Dear NWSL Gear/Mechanism Modeler,

With the introduction of a wide variety of miniature gearboxes over the years, NWSL has enabled a greater number of model builders to upgrade and improve the operating qualities of their models with more ease and success than previously possible. Although returns on our gear products have always been extremely low, we still want to guide model builders to improve their record of successful project accomplishment even further with usage reminders and hints beyond the general comments elsewhere in the catalog.

YOU CAN'T WEAR A GEAR IN -YOU CAN ONLY WEAR IT OUT!

Over the years models and mechanical components have often been of second quality or less in order to keep your costs (prices) as low as possible. As a result, modelers have become used to "wear-in" procedure in an attempt to remove binds and other problems caused by the non-precision components and/or inadequately engineered and built mechanical components. Proper procedure is to determine the bind cause (ie. eccentric gear; improper gear mesh whether too tight or too loose; foreign object in gear teeth; gear wobble; gear warpage such as often found in molded plastic gears; tight or misaligned bearings; etc.) and eliminate it.

In an apparently properly operating mechanism, excessive gear wear may occur. Our experience in modeling and more recently in gear manufacture has led us to conclude that the most common causes of excessive wear are:

1. Poorly made (or damaged) worm.
2. Improperly selected materials (most commonly a brass worm driving a brass wormgear - ie. Same materials - wear out rate will be very high, usually whether lubricated or not). Driving gear should be harder material than driven gear.
3. Worm not centered or too short for running mate wormgear.
4. Inadequate lubrication or lubricant (use a gear oil).
5. Improperly matched worm and wormgear.

And NWSL attacked these problems thusly:

1. NWSL uses a premium manufacturing technique to assure worms of very high surface quality. It is possible of course to damage worms during installation or handling or at any point in the manufacturing process.
2. Some NWSL gear sets require the user to locate the position of the worm in relation to the wormgear. The worm MUST be centered (front to rear) over the wormgear (and is best centered side-to-side) or the start of the worm thread can catch gear teeth as the wormgear rotates under the worm.
3. Virtually all of the confirmed instances of premature/excessive wormgear wear of NWSL products has been from inadequate lubrication and/or overload. Often due to the user purposely not lubricating while they "break it in" or "wear it in" or whatever (which translated means "wear it out"!). Would you drain the oil from your new automobile to break it in?

YOU MUST USE A GEAR OIL for adequate lubrication of gear teeth working surfaces. Light oils, while suitable for wormshaft bearings, etc., will not remain on the working surfaces of gear teeth and therefore cannot provide adequate lubrication. We use LaBelle #102 gear oil with good success and there are other suitable oils available. LaBelle #101, 107 and 108 are NOT suitable for this application (gear working surface lubrication), but are suitable for other lubrication such as shafts , axles, etc.

If you have incurred heavy wormgear wear, it would be most helpful to us at NWSL if you will advise us of the type of lubrication you have used and return the worm for inspection, repair or replacement. Re-using a damaged worm (whether from manufacturing, handling, installation or lack of lubrication) will only result in additional damaged wormgears even if appropriate lubrication is used.

We at NWSL will continue to provide you with top quality products precision manufactured specifically to increase your modeling skills and pleasure.

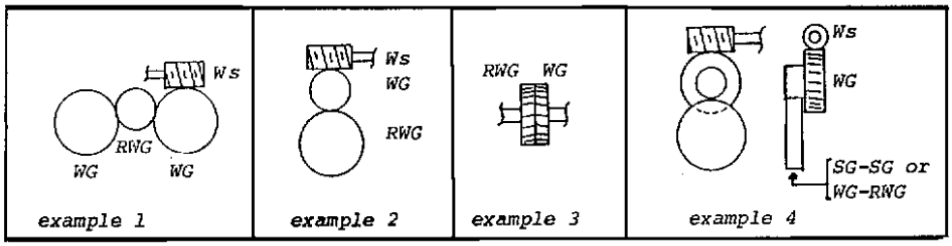
QUALITY GEARS FOR MODEL BUILDERS, TINKERERS, Etc.

These gears and suggestions are intended to aid you modeling pleasure. The examples below are meant to aid your understanding and maybe jog your imagination into figuring ways in which to accomplish your project. 72DP is a size of gear tooth in the English measuring system, a similar size in the Metric measuring system is 0.35module (abbreviated as 'mod'.). Some HO models have larger 64DP/0.4mod. toothed gears or 48DP/0.5mod. If any combination of the NWSL 72DP gears can provide the same center-to-center distance to replace a larger toothed gear, the additional teeth provided in the same diameter can increase your reduction ratio (resulting in lower operating speed). Keep in mind that load carrying capacity decreases significantly as tooth size diminishes. In the DP system of measuring gears, the larger the number, the smaller the tooth size. In the metric system, the smaller the number, the smaller the tooth size. 72DP is almost exactly equivalent to 0.35mod. Tooth size determines the load carrying capacity of a gear, the smaller the tooth size, the lower the capacity. Excessive load causes rapid tooth wear and gear failure.

Family of 72DP Gears—Dims.

GEAR		O.D.	P.D.
WORM		.1875/4.8	.160/ 4.1
WG-RWG-SG	10T	.178/ 4.5	.150/ 3.8
	15T	.240/ 6.1	.212/ 5.4
	20T	.306/ 7.8	.278/ 7.1
	24T	.361/ 9.2	.333/ 8.5
	30T	.444/11.3	.417/10.6
	36T	.527/13.4	.500/12.7
	40T	.583/14.8	.556/14.1

note: dimensions shown in inch/millimeter. 72DP and 0.35mod essentially the same.



What are referred to as 'worm gears' in common model applications are known technically as spiral or helical gears. A true worm gear is also referred to as a 'worm wheel'. This type gear has teeth which are cupped to the fit worm diameter providing more contact surface. Their manufacturing cost is too great to be practical for model building applications as well as being virtually impossible in these miniature sizes. The following abbreviations are used here: Ws = steel worm (the part that looks like a screw and is frequently mis-identified as a wormgear); WG = worm gear = RH (the gear that is driven by the worm); RWG = reverse worm gear = LH (gear that mates with WG but not a worm); SG = spur gear (gear with teeth straight across—ie. Parallel with its shaft). The above assumes a normal right hand worm. A left hand worm will mate with the RWG but not the WG.
Reverse worm gears and worm gears can be combined to build a herringbone type gear (eliminates end thrust). To determine gear shaft center-to-center distance, add their respective P.D. (pitch diameter) and divide by 2; add approximately .004" (thickness of this paper) for clearance. Bore is made for a light press fit, however, tolerance variations may not make this a tight fit. If so, knurl or 'upset' the shaft at the gear location or bond the gear in place with solder, Loctite, or similar. Before pressing a gear on the shaft, clean gear bore face of any burrs, sharp edges and keep gear perpendicular to shaft to assure 'square' assembly without gear wobble. THE SENSIPRESS+ can assist in this assembly. Another NWSL tool helpful in achieving precision operation is THE ALIGNER which can check for gear wobble and in many instances can remove gear wobble.

Reduction ratio is determined by number of teeth on the worm gear - ie. a 30 tooth worm gear mated with a worm will provide a 30:1 ratio or reduction. With an 'idler' or multiple intermediate gear (examples 1 and 2) type gear train, the final gear determines the reduction. On a multiple intermediate type gear arrangement (example 1), each axle gear must have the same number of teeth, but the intermediate gears can have any number as required by spacing. Worm gears and reverse worm gears can be mated in place of spur gears to obtain quieter operation and longer gear life, but the slight axial thrust must be taken into consideration using thrust washers where appropriate. Example 4 provides a double reduction, Ws-WG ratio multiplied by the SG-SG (or WG-RWG) ratio.

Better gear life and less noise usually result if gears of dissimilar materials are mated with the driving gear harder (ie. steel worm to brass or plastic wormgear; brass worm to plastic wormgear, etc.). Noise is also a function of proper gear quality, spacing, bearing precision, and lubrication. Worn or sloppy bearings permit the shaft to vibrate causing both noise and excess gear wear. NWSL gears are of high quality and fine surface, but if you decide to lap the gears, toothpaste works well and is easy to wash out. Take extra effort to assure complete removal of ALL lapping compounds to avoid excessive mechanism wear, then lubricate the gears and bearing surfaces.

Most import models use metric (mod.) gears. U.S. manufactured models usually use DP gears. NWSL can provide, on special order, custom manufacture of metric worm gears and spur gears to match most models and sometimes the worm also. However, special handling and set-up charges are significant. Additionally, just replacing a worn or broken gear may not solve the problem that caused failure of the gear. If failure is due to wear, you should consider replacement of the gearbox or drive with a complete new drive for a longer lasting, better operating performance of your model. If failure is due to gear breakage, a replacement gear should serve satisfactorily in the original gearbox. The breakage (cracking) often occurs with moulded plastic gears pressed on a metal shaft or boss - this occurs due to natural shrinkage of the molded plastic over time. The gear cannot be repaired.

To keep your cost to a minimum, special order custom made gears are made on a 'time available' basis and may take anywhere from a day to several months, depending on shop workload. To inquire, send a sample of the gear to be replaced, even if worn or broken, and the O.D. of the worm. Advise what model the gear is from and provide a sketch of the gearbox/gear train showing which gear is required, Because of the wide variety of models and sometimes varied gears between production runs, we usually cannot reliably supply gears based only on model or manufacturer/importer name.

Imported HO locomotives usually have 3.0mm axle while U.S. manufactured HO locomotives usually have 1/8" axles. Many motors (both U.S. and imported) have 3/32" shafts (or 2.4mm which is .0007" larger). The 72DP 'Family of Gears' is available with bores to fit the 4 most commonly found shaft sizes for small models.

4. Designing for gears: If you are designing a model or mechanism, we recommend that metric size gears be planned. They are easier to calculate as well as the fact that you'll be ahead of the game in the coming conversion to metrics. NWSL will continue to offer 72DP size gears (0.35mod and 72DP happen to be interchangeable for all practical purposes), but we specialize in fine pitch metric gears. Metric sizes are easy to determine as shown above. Please keep in mind that tooth form changes in gears of less than 18 teeth causing both difficulty in manufacture (higher cost) and higher wear rate. It is not practical to make gears of less than 8 teeth due to the tooth form changes.

Ratio = number of teeth on final driven gear (if worm is single lead as are most NWSL worms). In the above idler type arrangement, if RWG is 36 tooth, ratio is 36:1 regardless of WG number of teeth. In non-idler boxes (Ws and WG only), number of teeth in WG determines ratio in the same manner. If the worm were a 2 lead type, the ratio would be 36/2 = 18:1. In double reduction arrangement (ie. WG shaft carries a second gear which engages the bottom gear - RWG in above illustration), the ratio is the product of the two separate ratios (ie. Ws-30T = 30:1; if a 10T on WG shaft mates to a 20T on bottom shaft /axle = 20/10 = 2:1; the total ratio is 30 x 2 = 60:1).

CHART OF RELATIVE SIZES - DP versus MODule GEARS

Typical Module Sizes	Approx. DP (for compari-son	Typical DP sizes	OD of 40 tooth gear (approx.)	Sizes NWSL makes*	Dimensions of NWSL Std. Worm OD	Dimensions of NWSL Std. Worm PD	Appropriate range of sizes used in various models (*Use lower end of range for heavy loads (locomotives, etc.) and upper end for lighter loads (trolleys, railcars, etc.)*
0.2	127.0		.38"				
		120	.35"				
0.25	101.6		.41"	x			
		96	.44"				
0.3	84.7		.50"	x	6.0	4.4	
0.3				x	3.1	2.5	
		80	.53"				
0.35	72.6		.58"	x			
		72	.59"	x	3/16"	.160"	
0.4	63.5	64	.66"	x	6.0	5.2	
0.45	56.5		.74"				
		56	.75"	x			
0.5	50.8		.82"	x	6.5	5.5	
		48	.88"	x			
0.55	46.2		.91"				
0.6	43.3		1.00"	x	8.0	6.8	
		40	1.05"	x			
0.7	36.3		1.16"				
0.75	33.8		1.24"	x			
		32	1.31"	x			

*All NWSL gears are 20 degree pressure angle

The chart above shows all commonly made fine pitch gear sizes. The finer tooth (higher DP or lower mod.) the lower the load carrying capacity and the higher the precision required in the mechanism to assure proper mesh and gear life. The chart is only a general guide of applicable sizes. the size, weight, life desired and power to be transmitted must be considered when determining tooth size to be used.

5. SPECIAL GEARS: All gears have theoretical specifications (OD, PD) which we manufacture for normal applications. However, we can often modify these specifications to fit a specific situation. For example, if a gearbox has been inadvertently made with wrong gear spacing, we may be able to modify gear PD and save you re-tooling and scrappage.

6. TO REPLACE A WORMGEAR, SPURGEAR OR REVERSE WORMGEAR:

It is relatively inexpensive to duplicate these gears (relative to Worm manufacturing cost). Setup will run approximately $90 and unit cost approximately $8 (brass or acetal). Quantity discounts apply on unit cost. To order gears or quote, send samples if possible and as much of the following information that you can determine. We MUST have the worm OD as well as the gear data if you are ordering a worm gear or reverse worm gear.

GENERAL DATA	WORM DATA	GEAR DATA
a. Pressure angle	g. OD	p. OD
b. Material desired	h. Number of leads	q. Number of teeth
c. Quantity	i. Length	r. Face width (thickness)
d. Date required	j. Bore	s. Bore
e. Tooth size (DP/mod)	k. Type bore#	t. Type bore#
	m. Material	u. Material
	n. Right or left hand	

#bore type - press-fit or slip-fit

For best gear life, the gears should be dissimilar materials with the driving gear harder. This is particularly important for high speed and/or high load interfaces such as worm to wormgear and less important in low speed situations such as idler gears between axles. Acetal is the generic name for the engineering plastic trade named Delrin (DuPont) and Celcon (Celanese). NWSL acetal gears are machined from stable, aged material to avoid the shrinkage and cracking problems inherent in inexpensive moulded plastic gears. Gears can be machined in material of your choice with appropriate handling and difficulty charges (ie. gears in bronze usually require a 50% surcharge compared to brass because of added machining time and tool wear).

7. NOISE: Noise generation in gearing is a function of several factors including gear quality, mechanism quality, load and luck (it is considered an 'art' to achieve a quiet gear transmission). Literally, noise is vibration, so any sloppiness in bearings, shafts, etc. will translate into noise. Spur gears running at high RPM are inherently noisy and even with exceptional bearing clearances and precision assembly should be avoided if possible. Our experience is that tight gear mesh causes more noise than loose gear mesh. In worm and gear arrangements, a minimal worm end thrust is desired, not only to minimize noise, but to minimize downhill lurch common to many mass production model locomotives.

8. QUALITY: All NWSL gears are cut, including the acetal gears, assuring consistency and accuracy rarely achieved with injection moulded and cast gears. Gear TIR is less than 0.003". Closer tolerance can be provided with commensurate surcharges. Defective gears will be replaced free of charge upon return within 6 months of shipment. Gear wear is not within our control and therefore is not considered a defect. NWSL accepts no responsibility beyond the net sale price of the gear for any loss or costs incurred in the event of gear failure, or failure to perform in any particular manner. NWSL manufactures commercial quality fine pitch gears by process control.

9. MATERIAL: NWSL makes worms only of steel. Gears are cut from free machining half hard brass and acetal plastic. Gears can be cut in other materials to customer specification. NWSL specializes in fine pitch metric gears of 16mm (5/8") or smaller OD. Larger gear sizes to 25mm (1") OD can be manufactured. All costs noted above are approximate for illustration purposes - inquire for current costs for your specific requirements. For assistance or further information, write or phone (206-932-1087) or fax (206-935-7106) or e-mail (info@NWSL.com).

SIZE	DECIMAL INCHES	SIZE	DECIMAL INCHES	SIZE	DECIMAL INCHES	SIZE	DECIMAL INCHES	SIZE	DECIMAL INCHES	SIZE	DECIMAL INCHES
97	.0059	59	.0410	2.75mm	.1083	5mm	.1969	N	.3020	13mm	.5118
96	.0063	1.05mm	.0413	7/64	.1094	8	.1990	7.7mm	.3031	33/64	.5156
95	.0067	58	.0420	35	.1100	5.1mm	.2008	7.75mm	.3051	17/32	.5312
94	.0071	57	.0430	2.8mm	.1102	7	.2010	7.8mm	.3071	13.5mm	.5315
93	.0075	1.1mm	.0433	34	.1110	13/64	.2031	7.9mm	.3110	35/64	.5469
92	.0079	1.15mm	.0453	33	.1130	6	.2040	5/16	.3125	14mm	.5512
.2mm	.0079	56	.0465	2.9mm	.1142	5.2mm	.2047	8mm	.3150	9/16	.5625
91	.0083	3/64	.0469	32	.1160	5	.2055	O	.3160	14.5mm	.5709
90	.0087	1.2mm	.0472	3mm	.1181	5.25mm	.2067	8.1mm	.3189	37/64	.5781
.22mm	.0087	1.25mm	.0492	31	.1200	5.3mm	.2087	8.2mm	.3228	15mm	.5906
89	.0091	1.3mm	.0512	3.1mm	.1220	4	.2090	P	.3230	19/32	.5938
88	.0095	55	.0520	1/8	.1250	5.4mm	.2126	8.25mm	.3248	39/64	.6094
.25mm	.0098	1.35mm	.0531	3.2mm	.1260	3	.2130	8.3mm	.3268	15.5mm	.6102
87	.0100	54	.0550	3.25mm	.1280	5.5mm	.2165	21/64	.3281	5/8	.6250
86	.0105	1.4mm	.0551	30	.1285	7/32	.2188	8.4mm	.3307	16mm	.6299
85	.0110	1.45mm	.0571	3.3mm	.1299	5.6mm	.2205	Q	.3320	41/64	.6406
.28mm	.0110	1.5mm	.0591	3.4mm	.1339	2	.2210	8.5mm	.3346	16.5mm	.6496
84	.0115	53	.0595	29	.1360	5.7mm	.2244	8.6mm	.3386	21/32	.6562
.3mm	.0118	1.55mm	.0610	3.5mm	.1378	5.75mm	.2264	R	.3390	17mm	.6693
83	.0120	1/16	.0625	28	.1405	1	.2280	8.7mm	.3425	43/64	.6719
82	.0125	1.6mm	.0630	9/64	.1406	5.8mm	.2283	11/32	.3438	11/16	.6875
.32mm	.0126	52	.0635	3.6mm	.1417	5.9mm	.2323	8.75mm	.3445	17.5mm	.6890
81	.0130	1.65mm	.0650	27	.1440	A	.2340	8.8mm	.3465	45/64	.7031
80	.0135	1.7mm	.0669	3.7mm	.1457	15/64	.2344	S	.3480	18mm	.7087
.35mm	.0138	51	.0670	26	.1470	6mm	.2362	8.9mm	.3504	23/32	.7188
79	.0145	1.75mm	.0689	3.75mm	.1476	B	.2380	9mm	.3543	18.5mm	.7283
1/64	.0156	50	.0700	25	.1495	6.1mm	.2402	T	.3580	47/64	.7344
.4mm	.0157	1.8mm	.0709	3.8mm	.1496	C	.2420	9.1mm	.3583	19mm	.7480
78	.0160	1.85mm	.0728	24	.1520	6.2mm	.2441	23/64	.3594	3/4	.7500
.45mm	.0177	49	.0730	3.9mm	.1535	D	.2460	9.2mm	.3622	49/64	.7656
77	.0180	1.9mm	.0748	23	.1540	6.25mm	.2461	9.25mm	.3642	19.5mm	.7677
.5mm	.0197	48	.0760	5/32	.1562	6.3mm	.2480	9.3mm	.3661	25/32	.7812
76	.0200	1.95mm	.0768	22	.1570	E	.2500	U	.3680	20mm	.7874
75	.0210	5/64	.0781	4mm	.1575	1/4	.2500	9.4mm	.3701	51/64	.7969
.55mm	.0217	47	.0785	21	.1590	6.4mm	.2520	9.5mm	.3740	20.5mm	.8071
74	.0225	2mm	.0787	20	.1610	6.5mm	.2559	3/8	.3750	13/16	.8125
.6mm	.0236	2.05mm	.0807	4.1mm	.1614	F	.2570	V	.3770	21mm	.8268
73	.0240	46	.0810	4.2mm	.1654	6.6mm	.2598	9.6mm	.3780	53/64	.8281
72	.0250	45	.0820	19	.1660	G	.2610	9.7mm	.3819	27/32	.8438
.65mm	.0256	2.1mm	.0827	4.25mm	.1673	6.7mm	.2638	9.75mm	.3839	21.5mm	.8465
71	.0260	2.15mm	.0846	4.3mm	.1693	17/64	.2656	9.8mm	.3858	55/64	.8594
.7mm	.0276	44	.0860	18	.1695	6.75mm	.2657	W	.3860	22mm	.8661
70	.0280	2.2mm	.0866	11/64	.1719	H	.2660	9.9mm	.3898	7/8	.8750
69	.0292	2.25mm	.0886	17	.1730	6.8mm	.2677	25/64	.3906	22.5mm	.8858
.75mm	.0295	43	.0890	4.4mm	.1732	6.9mm	.2717	10mm	.3937	57/64	.8906
68	.0310	2.3mm	.0906	16	.1770	I	.2720	X	.3970	23mm	.9055
1/32	.0312	2.35mm	.0925	4.5mm	.1772	7mm	.2756	Y	.4040	29/32	.9062
.8mm	.0315	42	.0935	15	.1800	J	.2770	13/32	.4062	59/64	.9219
67	.0320	3/32	.0938	4.6mm	.1811	7.1mm	.2795	Z	.4130	23.5mm	.9252
66	.0330	2.4mm	.0945	14	.1820	K	.2810	10.5mm	.4134	15/16	.9375
.85mm	.0335	41	.0960	13	.1850	9/32	.2812	27/64	.4219	24mm	.9449
65	.0350	2.45mm	.0965	4.7mm	.1850	7.2mm	.2835	11mm	.4331	61/64	.9531
.9mm	.0354	40	.0980	4.75mm	.1870	7.25mm	.2854	7/16	.4375	24.5mm	.9646
64	.0360	2.5mm	.0984	3/16	.1875	7.3mm	.2874	11.5mm	.4528	31/32	.9688
63	.0370	39	.0995	4.8mm	.1890	L	.2900	29/64	.4531	25mm	.9843
.95mm	.0374	38	.1015	12	.1890	7.4mm	.2913	15/32	.4688	63/64	.9844
62	.0380	2.6mm	.1024	11	.1910	M	.2950	12mm	.4724	1	1.0000
61	.0390	37	.1040	4.9mm	.1929	7.5mm	.2953	31/64	.4844		
1mm	.0394	2.7mm	.1063	10	.1935	19/64	.2969	12.5mm	.4921		
60	.0400	36	.1065	9	.1960	7.6mm	.2992	1/2	.5000		

QUICK CROSS REFERENCE of MILLIMETERS versus INCH MEASURE