US DOT PHMSA AID Situational Awareness for Employees: SAFE Bulletin[1]

Side-Entry Tank Mixer Product Releases from Crude Oil Breakout Tanks Due to Hinge Assembly Disengagement and Other Causes

49 C.F.R. Part 195 Transportation of Hazardous Liquids by Pipeline

Summary: The Pipeline and Hazardous Materials Safety Administration's (PHMSA) Accident Investigation Division (AID) is issuing this SAFE Bulletin to alert PHMSA Office of Pipeline Safety (OPS) inspectors of the need for hazardous liquid pipeline operators to inspect pre-2008 variable angle side-entry tank mixers for signs of movement of the mixer's hinge pin and to determine whether the mixer's hinge assembly is susceptible to disengagement. Operators may need to contact the mixer manufacturer to determine if the age and condition of the mixer allows the hinge pin assembly to be susceptible to possible disengagement, if the hinge assembly needs to be repaired/replaced, or if the hinge assembly is in normal working condition with the most recently-applied component design. Operators reported hinge pin assembly events in 2006, 2010, 2011, 2016, and 2020 resulting in large crude oil releases. Several operators failed to heed a mixer manufacturer's advisory notices recommending that they take immediate action to inspect the mixers, and to replace the hinge pin with the most current design if applicable. Recently, on January 11, 2020, a snap ring that held a hinge pin in place for several decades broke, causing the hinge pin to creep upward until it released the main hinge plate, allowing uncontrollable leakage to occur around the mixer, and resulting in 6,034 barrels of crude oil being released into the dike area.

Operators have a responsibility to assess risk conditions to their pipeline when manufacturers notify them of a potential safety issue and to mitigate the risk. Inspectors should ensure operators of side-entry tank mixers are aware of the manufacturer notifications, have inspected their mixers, and have installed the manufacturer's most recent hinge pin. Operators must take action(s) to continually verify the serviceability of mixers, such as periodic inspections by personnel who are Operator Qualified (OQ) in mixer inspection. Verification of mixer serviceability, some operating since the 1950s, could potentially be coordinated with monthly API Std 653[2] tank inspections.

AID performs data analysis to identify national pipeline incident trends and/or novel causes. Tank mixer events reportedly caused by hinge assembly issues resulted in very large releases (5 events described in this bulletin have a combined unintended release of ~44,000 barrels) while mixer events due to other causes such as seal leaks, tend to result in small releases (81 releases since 2010 have a combined unintended release of ~1,000 barrels). This bulletin also provides information about other causes of tank mixer unintended releases and methods operators used to remediate the risk of future events.

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[1]This bulletin is not intended to revise or replace any previously issued guidance. It is not legally binding in its own right and will not be relied upon by the PHMSA as a separate basis for an affirmative enforcement action or other administrative penalty, and conformity with the bulletin (as distinct from existing statutes and regulations) is voluntary only, and nonconformity will not affect rights and obligations under existing statutes and regulations.

[2] Inspections required to be performed to API Std 653 Tank Inspection, Repair, Alteration, and Reconstruction

Supplemental Information:

Background

Under 49 C.F.R. Part 195, PHMSA regulates crude oil storage tanks that are classified as breakout tanks. Breakout tanks, defined in 49 C.F.R. § 195.2, are tanks that are used to relieve surges in a hazardous liquid pipeline system or tanks that receive and store hazardous liquid transported by a pipeline for reinjection and continued transportation by pipeline. These crude oil storage tanks typically have mixers to prevent the settlement of sludge, water, sand, and other products referred to as basic sediment and water (BS&W)[3]. In 2019, PHMSA and State pipeline safety partners regulated 8,259 breakout tanks.[4]

Typically, large tanks require the mixing of contents to prevent stratification and settlement. Without mixers, denser materials settle to the bottom of the tank creating an environment for internal corrosion and complicating the task of cleaning a tank in preparation for an API Std 653 out-of-service inspection. Mixers can significantly lower cleaning costs and increase the life expectancy of the floor plates, but must be regularly inspected and maintained. Mixers on breakout tanks are generally side-entry mounted. Side-entry mixers attach to a tank flange opening near the bottom of the tank using a cover flange or cover plate that is connected to the mixer via a hinge assembly at the top and bottom. Figure 1 shows an upper and lower hinge pin assembly circled in red.

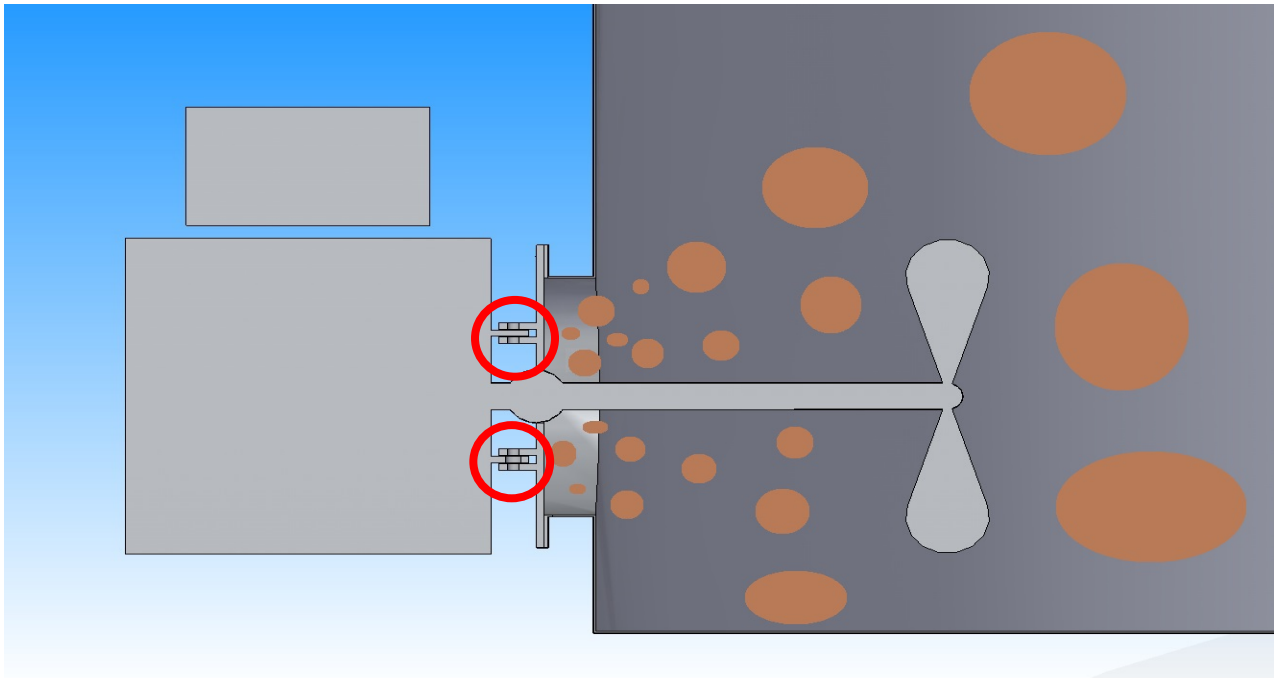


Figure 1: Upper and Lower Hinge Pin Assemblies Circled in Red

[3] Basic sediment and water is a technical specification of certain impurities in crude oil. When extracted from an oil reservoir, the crude oil will contain some amount of water and suspended solids from the reservoir formation.
[4] As reported on PHMSA Form 7001.1 Annual Report for Calendar Year 2018 Hazardous Liquid Pipeline Systems.

Manufacturers of Crude Oil Side-Entry Tank Mixer

PHMSA is aware of three manufactures[5] of side-entry mixers used on most of the crude oil tanks in the United States: Jensen Mixers International Inc. (Jensen), Philadelphia Mixing Solutions, and SPX FLOW Inc. Each manufacturer uses a different hinge pin assembly design to connect the mixer to the cover flange. Obsolete designs included the use of a retaining clip

Jensen Mixers

Obsolete Hinge Assembly Designs

For identification purposes, Figures 2 and 3 show hinge pin used prior to 1990 with a snap ring and Figures 4 and 5 show hinge pin used from 1990-2008 with a retaining ring over the snap ring. During operation of the mixer, over many years of usage, the lower clip ring could disengage allowing the top or bottom hinge pin to work its way up and out. The hinge pin could come out of the bracket holding it to the mixer, upsetting the mixer, and allowing crude oil to spill from the tank through the mixer cover flange penetration. While operators pump the product out of the tank, it is not possible to stop the product from releasing until the level of the product is below the mixer.

Figure 2: Pre-1990 Hinge Pin – Solid Pin with Snap Ring

Figure 3: Pre-1990 Snap Ring without Retaining Ring

Figure 4: 1990-2010 Hinge Pin -Solid Pin with Retainer Ring

Figure 5: 1990-2010 Hinge Pin Design Solid Pin with Retainer Ring

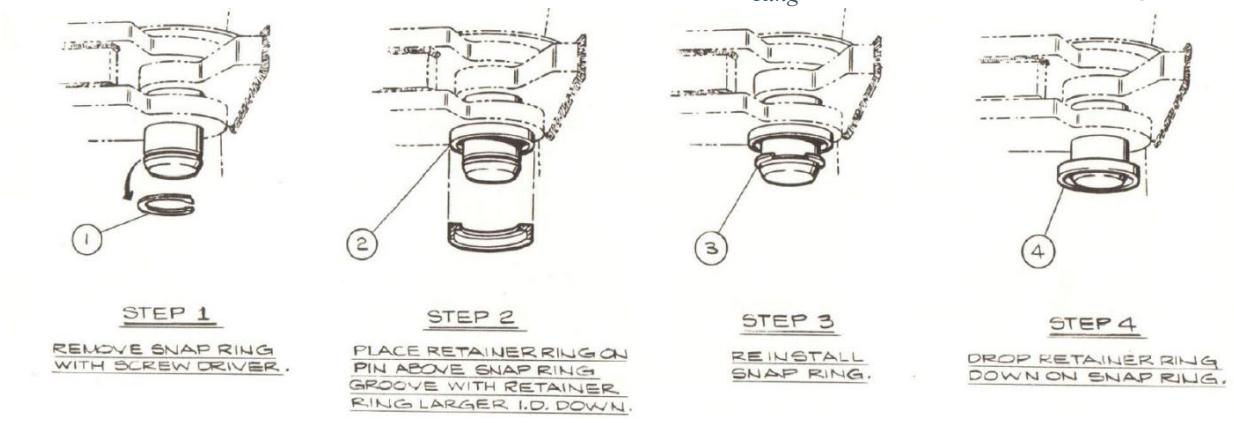


Figure 6: Hinge Pin Snap Ring Retainer Installation 1990 - 2010

[5] Philadelphia Mixing Solutions and Jensen Mixers International Inc. reviewed this SAFE Bulletin and provided feedback that was incorporated into this document. All of the drawings and photos of Philadelphia Mixing Solutions and Jensen Mixers International, Inc. were submitted by the companies with permission to copy in this document.

In 1990, Jensen notified customers via certified mail of potentially serious safety conditions that required their immediate attention. The 1990 notice advised customers to inspect the mixers for signs of movement in the top hinge pin, to move the hinge pin back to the normal position, and to not operate the mixer until the retrofit kit was installed (see Figure 6). The manufacturer further recommended inspections every six months to ensure serviceability of the retrofitted hinge assembly.

In 2011 Jensen informed their customers that there was an instance where the retainer ring at the lower end of the upper hinge pin disengaged allowing the pin to creep upward until it released the main hinge plate. Jensen advised customers to replace all prior hinge pins with a new two-piece hinge pin that incorporated solid end flanges (see Figure 7) for mixer models 680-VA, 650-VA, 620-VA, 605-VA, 480-VA, 450-VA and the 420-VA.

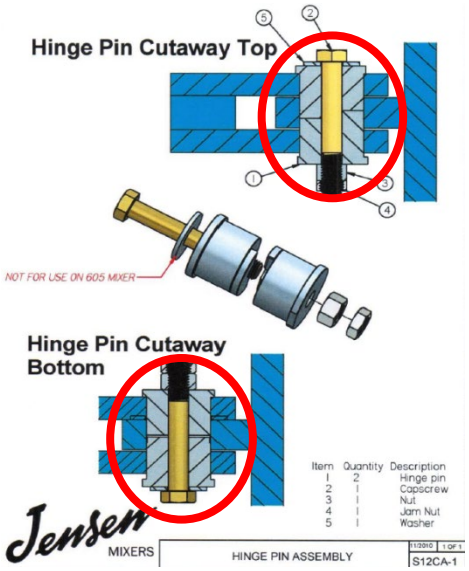


Figure 7 – Current Jensen Hinge Pin Design

Jensen Current Hinge Assembly Design

The manufacturer began using this new design, referred to as the "split pin" design, in 2008 on all newly manufactured mixers (see Figure 7). The split pin is manufactured from a solid piece of bar milled down the center area. When Jensen repairs or refurbishes any mixer at their facility, they bring the older mixer up to the current hinge assembly. Operators have not reported to PHMSA any events of Jensen's current hinge assembly design used since 2008. For more information on this brand, please visit the company's website at www.jensenmixers.com/.

Philadelphia Mixing Solutions Hinge Assembly Design

Figure 8 shows Philadelphia Mixing Solutions' hinge or swivel pin design. The design includes a swivel pin with an interference fit (a fastening between two parts achieved by friction after the parts are pressed together under force) to prevent the pin from moving up or down, and a snap ring. The interference fit plus snap rings (top and bottom of the hinge pins) provide a redundant design, if one fails there is a second mechanism to provide backup. The hinge pins require periodic greasing to lubricate the bushing. Operators have not reported to PHMSA any events of Philadelphia Mixing Solutions hinge assembly. For more information on this brand, please visit the company's website at www.philamixers.com.

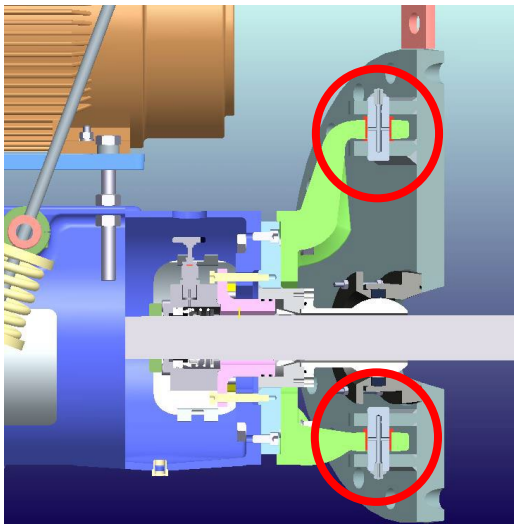


Figure 8: Philadelphia Mixer Solutions' Swivel Pin Arrangement

SPXFLOW Plenty Mixer

SPXFLOW did not provide information for or review this bulletin prior to publication. [6] As depicted in Figure 9, the Plenty mixer module is supported by two swivel hinge bearings which ensure ease of manual angle changing and the swivel seal is affected by a heavy-duty static Soloseal™ acting on a stainless steel spherical ball. For more information on this brand, please visit the company's website at https://www.spxflow.com/.

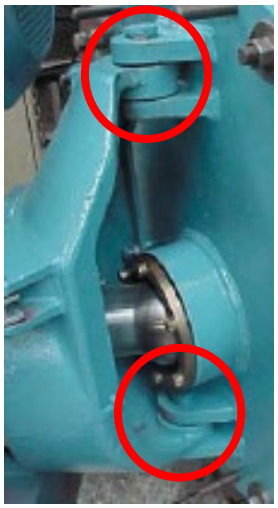


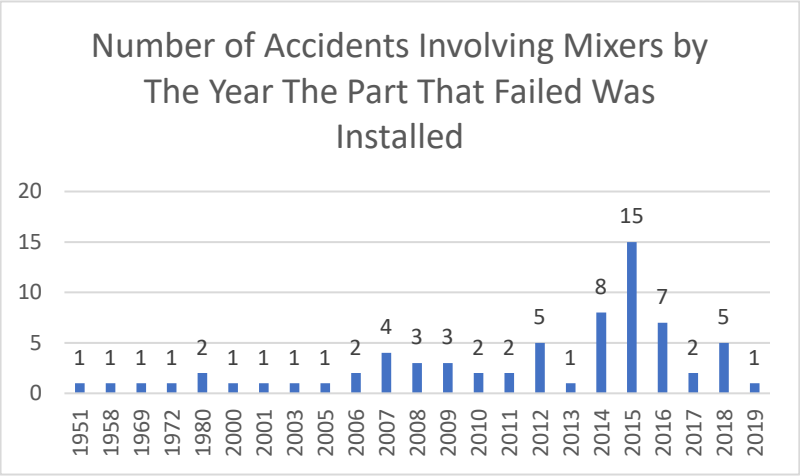
Figure 9: SPXFLOW Plenty Mixer Hinge Assembly

Breakout Tank Mixer and Operator Data Analysis [7]

PHMSA regulates approximately 226 operators with approximately 8,259 breakout tanks under 49 C.F.R. Part 195.

Statistics on Tank Mixer Accidents

- 99 of 4,001 hazardous liquid (HL) accident reports involved a tank mixer (~2.5% of all HL accidents).
- 30,828 barrels of crude oil were unintentionally released. Product was totally contained on operator-controlled property in 97 of the 99 accidents.
- 4 hinge assembly events on crude oil tanks resulting in the unintended release of 29,163 barrels.
- 81 'seal or packing' leaks
- No fatalities, injuries, or evacuations. Pipeline operations were shut down 20 times.
- 1 ignition which involved a bearing event that led to a mechanical seal leak.
- 1 ignition/explosion occurred during the replacement of the tank mixer when flammable vapors reached a source of ignition.
- 79 accidents were identified by local operating personnel, 4 by ground/air patrol, and 1 by Controller and 1 by CPM/SCADA.
- The highest number of reportable accidents involved a mixer where the part that failed was installed between 2014-2016.



[6] Photo of Plenty mixer is from SPXFLOW's website, *available at* https://www.spxflow.com/assets/pdf/plm-102_sideentrymixers_pty-us.pdf (last accessed April 23, 2020).

[7] Data source for this report: PHMSA F7000 1 Hazardous Liquid Accident Reports from Jan. 2010 to March 2, 2020 and 2018 Annual Reports.

Accident Investigation Summaries of Tank Mixer Hinge Assembly Events

1. Patoka, IL (6,034 barrels) Report No. 20200038

Summary: On January 11, 2020, operator personnel noticed a tank level drop. Field investigation discovered crude oil releasing from the tank mixer, which involved an older unit using an obsolete hinge pin design. While the product was pumped out of the tank to below the tank mixer level, 6,034-barrels were released into the tank dike. The investigation determined the snap ring on the top pin broke which allowed the pin to move up and disengage the hinge point. The mixer tilted causing damage to the propeller shaft seal. The damaged seal allowed crude oil to flow from the tank into the dike. A new mixer was installed. All tank mixers were inspected and retrofitted with the 2011 hinge assembly kits from the manufacturer. Figures 10-11 show the disengaged top hinge pin from the cover flange, the mixer, and the failed snap ring.

Figure 10: Disengaged Hinge Assembly

Figure 11: Broken Snap Ring.

Root Cause: A tank mixer leak occurred due a snap ring which broke after many years of service, which resulted in the pin for the top mounting bracket becoming disengaged. The mixer was installed with the first 1990 retrofit design from the manufacturer but had not been upgraded to the second, 2011, retrofit. The tank had been recently acquired and the new operator did not have complete records for the tanks. The manufacturer has confirmed that notices and replacement parts were received by the prior tank operator.

2. Hermleigh, TX (700 barrels)– Report No. 20160280

Summary: On August 8, 2016, delivery from breakout tank was completed at approximately 02:35 CT. The control center received tank creep alarms and contacted field operations personnel to investigate. At approximately 06:25 CT, field personnel discovered a release from the tank mixer area. Additional field personnel and resources were dispatched to location while the tank was pumped out to below the tank mixer level to stop the release. All free crude oil was recovered via vacuum truck and contaminated soil was remediated on site. Total volume released was 700 barrels, ~ 250 barrels were recovered, ~145 barrels were entrained in the soil, and ~ 305 barrels volatilized.

Root Cause: The mixer hinge assembly failed causing the release of crude oil from the tank. The mixer hinge assembly was removed and sent for third-party metallurgical analysis. Analysis concluded that the cause was failure of the upper snap clip of the mixer hinge assembly, causing

excessive vibration and ultimate disengagement of the mixer hinge. Other mixers of same design and manufacturer in the operator's system were inspected and repaired or retrofitted with the manufacturer's hinge assembly replacement kits.

3. Willow Creek, TX (70 miles northwest of Dallas – 12,229 barrels) – Report No. 20110210

Summary: On June 4, 2011, the control center observed the tank level dropping at faster than normal pumping rates. The operator's technician identified that the tank mixer failed, and a vapor cloud formed inside the dike. An estimated 12,229 barrels released into the dike.

Root Cause: The retaining ring that holds the snap ring failed. After contacting the manufacturer, all the mixers in the operator's system were inspected and modifications were made to replace obsolete hinge assemblies with the current design.

4. Sundown, TX (10,200 barrels) – Report No. 20100240

Summary: On October 11, 2010, at approximately 07:30 CT an operator discovered a tank release. 10,200 barrels of crude oil released into the dike. Upon discovery of the release, operator personnel immediately assessed the situation, and verified there was no potential to impact sensitive areas. Operator personnel attempted to mitigate further release by stopping the flow of oil, and responded with quick clean-up of the area by deploying an appropriate level of response resources.

Root Cause: The operator conducted a TapRooT® investigation of the incident and an outside metallurgist analyzed the hinge assembly on the mixer. Both determined that equipment event was the apparent cause of the incident. Specifically, the operator determined that the hinge assembly on a mixer disengaged, causing a separation of the mixer from the tank.

5. Borger, TX (15,000 barrels)- Report No. 20060353

Summary: On December 3, 2006, the operator reported a release from a full 130,000-barrel crude oil tank from the previous day due to a mixer event. Although the operator discovered the leak soon after the release began, it took several hours to transfer the product below the opening where the mixer separated from the tank. Ultimately, 15,000 barrels of product released into the dike area of which 14,446 barrels were recovered.

Root Cause: The snap ring holding the tank mixer top hinge pin in place failed. This allowed the pin to come out due to the movement of the mixer. The bottom hinge pin remained in place, but the top portion of the mixer fell away from the tank, partially pulling the mixer shaft out of the flanged housing attached to the tank. The oil in the tank then sprayed out from around the shaft and displaced packing.

Accident Investigation Summaries of Tank Roof Legs Contacting Mixer

1. Jones Creek, TX (20 barrels) Report No. 20200038

A tank was placed into service in December 2019. The roof leg settings had been on high until March 26, 2020, when the operators changed products in the tank. The pins were not set for low legs and drew the

volume down far enough that the roof came into contact with the mixers, causing mechanical damage. A few days later, the mixer seals failed.[8]

2. Cushing, OK (2 barrels) Report No. 20190218

On June 12, 2019, the tank mixer start/stop settings were set for proper mixing, but did not take into consideration the proximity to the roof leg. Product was forced through the roof leg penetration and onto the external floating roof.

3. Gillette, TX (0.6 barrels) Report No. 20190094

On March 3, 2019, an operator discovered condensate on the ground near the roof drain and a roof leg sleeve positioned above the tank mixer. When the floating roof height reached a lower level, the turbulence from running the mixer pushed condensate through the leg sleeve and followed the roof drain to the ground. To prevent reoccurrence, sleeve caps were placed on the leg sleeves of similar leg-over-mixer configurations.

4. Cygnet, IL (2 barrels) Report No. 20160204

On June 2, 2016, a tank was being pumped out to change from a sweet to a sour crude. The roof legs were in the lower position which allowed the roof to hit the mixer propeller causing the seal to fail.

5. Hope, TX (10 gallons) Report No. 20150178

On May 7, 2015, operating personnel identified crude oil under the tank mixer. The investigation found that one of the pontoons on the roof contacted the mixer propeller causing stress on the ball-packing gland. The mixer was repaired and the tank will now only be allowed to rest on high legs.

Summary of Causes and Remediation of All Mixer Product Releases from 2010 to March 2020

Most mixer releases are due to small seal leaks with minimal repair cost.

Remediation Measures – Good Practice
Some operators install a seal pot or tattletale that serves to contain, detect, and alert the operator of a leak before it affects the environment. Operators can identify small leaks during periodic inspections, or with the addition of telemetry/sensors, can remotely monitor the seal pot.

The following is a summary of the product release causes and remediation measures operators reported to PHMSA related to mixer failures between January 2010 and March 2020:

Product Release Cause	Remediation
Vibration caused hinge pin to disengage.	Replace hinge assembly using the newest (2011) retrofit kit. Monitor for vibration readings. Remediate condition causing vibration.

[8] This event is still under investigation. Information provided is preliminary.

Seal and bearing leaks (Note: The mixer created two points of potential release. The mixing shaft seals and for those mixers that pivot, the pivot ball seal.) • Normal wear and tear on mixer seals and bearings. • Product is leaking out of top pinion O-ring allowing gearbox reservoir to run dry. Shaft seizes and motor overheats causing seal leaks. • Solid material in the crude oil caused seal abrasion. • Defective mechanical seal. • Seal damaged due to improper belt tension. • Vibration allowed the shaft to move axially or come out of alignment. The thrust bearing failed causing the seal to leak. • Vibration caused the bolt that connects the mixer shaft to the drive yoke to disconnect. Once disconnected, the mixer shaft moved forward into the tank causing the mechanical seal to separate causing oil to fill the gear box housing and overflow. • Cracks in the seal of the gear box caused by paraffin building up (from crude oil) on the propellers resulting in vibration and misalignment. • Tension spring designed to hold the seal with the proper force failed. Possible lack of evenly distributed tension around the seal face from multiple springs. • The seal dried out and cracked due to the mixer sitting idle.	• Replace seals, bearings and other parts as needed. Upgrade to improved seal and bearing materials. • Realign propeller shaft. • If vibration was a contributing factor, evaluate and remediate the vibration cause. Vibration may be result of improper mixer specification.
Manufacturing defects • Failed to properly seat the tubing ferrule on compression fitting on vent tube on mixer. Product releases through vent tube. • Drain plugs were not installed at the factory. • Failed cover flange. Possible manufacturing defect. Operator did not provide update.	• Manufacturer implemented a pressure test on the vent tube assembly. • Manufacturer reviewing their equipment inspection process and developing improved quality control.
Improper mixer selection. • A tank valve release due to oxygen accelerated carbon dioxide corrosion. The mixer was inadequate and allowed water/oxygen to accumulate in the tank.	Perform an engineering assessment of tank and product for compatibility with mixer prior to installation.

• A seal release occurred due to high vibration caused by large clearance between inboard bearing sleeve and shaft.	
Gear box was contaminated with water when a tank mixer seal failed during a hurricane. Operator flushed gear box oil with new oil but subsequently, a release occurred.	Replace gear boxes when they are contaminated with flood water.
Seal releases due to mixer contacting floating tank roof. • See accident summaries above.	Verify adequate clearance between propellers, sleeves, and the tank structure when selecting mixers and operating tank.

Regulatory Requirements for Tank Inspections and Associated Appurtenances:

Pursuant to 49 CFR § 195.402(c)(3), operators must have a manual of written procedures to provide safety during maintenance and normal operations for operating, maintaining, and repairing its pipeline system in accordance with the requirements in Subpart F (Operations and Maintenance), including § 195.432 *Inspection of in-service breakout tanks* and Subpart H – (Corrosion Control).

- § 195.432 (b) Inspection of in-service breakout tanks

  This section promulgates the requirements for operators to inspect the physical integrity of in-service atmospheric and low pressure above-ground breakout tanks per API Std 653, "Tank Inspection, Repair, Alteration, and Reconstruction" 3rd edition.

- API Standard 650 "Welded Steel Tanks for Oil Storage" 11th edition (Incorporated by Reference, *see* § 195.3)
  - Section 6.3 Inspections from the outside of the tank, states that these inspections should be performed on regular intervals not to exceed 1 month.
  - Section 6.3.1.3 This routine in-service inspection shall include a visual inspection of the tank's exterior surfaces. Evidence of leaks; shell distortions; signs of settlement; corrosion; and condition of the foundation, paint coatings, insulation systems, and appurtenances should be documented for follow-up action by an authorized inspector.
  - Section C.1.3.6 is a sample checklist for inspecting tanks. This check list calls out inspecting for proper mounting and support and to inspect for leakage.

AID Recommendations for Inspectors

- Inspectors are advised to ensure that operators have reviewed manufacturers' safety advisories and act where needed to mitigate the risk identified in the advisory.
- Inspectors are advised to ensure that operators take the following measures to inspect mechanical hinge assemblies on all crude oil mixers in use on breakout tanks used for crude oil:

  - Examine the top and bottom hinge pin fastener to ensure they are in the proper position;
  - Determine whether Jensen mixers have been retrofitted with the 2011 hinge assembly;
  - Make all needed modifications to install a preventive and mitigative repair.

- Inspectors are advised to ensure that operators conduct periodic examination coordinated with monthly API Std 653 tank inspections of mixer mechanical fasteners after retrofit to ensure integrity and safety of the retrofit, and should consider including this in their Operations and Maintenance (O&M) Procedures covering breakout tank inspections.
- Inspectors may encourage operators to mitigate the risk of catastrophic seal releases. A good practice for operators is to install an early leak identification device such as a seal pot that collects leaking product so the operator might identify a leak while it is small. The collection pot should have a sight glass or other method to allow observation of any collected product. Periodic observations of these collection pots can prevent product from reaching the ground. In addition to visual detection, the collection pots can be equipped with a level switch. The level switch can be designed to alarm locally and/or to SCADA control centers. The switch may also be designed to automatically shut down the mixer to prevent any further damage and product release from the seal.
- Inspectors may encourage operators to mitigate the risk of product release due to vibration. A good practice for operators is to install a vibration sensor to notify personnel of needed maintenance and/or shut down the mixers.

Additional Resources

See Attachments for the following files[9]:

- Hinge Pin Notification 1990
- Hinge Pin Notice 2011
- Jensen 600 Series Installation, Operations and Maintenance Manual
- Philadelphia Mixer Solutions Guardian Environmental Leak Detector Brochure
- Cutlass™ Side Entry Belt Tank Mixers Installation, Operations and Maintenance Manual

[9] Documents provided by Jensen and Philadelphia Mixer Solutions.