is frequently accompanied with many difficulties.

It is well known that the properties and characteristics of the drilling mud are affected by the nature of the material introduced to the drilling fluid in the form of cuttings from the formations traversed by the drill. Thus, when the drill is passing through a formation having a high content of colloidal material (for example a stratum of bentonitic clay) the mud fluid which is circulated past the drill while it is traversing such a stratum will have added to it, in the form

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of cuttings from the drill, such an amount of colloidal material that its viscosity will be substantially increased. Conversely when the drill passes through a formation having a high salt content the drilling fluid will become so saline that the clay particles therein will be flocculated and the viscosity of the drilling fluid will be decreased materially. Due to these and other causes, among which may be mentioned the deliberate variations of the properties and characteristics of the drilling fluid, by chemical or other treatment, to meet conditions encountered in drilling, the properties and characteristics of the mud fluid issuing from the well, i. e. at the point at which it is generally examined, are subject to rapid and large variations, and in time the entire amount of drilling fluid being circulated will be altered in character.

We have discovered that such variations in the properties and characteritics of the drilling fluid will cause serious errors in analysis of the drilling fluid. Thus, a highly viscous mud containing a certain amount of hydrocarbons, for instance gas, will, in most methods of analysis, show a different gas content from that of a thin mud having the same actual gas content.

It is an object of this invention to provide an improved method for examining drilling fluids and particularly for detecting and analyzing hydrocarbons in drilling fluids obtained from a bore hole.

A more detailed object of the invention is to provide a method for analyzing and detecting the presence of hydrocarbons in a drilling fluid which will materially decrease the errors in analysis caused by variations in the properties and characteristics of the drilling fluid.

Other further objects will be apparent as the description progresses.

For better understanding of the present invention, reference should be made to the accompanying drawing, Fig. 1 of which is a diagrammatic representation of a well being drilled in accordance with the present invention, while Fig. 2 is a representation of a slight modification of our invention.

In the drawing 1 designates a mud pit, from which mud is withdrawn, by pump 2, and forced through line 3, down the drill pipe 4 to the drill bit 5. The mud issues through eyes 6 in the bit and cools or lubricates the bit and picks up the cuttings. The mud, with cuttings suspended therein, ascends in the annular space between the walls of the bore hole 7 and the drill pipe 4. The lower portion of the drill hole 7 is shown as being uncased while a string of surface casing 8 has been set in the upper portion. At the surface the mud from the annular space between the drill pipe and surface casing, 4 and 8 respectively, flows through line 9 to a shale shaker 10, the mud pass-

ing through the shale shaker and being returned to the mud pit 1 while cuttings are separated out on the shale shaker and are removed therefrom. A portion of the mud is withdrawn from the stream of mud fluid issuing from the well preferably before the mud fluid reaches the shale shaker, as illustrated in the drawing. This portion of the mud fluid is withdrawn through line 11 by pump 26 and passes therethrough to a heat exchanger 23, wherein the mud may be either heated or cooled to a predetermined temperature. Thence the mud fluid flows to a mixer 12 where it may be chemically treated, as hereinafter more fully explained, by adding chemical or other treating agents thereto through line 24. Suitable means (not shown) are provided in mixer 12 to thoroughly agitate and mix the treating agents added through line 24 with the mud fluid. From the mixer 12 the mud fluid passes to a stripper 13 wherein light hydrocarbons present in the mud fluid may be separated therefrom. The mud fluid, stripped of light hydrocarbons, is discharged therefrom to a line 14, either being disposed of as waste or returned to the mud pit 1. A suitable agent for removing hydrocarbons, which will hereinafter generally be referred to as a gas, is introduced in the stripper 13 through line 15 and bubbled up through the mud fluid therein and is removed therefrom through line 16. In passing through the mud fluid the gas will strip out hydrocarbon gases present in the mud flow and possibly also low boiling liquid hydrocarbons. The gas with hydrocarbons stripped from the mud flows through line 16 to a caustic treating tank 17 where it is bubbled through a solution of caustic soda or other suitable alkali, thence it flows through line 18 to a dehydrator 19 and thence through line 20 to a gas detector or analyzer 21, whence it may be vented to the atmosphere through line 22.

As heretofore stated, it is well known in the art that as drilling progresses the character and properties of the mud flow are subject to wide variations due both to the character of material mixed with the mud flow from the formations penetrated by the drill and also due to deliberate variations in the character and property of the mud fluid by chemical or other treatment. We have discovered that when a gas is bubbled through the mud fluid being analyzed for the presence of light hydrocarbons the variations in the characteristics of the mud fluid do not affect the results obtained as greatly as when other methods for removing the gaseous or other light hydrocarbons from the mud flow are employed.

There are three possible means by which the gaseous or other hydrocarbons may be held in the mud fluid: (1) by suspension in the form of minute bubbles of free gas or oil droplets, (2) by absorption in the liquid portion of the mud fluid, and (3) by adsorption on the surface of solid particles dispersed in the mud fluid. By means of methods known heretofore, such as methods employing heat and/or vacuum for driving out the hydrocarbons, it has been very difficult to remove substantially all of the gaseous and light liquid hydrocarbons present in the various forms and the amount of such hydrocarbons retained by the mud has been subject to variation depending on the properties of the mud fluid. Thus, when the mud was relatively viscous, the content of removable hydrocarbons as determined by these known methods was substantially less than when the mud was more fluid. Such methods are thus unreliable and give erroneous indications as to variations in light hydrocarbon content.

We have discovered that by passing gaseous carbon dioxide through the mud fluid we are able more readily to remove the light hydrocarbons therefrom, so that the effect of variations in the properties of the mud fluid, resulting in variations in its ability to retain light hydrocarbons, is minimized. Since changes in relative amounts of hydrocarbons in the mud fluid serve as well as absolute amounts to indicate differences in the nature of the strata penetrated, the use of carbon dioxide as the stripping agent permits determining relative amounts of light hydrocarbons indicative of the nature of the formations penetrated, such determinations varying more in accordance with the hydrocarbon content of the formation and less in accordance with variations in properties of the mud than by methods heretofore employed.

Certain other gases, for example, air, steam, methane or ethane, may be employed for stripping out the hydrocarbons. However, it has been found that these other gases are much less effective in removing the hydrocarbons than carbon dioxide. Accordingly, if such other gas is used as the stripping medium, a much larger proportion of gas is required to minimize variations in the amounts of removed hydrocarbons caused by changes in the properties of the mud than would be the case if carbon dioxide were employed and, consequently, the time required for treating a given amount of mud fluid is unduly prolonged. It is not known precisely why carbon dioxide is so much more efficient in removing the hydrocarbons than other gases, but among the possible reasons may be mentioned the following: (1) the relatively high solubility of carbon dioxide in water which allows it to dissolve in the water of the mud fluid and displace hydrocarbons dissolved therein; and (2) the high adsorptive power of clay or sand particles for carbon dioxide as compared to other gases which results in the displacement, by the carbon dioxide, of hydrocarbons adsorbed by the solid matter in the mud fluid. Perhaps, also, the relatively high solubility of carbon dioxide in oil, even as compared to gaseous hydrocarbons such as methane or ethane, may play a part. It should be understood, however, that these reasons are proposed only as possible explanations of the effectiveness of carbon dioxide and that we do not wish to be bound by such theories.

Carbon dioxide has another advantage over most other gases that may be employed for stripping out the hydrocarbons in that it may easily be separated from the hydrocarbons, subsequent to their removal from the mud fluid, by absorption in alkali, thus permitting the hydrocarbons to be tested separately. Also, if it is desired to analyze the removed hydrocarbons without first separating the stripping agent therefrom, as by the well known combustion analysis, carbon dioxide is particularly satisfactory since it will not undergo combustion to liberate heat interfering with the analysis. Further, if it is desired to use known spectral methods of analysis such as by the mass spectrograph or infra-red analysis, carbon dioxide will not interfere with such analysis so that it need not be first removed.

It is therefore preferred to use carbon dioxide as the gas which is introduced through line 15 into the stripper 13. This carbon dioxide with the hydrocarbons stripped from the mud fluid passes through line 16 and may be analyzed in any

known or desired manner. As illustrated in the drawing, it may be passed to caustic treating tank 17 wherein it is bubbled through a solution of sodium hydroxide or other alkali. The carbon dioxide, by reacting with the alkali in caustic treating tank 17, is removed from the separated hydrocarbons and hydrocarbons pass through line 18 to dehydrator 19 where they pass through a body of calcium chloride or other dehydrating agents and thus only hydrocarbons are sent to the gas detector or analyzer 21, wherein their amount and character may be determined. It is, of course, to be understood that if some other gas or vapor is employed in place of carbon dioxide suitable means for separating the gas from the hydrocarbons admixed therewith may be provided. For instance, if air is used as the stripping medium, the mixture of air and hydrocarbons passing from the stripper 13 through line 16 may be subjected to a step designed to separate the hydrocarbons from the air, for example, to a distillation step. Likewise, if steam is employed as the stripping medium, the mixture of steam and hydrocarbons issuing from the stripper 13 may be passed directly to dehydrator 19 in which the water vapor is removed, the dry hydrocarbon vapors passing out of dehydrator 19 through line 20 to gas detector 21. In case hydrocarbon gas is used as the stripping medium, the gas removed from the stripper 13 through line 16 is subjected to a type of analysis in which the various individual hydrocarbon gases are determined. Thus, if methane is introduced through line 15, the hydrocarbon gases removed through line 16 will be subjected to the analysis required to separately determine the amount of methane and the amount of ethane and any higher members of the series, the latter determination identifying hydrocarbons present in the mud. If it is desired to determine the amount of methane present in the mud fluid, ethane may be introduced through line 15 to gas separator 13 and the ethane and methane removed through line 16, separated and the amount of methane in the mud fluid determined. However, it is distinctly preferred to use carbon dioxide since, as stated, this has great effectiveness in removing the light hydrocarbons from the mud fluid, and the apparatus for practicing the illustrated embodiment of the invention has been shown and described particularly for the use of carbon dioxide.

In order to still further reduce the effect of variations in the properties and characteristics of the mud fluid on the detection of gaseous or other light hydrocarbons therein, we have provided the treater or mixer 12 in the line 11 through which the mud passes. As the mud fluid passes through the treater 12 suitable and conditioning chemicals, or preferably solutions thereof, may be added thereto by introducing them through valved line 24 and mixing them therewith. We are thus able to control the viscosity, salinity and other characteristics and properties of the mud fluid within a fairly definite or fixed range. For instance, the visocity of the mud may be controlled by adding aqueous solutions of various alkali metal phosphates in the well known manner, or at times merely by the addition of water or of concentrated solutions of suitable salts the salinity may, of course, be readily controlled. Numerous specific methods of controlling various properties and characteristics of the mud fluids used in drilling are well known and such specific methods do not form a part of the present invention. Also, by means of heat exchanger 23 we can maintain

the temperature of the mud fluid being analyzed substantially uniform. Thus, substantially uniform conditions are maintained on the mud being analyzed throughout the drilling operation or changes in the properties and characteristics of the mud can be caused to occur gradually so that the results of the analysis of the mud vary only in accordance with the amounts of gaseous or other light hydrocarbons in the mud and not in accordance with variations in the aforesaid characteristics and properties affecting the ability of the mud to retain hydrocarbons. In other words predetermined substantially uniform hydrocarbon-retentive properties are imparted to the mud prior to the stripping operation in stripper 13, thereby facilitating the determination of a light hydrocarbon content indicative of the nature of the formation penetrated regardless of variations during drilling in the properties of the mud which affect its ability to retain light hydrocarbons.

While the present invention has thus far been described in connection with the detection of hydrocarbons in the strata traversed by a drill during the drilling of a well, it frequently is desirable to log the formations traversed by the drill after a well has been completed. For instance, during the course of drilling the well 7, certain strata may have been passed through by the drill bit which showed promise of being oil or gas producing formations and it may be desired to obtain additional information concerning the strata; or an electric survey may be run in the well 7 which indicates that certain strata were passed through by the drill which were not located by other logging means, and it is, therefore, desired to obtain cuttings from such formations in order to more fully determine their value. Regardless of the reason for which it is desired to obtain additional information concerning any particular formation, this information may be obtained in the following manner.

The bit 5 is replaced by an under-reamer 5' (Fig. 2), and the drill pipe 4 with the under-reamer 5' secured to the end thereof is lowered into the well 7 until the cutters 25 on under-reamer 5' are opposite the formation x concerning which information is desired. Drilling mud is circulated from mud pit 1 by pump 2 through line 3 down drill pipe 4 and issues from openings or eyes 6' in the under-reamer 5' and near the cutters 25 thereon. The drill pipe is rotated in the usual manner so that the cutter 5' will undercut the walls of well 7 in the usual manner. The drilling mud circulated down drill pipe 4 returns to the surface in the annular space between drill pipe 4 and the walls of well 7 carrying suspended in it the cuttings from the walls of well 7 at the formation x formed by the action of the under-reamer 5'. The drilling mud issues from the well through line 9 and a portion thereof is withdrawn through line 11. The treatment of the drilling mud passing through line 11 will be the same as that heretofore described, and the mud is subjected to analysis to detect the presence of hydrocarbons therein from the cuttings from formation x obtained by the action of under-reamer 5'. If desired, the cuttings may be separated from the mud by usual methods, for instance, by the shale shaker 10, the cuttings washed and subjected to detailed analysis in order to obtain additional information concerning the nature of the formation x.

This method of operation permits the analysis of mud returns from particular portions of the

bore hole and thus makes it possible to make a more detailed and careful study of the more promising strata traversed by the bore hole, and also permits a check to be made on the survey made during drilling in case there are any indications that such survey was not accurate for some reason, for instance, due to a partial breakdown of the apparatus, or the like.

At times it may be desirable to use the latter method of analysis exclusively. In this case an electrical survey may be made of the well and the most promising formations under-reamed and logged in accordance with the present invention, to thereby obtain the detailed information concerning the nature of the strata traversed by the bore hole and their fluid contents. This method of operation frequently permits a substantial saving to be made in the cost of drilling a well, since the special apparatus necessary for mud analysis and the trained operators and engineers required for its operation, need be employed at any particular well for only a limited time and thus a single crew can log a number of wells being drilled simultaneously in contrast to the usual requirement of an expensive crew for each well during the entire course of drilling. Further savings are made possible since it is unnecessary to conduct the original drilling of the well in any special manner in order to facilitate the analysis of mud and the well may be drilled and completed in the most economical and expeditious manner.

As thus far described, our invention relates to detecting and determining the hydrocarbons in the mud fluid. However, it is recognized that much useful information can be obtained by determining the viscosity and salinity and other properties of the mud as it issues from the well, both by itself and also in conjunction with a determination of these same properties of the same component of the mud as it enters the well. Therefore, it is contemplated that we may either continuously or intermittingly obtain samples of the mud fluid issuing from the well through line **9** and determine the properties and characteristics of this mud fluid before it is subjected to any treatment hereinbefore specified. Also, samples of the mud from line **3** as it enters the well may be continuously collected and subjected to analysis to determine the properties and characteristics of this mud. Likewise the rate of flow of the mud fluid should be noted and recorded in order that in conjunction with the depth of the well the depth at which any component member of the mud fluid passes the bit **5** may be determined. It is also to be noted that much useful information can be ascertained by determining the nature and properties of the cuttings separated from the mud fluid by shale shaker **10**. However, we do not herein claim the analysis of such cuttings since this is a feature of our co-pending application, Serial No. 407,956.

It is well known in the art of drilling wells, that in determining the depth at which any material from the formations traversed by the drill enters the mud stream, allowance must be made for the time necessary for the drilling mud to travel from the drill to the surface, and the distance that the drill has advanced during the interval that a particular portion of the mud fluid was travelling to the surface must be subtracted from the depth at which the drill is operating when this portion of the mud fluid reaches the surface,

in order to accurately determine the depth at which the particular portion of the mud fluid under consideration passed the drill. However, various methods of determining and making allowance for this lag in the returns of mud from the drill are well known and, since they form no part of the present invention, they are not herein described.

What we claim and desire to protect by Letters Patent is:

1. The method of logging oil and gas wells that are drilled with the aid of a circulating drilling fluid in order to determine a light hydrocarbon content of the drilling mud emerging from the well indicative of the nature of the formation penetrated regardless of variations during drilling in the properties of the mud causing variations in its ability to retain hydrocarbons, which comprises diverting a minor portion of the circulating drilling fluid from the main stream, subjecting said minor portion to a treatment which comprises the addition thereto of materials which will impart uniform hydrocarbon-retentive properties to the minor portion under the same fixed standard external conditions of stripping, subjecting the thus treated drilling fluid to the stripping action of a gas to remove hydrocarbons, separating the mixture of stripping gas and hydrocarbons from the drilling fluid and subjecting said mixture to further treatment including an analysis to determine the amount of removed hydrocarbons.

2. The method of logging oil and gas wells that are drilled with the aid of a circulating drilling fluid in order to determine a light hydrocarbon content of the drilling mud emerging from the well indicative of the nature of the formation penetrated regardless of variations during drilling in the properties of the mud causing variations in its ability to retain hydrocarbons which comprises diverting a minor portion of the circulating drilling fluid from the main stream, subjectng said minor portion to a treatment which comprises the addition thereto of materials which will impart uniform hydrocarbon-retentive properties to the minor portion under the same fixed standard external conditions of stripping, subjecting the thus treated drilling fluid to the stripping action of carbon dioxide, thereby effecting the removal, with the carbon dioxide, from the drilling fluid, of hydrocarbons, and subjecting the carbon dioxide with the hydrocarbons admixed therewith to further treatment including an analysis to determine the amount of removed hydrocarbons.

3. The method of logging oil and gas wells that are drilled with the aid of a circulating drilling fluid in order to determine a content of light hydrocarbons in the drilling mud emerging from the well indicative of the nature of the formation penetrated, which comprises diverting a minor portion of the circulating drilling fluid from the main stream, subjecting said minor portion of the drilling fluid to the stripping action of carbon dioxide, thereby effecting the removal, with the carbon dioxide, from the drilling fluid, of hydrocarbons, and subjecting the carbon dioxide with the hydrocarbons admixed therewith to further treatment including an analysis to determine the amount of removed hydrocarbons.

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