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OEM Technical Bulletin:
Fire Apparatus Drivelines

Driveline problems include vibration, worn parts, loosening components and outright failure and have been a part of our industry since the advent of motorized apparatus. While the problems have always existed, there has been an increase in recent years of reported incidents. The information presented here is intended to provide an update on recommended driveshaft design and installation for split-shaft midship fire pumps.

What has changed in the last 10 years:

1. Higher apparatus road mileage
2. Zero tolerance for vibrations and harshness
3. Sophisticated vehicles which are much smoother and quieter
4. Truck transmission designs that compound problems
5. Advanced isolation mountings which mask low level vibrations from reaching the truck cab
6. Overdrive transmissions which increase drive line speed which multiplies any driveline problems
7. Longer cabs and wheelbases requiring longer drive shafts
8. Heavier drive shaft components to accommodate higher engine horsepower
9. Greater travel and more sophisticated suspension systems

What we have learned:

1. The problems we have seen include: failed driveshafts, loosening drive ends on pump gearboxes, broken mounting brackets, drive line joint or slider wear, bearing wear on pumps and rear axles, and vibrations at specific road speeds. These problems have been experienced on all brands of midship fire pumps and chassis brands. They do not happen often but they are expensive to fix and easy to avoid.
2. Problems can occur with or without noticeable vibration.
3. Even if the driveline was “engineered” it still might not be built to spec. Always measure the driveline after construction (with a loaded vehicle).
4. Suspension travel and torque wrap-up can change a marginally acceptable driveline into a problem driveline. Always lay out all the suspension movement variables.
5. Not all driveline computer scans are equal. The website called Data Expert is very good (www2.dana.com/expert).

6. If you don't individually have shaft cancellation and phasing going to and from the midship pump transmission, you can expect potential problems. Driveline scans should be done three times for each application – once for the front shaft assembly, once for the rear shaft assembly, and a final scan of the total system which assumes the pump is a shaft with the correct yoke phasing.
7. Always try to achieve the lowest possible driveline torsional and inertial scan readings.
8. Center your driveline sliders, look at suspension travel and vehicle loading to verify the sliders are not going to pull apart or bottom out.
9. Avoid high driveline angles, even if they pass scan. They can generate high thrust loads in various components in the driveline leading to unusual wear or failure. Check angles at suspension limits.
10. Long drivelines can lead to components vibrating or total driveline tube failure. As the driveline approaches ½ critical speed, a vibration will develop which may not be felt but can shake the bolts loose from fixed components in the drive system. Chassis drive lines which approach the ½ critical speed can experience catastrophic tube failure (For more information see *Universal Joint and Driveshaft Design Manual, NO. AE7, SAE, Warrendale, PA 1979*). Follow Hale's maximum driveline chart (which is based on SAE design recommendations coupled with industry experience).
11. Be conservative. Pushing the envelope on driveline speed, unsupported length, or angles may work many times, but will eventually give you trouble. Stay within accepted guidelines and error on the side of safety.
12. Don't forget the tires. Many vibration problems are blamed on the drive shaft, when a wheel or tire may be the real root cause of the problem.
13. Provide adequate mounting for gearboxes and pumps. When mounting with rubber isolation, spread the mounting points as far as practical to provide more stable support. When hard mounting, make sure mounts are stiff enough to avoid excessive deflections.
14. Contact driveline equipment manufacturer for applications assistance and approval. Both Spicer and Merritor offer this service.
15. Finally, Do not measure drivelines with a bubble protractor. It is not accurate enough. Use a digital inclinometer. Also, be sure to remember to zero the inclinometer on the truck frame. Using earth as a base line can give you false readings. The Spicer Angle Master 2 from Dana Corp has adapters to make driveline measurements easier.

MAXIMUM DRIVE LINE LENGTH FOR SPLIT DRIVE LINE PTO OR TRANSMISSION PTO APPLICATIONS

Driveline tube size (Diameter) in inches

Shaft RPM	2	2.5	3.0	3.5	4.0	4.5
2400	47	53	58	63	67	71
2600	45	51	55	60	64	68
2800	44	49	53	58	62	65
3000	42	47	52	56	60	63
3200	41	46	50	54	58	61
3400	39	44	48	53	56	59
3600	38	43	47	51	55	58
3800	37	42	46	50	53	56
4000	36	41	45	48	52	55

Numbers indicate the absolute maximum driveline length in inches

NOTE:

1. These are absolute maximum driveline lengths based on approximately 42% of Critical Speed. There is theory and field experience which indicates that operating a drive shaft for prolonged periods of time at a steady speed which approaches or exceeds one half the shaft's calculated critical speed could lead to component failure or loosening of drive components. This condition can be achieved on a fire apparatus during truck delivery, or response.

2. Driveshaft tube wall thickness will also affect critical speed but the effect on maximum driveshaft length is often minimal. The effect of wall thickness variation in the critical speed calculation is usually less than 5%. Thicker drive shaft tube wall thickness will lead to lower critical speed numbers of less than a couple hundred rpm. The above table represents recommendations based on 0.134 inch tube wall thickness and 42% of critical speed as a limit for drive shaft lengths. Extra heavy wall thickness drive shaft tubes up to 0.238 inch could reduce maximum lengths by a couple inches.

3. This chart provides a minimum factor of safety. Violating this chart or the 42% of critical speed recommendation, will reduce the factor of safety for the driveline and increase the chance of driveline damage, including damage to the pump assembly and could void warranties.

This information is offered by Hale Products Inc. to assist the installer.
However, no liability for final installation can be accepted by Hale Products Inc.

Five Steps to Fix Driveline Vibration

1. Measure the truck as built and properly loaded.
    - Use a digital inclinometer. Measure driveline angles very carefully
    - Set the inclinometer at zero on the frame rails of the truck
    - Read the angles of the following: engine/transmission, each driveshaft, pump gear box and rear axle
    - Measure the length, cross to cross, of each driveshaft
    - Measure the offsets, side to side, of the engine/transmission, pump, and rear axle
    - Determine the maximum driveline RPM
    - Indicate phase of each yoke.
2. Run the driveline measurements on a driveline program (Dana Expert is very good, www2.dana.com/expert). Run the program three times – once for the font driveshaft(s) only, once for the rear driveshaft(s) only, and once for the total system assuming the pump is a shaft. Look for lowest numbers possible. Do not exceed .42 times critical speed.
3. Check maximum driveshaft length with Hale's Suggested Driveline Length chart
4. Readjust driveline to design parameters from program and chart.
5. If you still have a vibration, do the following, step by step testing at each point:
    - Flip the driveshaft around, where sliders are closest to the pump
    - Rebalance driveshafts at or above the maximum driveshaft speed
    - Replace the end yokes on the transmission and rear axle.
    - Replace the flange yokes on the pump
    - Replace carrier-bearing assembly with another style, if applicable
    - Add a carrier-bearing assembly to longest driveline
    - Evaluate gearbox or pump mounting for adequate stiffness.