Over the past few years we are seeing field reports from OEM's and third-party inspection services that claim sheave grooves that are supposedly worn out and we see by the photos and returns via urgent airfreight that sheave grooves are not worn at all. We actually had one contractor send sheaves for repair that were found to be new. It seems apparent that many do not understand what sheave groove wear is or how sheaves wear in general. This document has been written to address sheave grooving, flame hardening, contour of the groove and groove wear during a sheaves life cycle and explain what to look for during a sheave inspection.

Examine the sheave grooves for wear and proper groove size. To check the size, contour and amount of wear, use an API worn sheave gauge (Nominal rope diameter PLUS 2.5 %.) See attached table at the end of this document for groove dimensional info. These gauges will have written on them "Minimum for worn grooves" stamped in the largest gauge of the set. And example for one-and-a-half-inch rope 1-1/2 DIA +1/32 This is the standard gauge in use today found on most rigs. Gauges can be bought or made from any material but should be whatever the nominal rope diameter is plus 2.5% as per API RP9B. (found gauges for sale on Amazon website) That is the spec from API RP-9B for worn sheaves. Please note this is a smaller groove profile than that for new sheaves. The worn gauge in a worn groove will contact the groove for about 120 to 150 degrees of arc in the bottom of the groove and may show a daylight gap at the very bottom if severely worn.

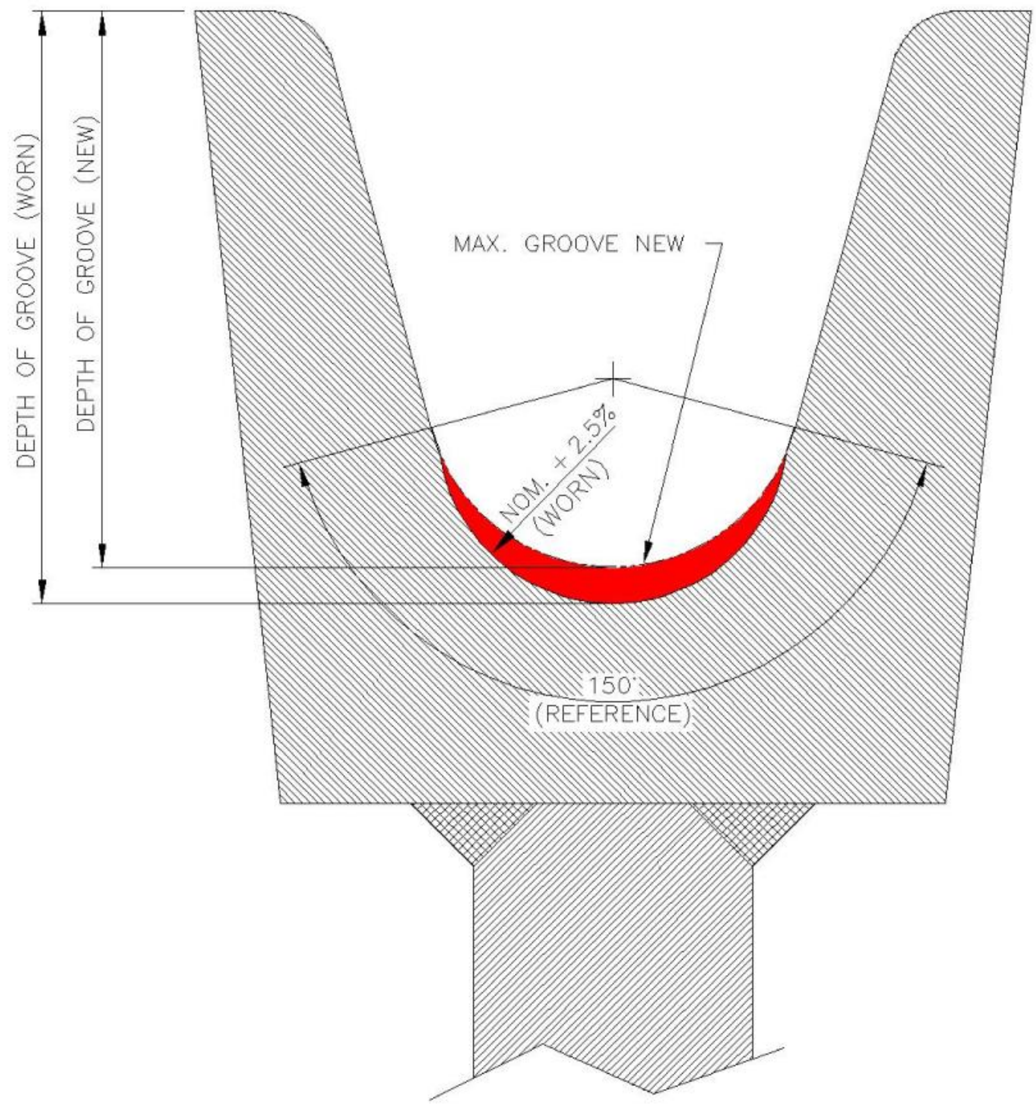
The actual width of the groove in the contact area can be confusing when reading the API documents. Maximum sheave wear always equates to a smaller groove diameter just as wire rope wear shows up as smaller rope diameter. It is that worn smaller rope diameter that causes sheaves to wear out prematurely.

API only references the radius of the groove, that radius dimension when drawn out is the width of the gauge at its widest point. (Radius times 2) This is taking into account that the sheave gauge is a standard teardrop style seen further along in this document.

Most all sheaves in use today are flame hardened in the groove area. In discussion with sheave experts we know that the depth of hardness obtainable through flame hardening is never more than 2.5mm or 0.100 inch.

Understanding this we realize that the best way to track and monitor sheave wear is by checking and recording the depth of the groove when sheaves are new as well as checking/recording the sheave groove contour and wear during yearly CAT 3 inspection. Once the depth of groove exceeds 1/8th inch or 3mm over the original manufactured depth, the sheave should be scheduled for replacement.

Monitoring depth of groove is a simple way to verify groove condition.

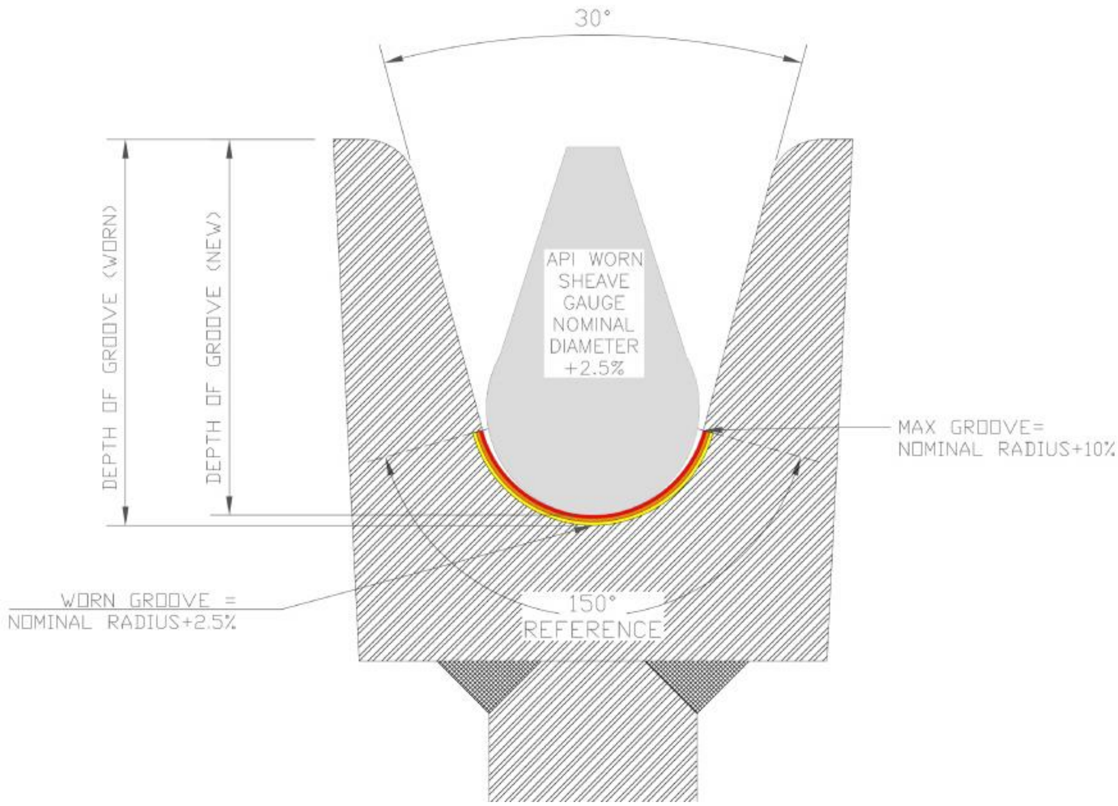


MAXIMUM ALLOWABLE WEAR ON SHEAVE
(NOMINAL ROPE DIAMETER + 2.5%)

Here we see a cut away of the standard 3 piece sheave construction where web is welded to a forged ring and a hub (not shown). The maximum new groove width is shown at the top of the red arc. The maximum wear (minimum groove size plus 2.5%) is shown at the bottom of the red arc. The red area denotes the flame hardened portion of the groove and the allowable wear that is normal to a sheave. Note that hardness diminishes as depth increases. Surface may be Rc 40 but within 1.5 mm depth the hardness might be down to Rc 35.

Here is how an API worn sheave gauge will set in a new or unworn groove shown below. The gauge will only contact at the bottom of the groove and there will be daylight along both sides.

New sheave with API worn gauge

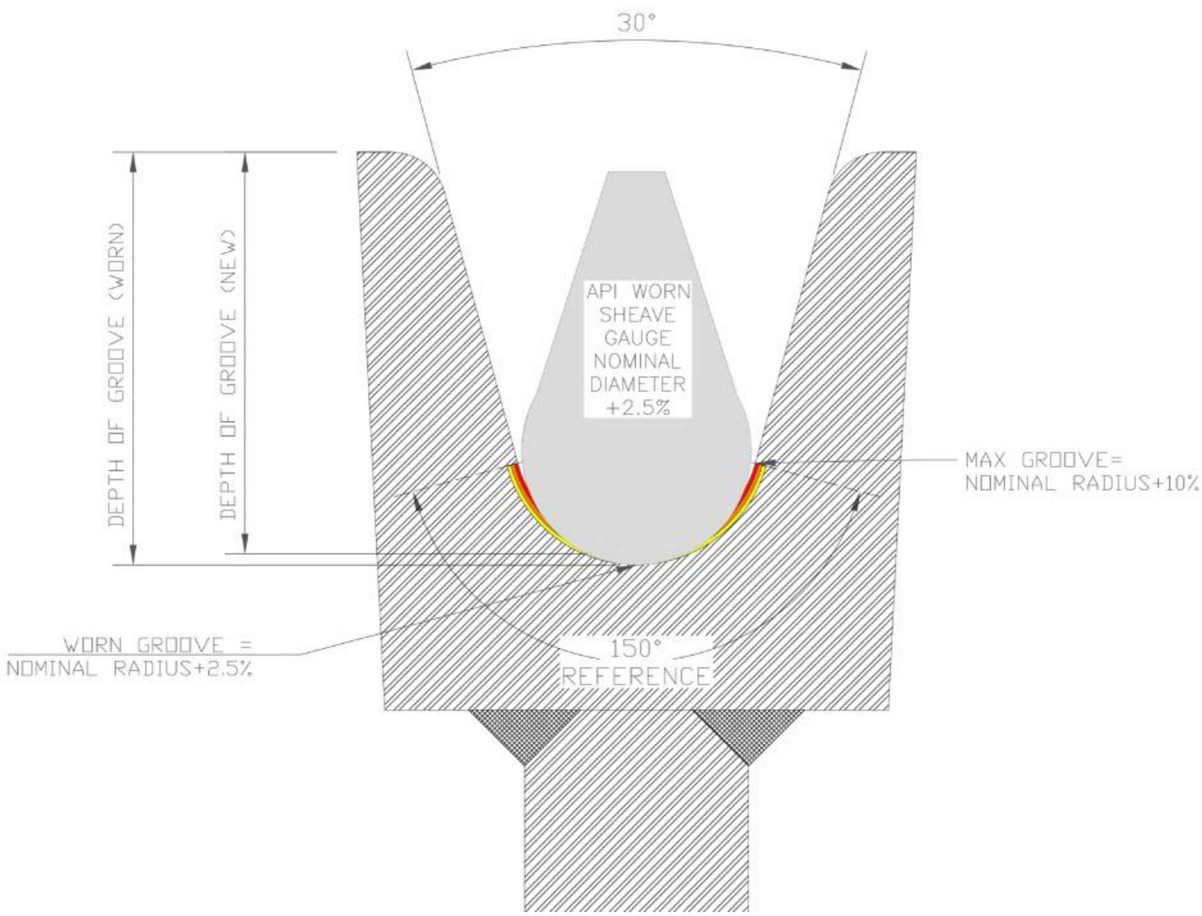


This is normal and sheave groove is as new condition with API worn gauge inserted. Note the groove hardness represented by 3 colors, RED, ORANGE and YELLOW. This is the best way to visualize the hardness as well as critical wear areas on sheave grooves. Radii for new sheaves is nominal +6% to nominal +10% and most manufactures try and machine grooves to nominal+8% as a start point.

Wear in the sheave groove is mostly associated with rope diameter running through the sheaves and to some extent lubrication. Adherence to a good cut and slip program will minimize potential sheave wear for many years. Generally, rope is 5% oversized from nominal diameter coming off the spool and is considered worn out when rope diameter at the drawworks drum has reached 5% under nominal diameter. This is why fast line sheaves always show the most wear, they are closest to drawworks and deal with worn/undersized rope throughout their working life.

Here is how an API worn sheave gauge will set in a worn groove below. At this point the original groove hardness is worn away and the sheave should be scheduled for replacement at the next Out of Service Period.

Worn groove with API worn sheave gauge

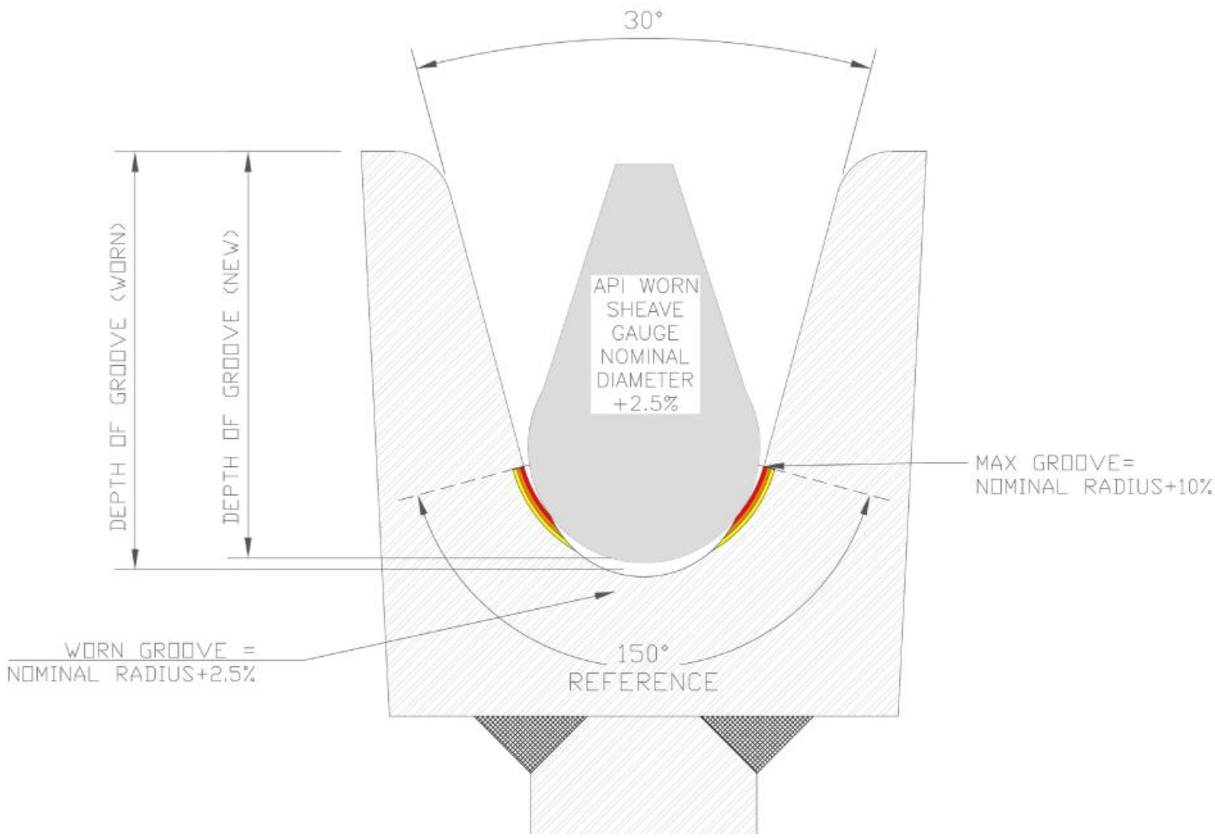


Note that the API worn sheave gauge fits snug and there is no gap along the sides. Had this sheave been checked for depth of groove when new we would now see that the depth had increased around 0.100" or 2.5 mm at this point. This is normally only found on fast line sheaves on block and crown if a good cut and slip program has been followed.

Note here that the hardened area of RED, ORANGE and YELLOW are gone in the center of the groove. Original groove hardness is worn away. It may have taken 10 years to get to this point but additional wear will happen much faster due to lack of hardness. Depending on design and original manufacturing depth of groove, the conventional 3 piece fabricated sheaves can be requalified via inspection and MPI, re-grooved and re-hardened and reused.

Below we see an API worn sheave gauge in a sheave that is excessively worn and should be removed from service at the next opportunity. In this case the groove width is adversely affecting the integrity of the wire rope due to pinching and high stranding. This has normally been seen in derrick traveling assemblies on the fast line sheaves closest to the Drawworks and is usually caused by a poor cut and slip program.

Severely worn sheave groove with API worn gauge



This is the condition we find when we are requested to inspect sheaves due to pre-mature wire rope strand breakage and the root cause is found to be sheave wear. That is an important point, today issues with wire rope wear has nothing to do with the sheaves or the sheave grooving.

Most common issues with wire rope wear/strand breakage are due to lack of adequate weight on the traveling assembly, spooling issues on drums at the crossover points, excessive wear on wearplates and kick pads on drum.

When hoisting heavy loads and there is a very loud POP noise as the wire rope reaches the end of each layer on drum spool and transitions to the next layer issues are on drum and not with traveling assembly or sheaves. This can get so bad that it shakes the rig and sounds like a gun shot as rope transitions from one layer to the next.

Misconceptions on sheave gauging.

Sheaves grooves very seldom if ever wear wider/larger than they were originally machined, wire rope reduced diameter causes sheave grooves to wear and the rope stretches and gets smaller as it runs through the reeving of the traveling assembly and accumulates ton miles through use. The stretched worn rope causes sheave grooves to wear deeper and the contour of groove to get smaller. The only reasons grooves could get wider are listed by probability below.

- Oversized wire rope installed in the reeving which opened the groove is the most likely reason a groove would be wider than API allowable specification.
- If the bearings collapsed and sheave wobbled severely. In this case the sheave bore would be badly damaged and the sheave would need to be replaced.
- Excessive fleet angle will eat one side of the grove flange wall away and in that case sheave may show a wider groove but the narrow flange on one side would show the root cause.

If during and inspection one finds what they think is and oversized groove, insert the next larger API worn gauge (in increments of 1/8th inch or 3 mm) into the groove and see how it fits. This actually works from 1.5 inch gauges and larger.

IE you are gauging 2 inch rope sheaves with a worn 2.5% gauge and one groove looks questionably wide. (usually at dead end side) Put in a 2-1/8th worn sheave gauge and see if it fits snug or has daylight around the bottom. If so the groove is good for 2 inch.

Maximum 2 inch groove width according to API nominal + 10% or 2.200 inches

Minimum 2-1/8th inch worn gauge +2.5% is 2.178" which is smaller than max allowable for a 2 inch groove.

The wider grooving found when gauging is usually always on the slower or deadman sheaves which see the new wider rope first during reeving.

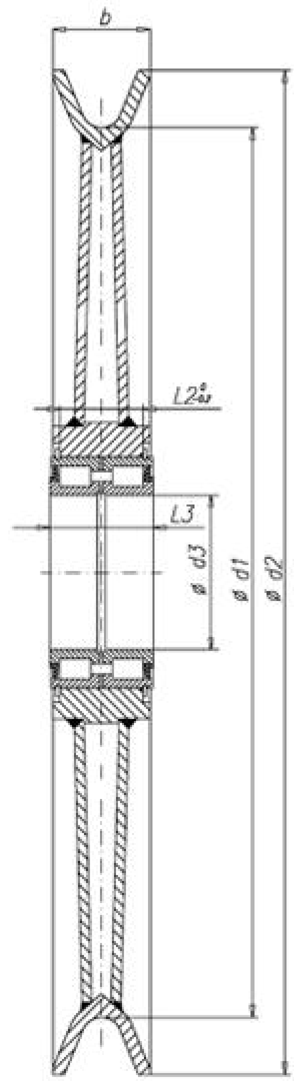
The following are photos of damage that would be considered reason for rejection when inspecting sheave grooves other than normal depth wear.

Fleet Angle Wear Here we have some severe wear from excessive fleet angle. This was a traveling block sheave that was in use with a retract dolly system.

This sheave was next to the one skipped, it dealt with the fleet angle from dolly retract plus and additional 6 inches of fleet angle due to the skipped sheave not used in reeving.

The conservative opinion is that when found in this condition these sheaves should be scrapped. We have seen contractors flip them to allow wear on the other side. We do not consider this advisable under most circumstances but if the sheave passes MPI in flange welds as well as the groove area it is acceptable for use if groove is within API allowable and the sheave is flipped. In this case MPI of the groove area would be important to look for any fatigue cracking from loss of material which may occur.

Dual web sheaves such as found in European and Chinese Manufactured Equipment today should never be used in any application where they are subject to fleet angle or side loading. The dual web sheaves routinely crack at the flange or hub welds when subjected to side loading due to the rigid nature of their design. Furthermore, the dual web sheaves usually have thin side walls in the wire rope groove areas that lack enough material for any side wall wear from fleet angle scrubbing of the drill line.



Above we see a dual web hub failure, it also appears there is a faint line at the bottom of the groove where it is staring to fail.

To the right we see a cut away of the dual web design, welds at flange to groove and hub areas are small fillet. None of these design sheaves could be manufactured to API-8C PSL-2 specification which requires full penetration welds.

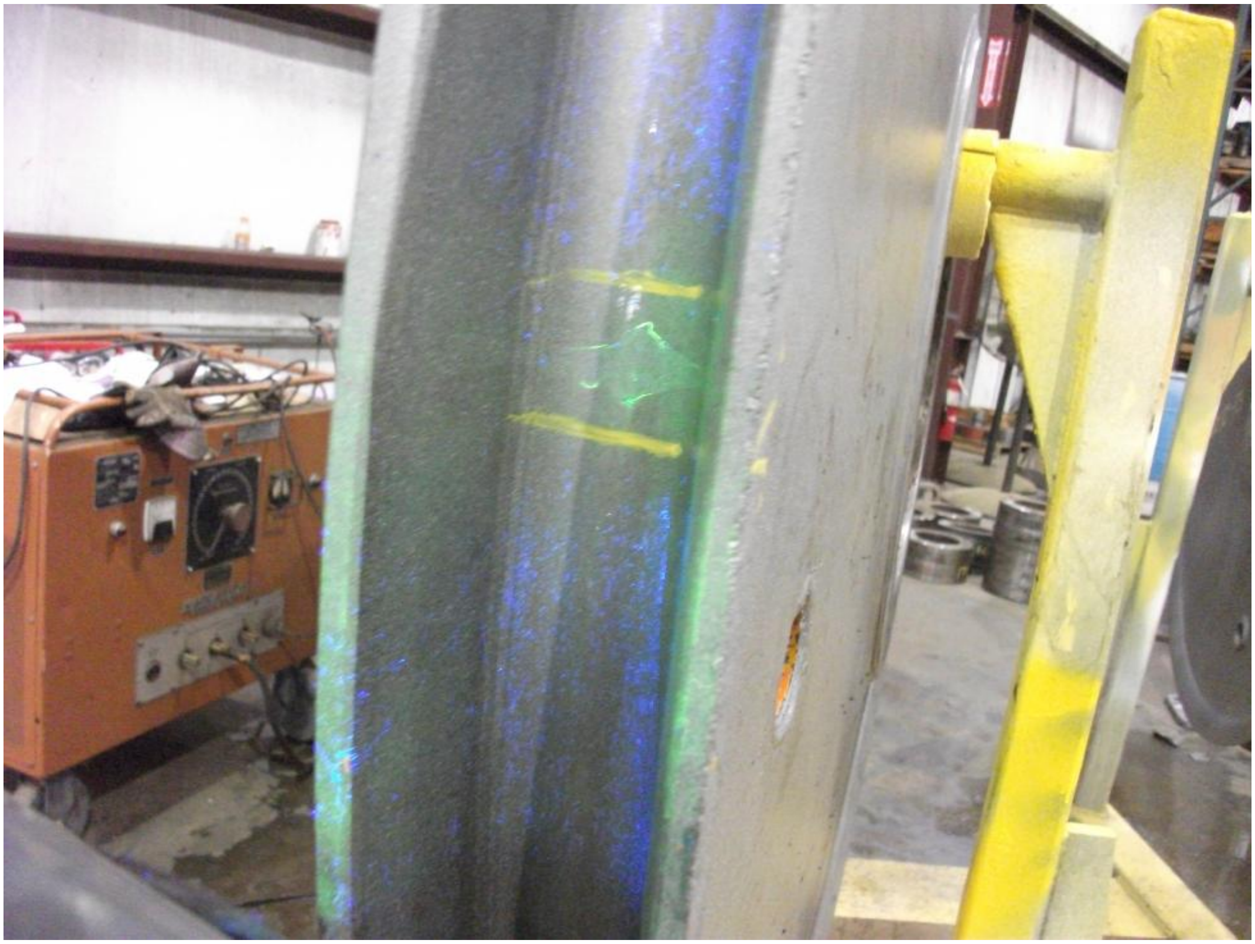
To stop any chance of receiving dual web sheaves always stipulate in the PO that sheaves must be manufactured to API-8C PSL-2 spec. This will give you the best chance of not receiving this style sheave which is being pushed by both primary equipment OEM's as their standard.

Duel web sheaves due to design (as seen below) do not meet the criteria for remedial repair; there is not enough material in the bottom of the groove to allow for wear let alone rework

Cut away of a dual web sheave with No-Go gauge depth set at 1.5 times rope diameter.

This style sheave should be removed and replaced when found, these dual web sheaves appear to be designed to wear out within 10 years or less. This cut away we found cracks starting at both webs inside. Also hardness depth can be seen in the bottom of groove discoloration.

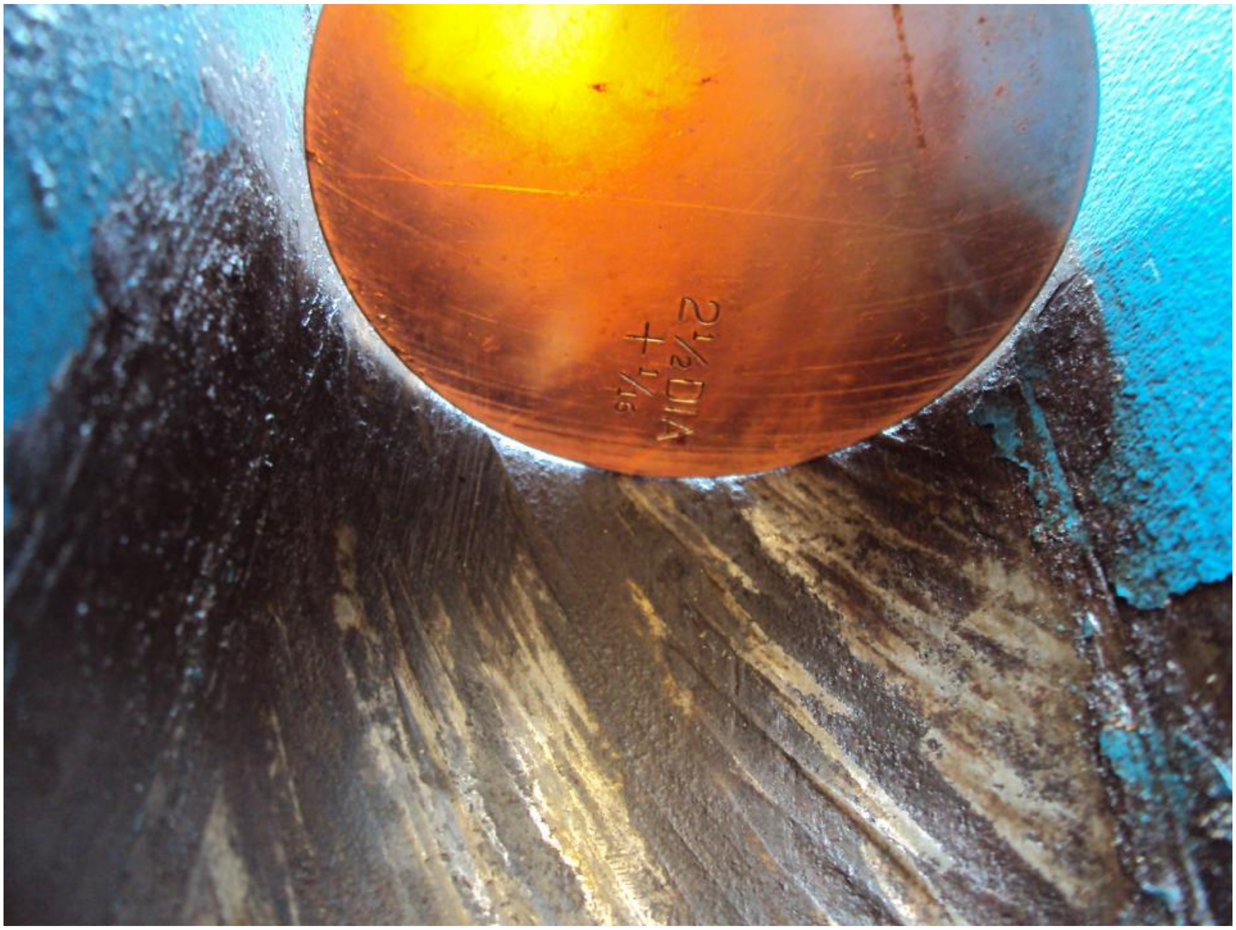
We have also noted during CAT 4 inspections on Dual web sheaves that many of them the groove is made from rolled and welded angle bar and the weld where it is joined together usually always has a transverse crack running through the groove.



Here you see the transverse indication and look closely at left flange and you can see it has been hand ground to match up the transition on the ends.

Negative Impression or Corrugation in Sheave Grooves

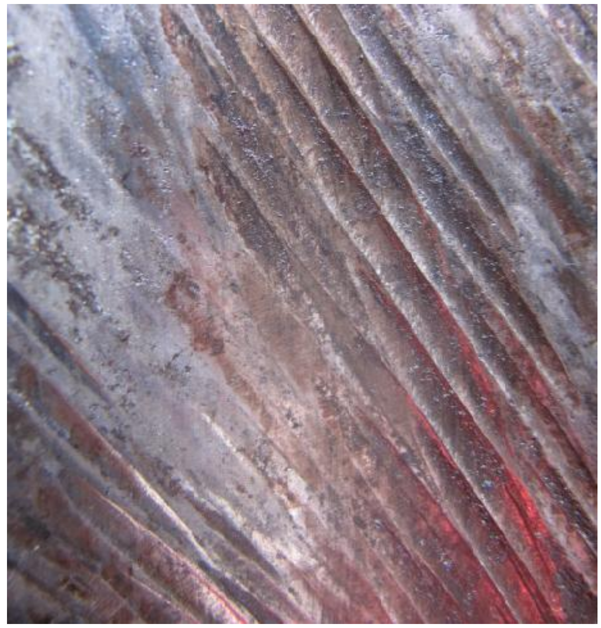
Sheaves in Marine Riser Tensioners, (known as MRT or Tensioner sheaves) and turn down sheaves do not follow normal wear sequence as sheaves in traveling assemblies. The MRT sheaves tend to spend a lot of time rocking back and forth. This has shown over time to cause the groove to pick up the rope impression in the bottom of the saddle as seen in the below photos.



Here we see a sheave that the groove checks good for width but the surface finish is badly damaged from wire rope. Many times these sheaves can be repaired by re-grooving and re-flame hardening but that has to be done in a shop by people who are familiar with the procedures.

Here again in this close up we see wire imprint into the groove and corrosive pitting; this is an MRT sheave.

The technical term here is “negative imprint”



Below we see corrosive pitting as well as faint imprint.

Both of these conditions will have adversely affected the life of the wire rope.

This will usually show up as breakage or wear of the individual rope strands and premature rope failure.

Most all of the MRT or Tensioner sheaves we have inspected were all originally machined to the minimum depth of groove as stipulated by API. That is 1.33 times the diameter of the rope.

In all cases with standard 3 piece sheave construction we were able to repair these sheaves after they were qualified by blast, dimensional inspection and passing NDT. The grooves were then re-cut 1/8th inch deeper or until the marks and pits were removed. In no case did we allow a re-cut depth greater than 1.5 times the rope diameter and in no case, did we have to.

Sheaves were then flame hardened again and put back in service.

Repair to sheave grooves (regrooving sheave) is normally only possible on single web 3 piece constructions, IE groove made into a forged ring welded to web plate which is welded to the hub. (Sheaves 60 inches and above generally).

Any sheaves that get reconditioned by re-grooving has to be re-hardened. We have done this via flame/quench as well as induction hardening. Both worked well.

Reported by Michael L Yoakum, Yoakum Technical Consulting LLC Opinions here are based on my experience performing inspection and repairs and working with sheave manufactures over the last 30+ years Last edit 5 June 2017

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Table 8—Grove Radii for Sheaves[a]

Nominal Wire Rope Diameter		Groove Radius Minimum Worn		Groove Radius Minimum New		Groove Radius Maximum	
in.	mm	in.	mm	in.	mm	in.	mm
0.250	6.5	0.128	3.25	0.134	3.40	0.138	3.51
0.313	8.0	0.160	4.06	0.167	4.24	0.172	4.37
0.375	9.5	0.192	4.88	0.199	5.05	0.206	5.23
0.438	11.0	0.224	5.69	0.232	5.89	0.241	6.12
0.500	13.0	0.256	6.50	0.265	6.73	0.275	6.99
0.563	14.5	0.288	7.32	0.298	7.57	0.309	7.85
0.625	16.0	0.320	8.13	0.331	8.41	0.344	8.74
0.750	19.0	0.384	9.75	0.398	10.11	0.413	10.49
0.875	22.0	0.448	11.38	0.464	11.79	0.481	12.22
1.000	26.0	0.513	13.03	0.530	13.46	0.550	13.97
1.125	29.0	0.577	14.66	0.596	15.14	0.619	15.72
1.250	32.0	0.641	16.28	0.663	16.84	0.688	17.48
1.375	35.0	0.705	17.91	0.729	18.52	0.756	19.20
1.500	38.0	0.769	19.53	0.795	20.19	0.825	20.96
1.625	42.0	0.833	21.16	0.861	21.87	0.894	22.71
1.750	45.0	0.897	22.78	0.928	23.57	0.963	24.46
1.875	48.0	0.961	24.41	0.994	25.25	1.031	26.19
2.000	52.0	1.025	26.04	1.060	26.92	1.100	27.94
2.125	54.0	1.089	27.66	1.126	28.60	1.169	29.69
2.250	58.0	1.153	29.29	1.193	30.30	1.238	31.45
2.375	60.0	1.217	30.91	1.259	31.98	1.306	33.17
2.500	64.0	1.281	32.54	1.325	33.66	1.375	34.93
2.625	67.0	1.345	34.16	1.391	35.33	1.444	36.68
2.750	71.0	1.409	35.79	1.458	37.03	1.513	38.43
2.875	74.0	1.473	37.41	1.524	38.71	1.581	40.16
3.000	77.0	1.537	39.04	1.590	40.39	1.650	41.91
3.125	80.0	1.602	40.69	1.656	42.06	1.719	43.66
3.250	83.0	1.666	42.32	1.723	43.76	1.788	45.42
3.375	86.0	1.730	43.94	1.789	45.44	1.856	47.14
3.500	90.0	1.794	45.57	1.855	47.12	1.925	48.89
3.750	96.0	1.922	48.82	1.988	50.50	2.063	52.40
4.000	103.0	2.050	52.07	2.120	53.85	2.200	55.88
4.250	109.0	2.178	55.32	2.253	57.23	2.338	59.39
4.500	115.0	2.306	58.57	2.385	60.58	2.475	62.87
4.750	122.0	2.434	61.82	2.518	63.96	2.613	66.37
5.000	128.0	2.563	65.10	2.650	67.31	2.750	69.85
5.250	135.0	2.691	68.35	2.783	70.69	2.888	73.36
5.500	141.0	2.819	71.60	2.915	74.04	3.025	76.84
5.750	148.0	2.947	74.85	3.048	77.42	3.163	80.34
6.000	154.0	3.075	78.11	3.180	80.77	3.300	83.82

Minimum worn groove radius = nominal rope radius + $2^1/_2$ %

Minimum new groove radius = nominal rope radius + 6 %

Maximum groove radius = nominal rope radius + 10 %

NOTE For wire rope sizes 0.375 in. (9.5 mm) and larger not found on this table use the following equations:

[a] See Figure 10.