SPINNAKER CORPORATION
EQUIPMENT AND PROCESS SOLUTIONS

Paper Machine Dryer Gearing

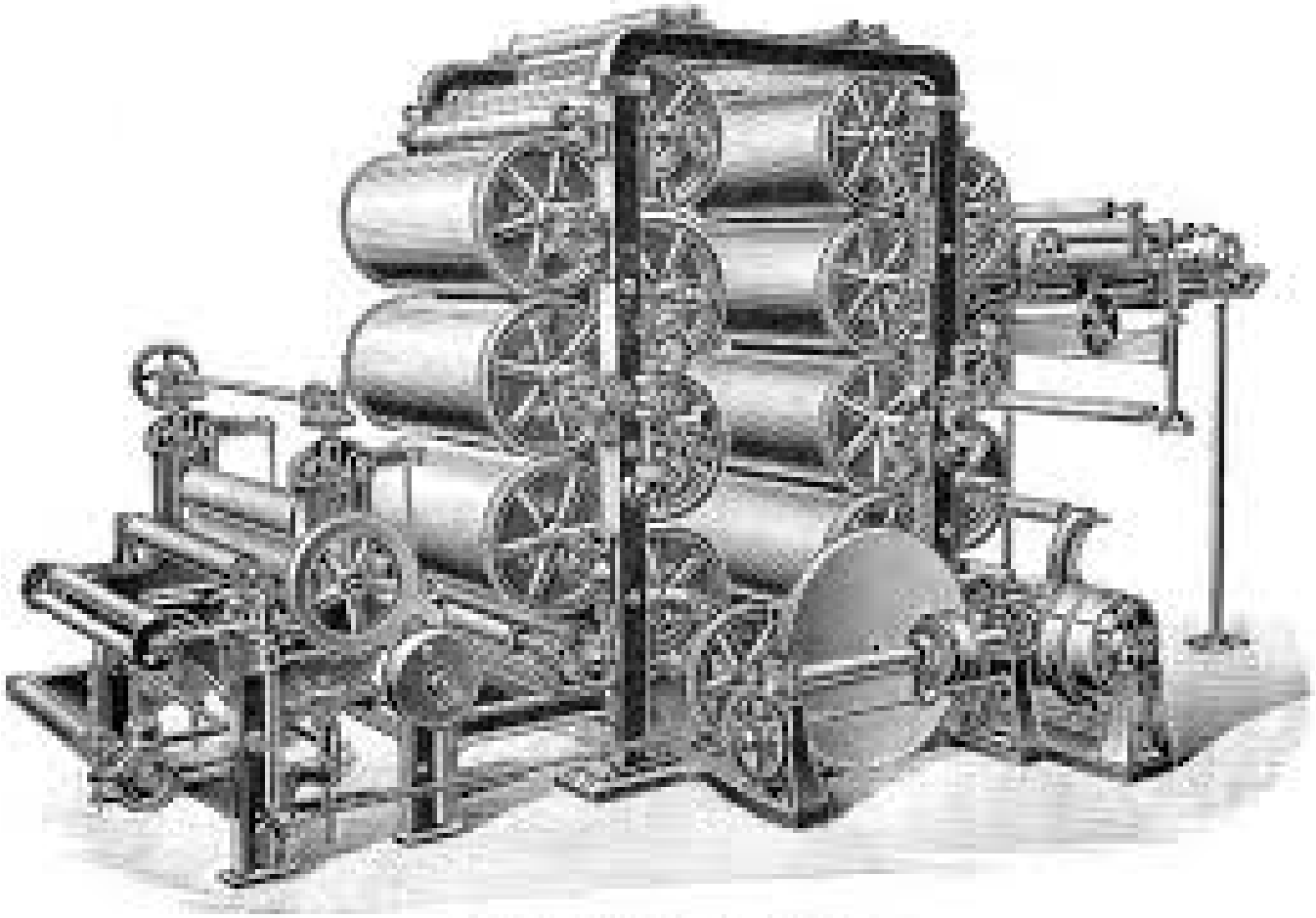

Fig. 32.—Cloth-drying Machine.

SPINNAKER CORPORATION
EQUIPMENT AND PROCESS SOLUTIONS

Paper Machine Dryer Gearing

AGENDA

Intro to Paper Machine Dryer Gears

Gear Tooth Form

Gear Center Distance: Backlash & Tip/Root

Paper Machine Conditions Affecting Dryer Gearing

Wear Conditions

Inspection of Dryer Gearing

Lubrication

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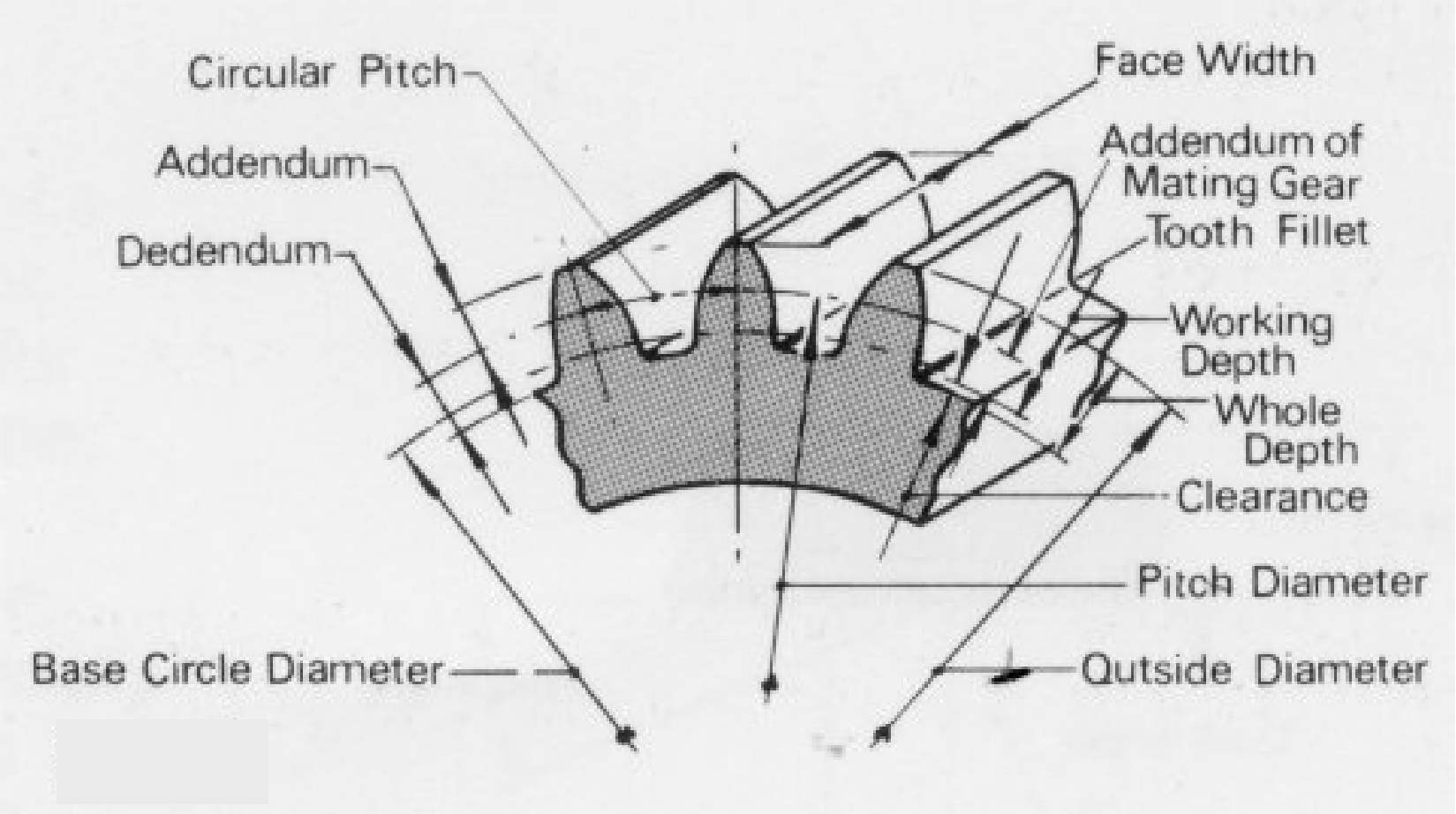
EQUIPMENT AND PROCESS SOLUTIONS

Paper Machine Dryer Gearing



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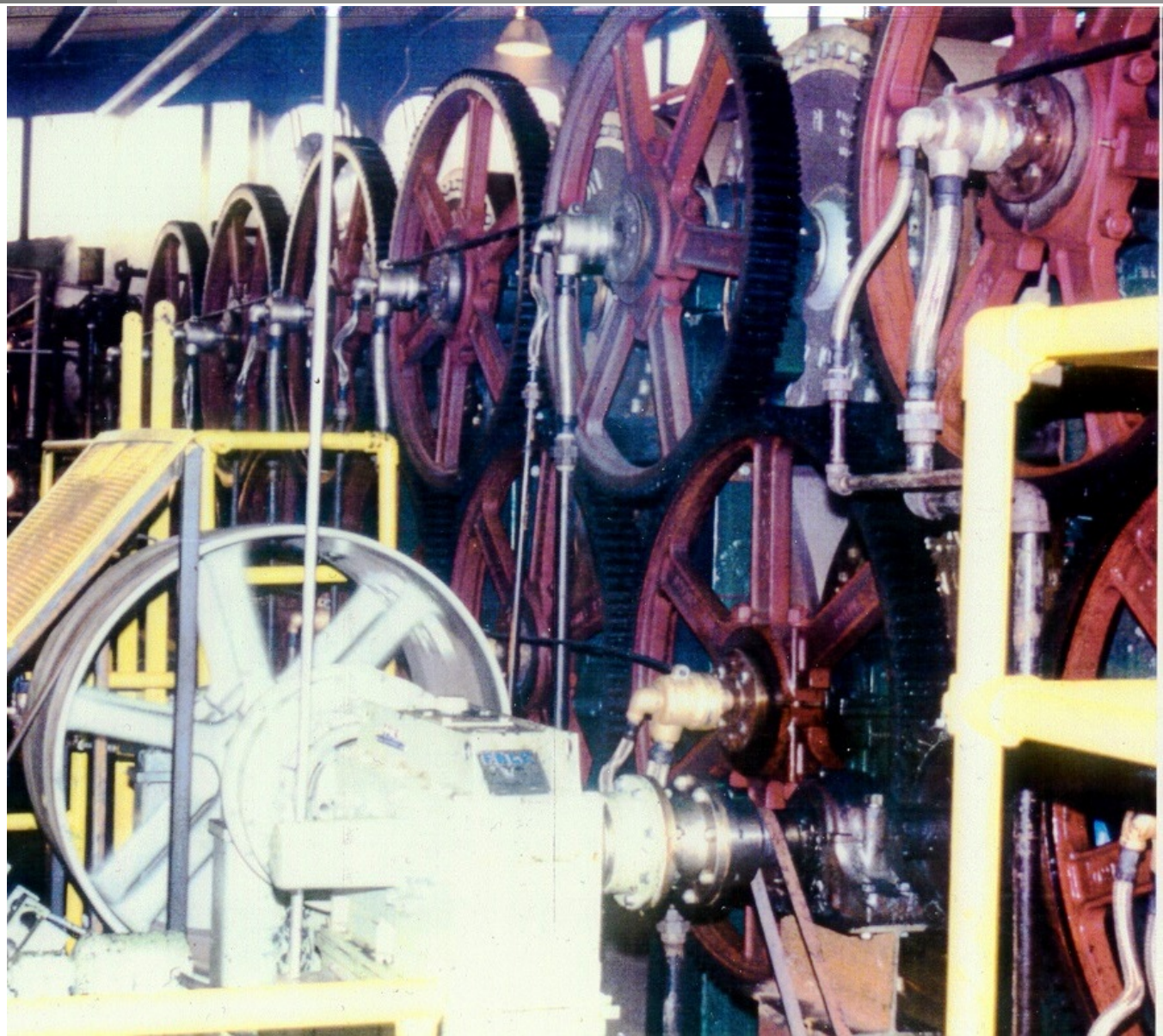
EQUIPMENT AND PROCESS SOLUTIONS

Paper Machine Dryer Gearing

Open type cast iron spur gears were the common dryer section drive systems in paper machines up through the 1960's.

Many were later converted to use a combination of cast iron and nylon gears. This reduces vibration, noise, and eliminates the need for lubrication.



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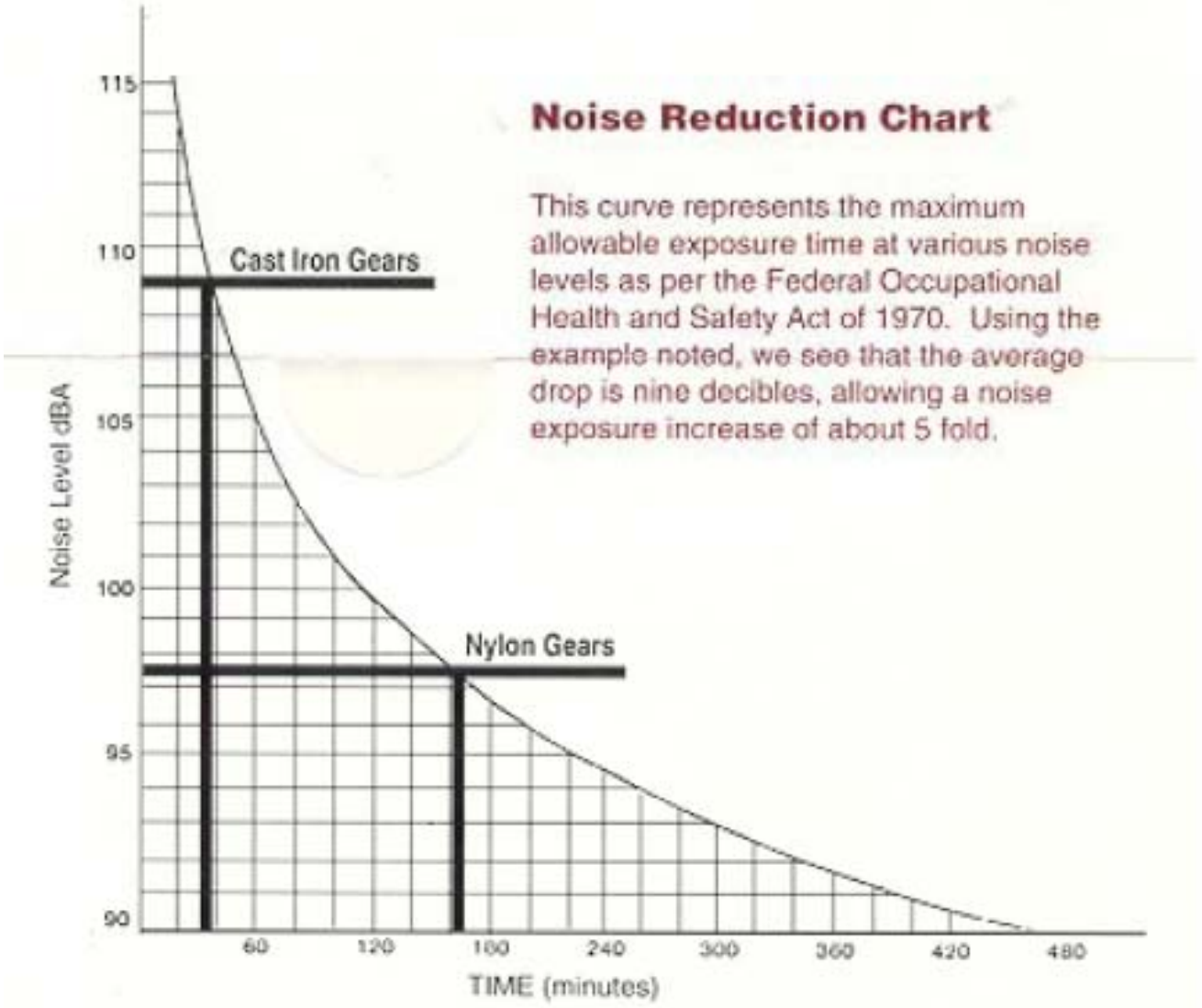
EQUIPMENT AND PROCESS SOLUTIONS

Paper Machine Dryer Gearing



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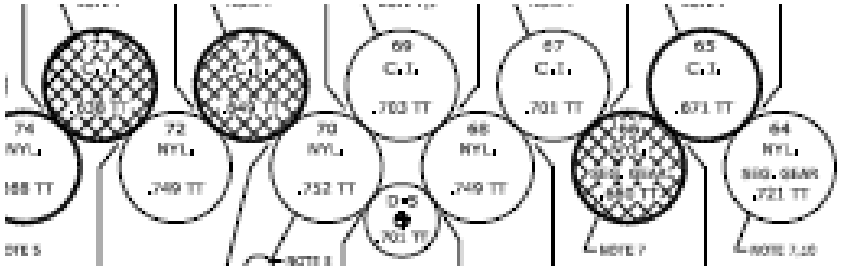
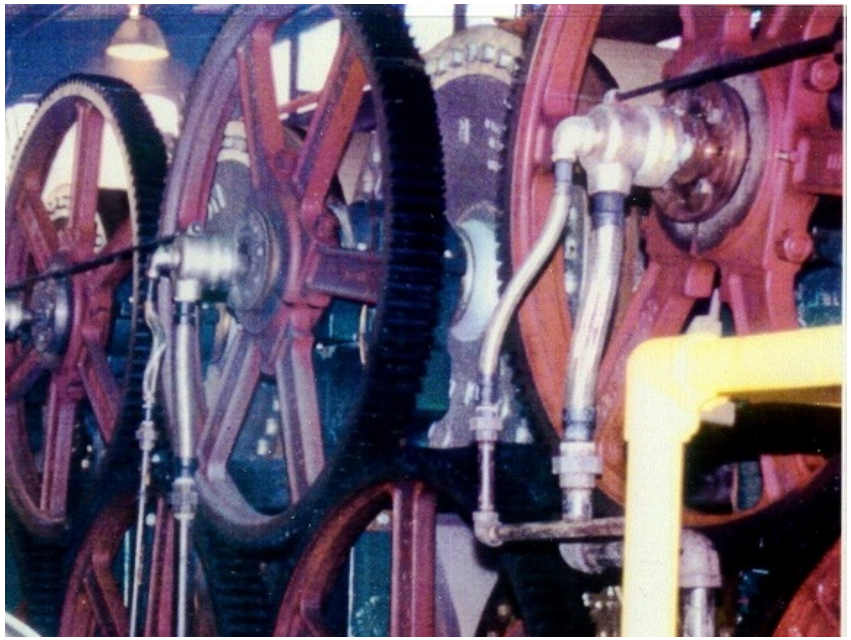
EQUIPMENT AND PROCESS SOLUTIONS

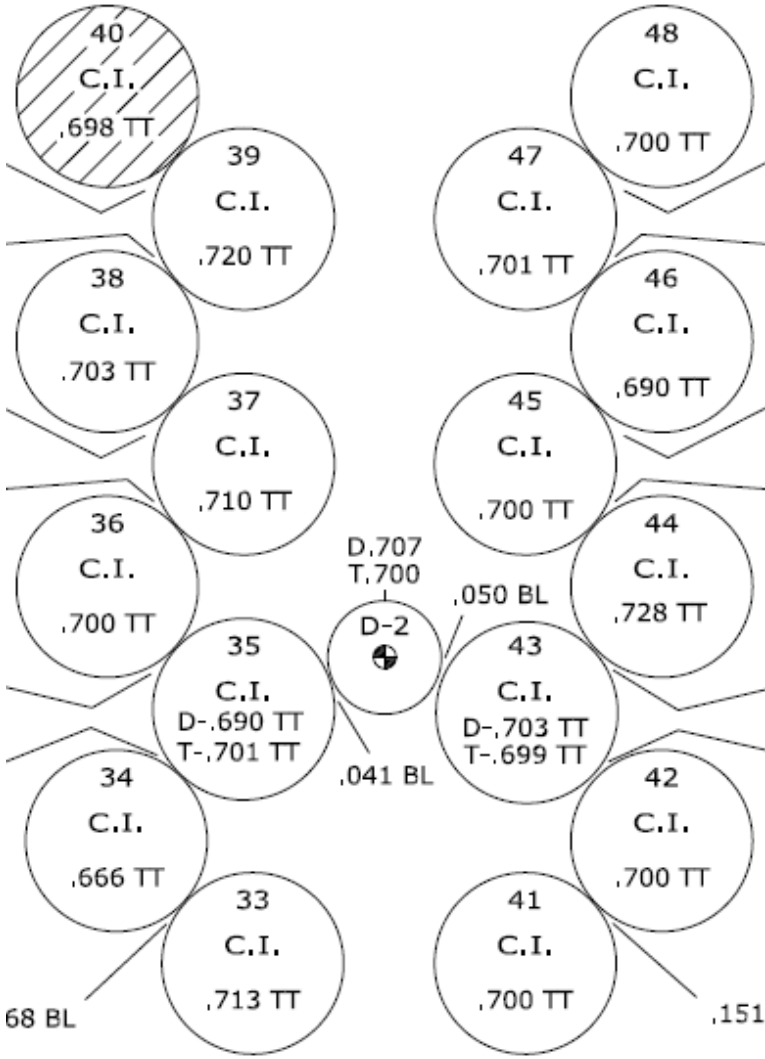
Paper Machine Dryer Gearing

Open Spur Gear Arrangements



Typical Horizontal
Dryer Arrangement





Black Clawson Stacked
Dryer Arrangement

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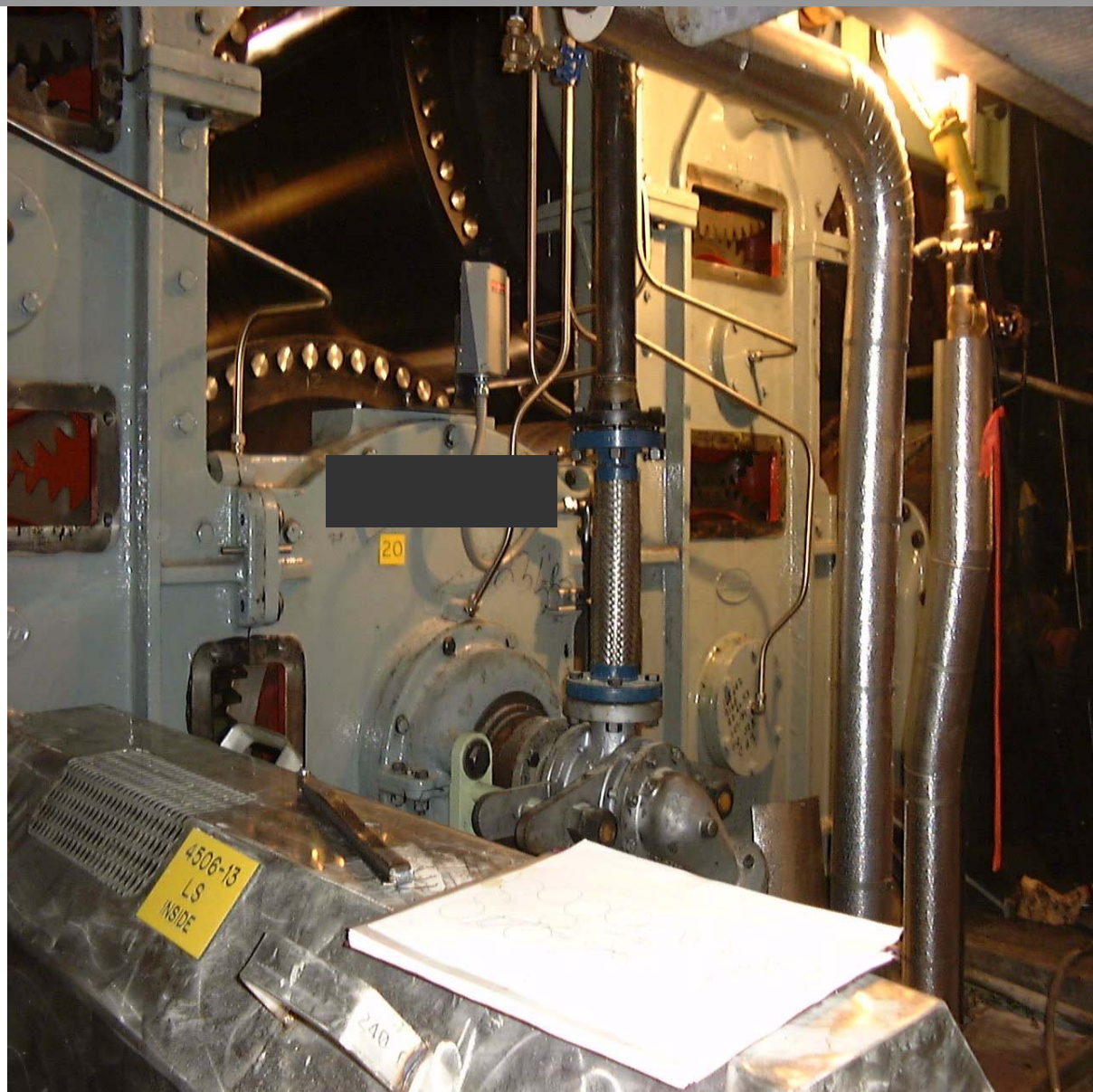
Paper Machine Dryer Gearing

As paper machine speed and widths increased, a gear arrangement with greater torque capacity became necessary.

Paper machinery builders began offering enclosed dryer gear cases with helical gears.

Due to the increased torque capacity of the helical tooth form, gear size could be reduced, simplifying and reducing manufacturing cost.



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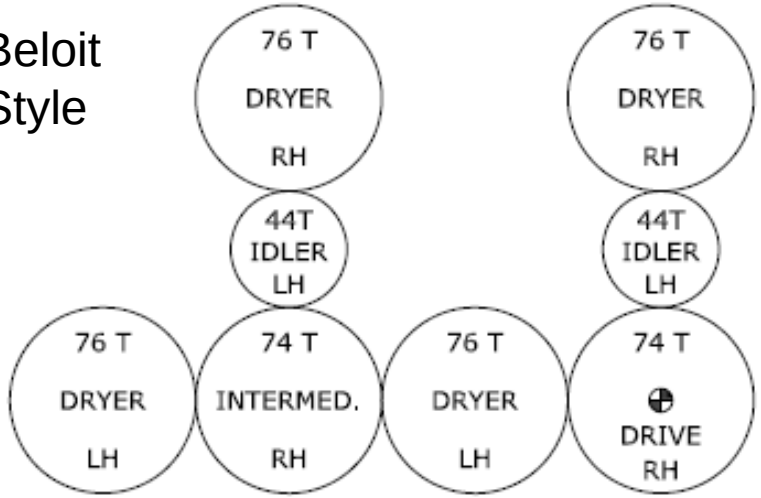
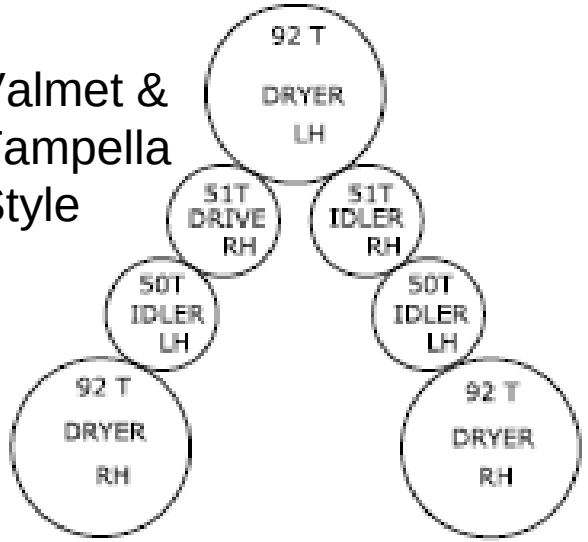
Paper Machine Dryer Gearing

Helical Gear Arrangements

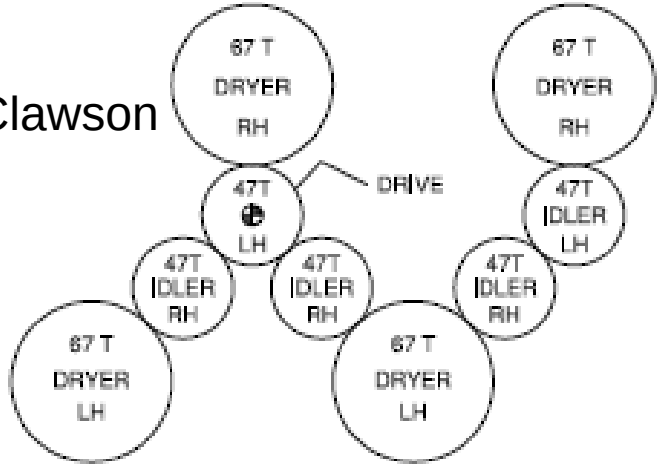
Beloit Style



Valmet & Tampella Style



Black Clawson Style



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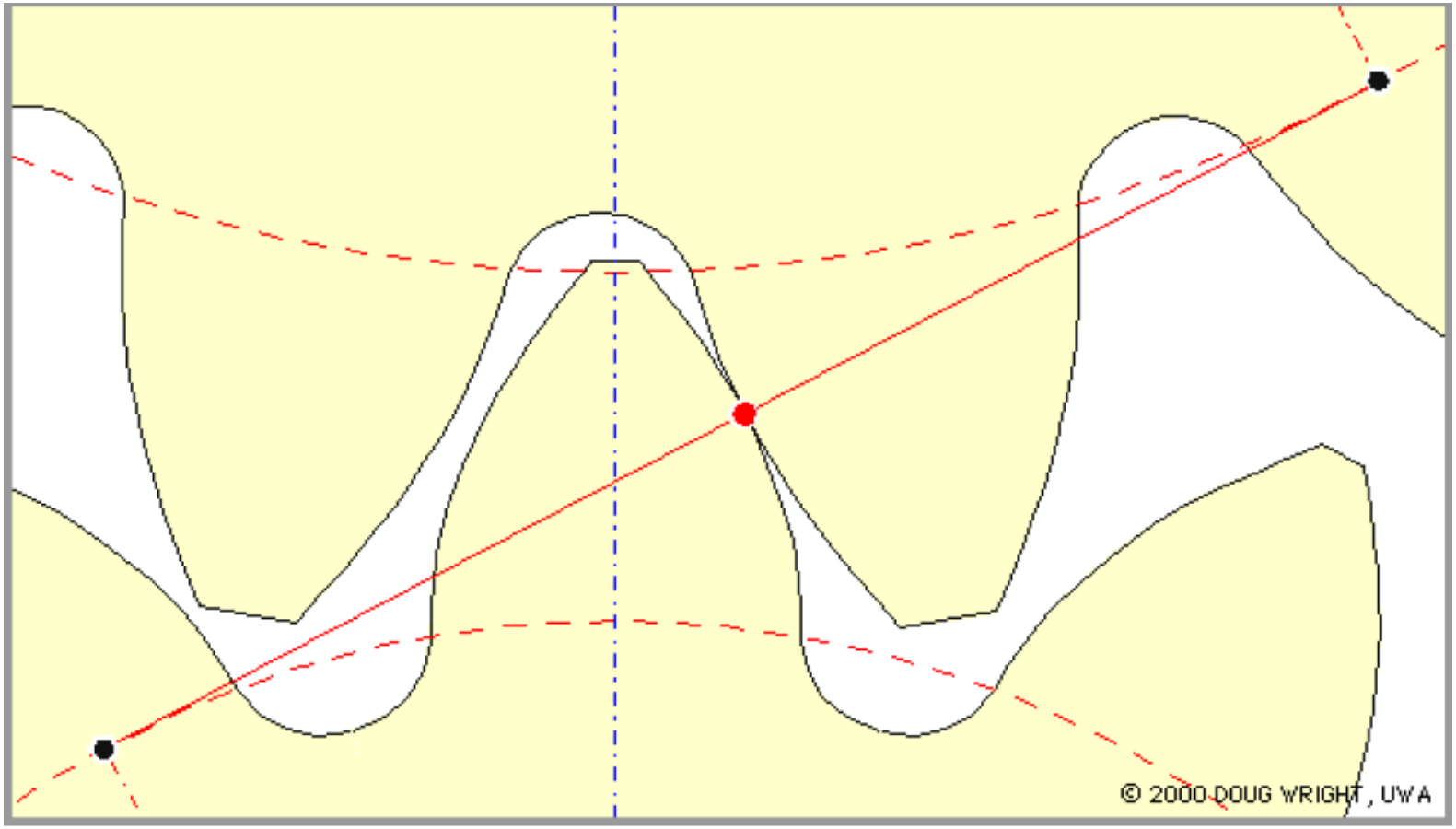
EQUIPMENT AND PROCESS SOLUTIONS

Paper Machine Dryer Gearing



A good tooth profile and good backlash equals smooth operation. Gear teeth have a curved (involute) surface to "roll" as they contact each other. When the involute curve is gone, the gears slide and vibration increases.

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EQUIPMENT AND PROCESS SOLUTIONS

Paper Machine Dryer Gearing

The angled teeth engage more gradually than do spur gear teeth, causing them to run more smoothly and quietly. Each pair of teeth first make contact at a single point at one side of the gear wheel; a moving curve of contact then grows gradually across the tooth face to a maximum then recedes until the teeth break contact at a single point on the opposite side.

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EQUIPMENT AND PROCESS SOLUTIONS

Paper Machine Dryer Gearing

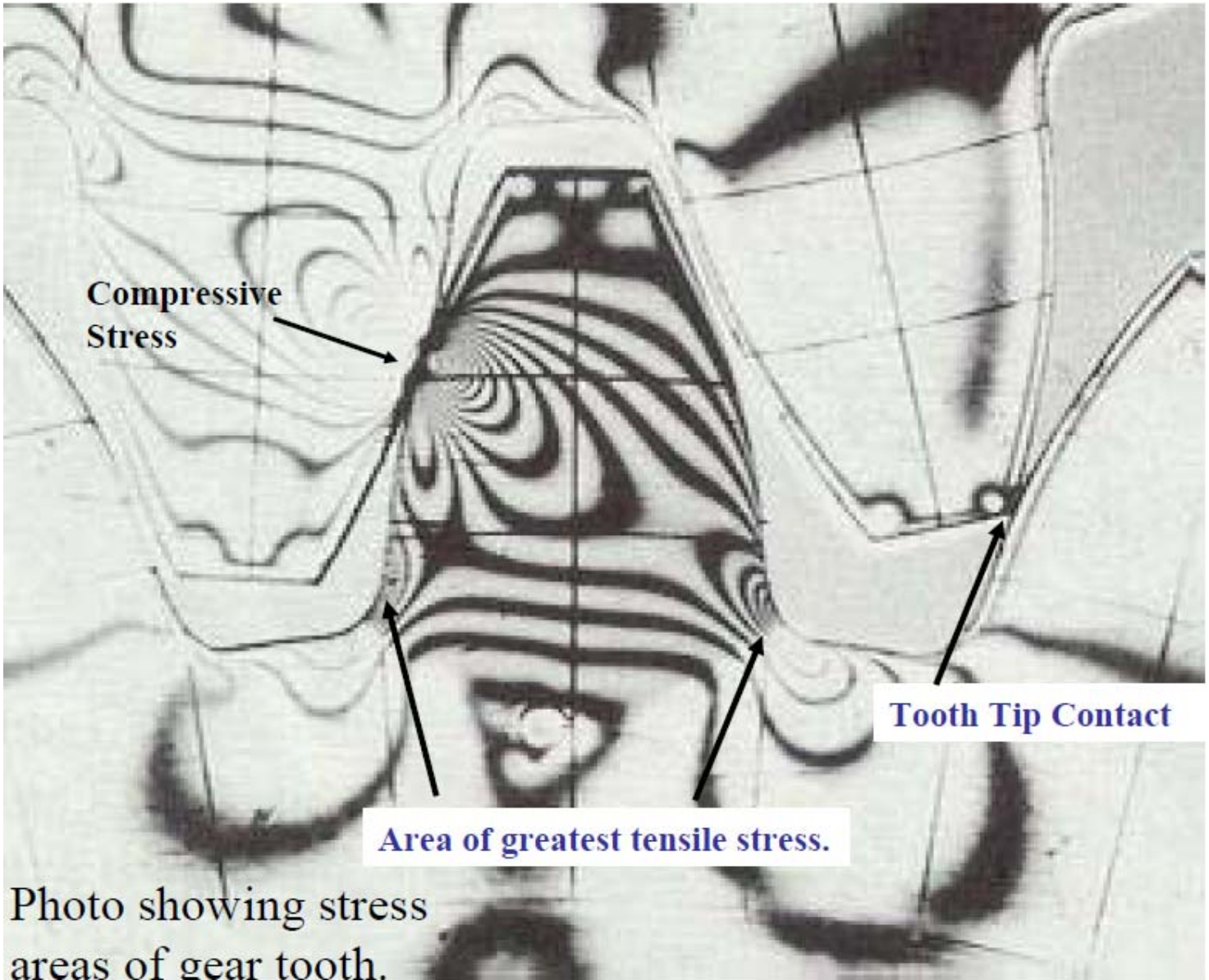

Photo showing stress areas of gear tooth.

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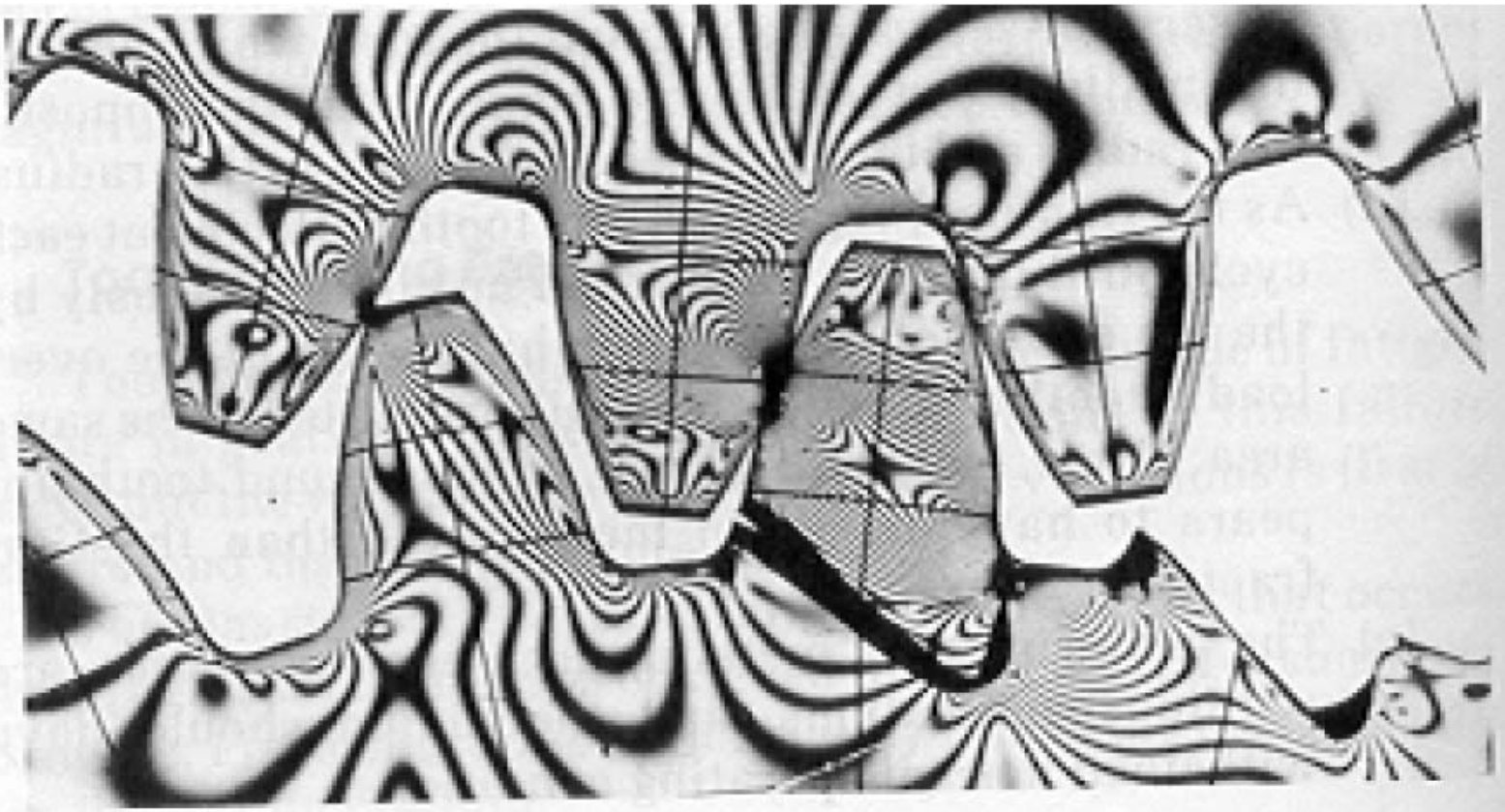
Paper Machine Dryer Gearing



Photoelastic study of mating teeth indicates the shift of the zero-stress point during crack propagation until final fracture reaches the opposite root radius. At the same time, deflection of the tooth allowed the adjacent tooth to pick up the load.

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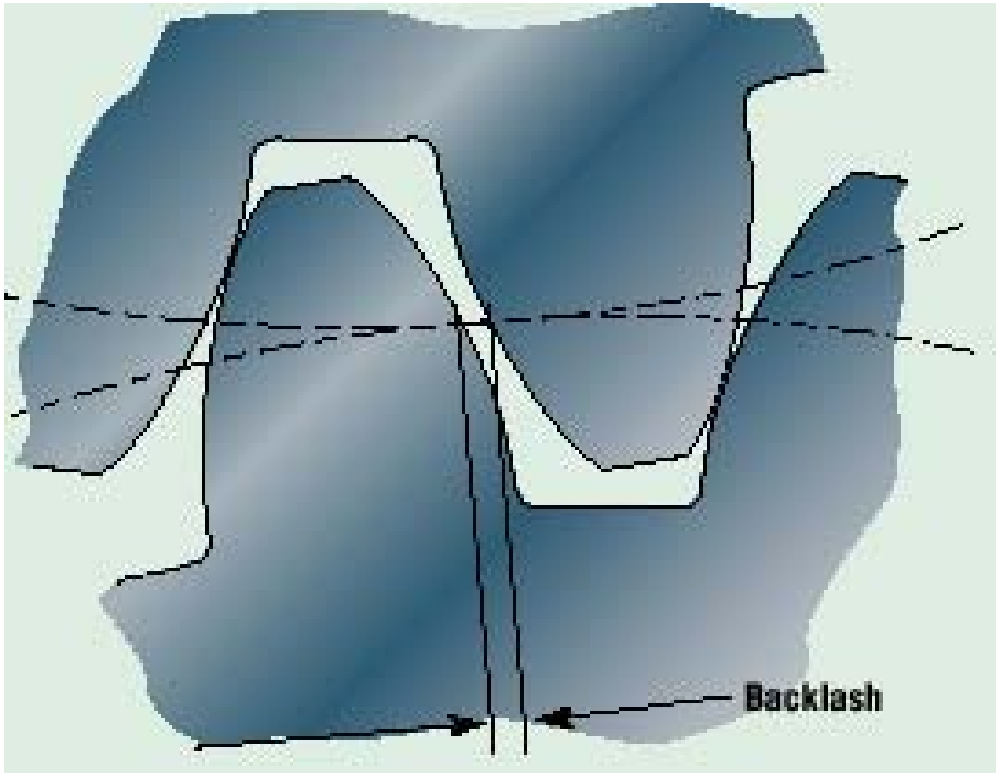
EQUIPMENT AND PROCESS SOLUTIONS

Paper Machine Dryer Gearing

Backlash, a clearance between mating **gear** teeth, is built into to let the gears mesh without binding and to provide space for a film of lubricating oil or grease between the teeth.



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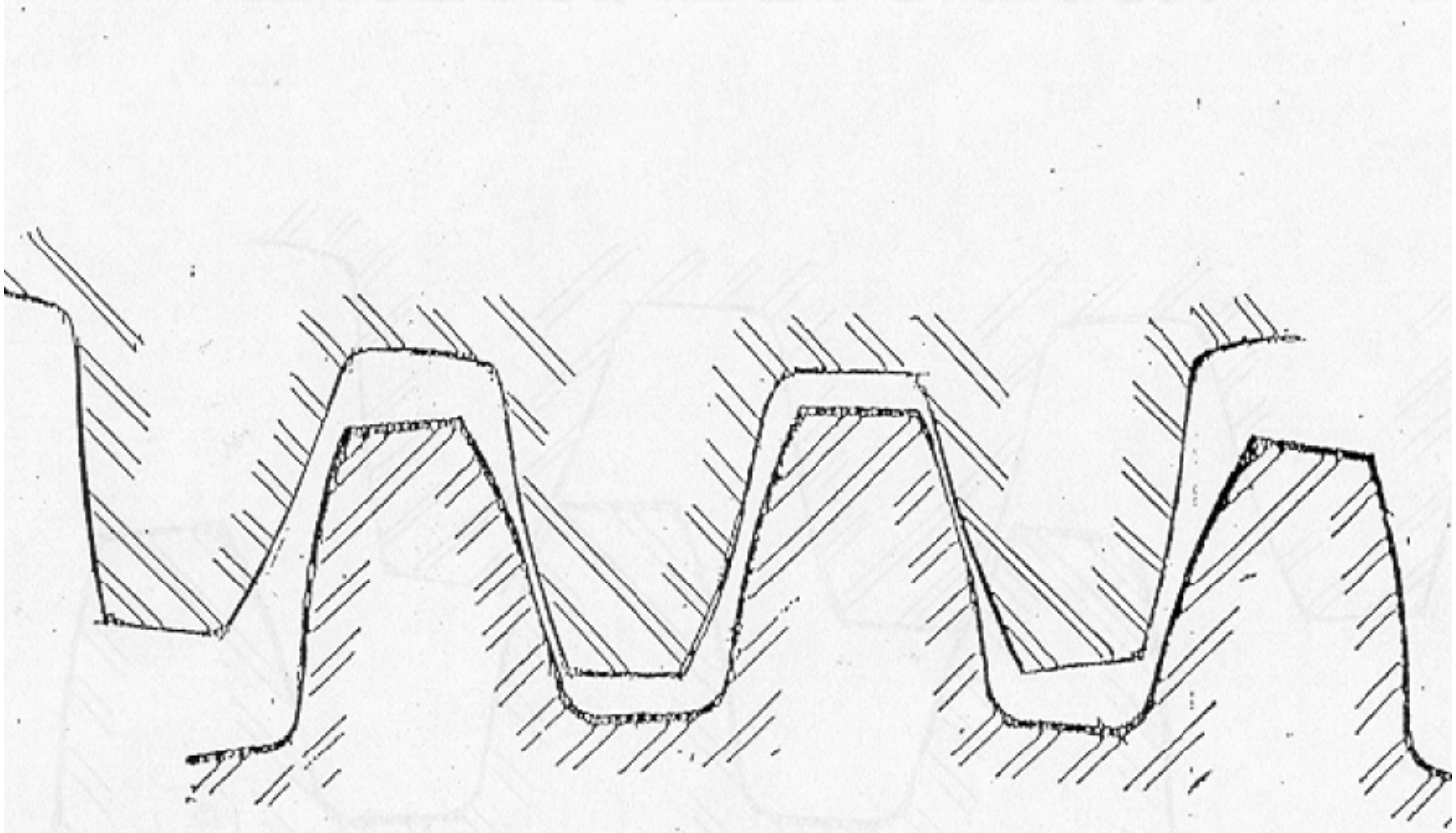
EQUIPMENT AND PROCESS SOLUTIONS

Paper Machine Dryer Gearing

When gears have the proper profile and backlash, they roll together smoothly.



NORMAL BACKLASH

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Paper Machine Dryer Gearing

Older paper machine helical gear mesh with fair to good tooth profiles, and good backlash.

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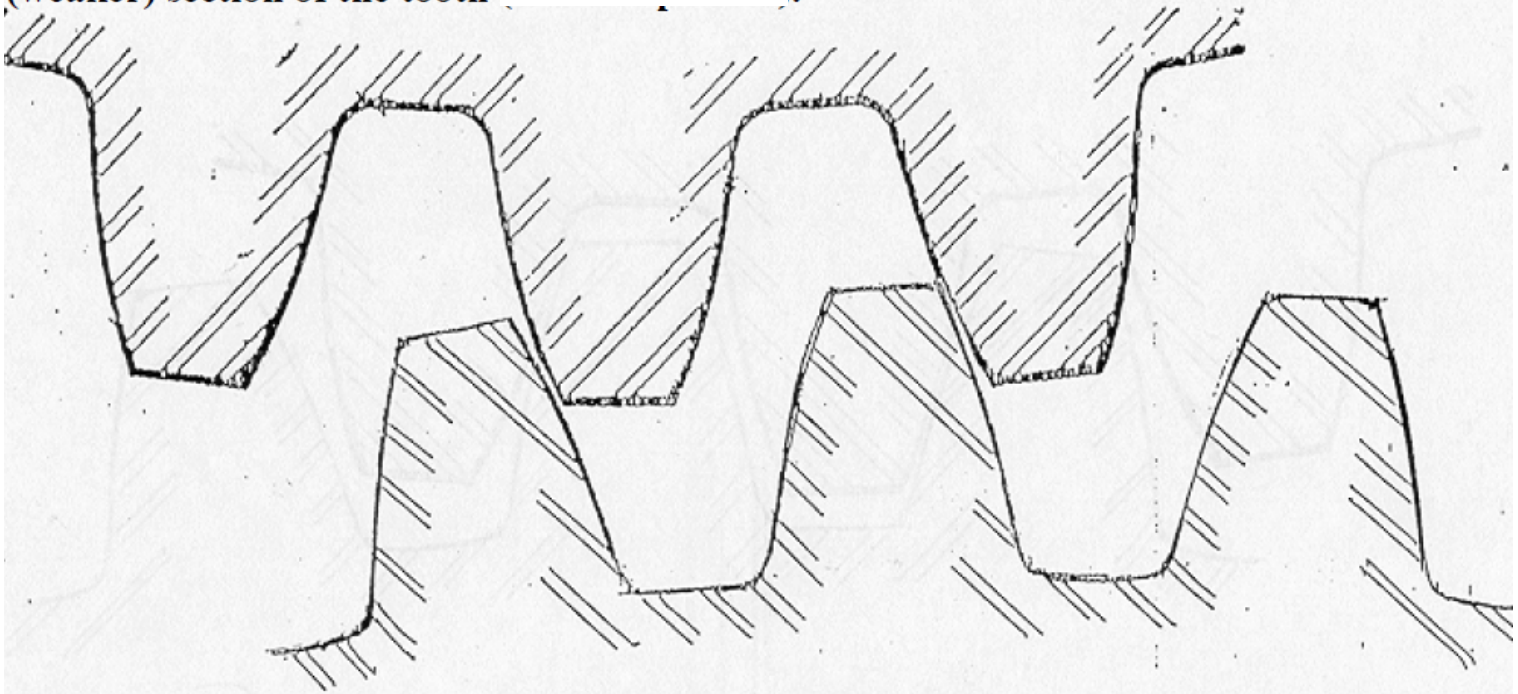
Paper Machine Dryer Gearing

Excessive backlash increases the "moment arm" distance between the tooth tip and root. This increases the stress on the gear. This increased stress is transmitted by a narrower (weaker) section of the tooth .



EXCESSIVE BACKLASH

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Paper Machine Dryer Gearing

Excessive Spur Gear Backlash

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Paper Machine Dryer Gearing

Excessive Helical Gear Backlash

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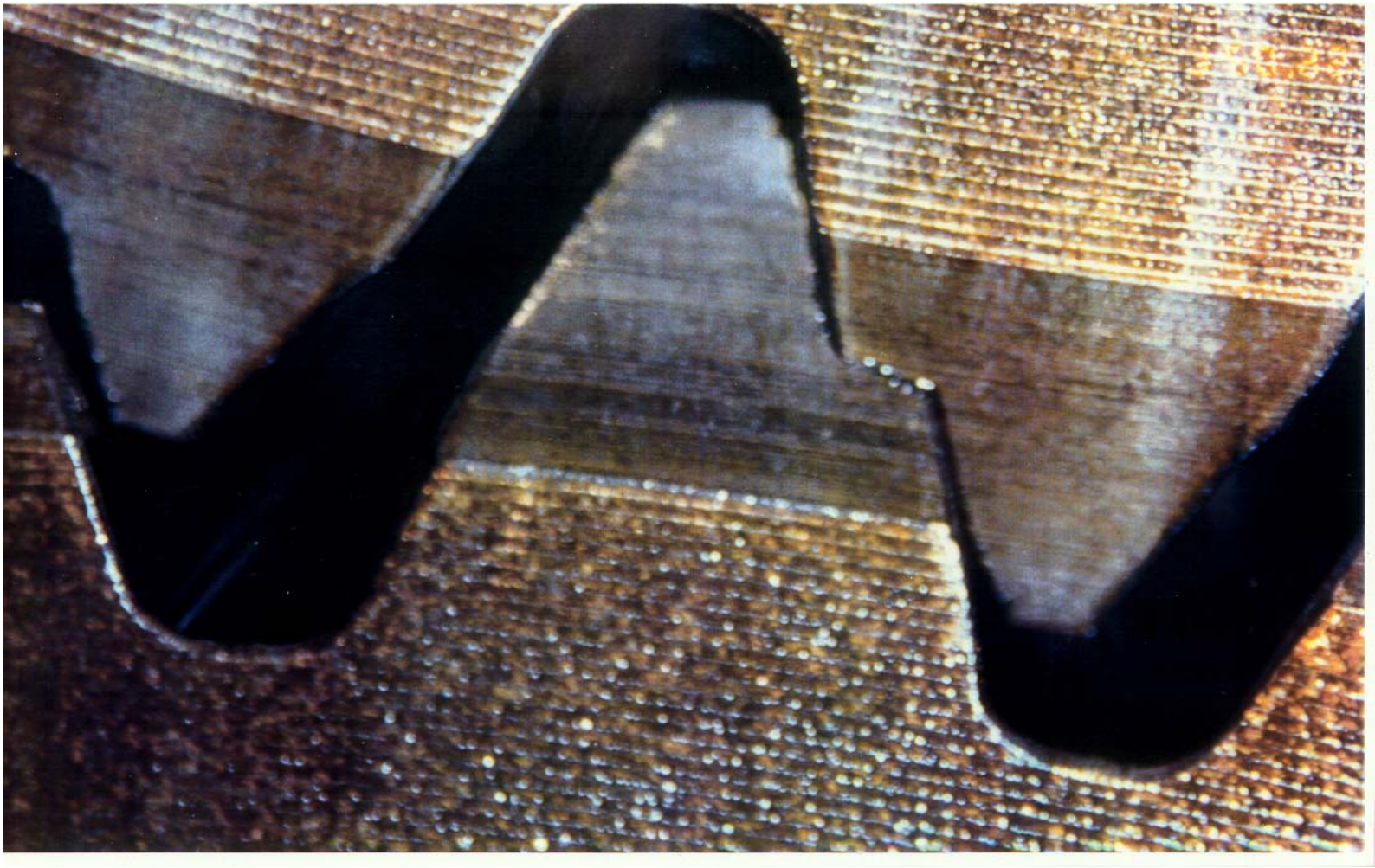
Paper Machine Dryer Gearing

Excessive Helical Gear Backlash Creating Overload



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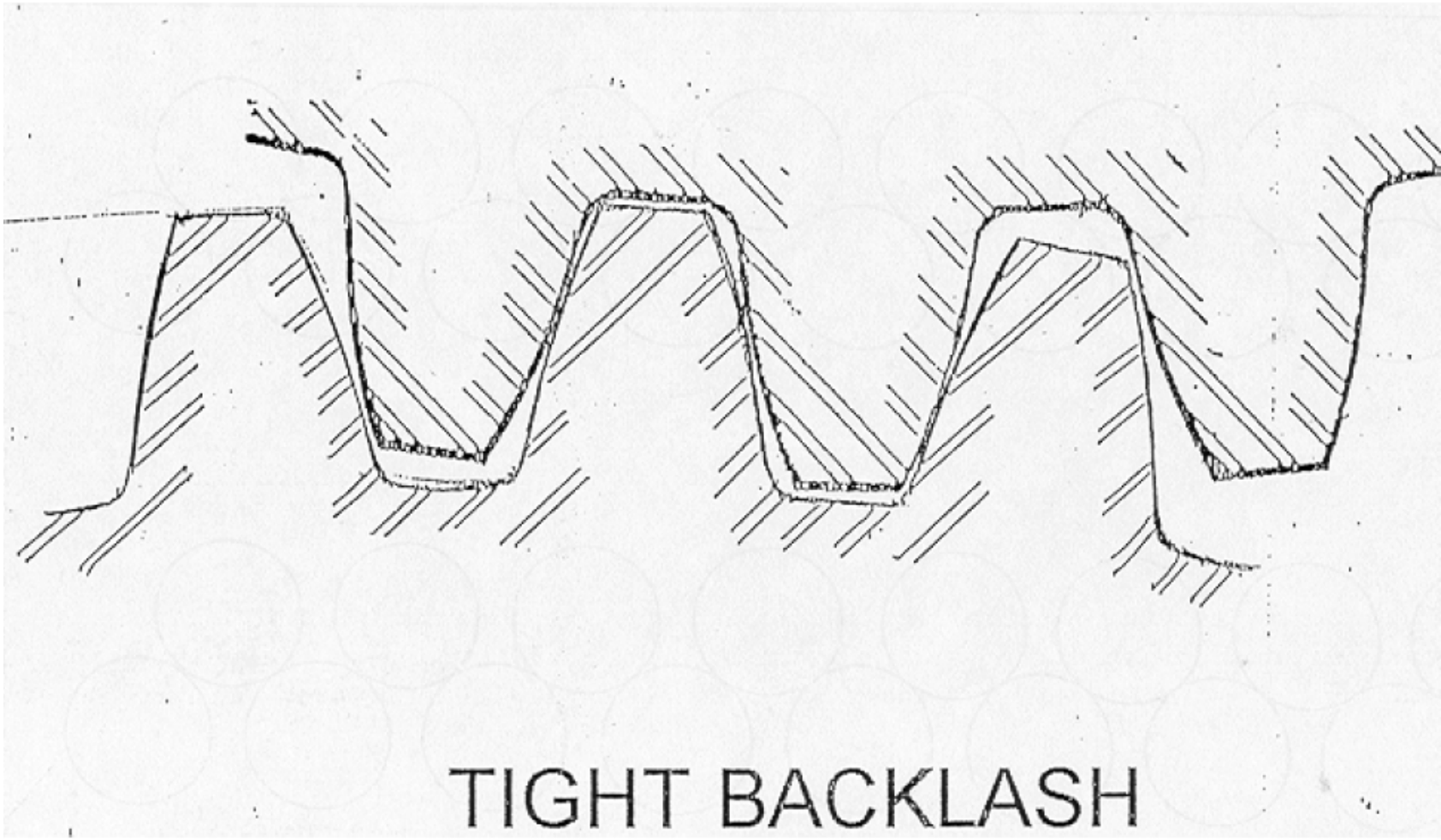
Paper Machine Dryer Gearing

When gears have tight backlash, they do not "roll" properly. The tips of the teeth will wear against the back-side of the mating teeth.



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Paper Machine Dryer Gearing

Tight backlash with potential tooth tip to flank contact.

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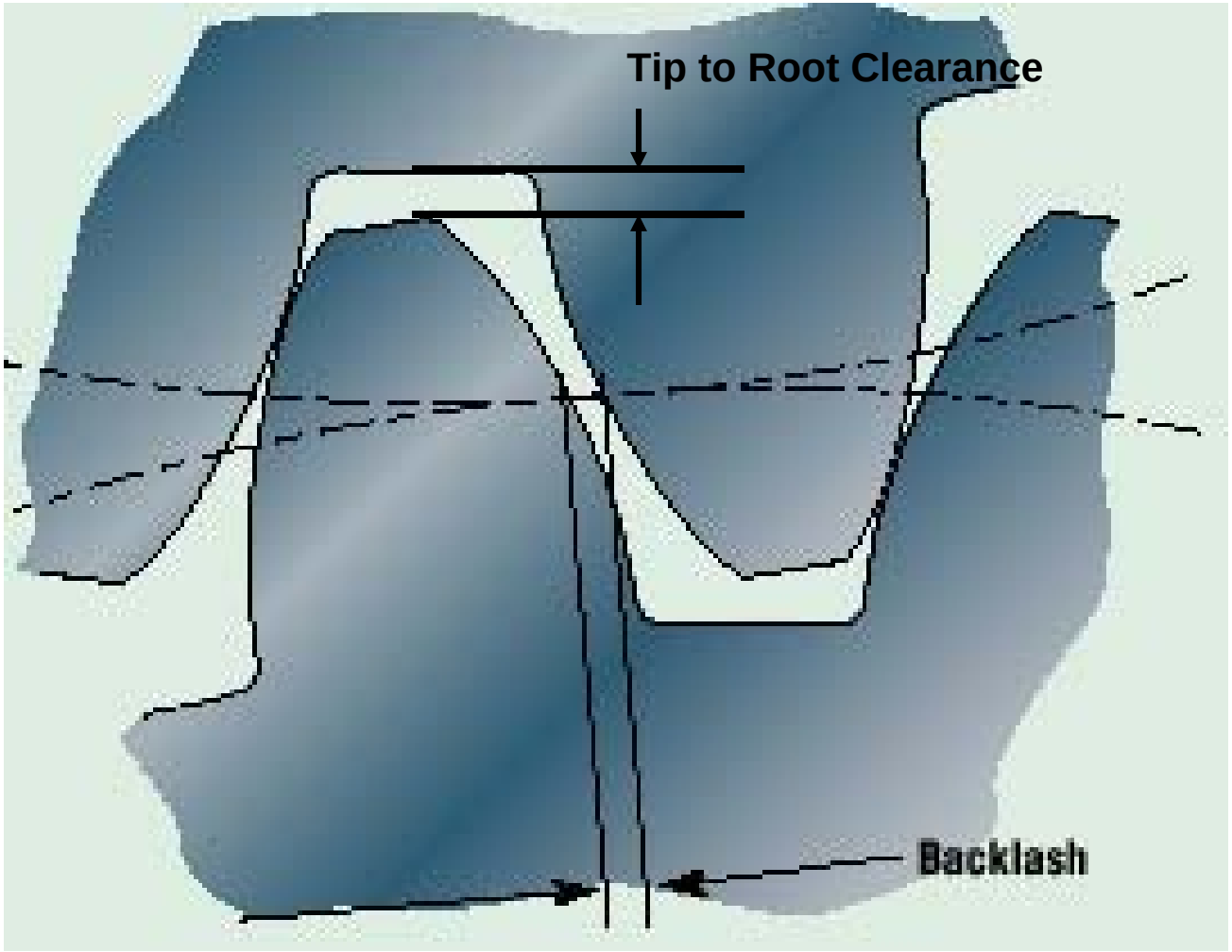
Paper Machine Dryer Gearing

TIP to ROOT CLEARANCE



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Paper Machine Dryer Gearing

Causes of Change to Tip/Root & Backlash

Spur Gears

- Loss of tooth thickness
- Shifted bearing housing(s)
- Worn or failed bearing
- Shifted or settling frame(s)

Helical Gears

- Loss of tooth thickness
- Worn or failed bearing
- Shifted or settling frame(s)

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EQUIPMENT AND PROCESS SOLUTIONS

Paper Machine Dryer Gearing

Detrimental Paper Machine Conditions

- Overdrive
- Backdrive
- Dryer Flooding
- Hard starting/stopping
- Lubrication Problems
- Misalignment

Paper Machine Dryer Gearing

OVERDRIVE & BACKDRIVE

Backdrive is when a driven gear is instead driving its input gear: the gear teeth are meshing on the normally unloaded side. For every backdrive condition, an overdrive condition also exists.

Often caused by excessive draw between sections: the sheet in the downstream section exerts a pull on the previous section. This pull is transferred by the sheet to the previous section dryers, and their gears. This overdrive pull may extend through the section.

This can also occur due to variations in dryer can diameter, which equates to a surface speed variation.

Areas where gears have been removed leaving the dryer(s) to be driven by the sheet and/or felt will result in overdrive and backdrive as the felt transfers the torque throughout the section, not just the ungeared dryers.

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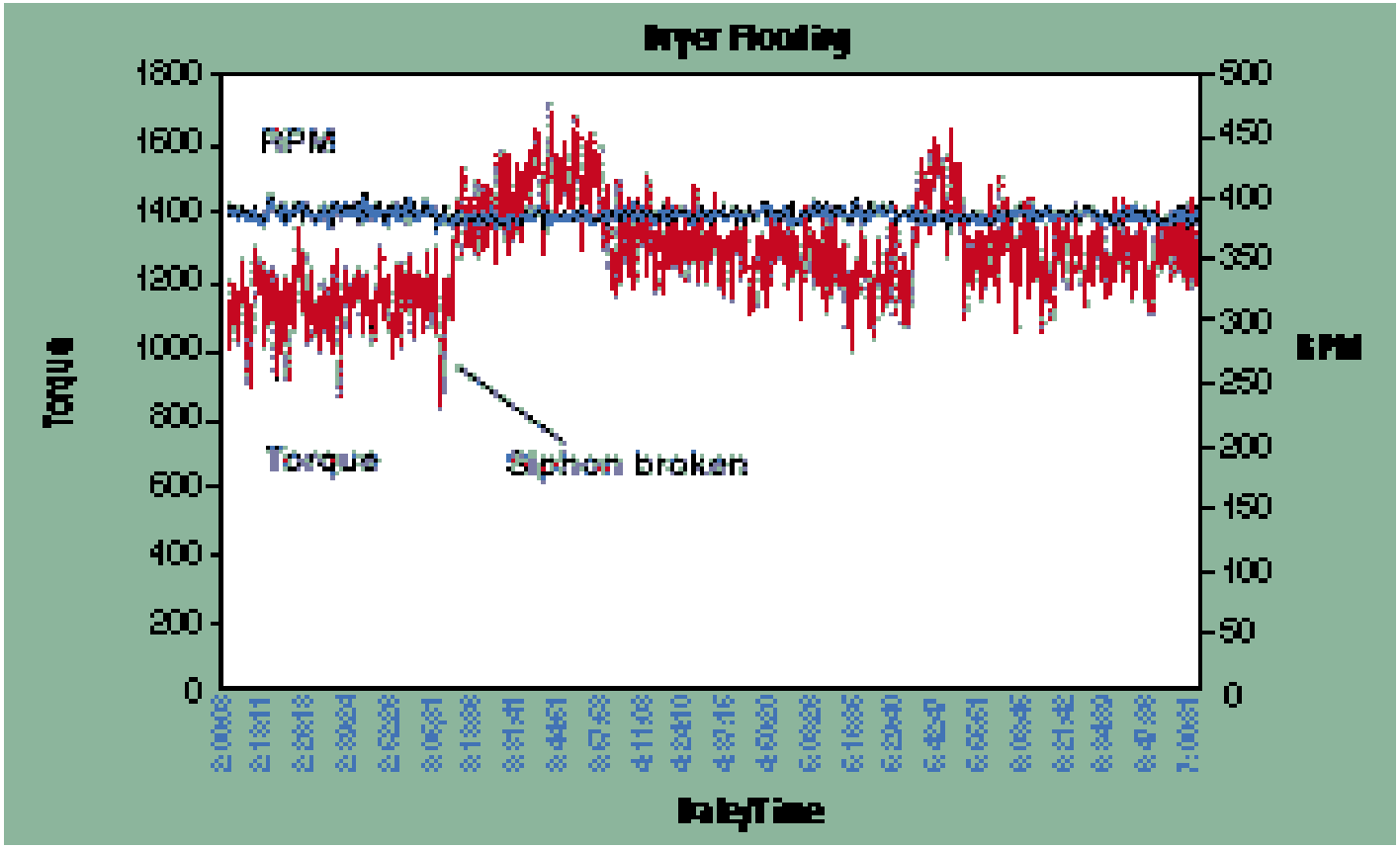
Paper Machine Dryer Gearing

DRYER FLOODING



A single flooded dryer can increase the torque load of the entire section by 40% or more.

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EQUIPMENT AND PROCESS SOLUTIONS

Paper Machine Dryer Gearing

DRYER FLOODING

The increased torque load due to dryer flooding increases the gear tooth load, and wear. The extreme wear of the gear in the photo occurred within days of two dryers in the section flooding. All of the gears in the section were affected

The dryers will typically surge when flooded as the water inside cascades from side to side, accelerating and decelerating the dryer. The surging will affect and can be heard in the gear meshes. In open gears, the surging can be observed with a strobe light: the backlash will shift from one side of the teeth to the other as the dryer speeds-up and slows down.

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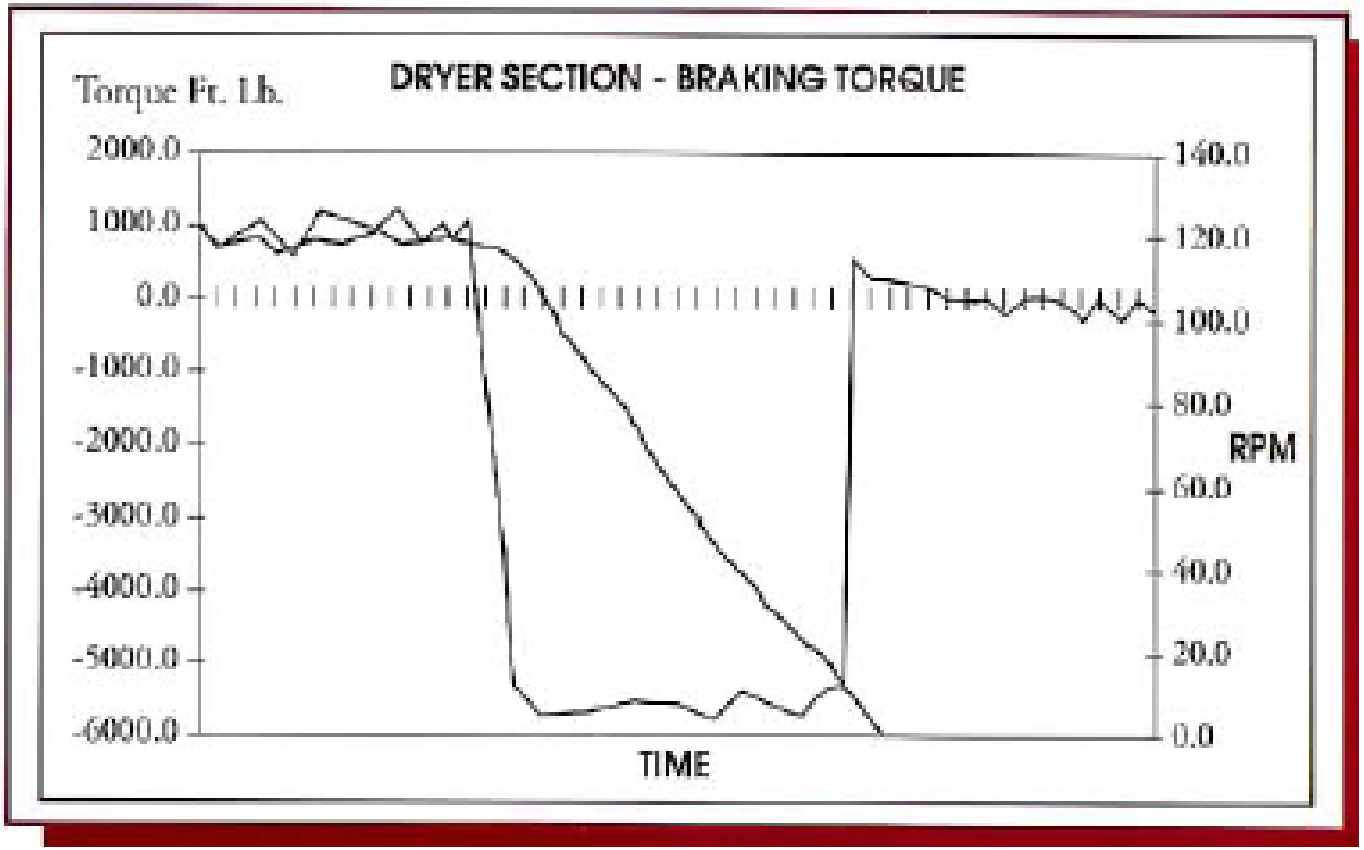
Paper Machine Dryer Gearing

HARD STARTING & STOPPING



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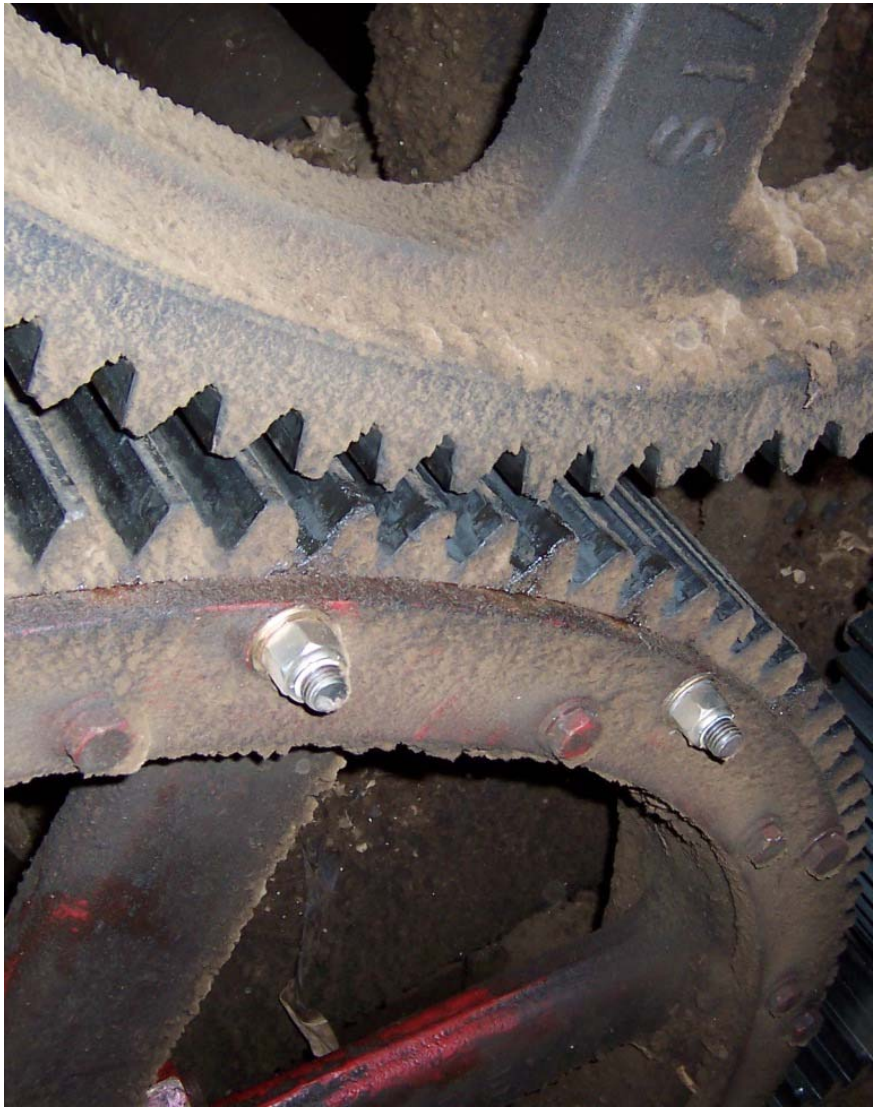
Paper Machine Dryer Gearing

Other Conditions: Misalignment



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Paper Machine Dryer Gearing

Other Conditions: Offset Wear due Misalignment

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Paper Machine Dryer Gearing

Wear Created by Poor Lubrication

ABRAVISE WEAR: Radial grooving and tearing along the tooth flanks.

SCORING: Radial scratching and grooving along the tooth flanks. Break down of the lube film at the point of contact and subsequent localized heating overheating create instantaneous welding and tearing out of material. Scoring can progress to pitting.

PITTING: typically occur in areas of high load concentration, often near the pitch line. They have an inverted cone shape; start small and become progressively larger. Can progress to Destructive Pitting, and Spalling, and ultimately lead to tooth failure.

SPALLING: Similar and often caused by Destructive Pitting, the voids are large and irregular in shape and cover a large area. Caused by high tooth stress and sliding action. Tooth failure probable as Spalling progresses.

RIPPLING: A cold flow surface deformation. Caused by high contact stresses and sliding action with attendant lube film breakdown.

PEENING: A cold flow surface deformation similar to but more severe than Rippling. Results in battered looking cold worked surfaces wear. Also caused by high loads and sliding action.

FOREIGN MATTER DAMAGE: An overload failure from contaminants passing through the gear mesh causing indentations, chipping, breakage or complete failure.

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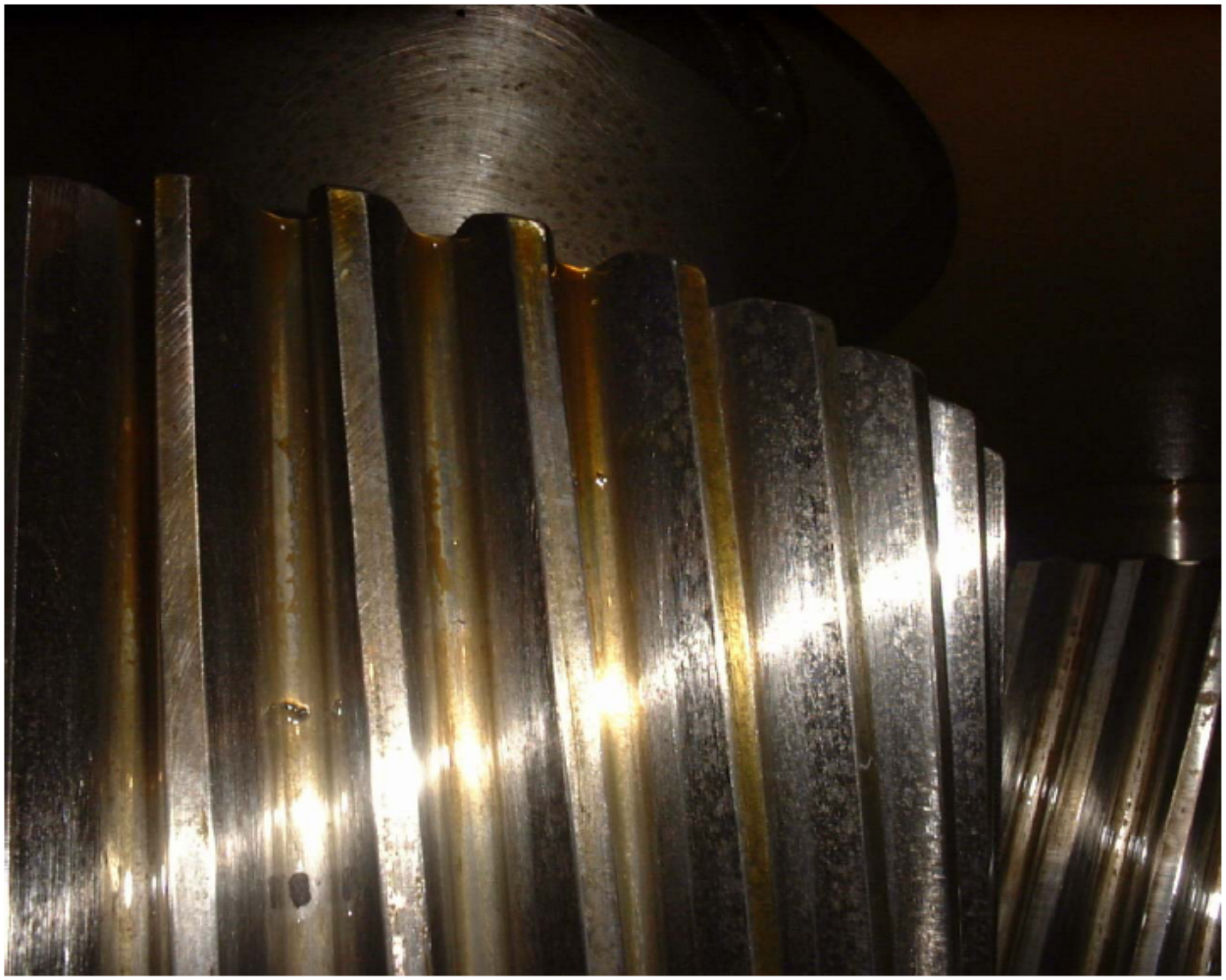
Paper Machine Dryer Gearing

Fine polishing is the removal of asperities on the gear surface during the break-in period. With good lubrication, polishing ends when the high spots have been worn down.



It's important to flush the oil system after running in new gears to flush the asperities out. Otherwise they become work hardened and act as abrasives.

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Paper Machine Dryer Gearing

Abrasive wear (and scoring). Typically caused by lubrication failure at gear mesh and/or particulate in the lube.

Will progress to destructive wear if not corrected.

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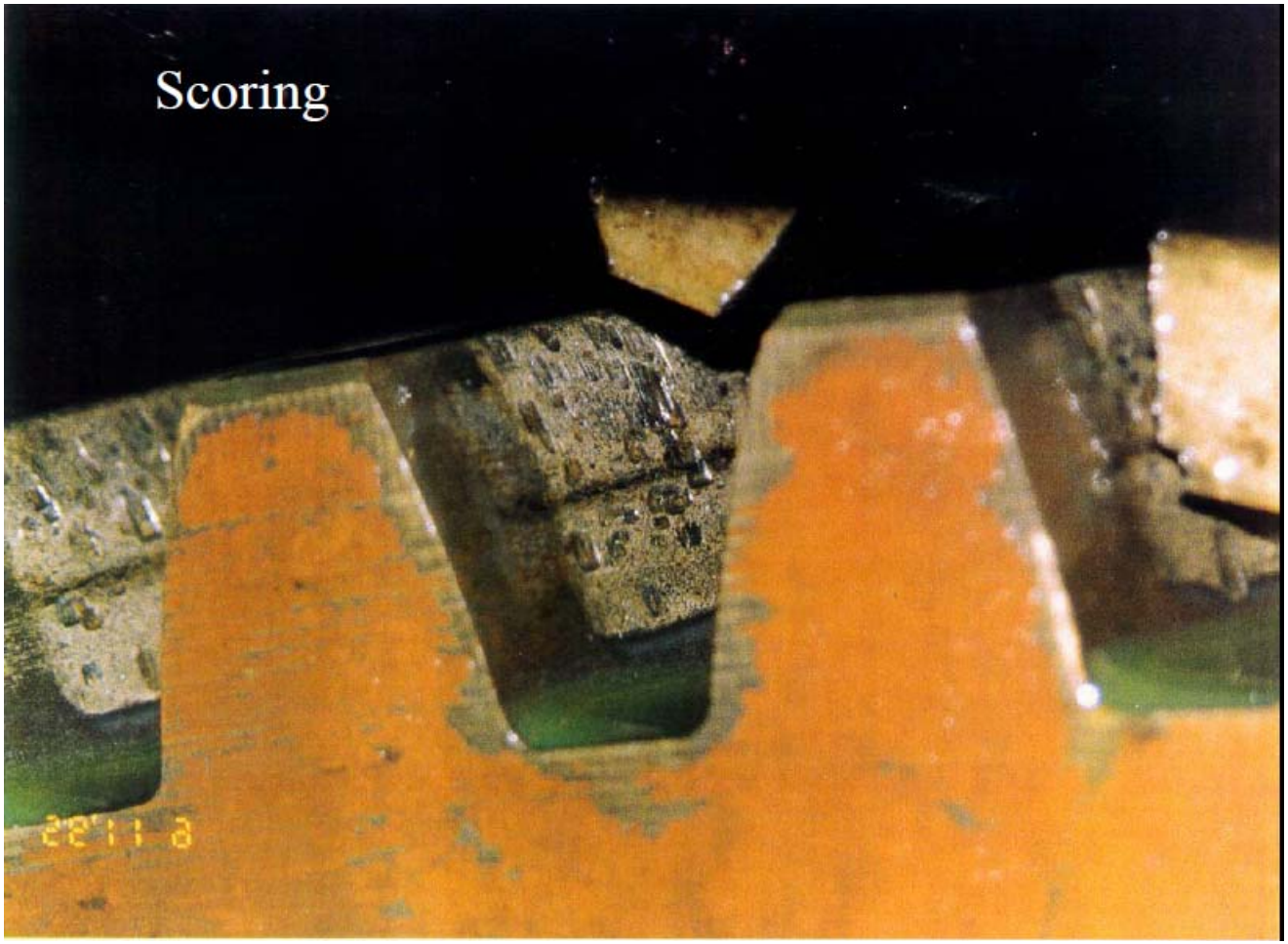
Paper Machine Dryer Gearing

Scoring is the instantaneous welding and tearing of contacting surfaces caused by localized overheating resulting from lube film breakdown.



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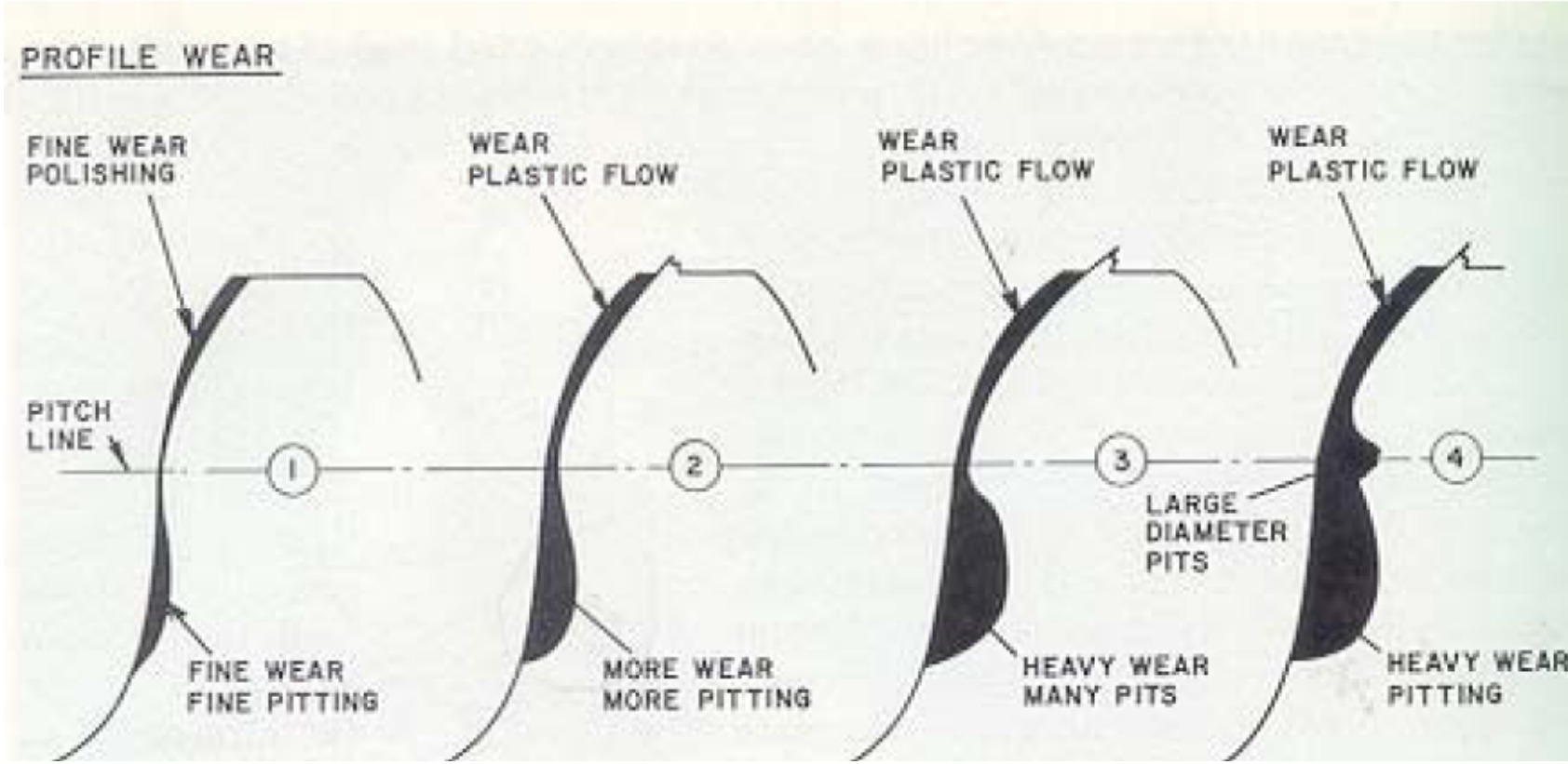
Paper Machine Dryer Gearing

Progress of Wear



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Paper Machine Dryer Gearing

ABRASIVE WEAR & SCORING W/LOSS of PROFILE

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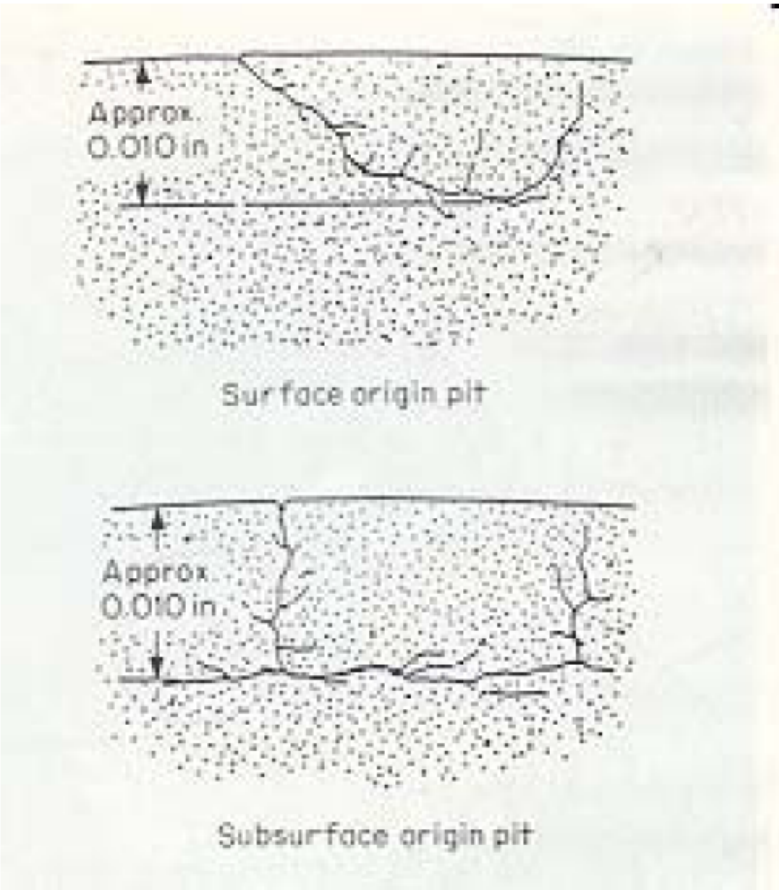
Paper Machine Dryer Gearing

PITTING & SPALLING

Occurs when the load exceeds the capacity of the gear material and/or the lube film thickness is inadequate. The repetition of high stress over many cycles produces surface & subsurface stressers. The material fatigues and fails either at or below the surface. The crack(s) then propagate to the surface and a small piece breaks free forming a pit. If not corrected, many smaller pits join to create larger craters called Spalls.



Pitting is often the first indication of a lube film problem caused by high temperature.

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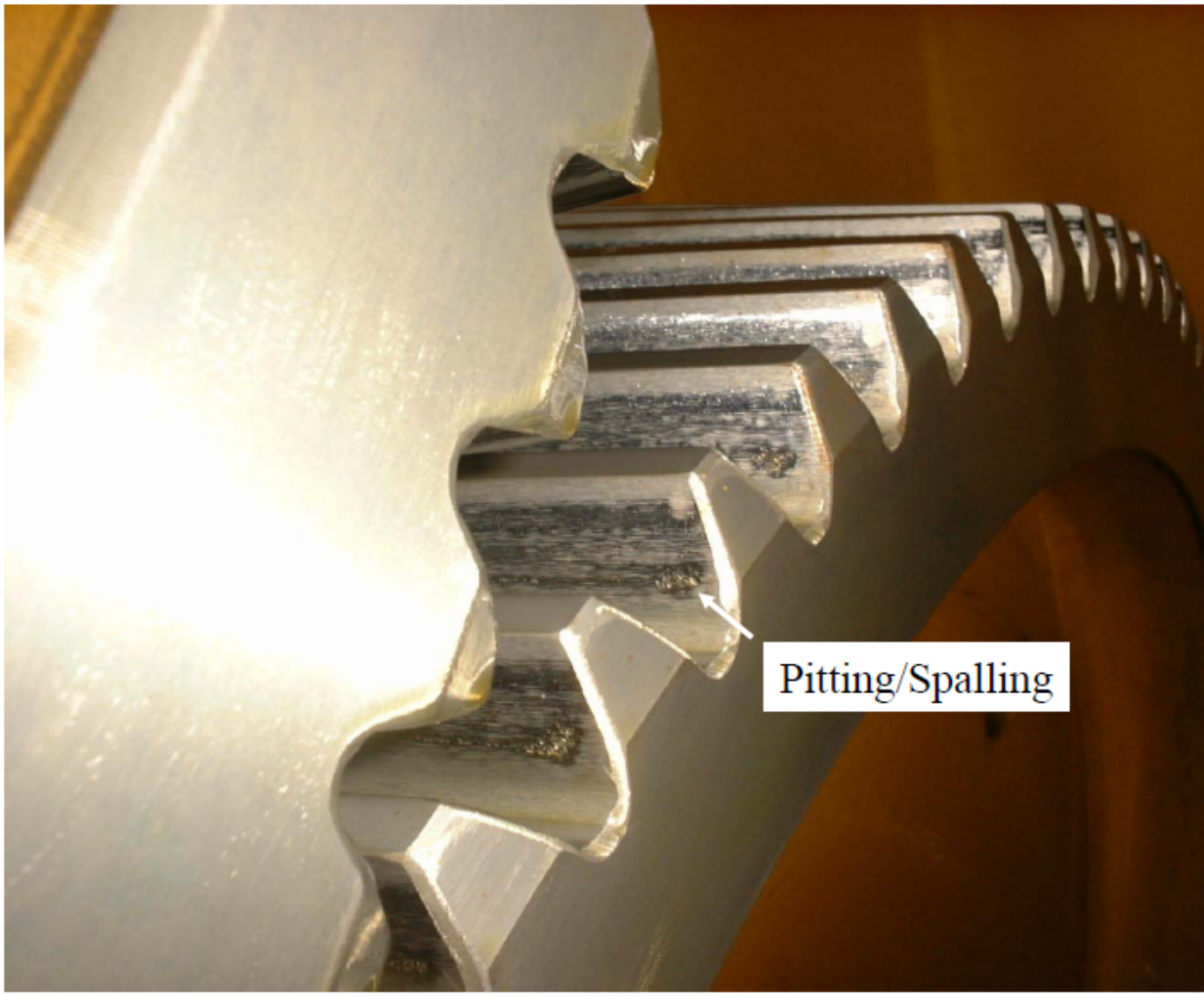
Paper Machine Dryer Gearing

Abrasion with Pitting and Spalling Below the Pitch Line

Inadequate lubrication creates a condition wherein high points on the gear surface contact causing high stressers resulting in pitting.



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Paper Machine Dryer Gearing

Destructive Pitting

Tooth failure may occur where pitting is destructive due to the loss of tooth material and strength.

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Paper Machine Dryer Gearing

The teeth in this dryer gear have failed due to loss of tooth material at the pitch line caused by destructive gear wear (destructive pitting and spalling).

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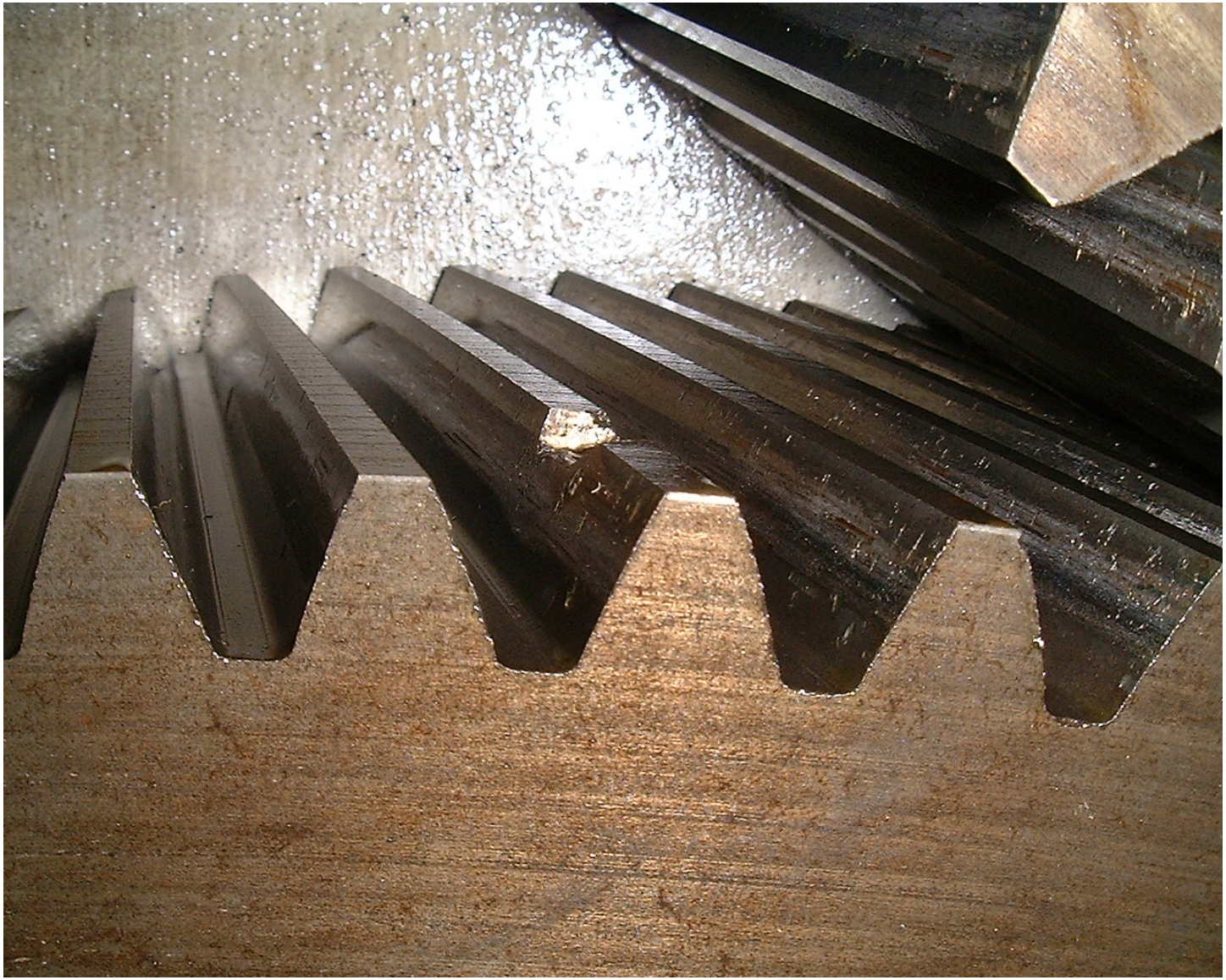
Paper Machine Dryer Gearing

Foreign Matter Damage



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Paper Machine Dryer Gearing

Foreign Matter Damage

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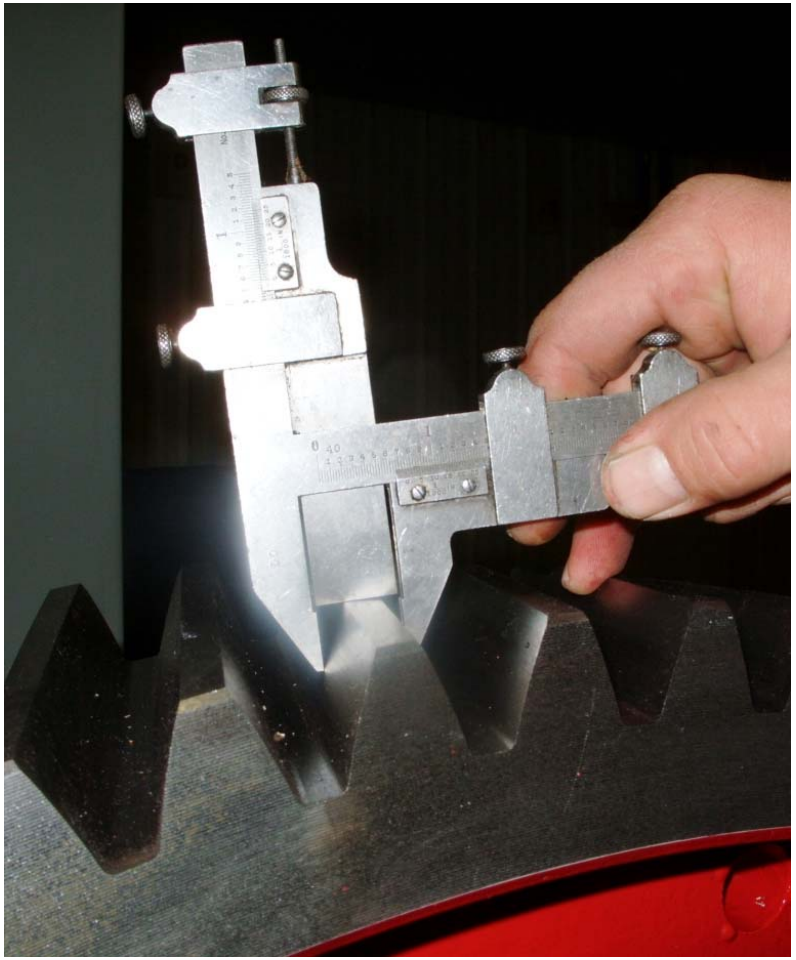
Paper Machine Dryer Gearing

Gear Inspection

Spur Gears

- Dynamic via strobe light
- Visual: tooth form, wear modes & severity,damage, alignment
- Backlash measurement
- Tooth thickness measurement



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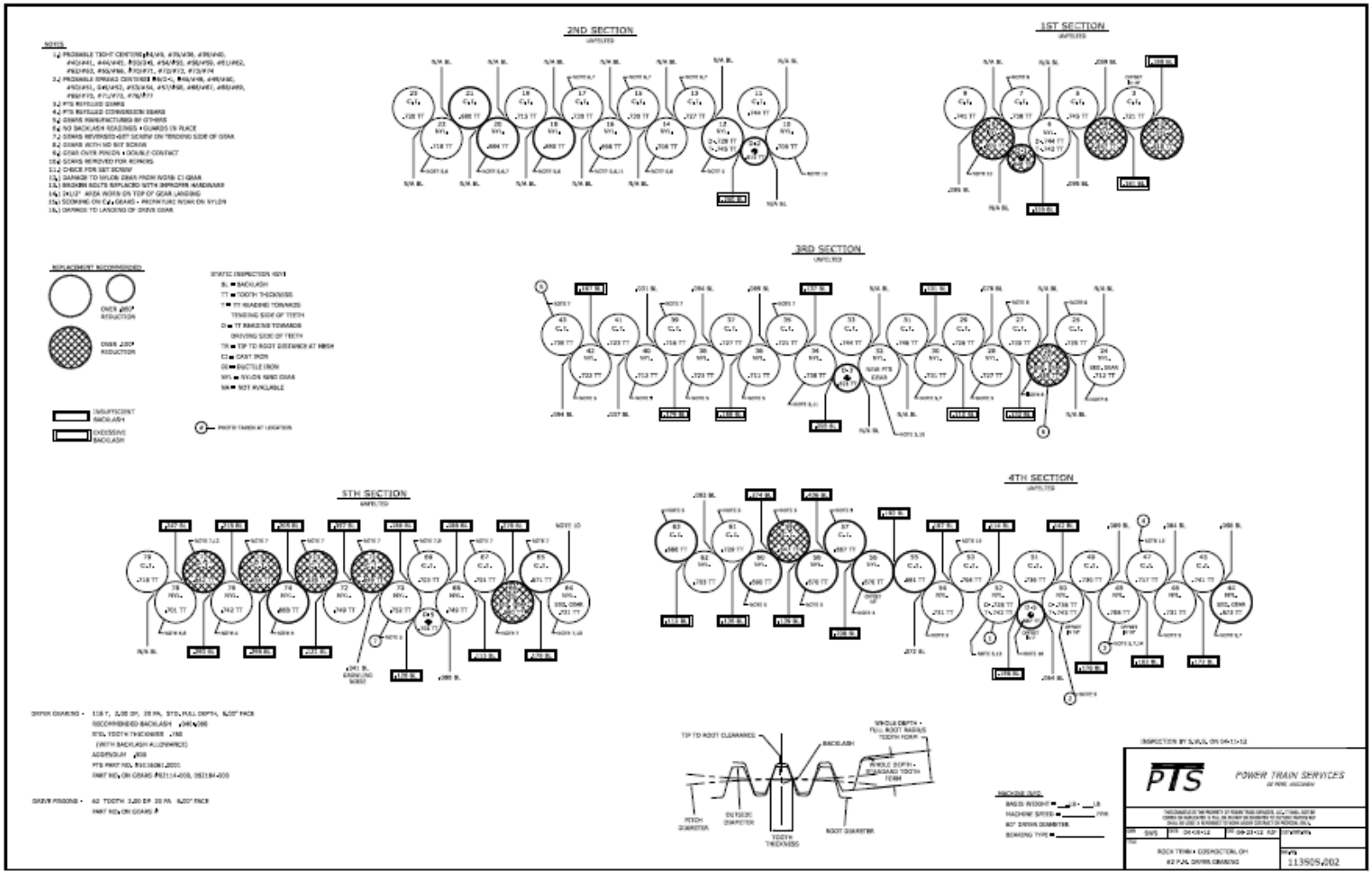
Paper Machine Dryer Gearing

Inspection Drawing: Spur Gears



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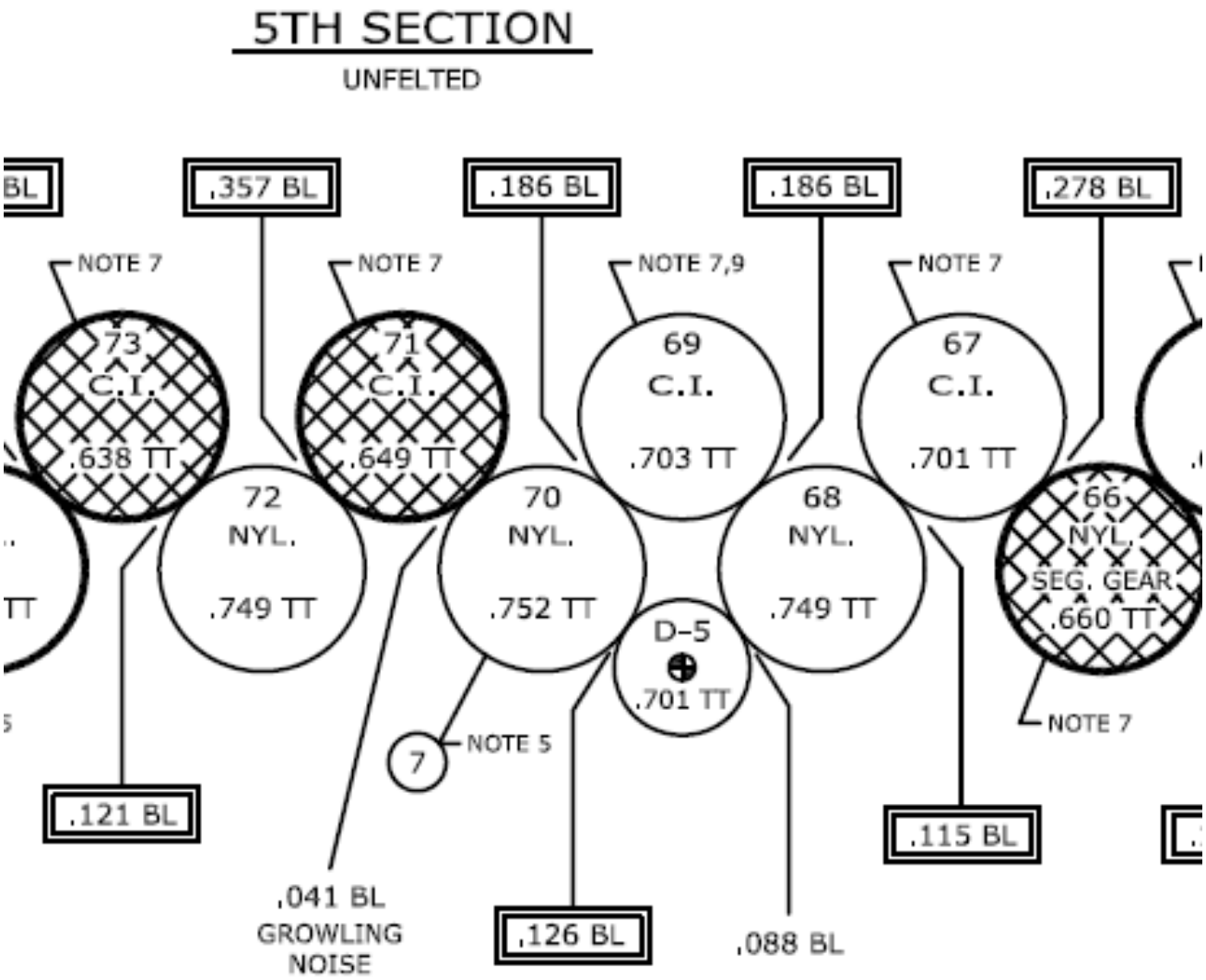
Paper Machine Dryer Gearing

Inspection Drawing Detail



SPINNAKER CORPORATION
EQUIPMENT AND PROCESS SOLUTIONS

Paper Machine Dryer Gearing

Inspection Drawing Gear Data & Notes

DRYER GEARING - 116 T, 2.00 DP, 20 PA, STD. FULL DEPTH, 6.00" FACE

RECOMMENDED BACKLASH .040-.060

STD. TOOTH THICKNESS .760

(WITH BACKLASH ALLOWANCE)

ADDENDUM .500

PTS PART NO. #5116061.0001

PART NO. ON GEARS #02114-000, 052184-000

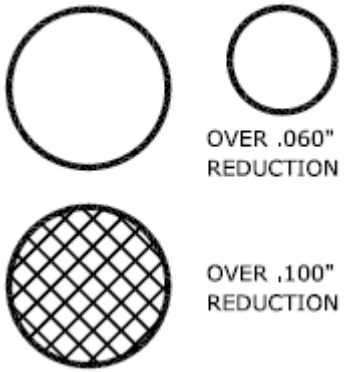
DRIVE PINIONS - 62 TOOTH 2.00 DP 20 PA 6.00" FACE

PART NO. ON GEARS #

NOTES

1.) PROBABLE TIGHT CENTERS: #4/#5, #35/#36, #39/#40, #40/#41, #44/#45, #50/D-5, #54/#55, #58/#59, #61/#62, #62/#63, #65/#66, #70/#71, #72/#73, #73/#74
2.) PROBABLE SPREAD CENTERS: #6/D-1, #45/#46, #49/#50, #50/#51, D-5/#52, #53/#54, #57/#58, #66/#67, #68/#69, #69/#70, #71/#72, #76/#77
3.) PTS REFILLED GEARS
4.) PTS REFILLED CONVERSION GEARS
5.) GEARS MANUFACTURED BY OTHERS
6.) NO BACKLASH READINGS - GUARDS IN PLACE
7.) GEARS REVERSED-SET SCREW ON TENDING SIDE OF GEAR
8.) GEARS WITH NO SET SCREW
9.) GEAR OVER PINION - DOUBLE CONTACT
10.) GEARS REMOVED FOR REPAIRS
11.) CHECK FOR SET SCREW
12.) DAMAGE TO NYLON GEAR FROM WORN CI GEAR
13.) BROKEN BOLTS REPLACED WITH IMPROPER HARDWARE
14.) 2-1/2" AREA WORN ON TOP OF GEAR LANDING
15.) SCORING ON C.I. GEARS – PREMATURE WEAR ON NYLON
16.) DAMAGE TO LANDING OF DRIVE GEAR

REPLACEMENT RECOMMENDED



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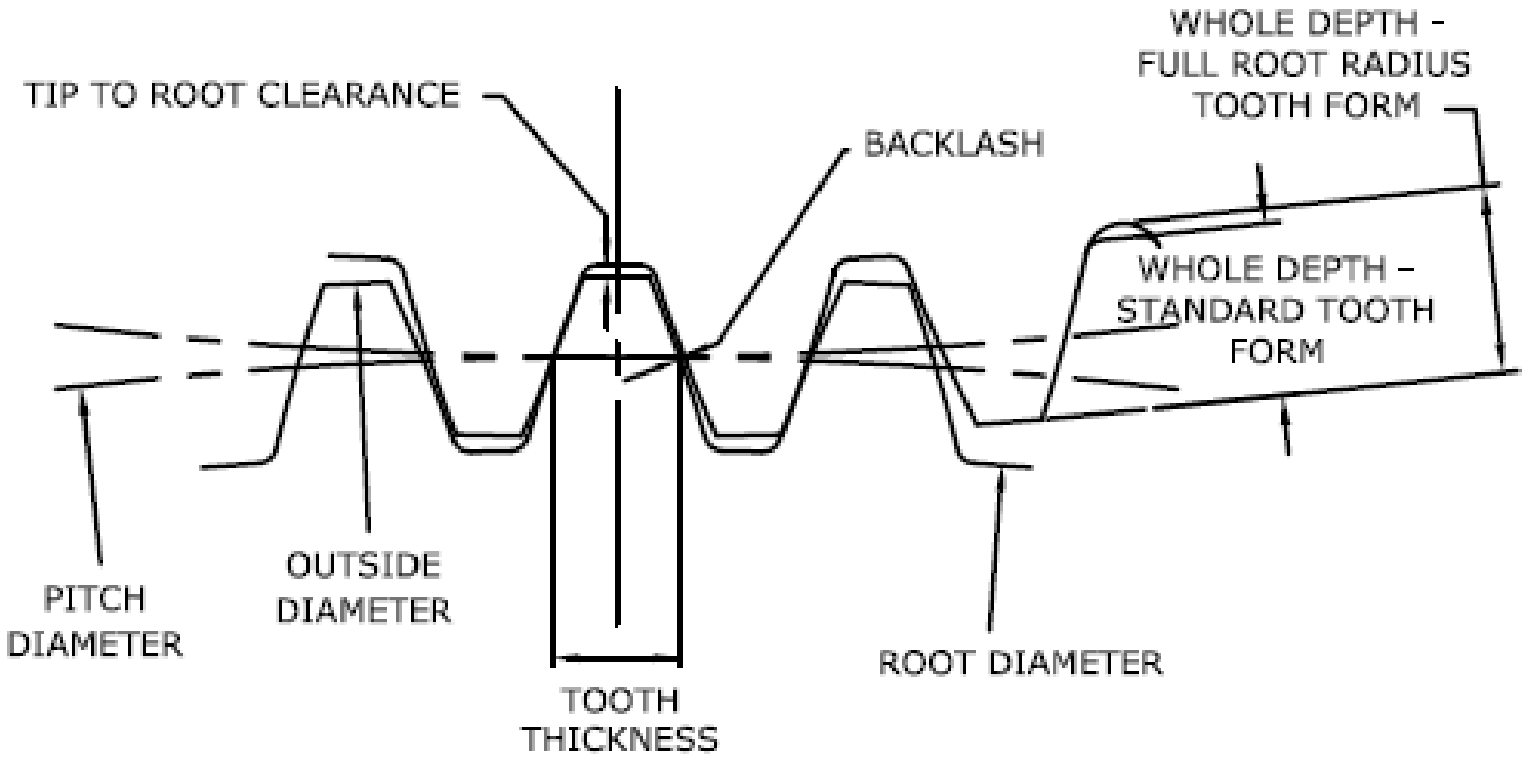
Paper Machine Dryer Gearing

Inspection Drawing Notes



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EQUIPMENT AND PROCESS SOLUTIONS

Paper Machine Dryer Gearing

Gear Inspection

Helical Gears

•Visual: tooth form, wear modes & severity,damage, alignment

•Backlash measurement (not all cases have suitable access ports)

•Video scope

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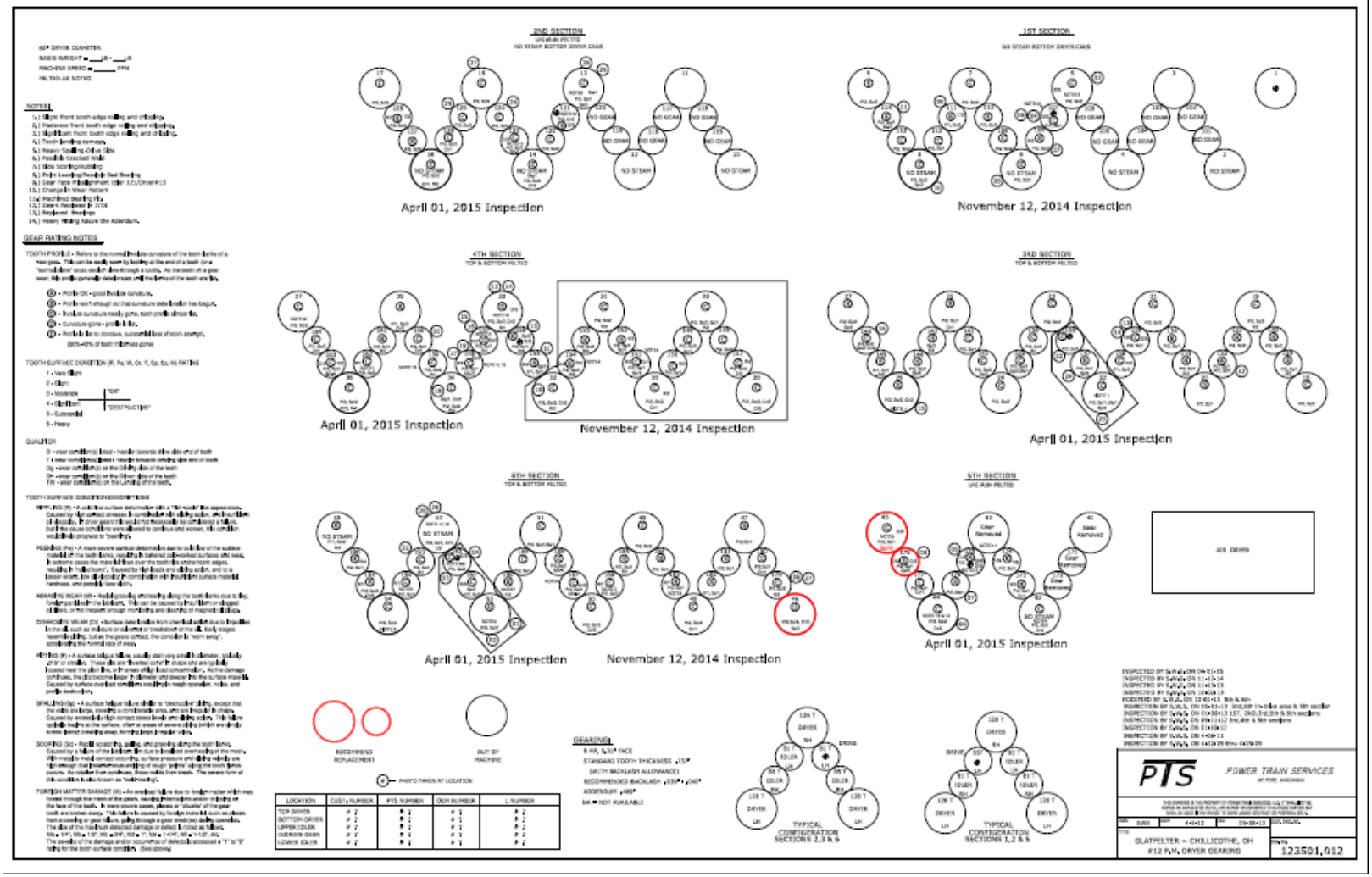
EQUIPMENT AND PROCESS SOLUTIONS

Paper Machine Dryer Gearing

Inspection Drawing: Helical Gears



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Paper Machine Dryer Gearing

Internal Gear Case Pics via Video Scope

Video Scope Photo. Note concentrated loading on one side of the gear teeth. Indicates a misalignment condition.

Video Scope Photo. Note cold flow of tooth edge; probably from contact with foreign matter.

Many of the photos of helical gears in this presentation were taken using the Video Scope. We also use this instrument for inspection of gearbox internals, and other mill components that lack good visual inspection access.

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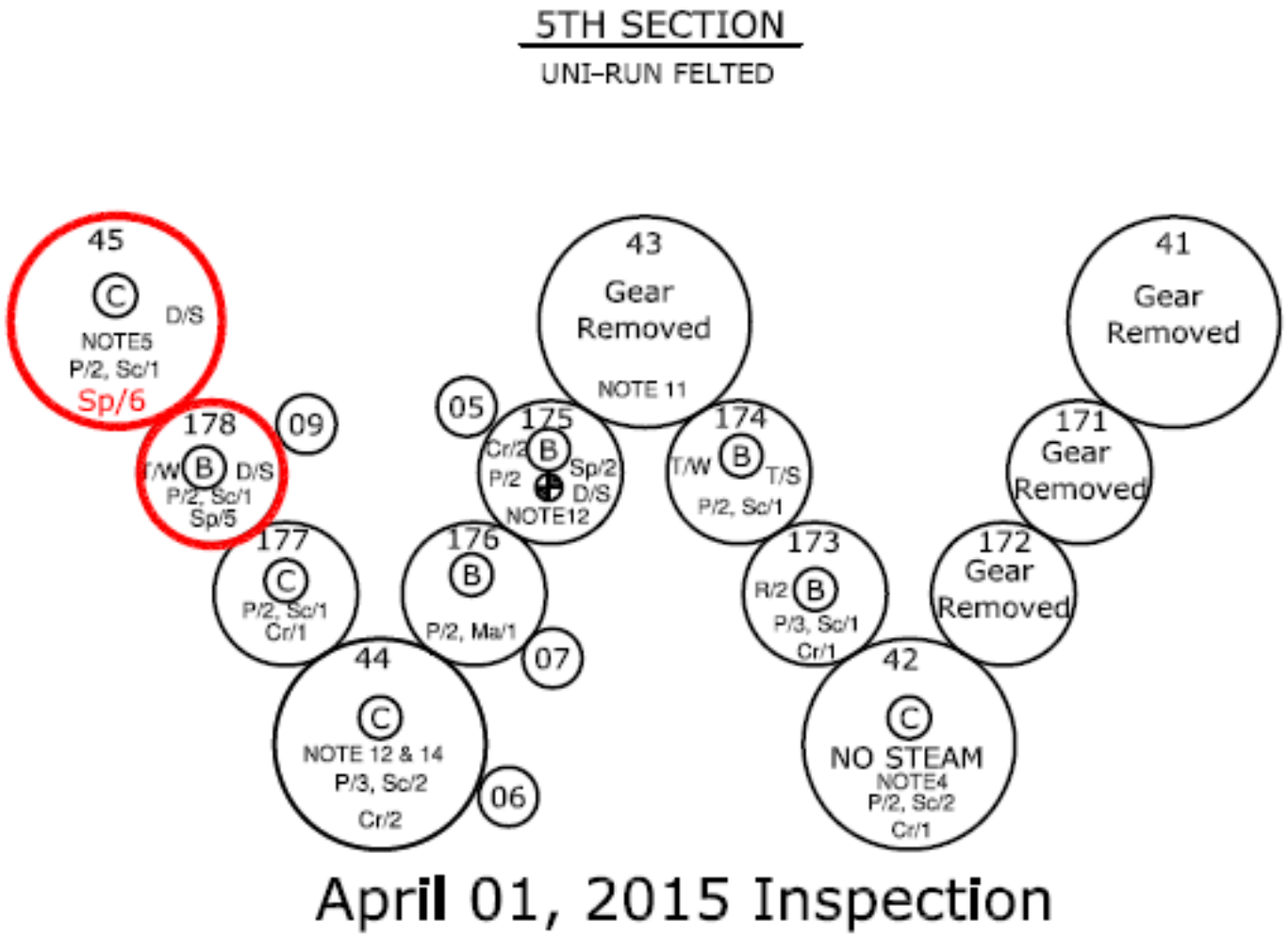
Paper Machine Dryer Gearing

Inspection Drawing Detail



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Paper Machine Dryer Gearing

Inspection Drawing Notes

NOTES:

1.) Slight front tooth edge rolling and chipping.
2.) Moderate front tooth edge rolling and chipping.
3.) Significant front tooth edge rolling and chipping.
4.) Tooth landing damage.
5.) Heavy Spalling-Drive Side
6.) Possible Cracked Weld
7.) Side Scoring/Rubbing
8.) Point Loading/Possible Bad Bearing
9.) Gear Face Misalignment Idler 121/Dryer#13
10.) Change In Wear Pattern
11.) Machined Bearing Fit.
12.) Gears Replaced in 7/14
13.) Replaced Bearings
14.) Heavy Pitting Above the Adendum.

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Paper Machine Dryer Gearing

Inspection Drawing Gear Data

GEARING;

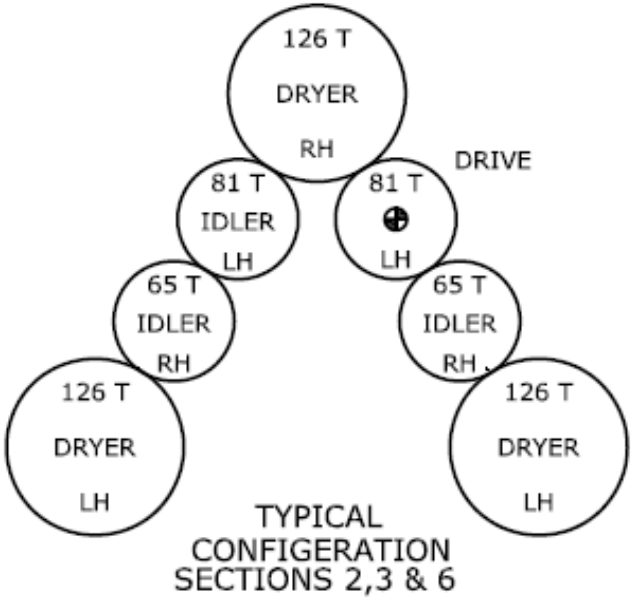
8 MP, 5.31" FACE

STANDARD TOOTH THICKNESS .737"

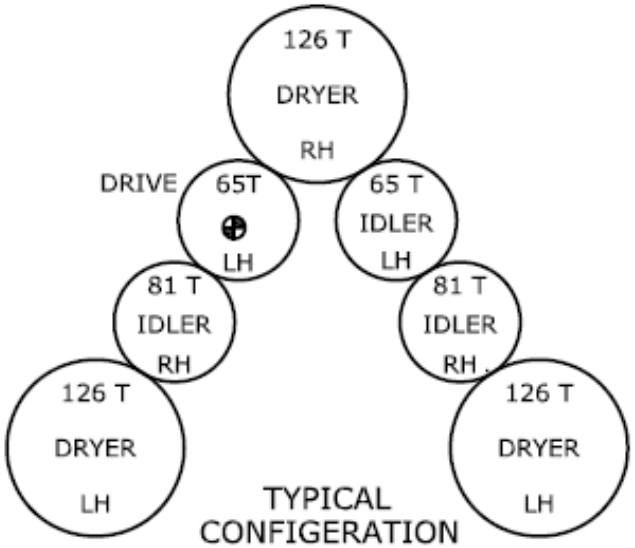
(WITH BACKLASH ALLOWANCE)

RECOMMENDED BACKLASH .030" - .040"

ADDENDUM .469"



TYPICAL CONFIGERATION SECTIONS 2,3 & 6



TYPICAL CONFIGERATION SECTIONS 1,2 & 5

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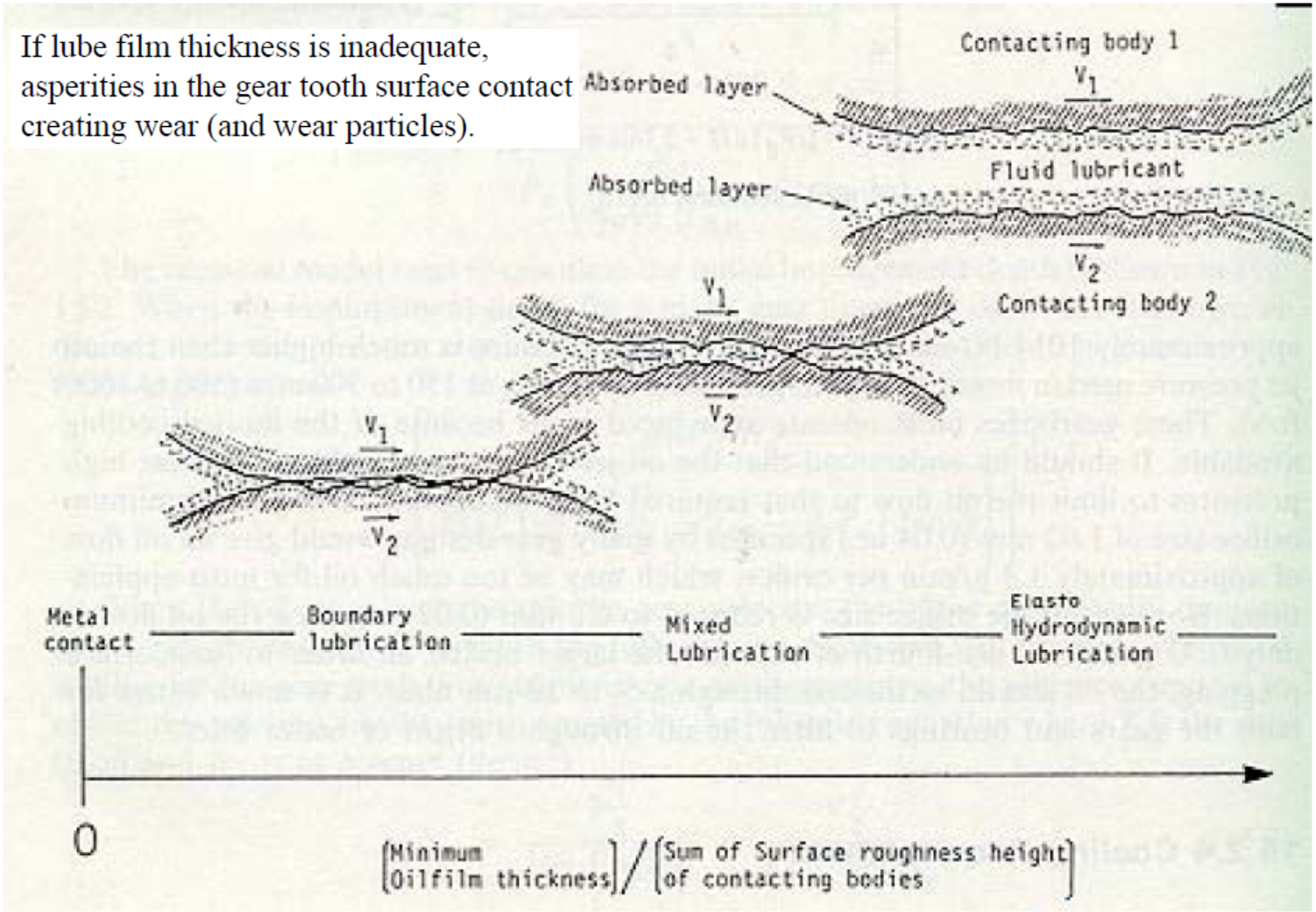
Paper Machine Dryer Gearing

EFFECT OF LUBE FILM THICKNESS

If lube film thickness is inadequate, asperities in the gear tooth surface contact creating wear (and wear particles).



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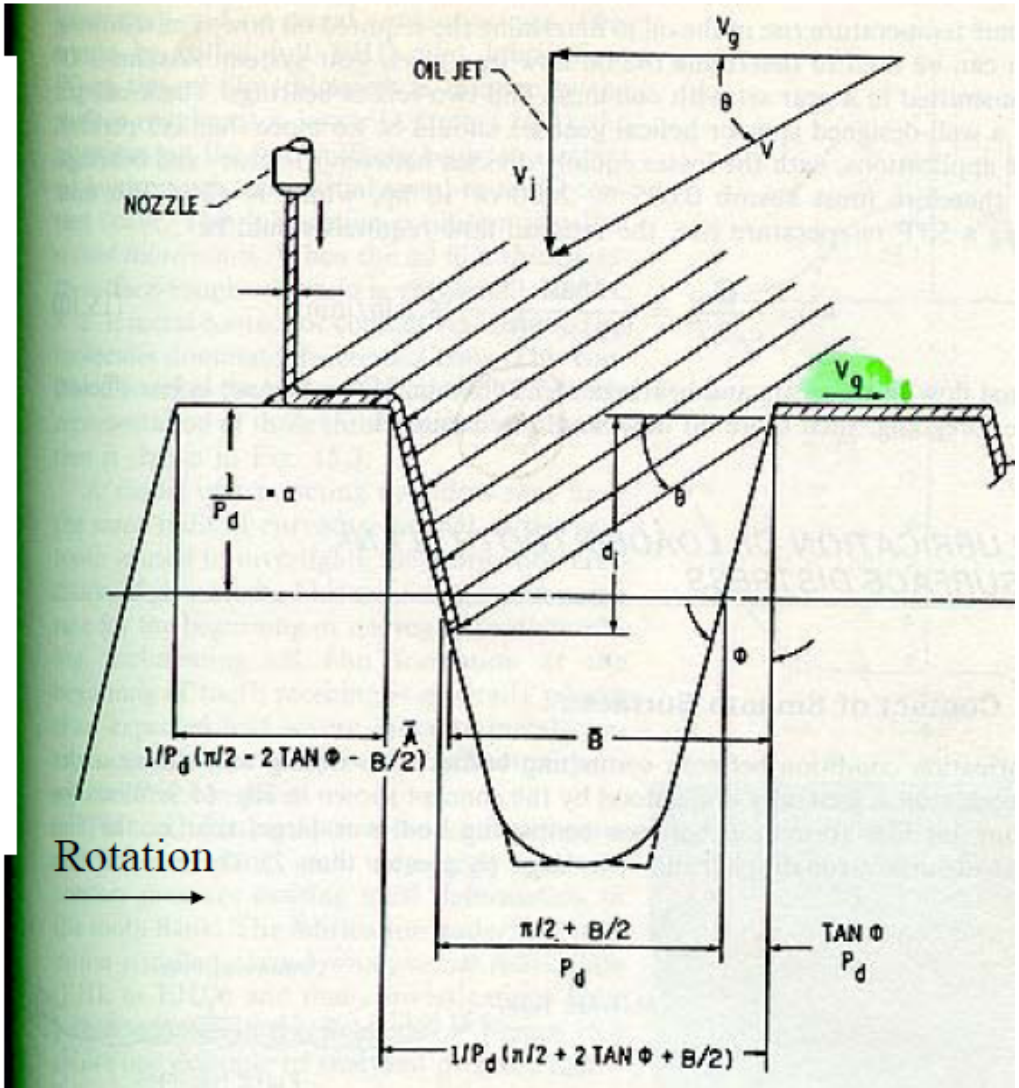
Paper Machine Dryer Gearing

OIL JET IMPINGEMENT

The optimum condition is obtained when the lubricating oil is directed <u>perpendicular to the tooth tip</u> <u>at a velocity equal to the tooth pitch-line velocity.</u>



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Paper Machine Dryer Gearing

LUBE IMPINGEMENT VELOCITY

TAPPI tip #0420-08 suggests a flow rate of 2 pints (.125 gal)/minute/gear mesh supplied through 1/2" NPT ports. Under these conditions, the oil obtains a velocity of 0.2 feet/second.

The case study paper machine has a gear pitch-line velocity of 35 feet/second (175 times faster than the oil velocity in the above recommendation).

Under these conditions, most of the oil will be deflected by the tooth tips and little will reach the tooth flanks where it is most required.

With the oil deflected by the tooth tips, it has little chance of being transported to the working depth of adjacent gears.

Lube velocity is equally important to flow. Flow alone will not provide good lubrication in paper machine dryer section gears.

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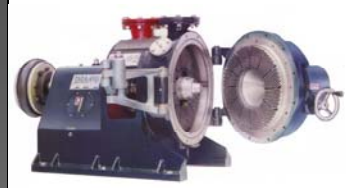
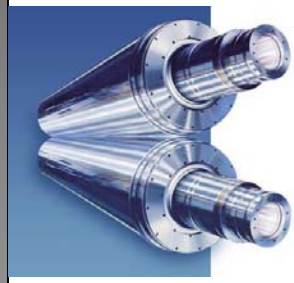
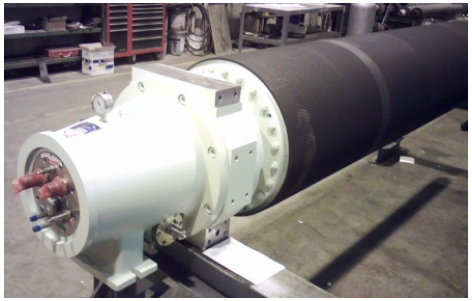
Paper Machinery





From Stock Prep to Finishing