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Effect of Sand invasion on Oil Well Production: A Case study of Garon Field in the Niger Delta

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ABSTRACT

The effect of sand and other BS&W invading the wellbore of an oil well has been studied using Garon field in the Niger Delta region. Garon field has unconsolidated formation and it has been producing for more than 10 years. This study is carried out to quantify the safety and economic effect of sand invasion on well productivity and not on the techniques in numerical models for the prediction of sand production. It tries to look out the sand evolution, analysis of previous well test done and a survey of sand identification, results of some wells production data and evaluation of the effect of sand invasion on subsurface and surface production facilities. In this study, Well X17 was routed into a test separator for 3days and immediately tested for 72hours. The test separator man way opened in other to ascertain the quantity of sand produced from the well for 72Hrs to validate the result obtained with Clampon DSC. Also presented are the effects of sand invasion on surface facility, choke, screen and tubing.

Keywords *– Well productivity, sand invasion, Wellbore, Unconsolidated formation, test separator, surface facilities, choke, screen and tubing.*

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I. INTRODUCTION

The probability/tendency of producing hydrocarbon from reservoirs to the surface production facilities in a safe and economical way without the inclusion of sand is very low from a typical Niger Delta field due to the unconsolidated nature of the formation. To maximize profit in this region, it is crucial to identify all the possible problems that affect the productivities of the wells drilled into the reservoir and sand production is one of these problems plaguing the production aspect of the oil industry. Moreso, geological formations that are shallow with little or no natural adherence to hold the individual sand grains together are normally prone to sand production but in some areas, sand problems may be encountered in high depths (Adams, 1986). To effectively control the invasion of sand, we need to have technology to estimate accurately the initiation conditions, predict the sand influx rate and the volume of sand production to prevent its effect on surface and subsurface production facilities which directly impact on the oil well productivity. Oluyemi and Oyeneyin (2010) stated that the economic, operational and safety implications of sand failures require real time efficient sand management. Since the effect of sand on facilities is costly, Coberly (1941) noted that expenditures of this magnitude obviously have a significant impact on profits. In spite of these costs, effective sand-control practices have yielded oil and gas from wells that otherwise would have been shut- in.

The rationale behind sand production is that; as soon as the well begins production of fluids, depending on the formation type and other factors, a point is reached when sand mobilization sets in. Sand production in oil and gas wells can occur if fluid flow exceeds a certain point governed by factors such as consistency of the reservoir rock, stress state and the type of completion used around the well, this happens when the wellbore pressure is lower than reservoir pressure, because drag forces are applied to the formation sand sequel to fluid production. The sand production takes place if the sand grains around the cavity is disaggregated and as the volume of sand dislodged is deposited and accumulated on production equipment continuously, cleaning will be required to allow for efficient production of the well. To restore production, the well must be shut-in, the surface equipment opened, and the sand must be manually removed. In addition to the clean out cost, the cost of the deferred production must be considered.

The design of the surface separator is to handle liquid and not sand production which essentially has no economic value with adverse effects on well productivity and equipment. This is one of the major challenges that is facing the petroleum industry especially the production operations in many oil fields in Nigeria whose formation is unconsolidated and some other countries such as US gulf coast, California, Indonesia, Trinidad, Venezuela, and Libya. If a separator is partially filled with sand, the capacity of the separator to handle oil, gas and water is reduced. For instance, in a two phase separator (oil/water), for every 5000 barrel of liquid per day on average is accompany by a corresponding 0.03 pptb of sand per day. It implies that at the end of say 6 months the separator must have accumulated about 5.472 pptb of sand and if this continues, an appreciable volume of the separator designed to handle liquid must have been partially filled with sand. In Garon field used as a case study, well X17 was routed into Test separator with the Test separator pressure set point at 20Bar. The well was routed out of Test separator after three (3) days. The well was tested for 72Hrs at 65/64" choke size. On the second day, test separator man way was opened in other to ascertain the quantity of sand produced from the well for 72Hrs. results are shown in Figures 2-6.

II. CAUSES OF SAND PRODUCTION

The causes of sand production can occur naturally as a result of the unconsolidated nature of the formation or by the activities on the well imposed by humans because there are only two ways to disturb a reservoir which are via production of fluid from it or injection of some fluid into it. When this happens, it causes agitation of the formation loose fines to disintegrate from the rock grains and as such leads to sand production along with hydrocarbon fluid. As stated by Anderson et al, (1986) that mechanical rock failure can be caused by any or more inherent rock strength, naturally existing earth stresses and additional stress cause by drilling or production. In totally unconsolidated formations, sand production may be triggered during the first flow of the formation fluid due to drag from the fluid or gas turbulence which detaches sand grains and carries them to the perforation. In the case of the unconsolidated formation, sanding can start due to changes in production rate, water breakthrough, change in gas/liquid ratio etc.

Therefore, these causes can be lead to several problems during the life time of the wells drilled in a particular reservoir which is a major production engineering problem. These can lead to one or more of the following complications:

- Formation damage or collapse by the flowing sand grains
- Wellbore instability
- Casing collapse
- Impairment or failure of down hole and surface equipment
- Lost production time due to shut in of the well to change damage equipment or clean the sand filled wellbore.
- Work-overtime and expense to service the well and production equipment
- Coiled tubing cost and possible complications
- Cost of separating sand from the produced fluid
- Environmental problems in the disposal of the produced dirty sand Fjaer, et al (1992)
- Cost of sand disposal and control measures at the pay zone

III. Collapse of the formation as result of sanding

Large volumes of sand may be carried out of the formation with produced fluid. If the rate of sand production is great enough and continues for a sufficient period of time, an empty area or void will develop behind the casing that will continue to grow larger as more sand is produced. When the void becomes large enough, the overlying shale or formation sand above the void may collapse into the void due to a lack of material to provide support. When this occurs, the sand grains rearrange themselves to create a lower permeability than what originally existed. This will be especially true for formation sand with a high clay content or wide range of grain sizes. For formation sand with a narrow grain size distribution and/or very little clay, the rearrangement of formation sand will cause a change in permeability that may be less obvious. In the case of overlying shale collapsing, complete loss of productivity is probable and in other cases, continued long term production of formation sand will usually decrease the well's productivity and ultimate recovery. The collapse of the formation is particularly important if the formation material fills or partially fills the perforation tunnels. Even a small amount of formation material filling the perforation tunnels will lead to a significant increase in pressure drop across the formation near the well bore for a given flow rate

IV. PREVIOUS STUDIES

Sand management has been identified as one of the key issues in field development in over 70% of the world's oil and gas fields. Sand management is not just about selection of sand control systems, it is about maximizing and maintaining production while managing sand at acceptable rates. Operators spend millions of dollars each year to prevent the production of formation sand and to deal with other sand related problems. Expenditures of this magnitude obviously have a significant impact on profits. In spite of these costs, effective sand-control practices have yielded oil and gas from wells that otherwise would have been shut- in (Coberly, 1941).In considering sand control or formation solids control, one must differentiate between load-bearing solids and the fine particles (fines) that are not usually a part of the mechanical structure of the formation. Some fines are probably always produced with the well fluids, which in fact, are beneficial, if fines move freely through the gravel pack, they will not plug it, and thus, sand control" actually refers to the control of the loadbearing particles, those that support the overburden. The critical factor to assessing the risk of sand production from a particular well is whether or not the production of load bearing particles can be maintained below an acceptable level at the anticipated flow rates and producing conditions which will make the well production acceptable (Penberthy and Echols, 1993)

Opposing the fluid forces are the resulting forces that act to hold sand grains in place. These forces arise from inter-granular bonds (natural consolidation), Inter-granular friction, a gravity forces and capillary forces. Internal pore pressure (reservoir pressure) helps support the weight of the overburden, thereby acting to relieve some of the stress on the sand grain. Of these forces, the inter-granular bonds are the most important factor in preventing sand production. The compressive strength of formation sand is probably the best measure of the intergranular bond (Penberthy and Shaughnessy, 1992). If good completion and production practices are followed, formation with a compressive strength exceeding 1000 psi will generally produce sand free. The exception is the case where the pressure drawdown around the well is high. If the pressure drawdown is low, however, sands with much lower compressive strength may also produce sand free. If an oil well is produced at a desired production rate which causes the well flowing pressure to be lower than formation collapse pressure, the formation consolidation breaks down, and sand tends to move toward the wellbore (Sanfilippo et al., 1997 and Suman et al., 1991)

It is no longer news that severe operational problems could result from the production of formation sand. These problems range from erosion and damage of downhole and surface equipment such as valves, pipelines, separators etc. to inhibition of production through well clogging. These issues could be mild or severe depending on the flow rate and viscosity of the produced fluid, and the rate of production and accumulation of fines and sand grains. Sand production costs oil companies tens of billions of dollars yearly (Wu and Tan 2005).

V. CHALLENGES AND CONSEQUENCE OF SAND PRODUCTION

Sand production is predominant in the Niger Delta because almost all the oil and gas reserves are located within the tertiary Agbada sandstones and the upper Akata formation (Adeyanju and Oyekunle, 2010). It is quite challenging to complete wells in this region in such a manner to keep formation sand in place without unduly restricting productivity. When wells sand-up, the productivity can decline, disposal of produced sand is a significant cost associated operation. Remedial procedures require hours of rig time. Extreme cases with catastrophic failures have shown massive sanding and well abandonment. In high-rate wells, sand can be transported to the surface and cause casing collapse, erosion of lines, joints, chokes, and valves. This poses serious safety risks to the workers. When sand production is identified, operators need monitoring devices and disposal systems in addition to remedial treatment or recompletions. In certain cases, such as heavy oil recovery, sand production is a deliberate production strategy and is utilized to enhance production.

The failure to develop an accurate sand production models; has costs the oil and gas industry hundreds of millions of dollars per year to either repair or reinstall affect equipment. As an oil field depletes, stress and pressure change in the reservoir. Water and gas breakthrough may occur which result to production decline. All these challenges have increase the propensity of sand production, limit production rates and bring forward the abandonment time of the field, premature failure of the wellbore, improper well completion and the production of unconsolidated formation. Also, sand may fill up the wellbore thus choking back the productivity or fills up the process system thereby halting the production operations due to the removal of sand or even system tripping; it erodes well equipment and facilities, causing breakdown and sometimes even blow outs. Sand production is a major risk to safe and economical operations. Therefore, casing may collapse; increase in the pressure drawdown along the well length as a result of high sand production. Table 1 presents some of the problems encounter from the reservoir to surface equipment.

Table 1: Sand problems encounter from reservoir to surface equipment

AREA	PROBLEM	EFFECT
Reservoir	Wellbore Fill	Access restricted to production interval Loss of productivity Loss of reserves
Surface Equipment	Sand Fouling	Malfunctioning/damage of DHSV Difficult Wireline operation
	Erosion	Frequent equipment failure Frequent equipment
Surface Installation	Sand Accumulation	Malfunction of control equipment Loss of capacity Unscheduled shut-downs Deferred production Sand separation and disposal

VI. OBJECTIVES OF STUDY

- To study the effect of sand production on the oil productivity and surface and subsurface facilities from sand producing wells.
- To determine the quantity of sand produced from the well for 72Hrs @ choke 65/64" on 2" choke trim.
- Compare the produced sand with the previous quantity (350 litres) produced from the same well for 72Hrs at 64/64" on 1"choke trim.
- To compare produced sand recovered from the test separator with that of Clampon sand sensor reading for the same period of 72 Hrs.

VII.RELEVANCE OF RESEARCH WORK

The aspect of research work on the effect of sand production in an Oil and gas well productivity cannot be over emphasized. It is no doubt that Nigeria (Niger Delta) is among the leading oil producers. Therefore, in other to produce these fields in a safe and economic way, a real time monitoring device should be installed and an adequate control measure in the case of sand influx. Hence, this work is important to:

- Increasing productivity index
- Increase personnel safety
- Protect surface equipment from destruction
- Prevent the collapse of subsurface equipment (tubing).
- Prolonged life of the reservoir for greater production-output by managing operational parameters.
- Reduced workover and operational costs from catastrophic breakdown of well and/or reservoir.

VIII. RESEARCH METHOD

In the study on "Garon field," a risk assessment was performed and sand management strategy was defined. This strategy contains a series of high level statements which will describe sand production, erosion assessment, sand monitoring system and inspection as shown in Figure 1. This strategy means that all wells producing sand will be equipped with down-hole sand control and that a monitoring system is in place to check the integrity of sand control equipment. In the event of down-hole sand control failure, a series of actions should be identified to mitigate the effects of sand production.

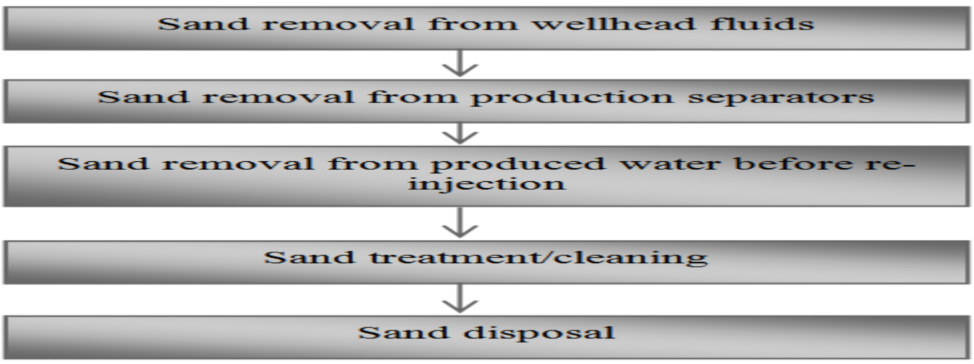

Figure 1: sand management equipment brake down processes

X. RESULTS AND DISCUSSION

Surface sand management systems are concerned with removing and processing sand that is co-produced with fluids from production wells. Sand can erode process piping and equipment and cause oil/water separation problems if it is present in sufficient quantities. It is therefore desirable to remove the sand from the process fluids and dispose of it in a safe and environmentally safe manner.

The sand will have the following effects on the process if not removed:

- Occupy volume that is designed to assist with oil and water phase separation, thereby, reducing the performance with increases in oil-in-water and water-in-oil concentrations on the outlets.
- Blockage of vessel internals rendering them ineffective e.g. motion dampening baffles and structured packing used on FPSOs, vane packs, water outlets etc.
- Block instrument nozzles, which can lead to ineffective bulk and interface level measurement.
- Stabilization of emulsions, fine particles are known to interfere with oil/water separation and coalescence of water droplets.
- Erode vessels and downstream equipment e.g. pumps and control valves that aren't designed to be sand tolerant.

Traditionally removal of the sand is a batch process. This can be carried out either by shutting down the required vessel for manual entry to dig the sand out or sand removal internals are provided that allows the sand to be removed without interrupting production. The results of the effect of sand production are shown in Figures 2-10.

9.1 Analysis of Garon field sand evolution

Production surveillance was conducted on Garon field for three (3) months, result obtained on average of all wells producing as indicated Figure 2 show that at the initial production stage of this field, the production of basic sediment and water was minima and began to rise toward the end of the first month. This trend continues which is reflected in the well test result (Table 2).

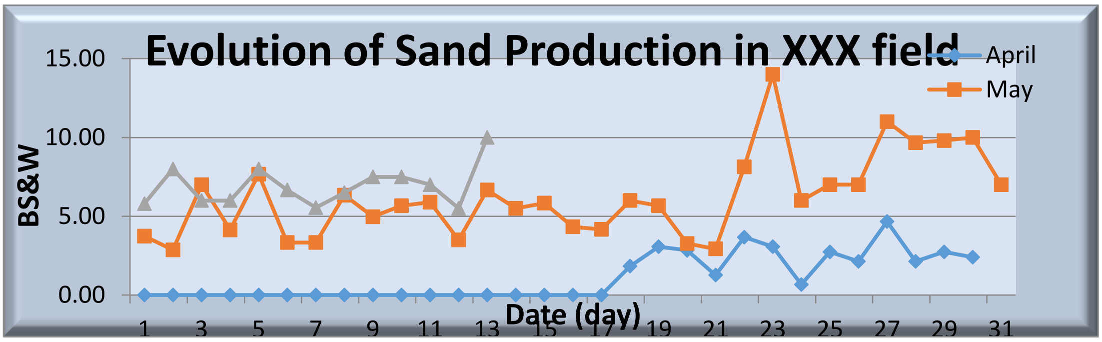

Figure 2: Sand production evolution

9.2 Analysis of previous well test done and a survey of sand identification using a thermo graphic tool

The flow of oil from the reservoir into the well bore depends largely on the differential pressure between the producing formation and the bottom hole pressure. Sand production become more intolerable when the well were producing up to 10ppth of sand. This resulted in a drop in the flowing bottom hole pressure (PWF). From the production data, it was discovered that an increase in the production of oil resulted in an increase in production of sand. Result of Garon field Well Test as at first of January – March 2007 is shown in Table 2

Table 2: Summary of Garon field well test result

Well	Well Head Pressures (bar)	Gross Production (bbls/day)	BSW (%)	Gas Production (Sm3/d)
7	18	446-1191	0.1 - 2.6	3986 - 7150
8	7	679-952	40 - 59.3	7310 - 10905
3	11	318-1037	51 - 65.5	1489 - 5993
9	6	4203-4292	40 - 48.5	10900 - 10957
11	6	2508-2822	72 - 91.7	3003 - 8987

9.3. Validation of real time sand detection and monitoring device

To further optimize production without compromising safety and environment, management of Garon field initiated a project in 2011 to minimize the risk of erosion damage to facilities by installation of real time sand detection and erosion monitoring device (Clampon DSC) on the wellhead and inlet manifold with varying choke sizes for maximum sand free rate (MSFR) or to a Maximum Acceptable Sand Rate (MASR). The result obtained (Figure 3) showed an appreciable amount of sand production.

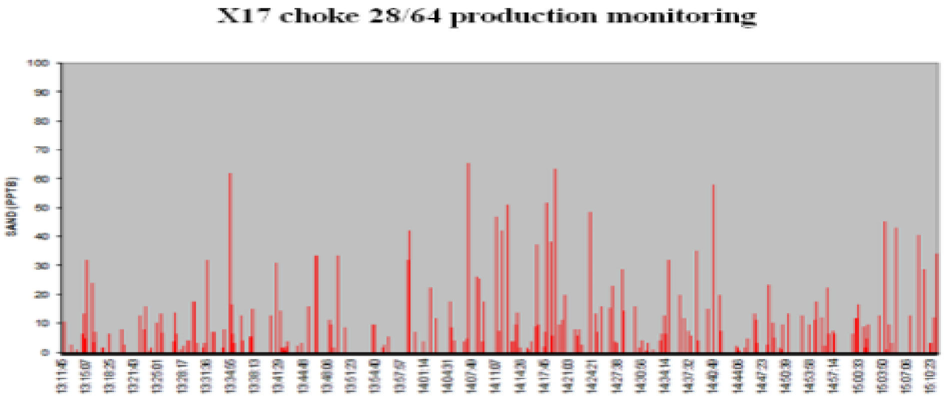

Figure 3: X17 production monitoring

To ascertain the results from the Clampon DSC, well X17 was routed into Test separator on the 8th of January 2015, at 2330Hrs with Test separator pressure set point at 19 Bar. The well was routed out of Test separator on 11th of January 2015, at 2330Hrs. The well was tested for 72Hrs at 65/64" choke size. On the 13th January 2015 at 0905Hrs, test separator man way opened in other to ascertain the quantity of sand produced from the well for 72Hrs. The results of the entire process are given in Figures 4 – 6.

Figure 4: Vessel before cleaning

When so much volume of sand is accumulated in/on equipment, cleaning will be required to allow for efficient production of the well. To restore production, the well must be shut-in for confined space entry, the surface equipment opened, and the sand manually removed. In addition to the clean out cost, the cost of the deferred production must be considered.

Figure 5: Vessel after cleaning

Figure 6: Quantity of sand contained in the vessel

9.4 Evaluation of the effect of sand invasion on subsurface and surface production facilities

The effects of sand production are nearly always detrimental to the short and/or long term productivity of the well. Although some wells routinely experience "manageable" sand production, these wells are exceptional. In most cases, attempting to manage the effects of severe sand production over the life of the well is not an economically attractive or prudent operating alternative. If the production velocity of the fluid is great enough to carry sand up the tubing, this sand may become trapped in the separator as seen in Figure 5, heater treater, or production pipeline. If a large enough volume of the sand becomes trapped in one of these areas, cleaning will be required to allow for efficient production of the well. To restore production, the well must be shut-in, the surface equipment opened, and the sand manually removed. In addition to the clean out cost, the cost of the deferred production must be considered. Figure 7 represents the effect of sand invasion of surface production facility of Garon field.

Figure 7: Sand accumulation in surface equipment.

If the production velocity is not great enough to carry sand to the surface, the sand may bridge off in the tubing or fall and begin to fill the inside of the casing and production tubing. Thus, if it continues to fall of the fluid, the producing interval may be completely covered with sand. In either case, the production rate will decline until the well becomes "sanded up", production ceases and possibly affect the tubing strings as shown in Figure 8. In situations like this, remedial operations are required to clean-out the well or change the bad or entire section of the affected tubing and restore production.

Figure 8: Sand accumulation effect on tubing

One clean-out technique is to run a "bailer" on the end of slickline to remove the sand from the production tubing or casing. Since the bailer removes only a small volume of sand at a time, multiple slickline runs are necessary to clean out the well. Another clean-out operation involves running a smaller diameter tubing string or coiled tubing down into the production tubing to agitate the sand and lift it out of the well by circulating fluid. The inner string is lowered while circulating the sand out of the well. This operation must be performed cautiously to avoid the possibility of sticking the inner string inside the production tubing. If the production of sand is continuous, the clean-out operations may be required on a routine basis, as often as monthly or even weekly. This will result in lost production and increased well maintenance cost. Figure 9 shows a choke that failed due to excessive erosion.

Figure 9: Sand accumulation effect on surface choke

In highly productive wells, fluids flowing at high velocity and carrying sand can produce excessive erosion of both downhole and surface equipment leading to frequent maintenance to replace the damaged equipment. Figure 10 is a photograph of a section of screen exposed to a perforation that was producing sand. If the erosion is severe or occurs over a sufficient length of time, complete failure of surface and/or downhole equipment may occur, resulting in critical safety and environmental problems as well as deferred production. For some equipment failures, a rig assisted workover may be required to repair the damage

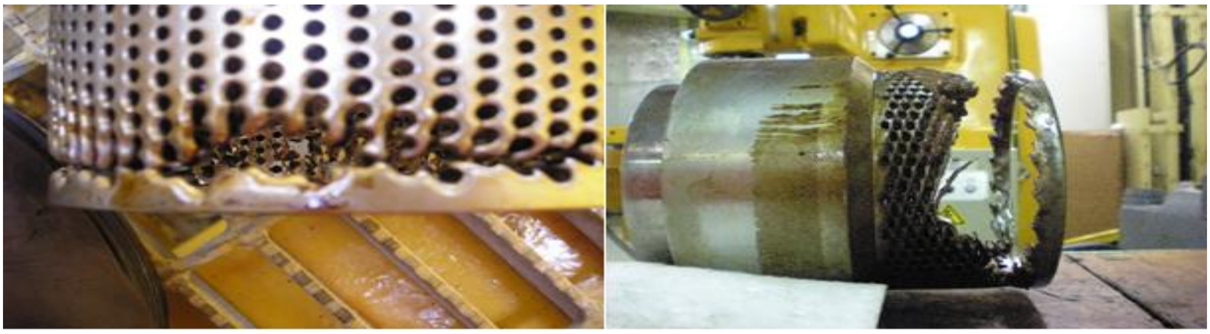

Figure 10: Screen Failure due to erosion

X. CONCLUSION

The Garon field in the Niger Delta was completed and produced from unconsolidated formation which produced sand along with crude oil. Approximately 800 litres of sand was drained and recovered from test separator. Comparing this quantity with the previously recovered sand at 64/64” on 1” trim choke (350 litres), the current sand quantity is higher than the former by 650 litres. Also the sand sensor reading gave a total quantity of 198.36 kg/d of sand produced for 72Hrs with choke 65/64” for the same test period which clearly indicates a wide range of difference between the sensor and the physically recovered sand. Series of event continuous production imposed serious damage on production equipment of Garon field. The effect as recorded in Garon field includes the following: The erosion of choke (surface), tubing, screen, Cuts production of flow line, Loads of treating facilities, Loss of production during work-over jobs and Loss of valuable man-hour during the period of close-in in terms of wages, which add up to overhead cost. Thousands of dollars were spent to carry out work over operation as well as installation of sand control measure.

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