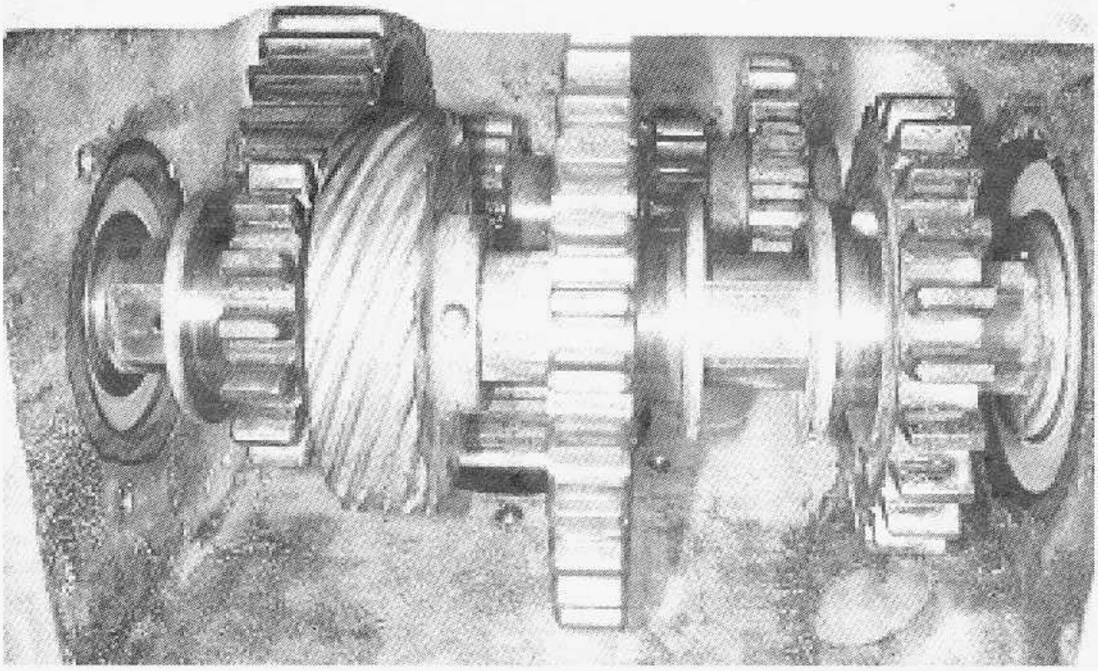
Determining the Dodge Brothers Transmission Gear Alloy

By Parker Ackley, Fairfield, CT



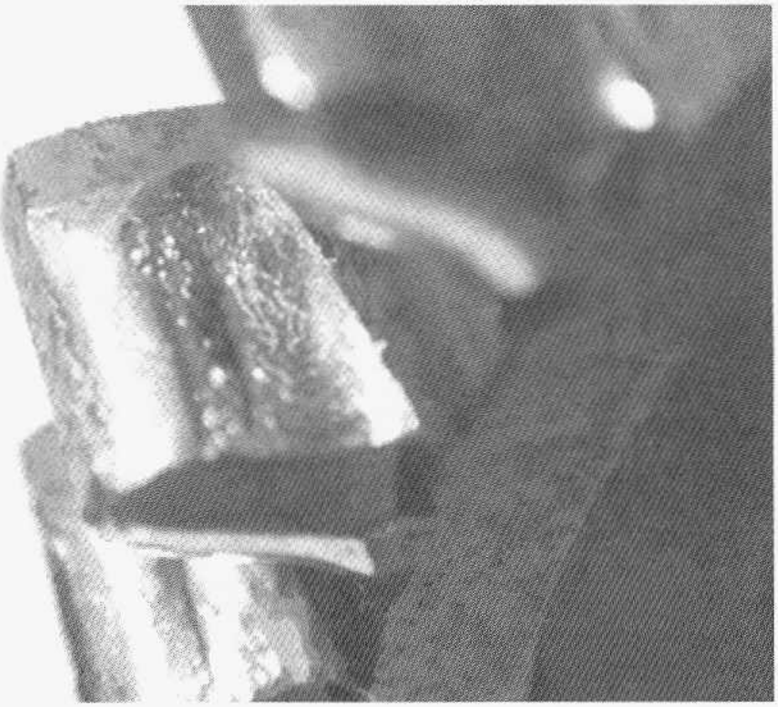
I decided the time had finally come to replace transmission gears on my 1915 DB Touring car when second gear became so loud in that you could not hear the navigator in the front seat — even when she was screaming at the top of her lungs. This would also provide an excellent opportunity to inspect and clean the clutch components and the original leather facing.

Recommended Vendors

Connecticut Antique Engine Restoration, http://www.enginerestoration.com. George King of CAER helped me to disassemble the transmission and evaluate the best course of action to take. (George rebuilt the engine two years earlier.) While all gears showed some signs of wear and pitting, it was decided to replace only the two intermediate gears and the high speed sliding gear (this was partly an economic decision).

We also determined that the bushings for the counter shaft and U-joint should also be replaced while everything was apart. George made the replacement bushing along with the counter shaft itself and helped to reassemble the counter shaft assembly back into the transmission housing. George also opened up a tight clearance on the replacement sliding gear splines. I would recommend sending the matching shafts to the gear vendor whenever new gears are being made to ensure a proper fit.

After obtaining estimate "quotes" ranging from $960 to $7,500 and up to 10 weeks delivery for the three gears, *Rempco, Inc*, 251 Bell Avenue, Cadillac, MI (http://www.rempco.com/) was chosen to manufacture new replacement gears. Rempco specializes in replacement machine tool parts and in recent years have offered their machining services to classic and antique vehicle owners. Parts are first reverse-engineered and then detailed CAD drawings are made; keeping them on file. (If you need a machined part for a vehicle, it may be worthwhile to check with Rempco first, they may already have drawings.) Copies of these drawings are sent to the customer with the completed work and the original samples. I had all three gears manufactured for $1,160 with a 3-week manufacturing time.



Close-up of gear tooth showing substantial wear. The dark spots are pitting of the metal caused by acids in the transmission oil.

Testing the Samples

Since only a partial set of gears were being replaced, a primary concern of mine was that the new gears not be harder than the remaining original gears. I am fortunate to have access to a Rockwell Hardness Tester and an XRF alloy analyzer at work where I can quickly and non-destructively determine the hardness and the alloys used in a sample. I measured the hardness of the original gears in several spots; all measured around 50 on the Rockwell 'C' scale (HRC 50). This same hardness range was confirmed by Rempco when they received the gears to reverse engineer.

Because the analyzer measures the alloy content at the surface of the metal, the sample must be first cleaned down to bare metal. (Who knows what may have accumulated over the last 94 years.) A non-metallic paint stripping wheel and "Scotch-Brite" pads work well. Wire brushes can not be used because they could leave a metallic film which may cause false readings on the analyzer.

Interpreting the Readings

The alloy analyzer can track up to 30 different elements simultaneously. After a measurement, the machine matches the measured data to an internal database of element composition and displays the closest commercial alloy match (i.e. 4130/40). If the measurement uncertainty is high, it will also display an alternate possible match. Table 1 – Alloy Content indicates variability in the Alloy1 and Alloy2 estimates of the analyzer, suggesting a poor match to modern alloys.

The alloy tests however do consistently show the elements present are Iron (Fe; ~97.48%), Manganese (Mn; ~0.63%), Chromium (Cr; ~1.07%) and Vanadium (V; ~0.15%). Trace amounts of lead (Pb), zinc (Zn) and copper (Cu) were also found in the samples. Since Nickel (Ni) was found in only one sample, most likely it is not part of the intended alloy.

Two of the samples indicated the Vanadium was less than the limits of detection for the alloy analyzer, but with an uncertainty of approximately 0.085%, these two samples probably contain something slightly less than 0.1% Vanadium.

Unfortunately, XRF technology cannot measure a number of elements important in modern alloys; these include Magnesium, Molybdenum, Phosphorus, Silicon and Sulphur. Nor can it measure the Carbon content in steel – needed in establishing the hardness limits of the steel. Other means must be used to make that estimate.

Using a Wilson Hardness Conversion Chart, an estimate of the Tensile Strength of steel can be derived by knowing the Rockwell Hardness. In this case, a HRC 50 hardness equates to a tensile strength of approximately 243,000 pounds per square inch.

Determining the Likely Alloy

We now know enough information to make a reasonable estimate on the kind of steel Dodge Brothers used to make transmission gears with. A 1917 Fifth Edition copy of *Machinery's Handbook* provides a good reference for accepted practice of the time and will help tie all of the data together.

Under the "Heat Treatment of Steel" section, there are several tables listing the Composition, Heat Treatment and Properties of various steel alloys defined by the SAE in 1912. From the alloys determined to be present by the alloy analyzer, the steel used for the transmission gears was known as a Chromium-Vanadium steel alloy. To achieve a Rockwell hardness of HRC 50 (tensile strength ~ 243,000 psi), would require a high carbon content followed by a complex multi-cycle heat treatment.

The table for "Chromium-Vanadium Steels" is reproduced in Table 2. Table 3 is an abridged version of "Heat Treatment of Carbon and Alloy Steels", both from the Machinery's Handbook. From these tables the missing elemental information can be determined.

The alloy analyzer suggests that 4130/40 or 1-1/4 Cr (similar to SAE 4140) is a close match. Rempco chose to use 4140HT to manufacture the new gears and is included in Table 1 as reference. Molybdenum is substituted for Vanadium in 4140HT, but otherwise is similar to the original alloy.

Manufacturing Process

The tooth form used in the Dodge Brothers transmission is a 6 diametrical pitch spur gear with an involute 14.5 degree pitch angle. The elastic limits of the heat treated alloy (as measured) should be approximately 243,000 psi. The nominal alloy composition for the transmission gears is:

Element	% by weight	Nominal Limits
Carbon	0.50	0.45 – 0.55
Manganese	0.65	0.50 – 0.80
Phosphorus	<0.04	< 0.04
Sulphur	<0.04	< 0.04
Chromium	0.90	0.70 – 1.10
Vanadium	0.18	> 0.12
Iron	Balance	Balance

The routing (manufacturing steps) that Remco used for the Countershaft Intermediate Gear involved the following operations:

- Saw (blank from 4140HT bar stock)
- Turning (as required)
- Milling (gear face & counterbore both sides)
- Slot (key)
- Hob (6 DP, 14.5 PA, 21 teeth)
- Tooth Rounding (provide lead-in to mating gear)
- Heat Treat to 48/52 HRC
- Grind ID (for counter shaft bushing)
- Deburr & Clean (as required)
- Inspection (per print & sample)

It is very likely that the Dodge Brothers used much the same manufacturing process with the exception of the saw operation and some of the turning and milling requirements because they started the process with a forged steel gear blank as opposed to bar stock.

Rempco used Flame-Hardening followed by a quench as the heat treating method. The heat treating method used by the Dodge Brothers was very likely similar to that listed in the Machinery Handbook (see Table 3).

Special thanks go to Gilbert Hall of Rempco for his help in providing manufacturing information used in this article.

Table 1 – Alloy Content As Measured by Alloy Analyzer

Component	Alloy1	Alloy2	Mo %	Pb %	Zn %	Cu %	Ni %	Fe %	Mn %	Cr %	V %
High Speed Internal Gear	IRON/CS	4130/40	<LOD	0.037	<LOD	0.166	<LOD	97.684	0.651	1.086	0.185
Low/Rev Sliding Gear	1-1/4 Cr	4130/40	<LOD	0.038	0.181	0.376	0.237	97.187	0.617	1.021	0.118
Intermediate Sliding Gear	4130/40	IRON/CS	<LOD	0.035	<LOD	0.295	<LOD	97.567	0.588	1.032	0.119
High Speed Sliding Gear	IRON/CS	1-1/4 Cr	<LOD	0.057	<LOD	0.339	<LOD	97.512	0.546	1.092	0.186
Countershaft Intermed Gear	4130/40	IRON/CS	<LOD	0.048	0.084	0.181	<LOD	97.749	0.638	1.006	0.123
Counter Shaft Drive Gear	4130/40	1-1/4 Cr	<LOD	0.056	0.115	0.460	<LOD	96.900	0.716	1.075	<LOD
Counter Shaft Pinion Gear	IRON/CS	1-1/4 Cr	<LOD	<LOD	<LOD	<LOD	<LOD	97.567	0.683	1.144	0.146
Reverse Idler Gear	IRON/CS	1-1/4 Cr	<LOD	<LOD	<LOD	<LOD	<LOD	97.656	0.578	1.114	<LOD
Average				**0.045**	**0.127**	**0.303**	**0.237**	**97.478**	**0.627**	**1.071**	**0.146**
Average Uncertainty Error				0.020	0.050	0.097	0.155	0.337	0.117	0.085	0.085
New 4140 HT Gear	4130/40	No Match	0.206	<LOD	<LOD	0.162	<LOD	97.386	0.977	0.978	<LOD

Note: IRON/CS = plain iron or carbon steel. <LOD = less than limit of detection.

Other Vehicle Component Alloys

COMPONENT	Alloy1	Alloy2	Sn	Al	Mo	Zr	Pb	Zn	Cu	Ni	Fe	Mn	Cr	V
Flywheel	IRON/CS	No Match	< LOD	< LOD	< LOD	< LOD	0.029	0.076	< LOD	< LOD	98.909	0.479	0.126	< LOD
Axle	IRON/CS	4130/40	< LOD	< LOD	< LOD	< LOD	< LOD	0.082	< LOD	< LOD	97.992	0.689	0.863	0.14
Drive Shaft	1-1/4 Cr	4130/40	< LOD	< LOD	0.337	< LOD	0.086	0.43	< LOD	< LOD	96.884	0.67	1.024	0.138
Transmission Housing	Al Alloy	No Match	< LOD	91.092	< LOD	0.003	0.01	0.203	7.756	0.031	0.793	0.091	< LOD	< LOD
Oil Pan	Al Alloy	No Match	0.079	92.147	< LOD	< LOD	0.084	0.875	5.421	< LOD	0.89	< LOD	< LOD	< LOD
Clutch Cone	Al Alloy	No Match	< LOD	93.472	< LOD	< LOD	< LOD	0.096	5.541	< LOD	0.559	< LOD	< LOD	< LOD

Table 2 – Chromium-Vanadium Steels

From 1915 Machinery Handbook

Carbon %	Manganese %	Phosphorus max %	Sulphur max %	Chromium %	Vanadium min (nom)	Heat Treatment*	Elastic Limit psi
0.10 – 0.20 (0.15)	0.50 – 0.80 (0.65)	0.04	0.04	0.70 – 1.10 (0.90)	0.12 (0.18)	S or T	T50,000 – 90,000
0.15 – 0.25 (0.20)	0.50 – 0.80 (0.65)	0.04	0.04	0.70 – 1.10 (0.90)	0.12 (0.18)	T	55,000 – 100,000
0.20 – 0.30 (0.25)	0.50 – 0.80 (0.65)	0.04	0.04	0.70 – 1.10 (0.90)	0.12 (0.18)	T	55,000 – 100,000
0.30 – 0.40 (0.35)	0.50 – 0.80 (0.65)	0.04	0.04	0.70 – 1.10 (0.90)	0.12 (0.18)	T	60,000 – 150,000
0.35 – 0.45 (0.40)	0.50 – 0.80 (0.65)	0.04	0.04	0.70 – 1.10 (0.90)	0.12 (0.18)	T	65,000 – 175,000
0.40 – 0.50 (0.45)	0.50 – 0.80 (0.65)	0.04	0.04	0.70 – 1.10 (0.90)	0.12 (0.18)	U	150,000 – 200,000
0.45 – 0.55 (0.50)	0.50 – 0.80 (0.65)	0.04	0.04	0.70 – 1.10 (0.90)	0.12 (0.18)	U	150,000 – 225,000

*(See Table 3)

Table 3 – Heat Treatment of Carbon and Alloy Steels from 1915 Machinery Handbook

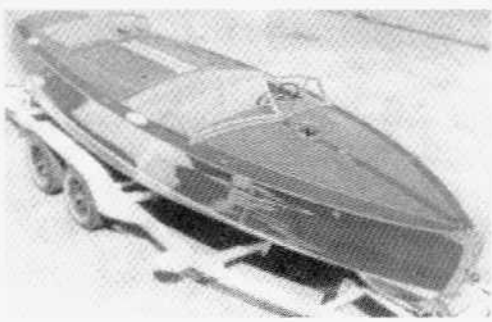
Heat Treatment S	Heat Treatment T	Heat Treatment U
After forging or machining: 1. Carbonize at a temperature between 1600° F and 1750° F. (1650°-1700° F desired). 2. Cool slowly in the carbonizing mixture. 3. Reheat to 1600°-1700° F. 4. Quench. 5. Reheat to 1475°-1550° F. 6. Quench. 7. Reheat to 250°-550° F and cool slowly.	After forging or machining: 1. Heat to 1600°-1700° F. 2. Quench. 3. Reheat to some temperature between 500° and 1300° F. and cool slowly.	After forging: 1. Heat to 1525°-1600° F. (Hold for about one-half hour.) 2. Cool slowly. 3. Reheat to 1650°-1700° F. 4. Quench. 5. Reheat to 350° and 550° F. and cool slowly.

DODGE BOATS — spring is around the corner!

Horace Dodge, Jr's boats, clipped from *Continental Comments* magazine by Jack Carpenter.

This one is a 1929 Dodge Watercar runabout, "Geri," 26-ft long, powered by a 6-cyl, 125 hp Gray Marine engine, also owned by Hawks.

This is identified as a 1929 Dodge Custom Runabout, "JerryLo," owned by Bill Hawks, Lake Minnetonka MN. It's 30-ft long, powered by a 650 hp Rolls Royce V-12. "GerriLo" looks like the boat on the back cover of our Dec/Jan 99 issue



Yet another Dodge boat, left and far left. Origin of these photos unknown.