SUMMARY OF EVENT

The importance of managing the maintenance modification interface is fundamental to maintaining the design reliability of systems and equipment. The following diesel engine fire event will illustrate the point. The fire event occurred during a fracking operation at a well site involving multiple equipment units for hydrating, blending, and pumping. Each of these separate functions consisted of operating specialized equipment mounted on separate tractor-trailers with mounted diesel engines as main power sources. The deck engine on the in-use blender at the time was of most interest. The fire investigation origin and cause analysis showed it to be the center of the event action, i.e., the area of origin of the fire.

In the month of September during a fracking operation, a fire originated on the pressure pumping blender that was in service at approximately 2315 hours. The blender unit consisted of two diesel engines and a variety of pumps, valves, and piping designed to deliver a conditioned fluid to the high-pressure pumps that were used in the fracking operation. One diesel engine provided hydraulic power for a variety of mechanical equipment including hydraulic motors that powered five chemical delivery pumps. The blender pumping engine, in the area the fire was first reported, was an approximately 800 horsepower, turbocharged diesel engine.

The arrows on this exemplar show the chemical addition pumps location just above the fuel tank and the blender operator's station to the left of the access ladder.

The three chemical addition pumps to the left are the pumps in the area of origin of the fire. Note the addition of a barrier to shield the pump assemblies from the exhaust manifold heat on this exemplar.

Just before the fire occurred, the crew was getting ready to secure a particular stage of the operation beginning with final adjustments to equipment and preparations for cleaning the chemical line to a standby chemical addition pump. This chemical line cleaning operation required flushing the chemical pump with diesel fuel. The diesel fuel truck operator shifted the inlet to the chemical pump from the chemical supply to a diesel fuel supply. The flushing diesel fuel would be pumped into the blender's mixing tub which is observable by the blender unit operator. The chemical truck operator advised the blender unit operator that he had shifted the chemical addition pump supply line to the diesel fuel supply. Within a matter of seconds the blender operator ramped up the speed on the standby chemical pump's hydraulic motor controller from zero to a higher value to flush the line. The blender operator noted that there was no flow out of the standby chemical addition pump into the blender's mixing tub and ramped down the chemical addition pump hydraulic motor controller at which time the fire erupted to his left in the area above the chemical pump platform and on the upper right side of the blender diesel engine.

FIRE ORIGIN AND CAUSE ANALYSIS

On or around 2315 hours on the day of the fire in September, the fire that is the subject of this report began with first a glow followed a few seconds later by a fireball of red and orange flames.

Eye Witness Accounts

On site observer-First saw a glow above the control panel to the left of the blender operator, then in the time it takes to secure his material canister and move three or four steps, he stated he saw flames shooting up 5-6-7 feet. **He recalled the flames were red in color.**

Water trailer operator-This operator was standing on the water trailer facing the blender unit chemical pumps. He observed that the blender unit suddenly was engulfed in flames. The area that he identified as being engulfed in flames was from just above the exhaust manifold to just below the exhaust muffler. He adds that the entire engine from the bottom up became engulfed in flames in the interval from when the fire started till he was able to reach for his headset and call for shutdown. He estimated the time interval from the start of the fire he first saw until the entire engine was engulfed in flames was less than five seconds. **He recalled the flames were orange in color.**

Blender operator-After ramping up the hydraulic motor control for the standby chemical pump, he noticed there was no fluid coming out of the chem addition pump discharge line into the blender mixing tub. He turned the control for the hydraulic motor for the standby chemical pump down for a second and was met by a wall of fire. He described it as a huge ball of fire that made a ”whoosh” sound, that it started in the area of the turbo and exhaust manifold (exhaust manifold temperatures typically exceed 1,000º F). **He further described the flames as reddish orange in color.** He shut the hydraulic motor for the standby chem pump off and ran off the blender. He further stated that he did not know what happened as everything was going as normal.

RELATED CIRCUMSTANCES

Considering that hydraulic fluid cannot be eliminated as the first fuel and that the credible ignition source in the area of origin of the fire on the blender unit were the right-side turbocharger and/or exhaust manifold, the question became “by what means did the first fuel and credible ignition source came together to cause the fire.” Since the original design and installation of the chemical addition pumping system had operated reliably since the blender unit was placed in service several years earlier, continued reliable operation would be expected. But new hydraulic pumps of a more desirable design were installed just seven months prior to the accident. With the design change, the reliable hydraulic chemical pump setup was altered. Examination of the design change document (that consisted solely of an improperly completed work order) revealed that the work was done with the following deficiencies noted:

- There was no work standard for the maintenance technician to follow even though the work was on a critical blender unit subsystem and involved safety critical equipment.

- There was no torque specification for the work and no torque values for the hydraulic hose fittings recorded even though the fittings and hydraulic motor casings were of dissimilar metals that required a narrow range torque specification to accommodate the dissimilar metal connection.

- There was no documented maintenance training program so the qualification of the mechanic for such work was suspect and non-verifiable.

- Even though the change out of the chemical addition pumps on the subject blender was in fact a design change, there was no engineering involvement in this work which was treated as a “skill of the trade” task.

- There was no control of this maintenance work as there were no supervisory reviews of the work, no qualifications specified for the task personnel, incomplete documentation regarding the work, and no post maintenance testing of the work even though it was on critical equipment with major safety implications.

- Even though five chemical addition pumps were replaced on the subject blender, there is only documentation for the three pump replacements completed 7 months earlier.

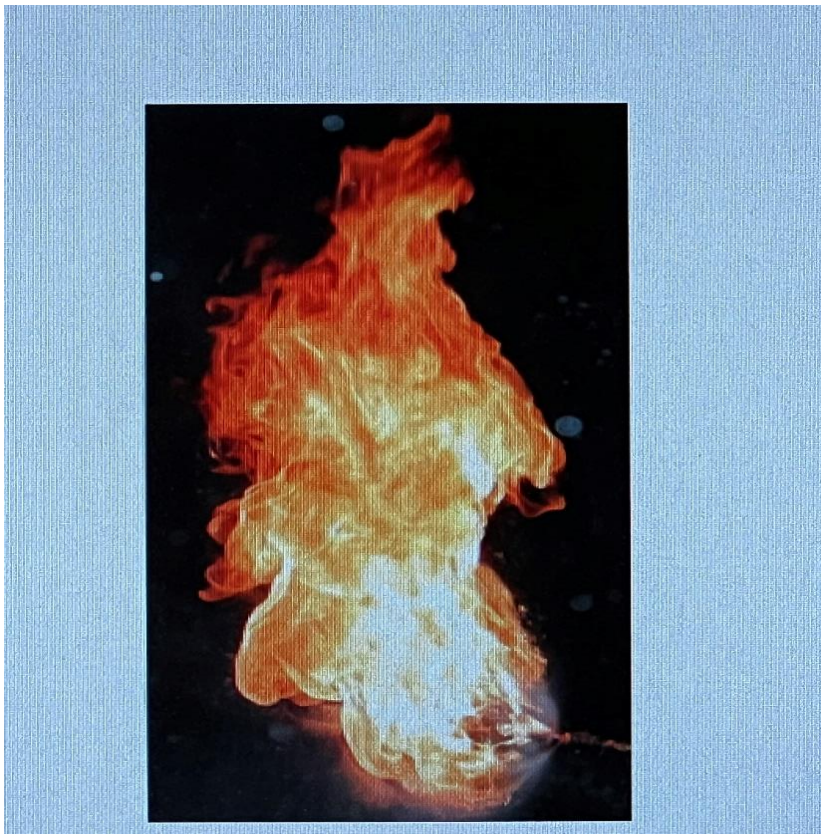
I reviewed the maintenance work orders and found the work order regarding replacing the chemical addition pumps that included cutting to fit and installing six hydraulic hoses including newly made-up fittings on those hoses. This change occurred on equipment within two feet of the exhaust manifold on the right side of the deck engine that could spray hydraulic fluid into the area of origin where it could be ignited by the exhaust manifold. There was no modification work package associated with this work order not even by reference.

THE CLINCHER

The flow data for chemical pumps 3 and 5 for the time period of the event indicated the output flow rate for each pump in service and standby. Chemical Pump 3 was in standby for flushing and Chemical Pump 5 was in service. When flushing with diesel fuel of Chemical Pump 3 began, this record indicated that Chemical Pump 3 flow rate began to increase reaching a peak value of 1.7 gallons/minute then dropping back from the peak flow rate to a flow rate of 0.404 gallons/minute within 4 seconds. This interval corresponds to the action of the blender operator in ramping up the hydraulic pump motor control for the flushing operation.

During this same period, Chemical Pump 5 went from a flow rate of 2.145304 gallons/minute to a flow rate of 2.031207 gallons/minute. This is indicative of a loss of high-pressure hydraulic fluid to Chemical Pump 3 hydraulic motor that caused a system pressure perturbation that also affected the hydraulic pump motor for Chemical Pump 5.

Meanwhile, the blender operator observed there was no flow into the blender mixing tub and was about to turn down Chemical Pump 3 motor control when a fireball occurred to his left above the Chemical Pumps in the area of the turbo and the exhaust manifold up as high as the exhaust muffler. Within a few seconds of evaluating the situation, he quickly left the deck area and climbed down a ladder on the adjacent, standby blender.



Typical hydraulic oil spray flame. Note the presence of both yellow and orange flames as observed by eyewitnesses at the fire scene. (Ref: Liming Yuan, Ignition of Hydraulic Fluid Sprays by Open Flames and Hot Surfaces, Pittsburgh Research Laboratory, NIOSH, 2006.)

https://www.cdc.gov/niosh/mining/userfiles/works/pdfs/iohfs.p

CONCLUSIONS

My conclusions as to the probable origin and cause of this fire and related items to a high degree of engineering and fire science certainty were as follows:

- Based on the eyewitness accounts of the beginning of the fire that started on the blender unit, I concluded that the area of origin of the fire was on the right side, exhaust manifold area of the engine.

- Based on the chemical pump #3 and #5 flow data, maintenance records, heat vector analysis, heat damage patterns, and the heat and flame dynamics and flame color of

the fire on the right side of the blender unit deck engine, I concluded that a fuel source for the fire was hydraulic fluid from a failed high pressure hydraulic line or fitting on chemical addition pump #3 hydraulic motor. This failure released high pressure hydraulic fluid onto the exhaust surfaces on the right side of the engine resulting in a fire.

- Based on the severe heat damage to components in the area of the small volume chemical addition pumps' platform, I concluded that there was a potential for a diesel fuel leak from the standby chemical addition pump inlet line fitting at the time of the fire that was likely another early fuel source as the fire progressed.

- Based on the deposition testimony of maintenance personnel and examination of maintenance records for the blender there appeared to be a lack of a maintenance-modification interface management that contributed to the cause of this fire. The following missing elements of the modification process illustrate this management shortcoming:

    - Lack of control of maintenance activities.

    - Lack of training of maintenance personnel to ensure they are capable of performing required tasks involving critical equipment and safety related equipment.

    - Lack of work standards that include critical engineering specifications applicable in maintenance activities.

    - Lack of review of maintenance work to ensure quality work is performed on critical and safety related equipment.

Destroyed blender (top photo) and high-pressure fracking pump unit. The loss for each of these units was approximately $1,500,000 (total loss $10,000,000).

OBSERVATION

For want of a nail, the kingdom was lost. For want of a fastener specification, $10,000,000 in fracking equipment was lost, and then some.