Sumitomo Drive Technologies

WHAT EXCELLENT GEARING & GEARBOX MAINTENANCE LOOKS LIKE

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NEW GEARBOX SELECTION

ALIGNING APPLICATION REQUIREMENTS WITH GEARBOX PERFORMANCE

Gearbox selection and operational success are closely connected. Success is largely dependent on effective communication between the customer and the gearbox OEM and/or supplier. For a gearbox to achieve optimum performance and life, the following factors must be considered:

- Demand Power Requirement (HP/kW)
- Nameplate motor HP/kW and speed
- Speed reducer or speed increaser
- Load cycles (i.e. – starts/stops per hour/day and typical number of hours per day runtime)
- External load considerations
- Input driver type (i.e. – electric motor, engine and number of cylinders, or other)
    - For electric motors, use a SF of 1.0. Depending on the number of cylinders, engines require 1.25 to 1.5 SF before application details are considered.
- Driven equipment description
- Input speed in RPM
- Ratio required or output speed of the gearbox
- Location of installation and the application site envelope
- Gearbox orientation
- Location operating environment (i.e. – Indoors/outdoors, dry/wet, hot/cold, washdown, and particulate accumulation)

WHAT IS SERVICE FACTOR?

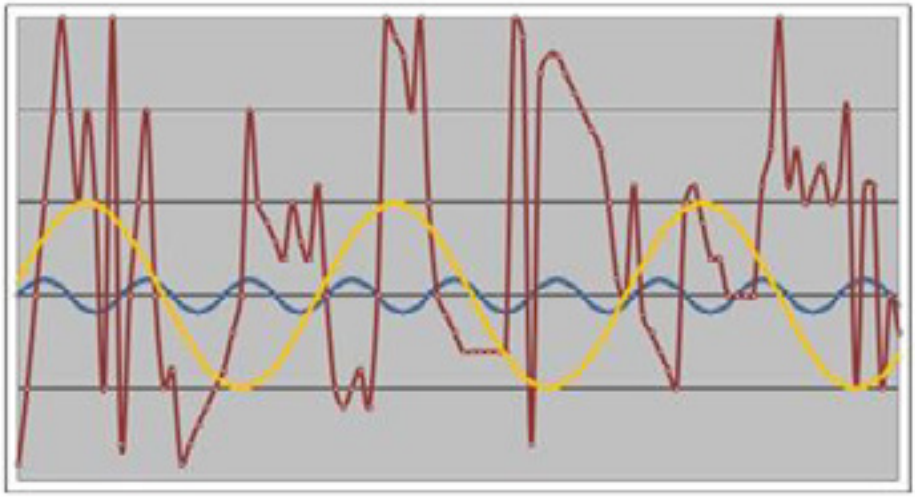
- Variables that influence how capable the unit is in accommodating operating punishment are used to assign a Service Factor (SF).
- Service Factor = Power Rating of the Gear Unit/Power Applied to the Gear Unit
- Said another way, SF = Gearbox Catalog Power Rating/Service Power Rating

WHY WOULD YOU WANT SF?

The higher the Service Factor the more capable the gearbos is for the application.
Governing bodies like AGMA tabulate recommended Service Factors for different industries and applications, but in some circumstances experience should override these recommendations to ensure acceptable reliability.

- Increase reliability of a gear drive
- Compensate for load variations during operations
- Known loading
- Frequent stops and starts
- Batch loading
- Vibratory loads
- Fluid contamination
- Unexpected loading
- Process contamination
- Cold start up
- Possible Operator error
- Mechanical failure of connected equipment

SERVICE CLASS DETERMINATION



Load classification (Shock Severity) defined as:

Class I
Uniform Loading

Class II
Moderate Shock Loading

Class III
Heavy Shock Loading

Taking all of the above into account, an application Service Factor (SF) will be applied to the gearbox HP and Torque rating in order to select a gearbox with optimum life opportunity.

But, how much SF is too much?

A large service factor means large components. Large components are mounted on larger bearings. Large bearings require larger forces to roll. Roller bearings not achieving their minimum load results in roller skidding and ultimately damage to the bearing

AFTERMARKET/GEARBOX REPAIR SELECTION

REASSESSING GEARBOX SELECTION AND APPLICATION DEMANDS

For a gearbox that is currently in service, avoid assuming that it has been selected properly. There are factors that can lead to a GB being undersized. One common flaw is that the initial selection procedure was not fully followed. It may be that the application engineer was not fully aware of all of the variables in the system that would impact the GB directly or indirectly. Sometimes, corners may have been cut to control the initial cost.

When a GB needs repair, and life of the GB has not been satisfactory, communication is also key. Maybe the GB initially ran for many years, then was repaired, and since that repair, the life is much shorter. It is recommended to do a full analysis of the application parameters and demand placed on the reducer. Follow the same steps outlined above for new GBs.

The higher the Service Factor the more capable is the gear box for the application.
Governing bodies like AGMA tabulate recommended Service Factors for different industries and applications, but in some circumstances experience should override these recommendation to ensure acceptable reliability.

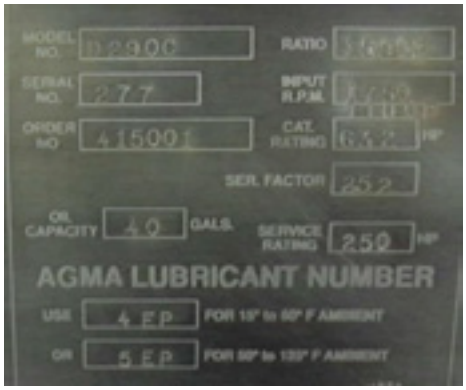
The following is what MUST be verified by the customer:

- Input driver description
- Driven equipment description
- Power requirement (demand HP/kW and Motor nameplate rating)
- Input speed
- Is this a reducer application or a speed increaser application

The items below can be determined during evaluation at the shop

- Ratio
- Net face width of gear
- Tooth count of all the pinions and gears
- Gear and pinion hardnesses
- Center distance between mating shafts
- Single or double helical
- List of the bearings
- Shaft extension diameters
- Grade of oil being used

Much information can be gathered from the original GB tag. **Never remove tags.**



GEARBOX STORAGE AND PRESERVATION

PROTECTING GEARBOXES DURING STORAGE

Proper location – The best location for a gearbox is in operation. The next best is stored indoors in a climate-controlled environment.

This is NOT good.

This is VERY good.

PRESERVATION BASICS

- The type of preservative selected should be based on the anticipated storage time.
- Preservative should be compatible with lubricating oil.
- Gear oils from run test only protect from corrosion for up to 30 days.
- Some rust preventatives protect the internal surfaces of a unit from corrosion for up to six months.
- The frequency of recoating is dependent on the type preservative used.
- For small units with contacting seals
    - May be preserved by filling them with oil. This can be used for lengthy periods with little further maintenance.
    - Small units and ferrous parts can be preserved by putting them in storage bags, which are available in many sizes including custom sizes. They are economical, and create their own corrosion-inhibiting environment. No further maintenance is required

SHAFT ROTATION

- Gearboxes that sit for long periods of time are at risk of corrosion and fretting. In efforts to combat this:
    - Manually turn the input or high speed shaft until the output or low speed shaft has made at least 2.5 complete revolutions
    - Minimum number of high-speed shaft rotations required = 2.5 x reducer ratio (see reducer nameplate)
    - This ensures proper coverage of rust inhibitors
    - Sumitomo recommends shaft rotation at least every 3 months.

SURFACE AND SEAL PREP

- Make sure the unit is adequately filled with an NP-20 or equivalent oil soluble Volatile Corrosion Inhibitor (VCI). Rotate the shaft of the reducer gearbox by hand to assure complete rust preventative coverage of the interior. *
    - *NOTE - This should be drained and reapplied/filled every 6 months unless your manufacturer advises otherwise. Depending on manufacturer, the VCI could be re-charged after 2-3 years depending on storage conditions*
- Replace the air vent (if installed) and close the air vent hole with a sealing plug.
- Apply bearing grease to completely cover the externally visible shaft seals. Seals can deteriorate if exposed to higher temperatures and UV rays. A proper grease layer covering would act as a barrier to protect it from deterioration and foreign particle infiltration.
- Apply corrosion preventative coating to cover the external machined surfaces (e.g. input and output shafts, screw holes, mounting surface) using "Black Bear Par-Al-Ketone", "Houghton Rust Veto 342" or any other NP-19 [JIS] equivalent
- Cover the reducer and shafts completely with waterproof plastic or better shielding material so the reducer is protected from dust, water and any substance that may be harmful to the reducer and seals. Desiccant between gearbox and plastic shall keep the unit dry from surrounding moisture

INSTALLATION AND START UP

PROPER GEARBOX INSTALLATION AND SHAFT ALIGNMENT

SINGLE HELICAL VS DOUBLE HELICAL GEARS

- You must know whether your gear is a single-helical or double-helical gear.
- The reliability of the machinery train depends on proper installation of the gear. They are aligned differently.
- All shafts on single-helical gears are independently positioned axially by their supporting bearings.
- If the unit is a double-helical unit, only one shaft is positioned axially by its bearings. Generally, that is the low speed shaft.
- The other shaft(s) has to be positioned by centering the pinion(s) within their axial float. Once centered, alignment can take place.

INSTALLATION SEQUENCE

- Align the gear unit to the most stationary machine in the mechanical system.
- Then align the other component in the train to the gear unit.
- For reducers, the general sequence is:
- Align low speed shaft of gear to driven machine
- Align prime mover to high speed shaft of gear reducer
- For increasers, the general sequence is to:
- Align the high-speed shaft of the gear to the driven machine
- Align the low speed shaft of the gear to the prime mover

INSTALLATION

- Using optics or laser alignment equipment determine the flatness of the foundation and record readings, particularly at the foundation holes.
- Using proper chains and slings, pick the unit up using the lifting eyes designated for lifting the entire unit.
- Clean the bottom of the gear housing mounting flange and the top of the foundation mounting flange. Use a file to remove any burrs
- Check with a feeler gauge at each foot connection point. If you are able to insert the gauge between the machine and its mounting surface, that indicates soft foot is present and needs to be addressed. Target should be < 0.003
- Establish rough alignment.
- Tighten foundation bolts
- Perform soft blue contact check on the gears
- Determine acceptable contact pattern
- Perform check
- Correct as necessary

ALIGNMENT OF LOW SPEED GEAR SHAFT

- Position the input shaft of the driven machine in the system to the manufacturer's recommended location.
- Loosen the foundation bolts of the gear unit
- Center the low speed gear in its axial end-float.
- Align the low speed shaft of the gear unit to the input shaft of the driven equipment by moving the gear unit as necessary. Take into account the required coupling gap.
- Take into account the thermal and mechanical movement of the gear box as well as that of the driven machine.
- The maximum variation to true alignment is shown in the following slide. This may be different than what the coupling allows. Use the smallest allowable value!
- Re-tighten foundation bolts.
- Through the inspection cover, verify contact with soft blue check.

Installation-limits of shaft end misalignment

Shaft Surface Velocity (Ft/Min)	Max. Runout (TIR) on Outside Diameter	Face Runout (TIR) per Inch of Radius
5000 and over	0.002	0.0004
3000-5000	0.004	0.0005
1500-3000	0.006	0.0006
500-1500	0.008	0.0008
500 and less	0.010	0.0010

SHAFT SURFACE VELOCITY (FEET/MINUTE) = SHAFT DIA (INCHES) X SHAFT SPEED (RPM) X 0.262

HIGH SPEED PINION ALIGNMENT OF SINGLE-HELICAL UNITS

- Push pinion to its active side.
- Determine the required coupling gap.
- Consider the allowable float for the coupling design
- Take into account thermal and mechanical movement of the gear as well as that of the prime mover.
- Align the prime mover to the gear unit using dial indicators or laser alignment equipment
- Align to the limits shown in the previous slide

HIGH SPEED PINION ALIGNMENT OF DOUBLE-HELICAL GEAR UNIT

- Center the pinion of each reduction in the axial backlash of its gear. Start with the low speed and work toward the high speed.
- Hold the gear stationary so as not to disturb the axial position of the pinions previously centered.
- Determine required coupling gap
- Consider the allowable float of the coupling design
- Align prime mover to the gear unit using dial indicators or laser alignment equipment to within the required limits.
- Take into account thermal and mechanical movement of gear as well as that of the prime mover.

FINAL PREPARATIONS FOR START-UP

- Tighten all foundation bolts.
- Perform final "soft-blue" contact check
- Record contact using tape lift-offs
- Clean area used for the soft-blue check
- Spray with layout blue lacquer
- Spray with oil to prevent gear teeth from rusting

START UP

LUBRICATION SYSTEM FILLING AND INITIAL STARTUP

- Fill unit to full mark on dipstick or to center of sight glass with the proper viscosity lubricating oil. Filter the oil as it is pumped into case.
- If a motor driven oil pump is installed, prime electric motor driven pump and start pump
- Run for 5-10 minutes and stop pump. Re-fill reservoir to full mark on dipstick or center of sight glass
- Restart pump and check for leaks
- Start machine.
- Initial operation
- If the unit has a shaft driven oil pump, make certain the oil pump "picks up" after 30 seconds operation. If it does not, stop the unit immediately and check for loose piping connections, particularly those in the suction line.
- Verify the oil level is correct.
- Re-prime the pump and re-start the system.
- If gear reducer is small and has a limited sump capacity, operate system for 2-3 minutes and then shut the machine down.
- Refill the unit with oil. This is especially important if the machine has a relatively large lube system. Be especially aware of the oil level if the unit has remotely mounted lube components such as an oil cooler.
- If the lube system has a greater oil capacity than that of the sump, the unit may require that you start the unit and let it run a few minutes, stop it and add oil and go through this process several times.
- Restart system.
- Immediately observe the oil pressure.
- Adjust the pressure to desired pressure shown on the installation plan or the unit specification sheet.
- Oil pressure will be somewhat higher prior to the oil reaching its normal operating temperature
- As the unit operates and heats up, observe the oil temperature.
- If you have a heat exchanger in the lube system, adjust the water flow to achieve the operating temperature shown on the installation plan or the unit specification sheet. (LUFTEX generally prefers the oil temperature be delivered at 120°F - 130°F.)

INSPECTIONS

ROUTINE GEARBOX INSPECTION AND MAINTENANCE SCHEDULE

DAILY INSPECTION

- Check oil level if possible
- Check level with unit stationary.
- Check and record oil temperature and pressure
- Measure and record housing temperatures around bearings
- Compare to previously established values.
- Check for oil leaks
- Check for unusual vibration and noise
- Any changes in temperature, oil pressure, noise or vibration should be investigated.

MONTHLY INSPECTION & MAINTENANCE

- Extract oil sample for spectrographic and ISO 4406 cleanliness examination.
- Check operation of auxiliary equipment and alarms
- Clean breather
- Check tightness of foundation bolts
- Clean/replace oil filter element

SEMI-ANNUAL INSPECTION & MAINTENANCE

- Perform vibration analysis
- Tooth related vibration
- Bearing related vibration
- Remove inspection cover and inspect gear teeth for wear or uneven contact.
- Maintain oil as suggested by oil analysis

ANNUAL INSPECTION

- Check shaft alignments.
- Check heat exchangers for erosion, corrosion and foreign material
- Inspect inside the gear case for metal shavings
- Check bearing clearances and end play.
- Check tooth contact pattern
- Look for area previously coated with layout blue.
- Make certain tooth contact is evenly distributed.
- Compare to previous contact
- A contact change suggests other issues
- Maintenance may be required
- Clean teeth and recoat with new layout blue

COMMON ISSUES

DIAGNOSING COMMON GEARBOX OPERATING PROBLEMS

CHANGES IN TOOTH CONTACT

- Changes in tooth contact are an indication of a problem with internal alignment of the pinion to the gear.
- Factors that affect tooth contact during operation:
  - Failed or failing bearings
  - Worn housings
  - Inadequate or deteriorating foundation
- Symptoms of internal misalignment
  - Gear tooth pitting
  - Metal in filter
  - Noise or vibration
- Internal alignment must be maintained during operation
- Internal alignment must be confirmed during installation

WHAT CAN CAUSE GEAR UNITS TO RUN HOT

- Failing bearing
- Plugged heat exchanger
- Inadequate cooling water flow
- Gear housing covered with foreign substances
- The oil level is too high
- Inadequate clearance
- Internal rubs
- If unit is a dry sump unit, inadequate drain
- Too little oil flow
- The oil isn't getting to the right place
- Too much oil flow

CAUSE OF VIBRATIONS

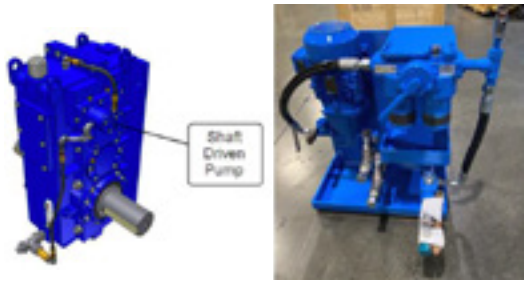
- Unbalance
- Shaft misalignment
- Inadequate foundation or loose foundation bolts
- Bearing failure
- Coupling problem - lockup, wear, no lubricant, too much lubricant
- Gear tooth wear
- Worn housing
- Lateral or torsional critical speed response

LUBRICATION PUMP START UP

LUBRICATION PUMP TYPES AND COLD-START REQUIREMENTS

TWO MAIN STYLES OF LUBE PUMPS USED ON GEARBOXES

- **Shaft Driven Lube pumps** – Mechanical
  - Pump operates via attachment to a gearbox shaft (usually HSS or next intermediate).
  - Shaft driven pumps require a minimum gearbox operating speed for adequate flow.
- **Motorized Lube pumps.** (Electric motor attached to pump head)

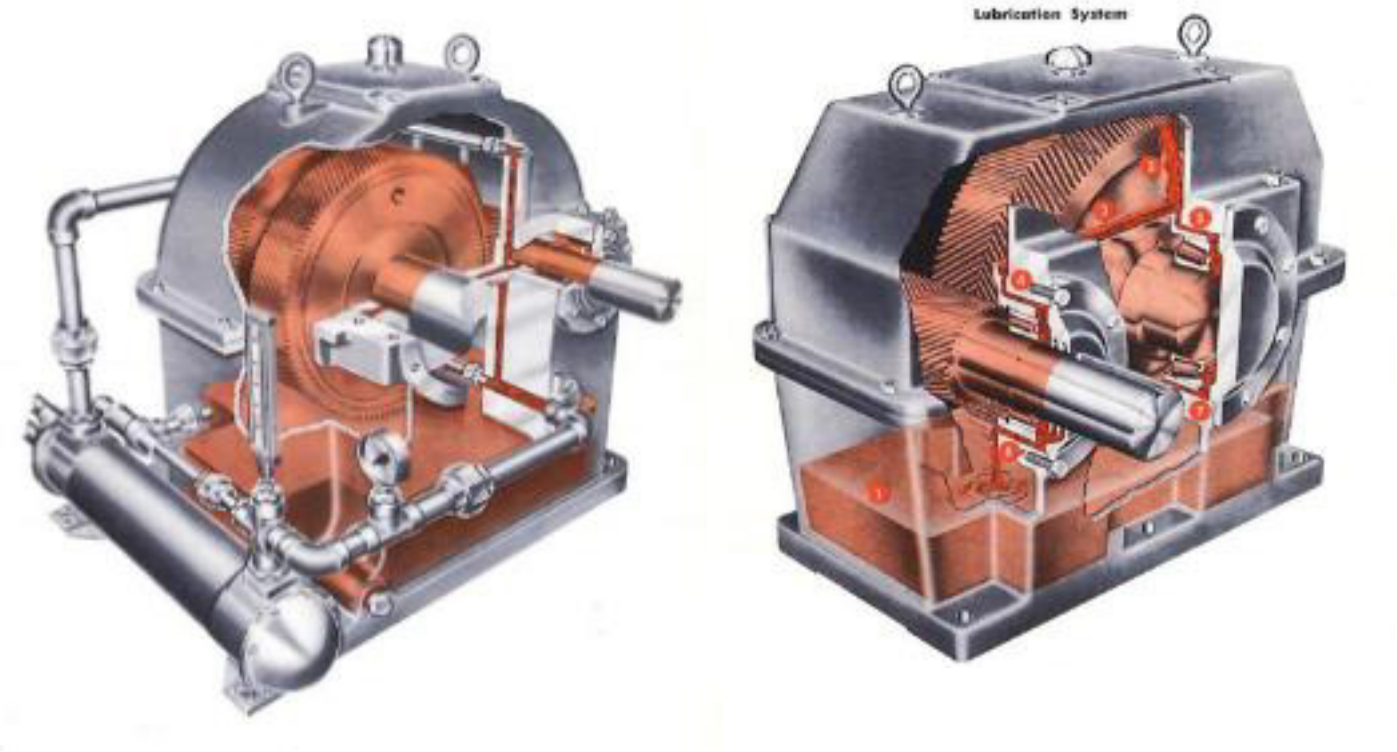


There are designs that can incorporate both styles of pumps on one gearbox.

MINIMUM STARTING TEMPERATURE

- Splash lubrication: the maximum oil viscosity has to be limited because of the insufficient flow of the oil across the oil distribution canals.
- Forced lubrication systems (mechanical lube pump)
- **AVOID COLD STARTS**
- **REMEMBER TO TOP OFF THE OIL LEVEL AFTER LUBE SYSTEM COMPONENTS ARE FILLED!**

(The operating conditions and oil selection should have been considered in the early stages of the gearbox design and selection) i.e.: Viscosity requirements and Flow rate requirements.



LUBE SYSTEM FLUSH AND FILTER

WHEN AND WHY TO FLUSH THE LUBRICATION SYSTEM

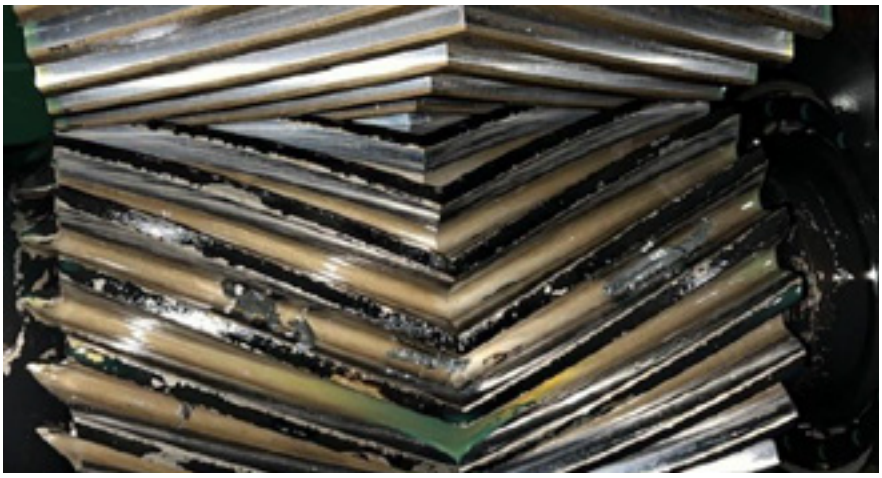
- Gearboxes and bearing housings periodically need a thorough flushing rather than a simple drain and fill.
- Several signs point to this requirement, such as overheating of the sump, reported liquid or solid contamination, and development of a severe gear and/or bearing wear pattern.
- Material evidence in the form of sludge, rust, moisture, wear metals, gel or other viscous residue that is present at the beginning of the drain should confirm to the technician that a flush is in order.
- A thorough flush is also useful for removing construction and assembly contaminants from equipment sumps prior to commissioning.

LUBE SYSTEM FLUSH AND FILTER

- Flushing is a clean fluid circulation process designed to remove water, chemical contaminants, air and particulate matter (not fixed to surface) resulting from construction, normal ingression, internal generation or component wear.
- Flushing can be useful in many different circumstances, such as the following:
- For new or rebuilt machines to remove contamination resulting from manufacture, service or overhaul. The fluid system can be contaminated due to dirty assembling elements, corroded surfaces, water, oxidation products and incompatible elastomers such as seals, sealants and coatings. Also, during the assembly process, dirt is ingested and debris is generated due to threading, joining, welding, etc.
- For in-service machinery after an oil change due to heavy fluid contamination, component failure, extremely degraded lubricant (oxidation), or if a system flushing has not been performed in the past three years.
- For gearboxes and bearing housings that are not fitted with filtration, flushing is required to remove contamination and sediment. Water, rust, excessive wear debris, sludge, varnish or lacquer, and hard-to-open drain ports suggest system contamination and indicate the need for a thorough flush.
- Ten percent of the old contaminated or depleted lubricant may be enough to use up most of the additives of the new oil.

Flushing?

Sludge buildup on gears in sump, sealant in oil visible.



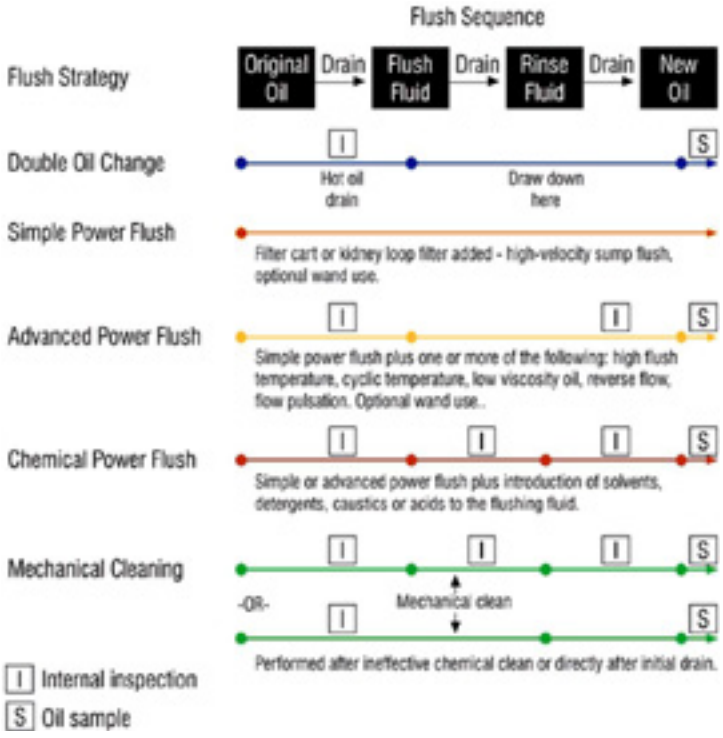
What equipment can or should be used for this purpose?

High flow system to force oil through sumps at a higher pressure/velocity through strainers and filters

Filter carts and Filter Skids are used at a lower pressure and flow rates to maintain oil quality

FINALLY, WHAT ITEMS SHOULD BE INCLUDED IN A DETAILED FLUSHING PROCEDURE?

- Establish Oil Cleanliness Goals
- Gear box target 16/13 – 18/14 typical ISO 4406
- Roller bearing life calculations assume 18/14 maximum
- First number is number of small particles(>5µ), second number is number of large particles (>15µ)
- Select the equipment required to support the flushing procedure.
- Document pre- and post-flushing conditions through an established sampling program.
- Sampling program.



GEARBOX FIELD INSPECTIONS

PREPARING FOR AN EFFECTIVE GEARBOX FIELD INSPECTION

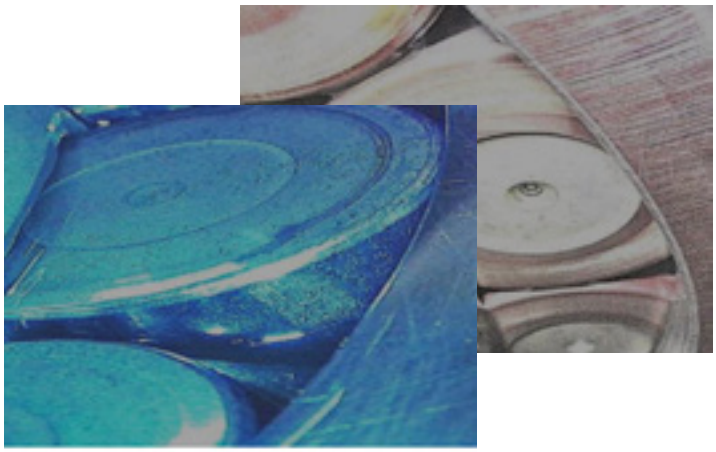
Do this
to
Prevent this

TOOLS AND EQUIPMENT

- Proper safety equipment for the facility
- Notepad and Pen
- Camera
- Borescope

BORESCOPE VS CAMERA

- Borescope is a tool, but does have its limitations
- Target has to still be accessible
- Dirty, oily environment can be a nightmare
- Right environment it can provide better insight



WHAT IS IMPORTANT TO NOTE

- Application
- Driver/Driven
- Type of couplings
- HS or LS unit
- Seal leaks or other visual signs
- Oil used
- Environment

THE MOST AFFECTED PARTS TO EXAMINE

- Gear teeth
  - Contact pattern
    - Loaded vs unloaded flank
  - Wear
  - Pitting
  - Cracks
  - Tempering
  - Indentations
  - Backlash
- Shafts
  - Cracks (dye pene)
  - Fretting
  - Key ways
  - Rub areas
- Seals
  - Rubbing
  - Cracking
  - Damage-impact, broken labyrinths
- Bearings
  - Babbitt Journal Bearings
    - Babbitt flow
    - Coking (burnt oil) marks
    - Scratches
    - Clearance
      - Feeler gauge
      - Lift check
      - Axial movement
- Anti-friction Roller Bearings
  - Cage damage
  - Brinelling
  - Pitting-rollers and/or races
  - Indentions
  - Tempering
  - Clearance
    - Feeler gaige
    - Lift check
    - Axial movement

For additional information regarding

What Excellent Gearing and Gearbox Maintenance Looks Like?

please contact:

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- OR -

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