MASTER TECHNICIANS SERVICE CONFERENCE

REFERENCE BOOK 70-12

REAR AXLE -PART I (Gears & Sounds)

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I'm going to tell you fellas to do something a little different this month. Hang on to this Reference Book until after you've seen Session 71-1. Since the subject of rear axles was covered in two parts, you can't see both films in succession, but you can read the Reference Books that way. I know that it will mean twice the amount of reading in one sitting; but, it will strengthen the relationship between the two sessions if you do. Of course, I'll leave the final decision to you.

In a majority of cases, axle noise can be attributed to one, or both, of two things – improper pinion depth or improper backlash setting. And most of the time, these noises can be effectively reduced or even eliminated by proper adjustment. And, believe it or not, the engineers and quality control people at the factory are trying their best to make your job a little easier.

That's what Part I of this dual session is all about. It tells you how quiet running gears are assured by carefully determining the thickness of the pinion depth adjusting spacer before the axle is assembled and installed in the car at the factory. Even the gear sets that are sent to the dealers as replacement parts are marked to eliminate any guesswork when you have to replace a gear set.

Part II will continue the rear axle story to show how the spacer thickness determined at the factory relates to service procedures and how to determine the right spacer thickness from the markings on a new gear set used for replacement. So you see, I do hope that you take my suggestion and read this month's and next month's Reference Books back to back.

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INTRODUCTION

Overhaul or adjustment of rear axle gear assemblies isn't the most frequent job that technicians tackle in a normal work week. There are probably some technicians who have *never* overhauled or adjusted an axle gear assembly. Generally speaking, axles are trouble-free and often last the life of the car without requiring service.

However, the day will probably come when every technician will be faced with a rear axle job. That's why it's important for technicians to develop or brush up on axle gear repair and adjustment skills.

NOISE IS THE TIP-OFF

The most common reason that an owner will *think* that he has rear axle trouble is noise. However, just *what is* noise? Anytime there are two gears meshing it's going to produce a certain amount of sound from the teeth coming into contact. It is usually a low-decibel sound that is not any louder than normal running noises such as engine, transmission, and tires. Most drivers do not object to these sounds unless they become excessive and objectionable. In this Reference Book, rear axle sounds will be referred to as "noise" only if they have reached that point.

Fig. 1—Gear noise is part of running noise

Fig. 2—Drivers object if noise becomes excessive

AXLE NOISE CAN BE REDUCED

Frequently, rear axle noise can be effectively reduced by readjusting the rear axle gears to mesh properly. And, no matter what you've heard, noisy gears will not get quieter with added mileage. They'll either stay noisy or get worse.

In most cases, axle gears can be readjusted to reduce excessive noise *if* they have been operated

Fig. 3—Noises reduced by readjusting axle gears

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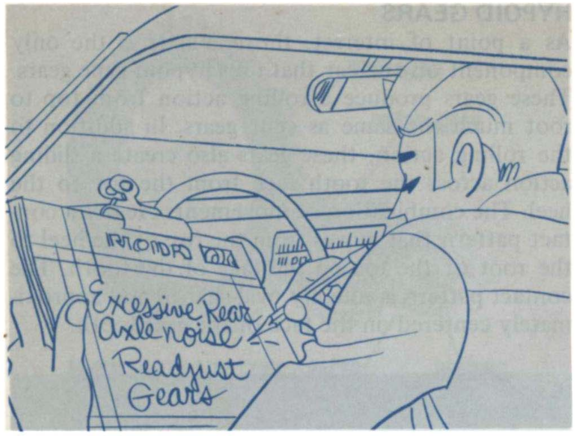

Fig. 4—Only if operated under normal conditions

under *normal* conditions. However, if the gears have been subjected to severe loads or heavy usage, the chances of getting rid of the axle noise may become pretty slim.

A BRIEF LESSON IN TERMINOLOGY

Axle noise is caused by gear teeth that are not meshing properly; and, the only way to determine whether they are is to check the gear tooth contact pattern. But, before we go any further, let's have a brief lesson in terminology and describe the various parts of a gear tooth. Since the tooth contact pattern is always checked on the drive gear, that's the one we'll be talking about. Incidentally, the drive gear is what some technicians are in the habit of referring to as the "ring" gear.

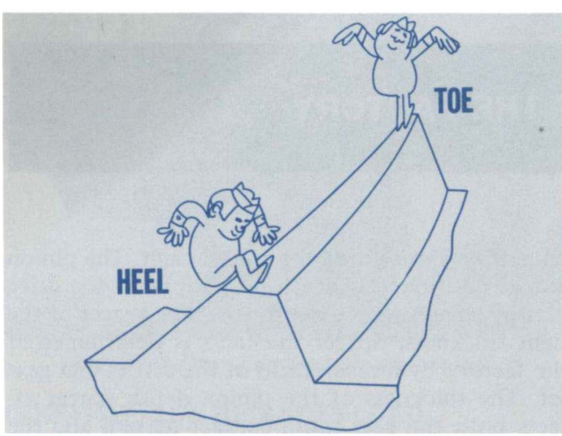

Fig. 5—Inner and outer edges of drive gear

The edges at the inner diameter of the drive gear will be called the toe of the tooth. The outer diameter edges will be called the heel of the tooth. The lower part of the tooth will be the "root" of the gear tooth and the upper part will be known as the "top". And, in case you didn't know, the convex side of the tooth is the "drive" side; and the concave side is the "coast" side.

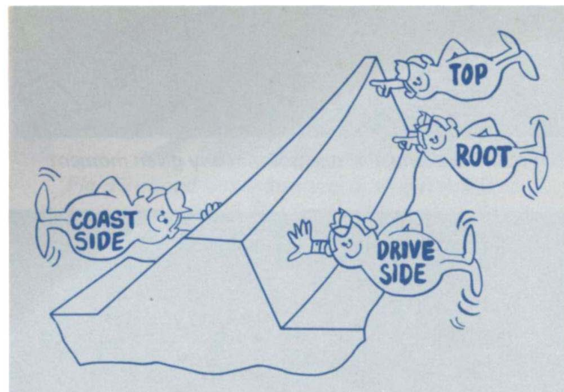

Fig. 6—Drive side - convex; coast side - concave

TOOTH CONTACT PATTERN

The hypoid-type gears used in the rear axle assembly have complicated tooth shapes and must be positioned correctly for the gears to mesh properly. Of course, the most positive way to check the axle gear setting is by taking a close look at the gear tooth contact pattern. Some technicians are in the dark when it comes to interpreting a gear tooth contact pattern; so, let's see how a pattern is *formed* before discussing pattern variations in regard to pinion depth setting.

SPUR GEARS

Because spur gears are straight and aligned with the gear shaft, the meshing teeth are in contact at only one point, or an imaginary line, across the tooth face at any given moment.

The initial contact point is near the top of the tooth face; and, as the teeth engage, the contact line moves toward the root of the tooth. As the teeth unmesh, the contact line moves back toward the top of the tooth. A rectangular-shaped contact pattern is developed by this in-and-out movement as the teeth mesh and unmesh.

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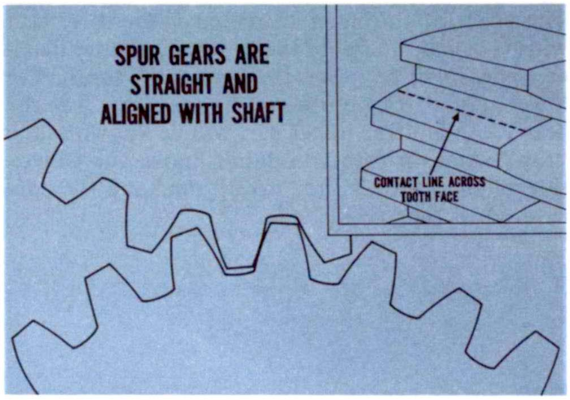

Fig. 7—In contact at one point at any given moment

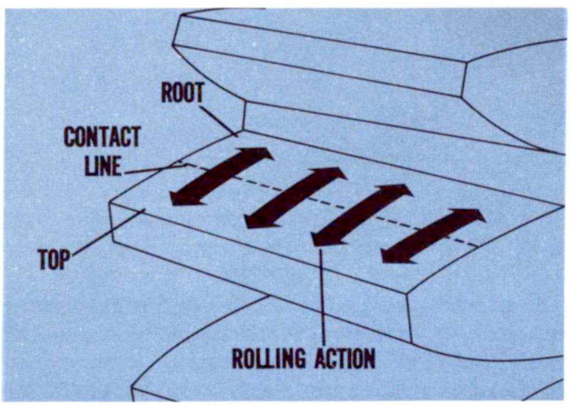

Fig. 8—Rectangular-shaped contact pattern

HYPOID GEARS

As a point of interest, the rear axle is the only component on the car that uses hypoid-type gears. These gears produce a rolling action from top to root much the same as spur gears. In addition to the rolling action, these gears also create a sliding action across the tooth face from the toe to the heel. The combination of movements creates a contact pattern that moves from the top of the heel to the root of the toe on the face of the tooth. The contact pattern is roughly oval-shaped and approximately centered on the face of the gear tooth.

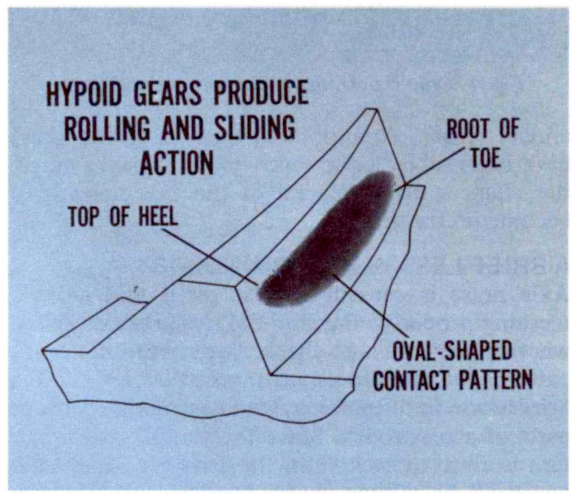

Fig. 9—Hypoid gears used only in rear axle

IT ALL STARTS AT THE FACTORY

Although a lot of you technicians are thoroughly competent at setting pinion depth and backlash, you should know how pinion and drive gears are matched in production to understand the importance of proper adjustment. Quiet-running gears are assured at the factory before they are installed during production or sent to the dealers as matched gear sets to be used for replacement. The pinion gear is positioned to mesh properly with the drive gear by using a pinion depth adjusting spacer of the right thickness. Spacer thickness is determined at the factory by measurement of the carrier and gear set. The thickness of the pinion depth spacer affects both the gear tooth contact pattern and the sound of the gears while they are meshing.

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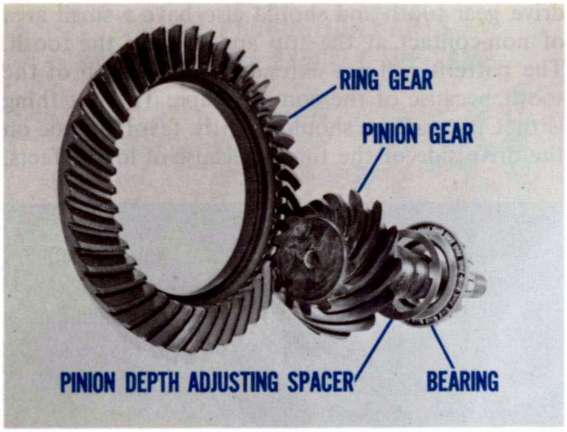

Fig. 10—Spacer positions gears for proper mesh

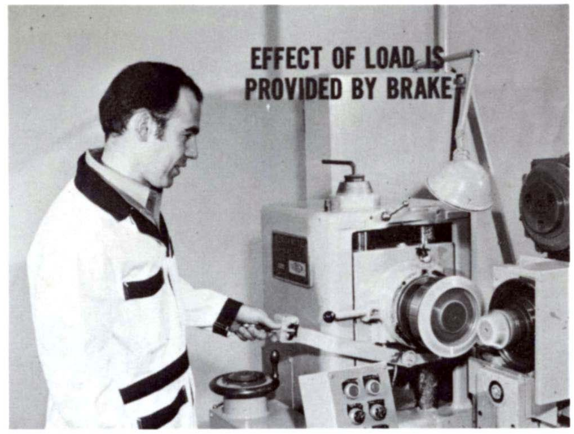

Fig. 12—Load simulates some driving conditions

IT'S CALLED A "GLEASON"

The gear tooth contact pattern of all gear sets is checked at the factory on a machine that is known as a "Gleason" gear-match tester. The gear sets are rotated in their normal operating position at r.p.m.'s equivalent to normal driving speeds. Road load can be simulated and gears can be checked under both "drive" and "coast" conditions. Once the gears are set in the chucks in the machine, they are coated evenly with either white, yellow, or red lead. In the accompanying photos, white lead was used to show the pattern with more contrast against the dark gray appearance of new gear teeth.

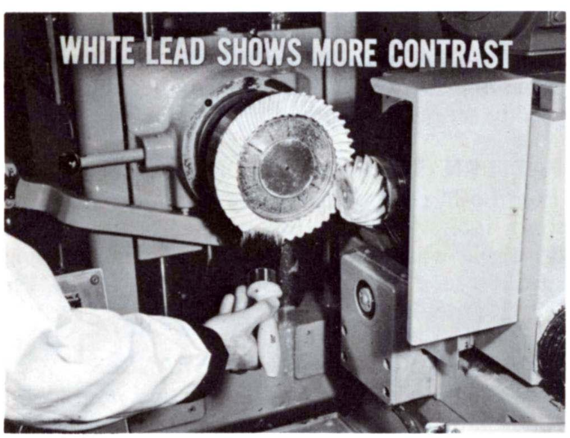

Fig. 11—Yellow or red lead can also be used

GOOD PATTERN REQUIRES LOAD

To insure a clear, distinct pattern, the gears are tested under loads equivalent to some, but not all, driving conditions. The effect of a load on the gears is achieved by use of a brake device on the machine. Without a load, the tooth contact pattern would be a little short and slightly blurred.

Another reason a load is desired is to properly position the tooth contact pattern on the face of the tooth. Any time gear teeth come into contact under load, the pattern will move because of normal gear deflection *caused* by the load.

Fig. 13—Load positions tooth contact pattern

The tooth contact pattern will move toward the heel on the drive side of the gear tooth when it is under load. So, if the pattern were toward the heel

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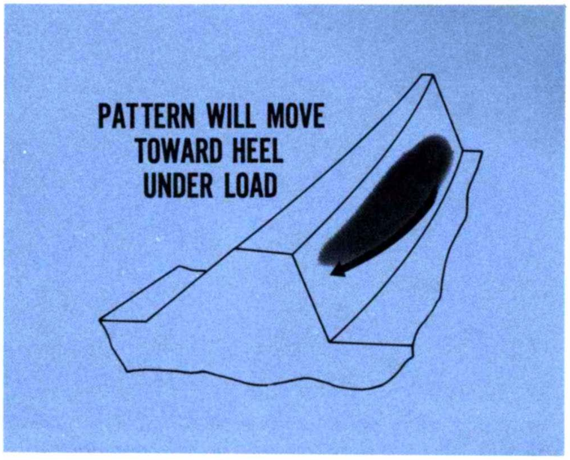

Fig. 14—Pattern too far on heel causes noisy gears

without a load, it would move farther toward the heel *under* load. That would more than likely result in a gear set that was objectionably noisy.

CHARACTERISTICS OF GOOD TOOTH CONTACT PATTERN

Now that you technicians know what the "Gleason" machine does, here are the characteristics of a good tooth contact pattern from a gear set that is meshing properly. You already know that the pattern should be roughly oval-shaped and approximately in the center of the tooth. The pattern should be at least one-half the length of the drive gear tooth and should also have a small area of non-contact at the top and root of the tooth. The pattern will not extend the full length of the tooth because of the convex shape. The last thing is that the pattern should slightly favor the toe on the drive side of the tooth because of load effects.

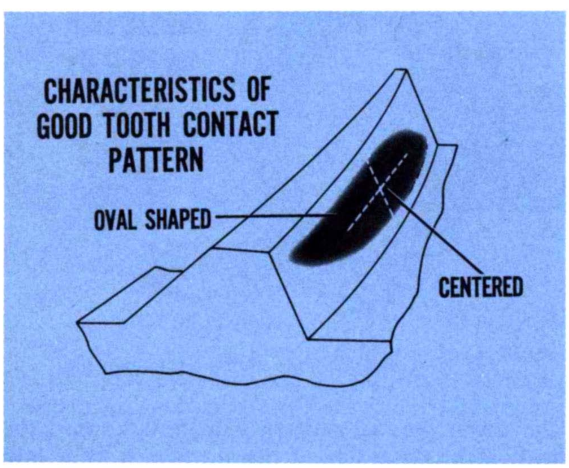

Fig. 15—Pattern from properly meshing gear set

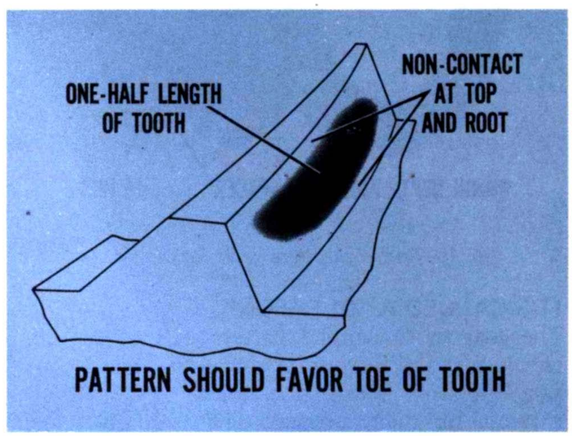

Fig. 16—Convex shape prevents full-length pattern

USE THE DRIVE SIDE

The drive side of the gear tooth should always be used as the main indicator of proper gear tooth contact patterns. Changing of loads under various driving conditions are more extensive on the drive side than on the coast side; and as a result, the drive side of the tooth is less tolerant of pattern errors than the coast side. Although the coast side will also show a distinctive pattern, it isn't as critical as the drive side and can cause trouble if it is used to set pinion depth.

PATTERN IS DEPENDENT ON SPACER

The tooth contact pattern is positioned on the tooth face by the depth of the pinion gear in the drive gear while meshing. A pinion depth adjusting spacer is used to properly position the pinion gear in the carrier in relation to the drive gear.

SPACER MAKES UP FOR TOLERANCES

Because of design tolerances, volume production parts that are machined and heat-treated are not all going to be exactly the same. The Gleason machine provides a means to determine the thickness of the pinion depth adjusting spacer to compensate for minor variations in dimensions.

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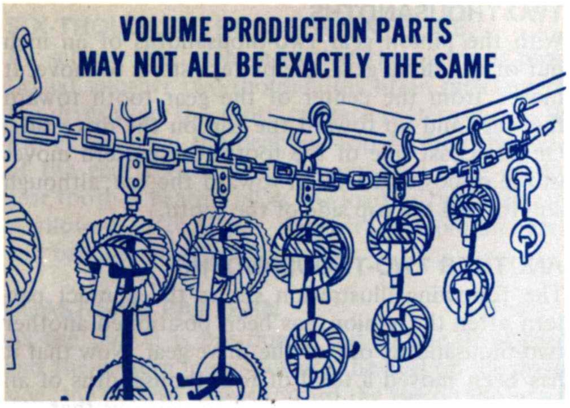

Fig. 17—Spacer compensates for minor variations

By positioning the pinion gear farther in or out of the drive gear, the machine operator can determine how many thousandths thicker or thinner the pinion depth spacer should be when the pinion and drive gears are assembled in the carrier.

Fig. 18—Machine operator determines spacer thickness

PINION DEPTH AND TOOTH CONTACT PATTERN

The following pictures demonstrate the testing procedure on the Gleason machine at the factory. They clearly demonstrate what happens to gear tooth contact pattern on both sides of the tooth when load is applied and also what happens if the thickness of the pinion depth spacer is not correct.

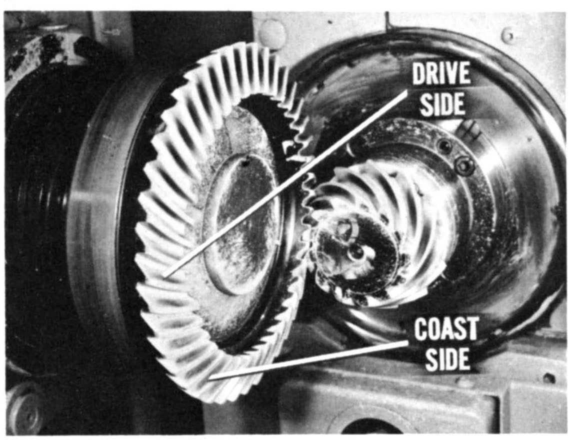

Fig. 19—Pattern fuzzy and small without load

PATTERN WITHOUT A LOAD

For this series of pictures, a gear set that was properly machined and could be assembled with a production pinion depth spacer was used. The first test was to run the gears without a load and see what the pattern looked like. A pattern was clearly visible on both the drive and coast sides of the gear tooth. But without a load, the tooth contact patterns will probably be slightly fuzzy and are apt to be rather small.

LOAD AFFECTS PATTERN

The next step in the test was to apply a load to the gear set by using the brake device on the machine. Under load, the rolling and sliding action is intensified and the contact pattern spreads and increases

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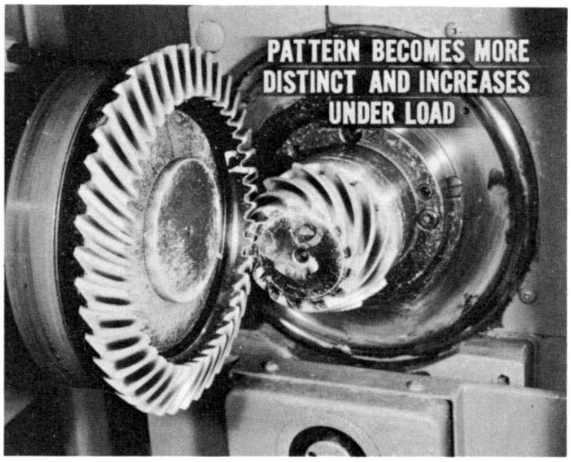

Fig. 20—Pattern also moves toward heel under load

in size. The pattern also becomes more distinct and moves slightly toward the heel because of normal gear tooth deflection caused by the load. The following picture shows a tooth contact pattern with proper pinion depth and a load applied.

TWO-THOUSANDTHS AT A TIME

Since pinion depth adjusting spacers are available in two-thousandths-inch increments, tooth contact patterns were developed by moving the gear positions two-thousandths at a time with a load applied. The first sequence of patterns were run by moving the pinion gear out of the drive gear – toward the heel of the gear teeth.

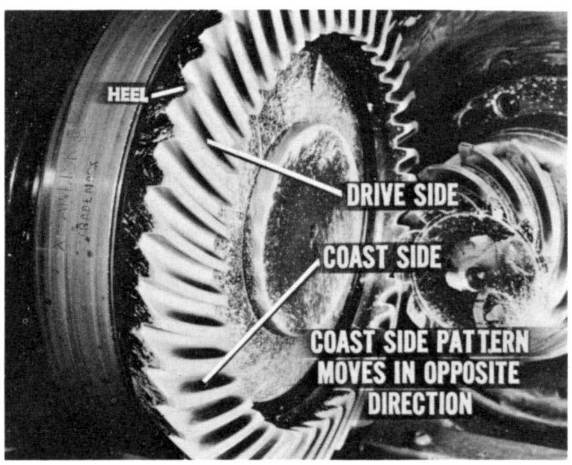

Fig. 21—Pattern moves toward top of heel

TWO-THOUSANDTHS

With the pinion gear two-thousandths of an inch out of the drive gear, the pattern starts to move. It moves from the center of the gear tooth toward the heel and up toward the top on the drive side. On the coast side of the tooth, the pattern moves in the opposite direction toward the toe; although still toward the top side of the tooth.

ANOTHER TWO-THOUSANDTHS

The following illustration shows the contact pattern after the pinion has been positioned another two-thousandths out of the drive gear. Now that it has been moved a total of four-thousandths of an inch out of the drive gear, you can see that the pattern has moved farther from the center on both the drive and the coast sides.

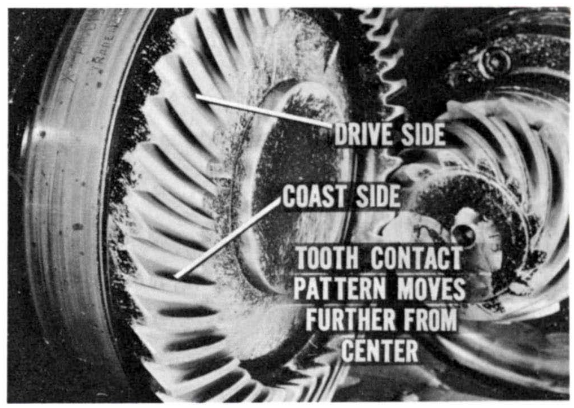

Fig. 22—Pattern moves farther on both sides of gear

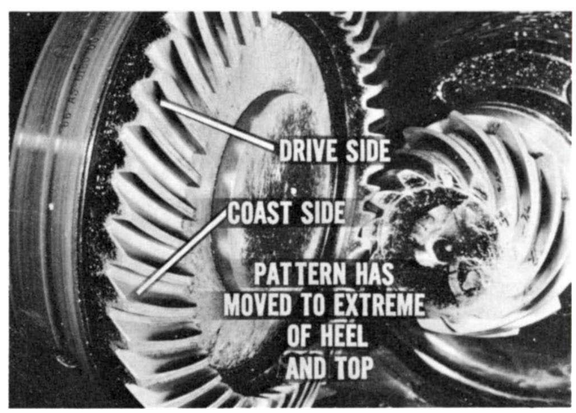

Fig. 23—At this point, noise becomes objectionable

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SIX-THOUSANDTHS IS THE EXTREME

By setting the machine so that the pinion is positioned another two-thousandths of an inch out of the drive gear, the tooth contact pattern moves to the extreme on the heel and top of the drive side of the gear tooth. At this point, the edge of the gear tooth is bearing all of the load. If this overload is allowed to continue, the drive and pinion gears will become objectionably noisy.

COAST SIDE PATTERN

As the pinion is positioned out of the drive gear and the pattern moves toward the heel on the drive side, the pattern moves toward the toe on the coast side of the tooth. However, the pattern on the coast side also moves toward the top of the tooth. Because of the cone shape of the pinion gear, the pattern moves up, toward the top, as the pinion moves out; and down, toward the root, as the pinion moves in.

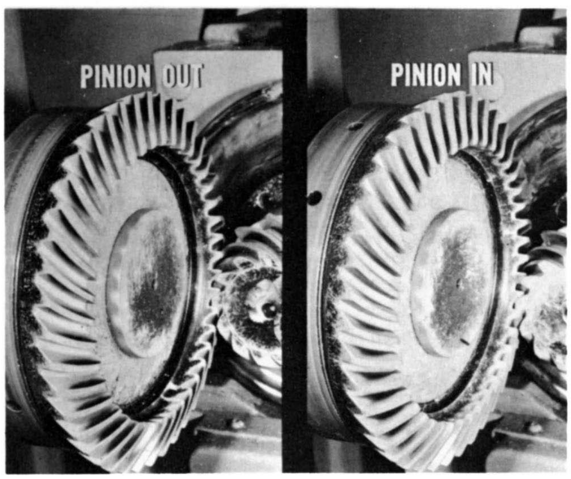

Fig. 24—OUT-pattern up; IN-pattern down

PATTERNS AS PINION MOVES IN

The following sequence of photos shows the pattern change as the pinion is positioned in toward the toe of the drive gear teeth. The first photo shows the contact pattern with the pinion moved in two-thousandths of an inch. The pattern has started to move toward the toe end and down into the root on the drive side of the gear. On the coast side it has also moved toward the root; but, has moved in the opposite direction toward the heel.

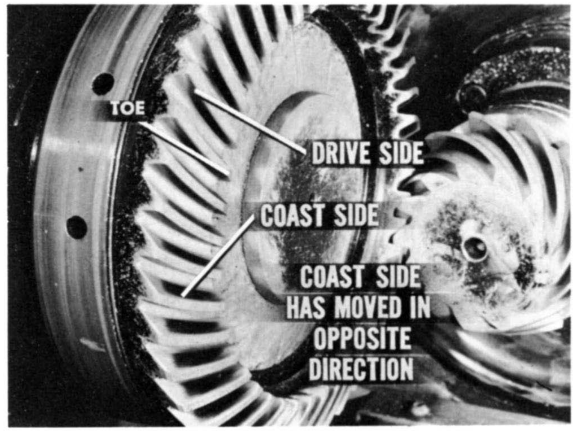

Fig. 25—Pinion two-thousandths "in"

PINION GEAR MOVED IN FOUR-THOUSANDTHS

With the pinion gear positioned another two-thousandths of an inch farther into the drive gear, the pattern moves farther toward the toe and deeper into the root on the drive side.

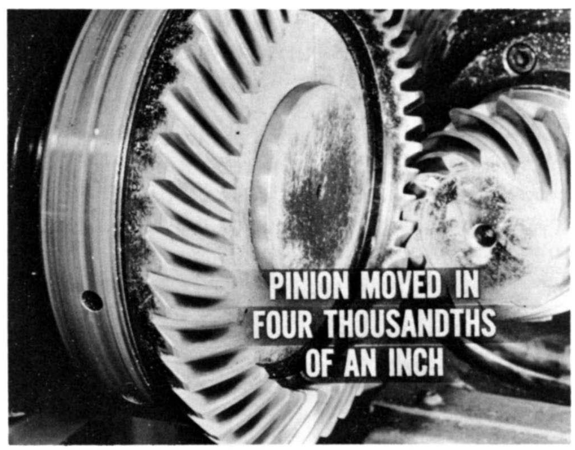

Fig. 26—Pattern continues to move

SIX-THOUSANDTHS IS LAST STEP

The next and last step in this sequence is to position the pinion gear another two-thousandths into the drive gear for a total of six-thousandths of an inch. The pattern at this point has moved to the extreme end of the tooth – in this case toe – on the drive side. The pattern at this point is also well down into the root of the tooth.

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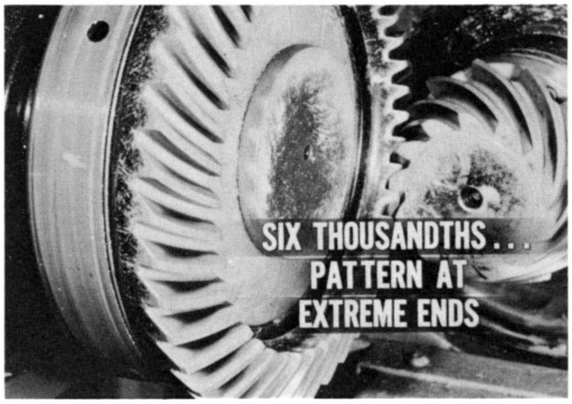

Fig. 27—Pattern heavy at toe and root

THE SEQUENCE IS REVERSED

The gears are sent to the Gleason to be tested for pinion alignment after they have been machined, heat treated and lapped. The previous sequence of tooth contact patterns were run to demonstrate how the pinion depth affects tooth contact patterns. Under actual production conditions, the reverse of the sequence would take place. The Gleason is set so that if a pinion that is machined right in the middle of the tolerance range is used, the tooth contact pattern will be good.

If the tooth contact pattern indicates that the pinion depth is not correct, he repositions the pinion head until a good tooth contact pattern is produced. Then he marks the drive and pinion gear set to indicate proper spacer thickness.

Fig. 28—Gleason operator marks gears

GEARS ARE MARKED PLUS OR MINUS

If the pinion has to be positioned in the Gleason farther toward the outside of the drive gear, the amount in thousandths is marked on the gear set preceded by a plus sign. If the pinion is repositioned toward the inside of the drive gear, the distance is indicated with a minus sign.

SOME GEARS ARE MARKED MINUS ZERO

All gear sets are marked for spacer thickness – even if the tooth contact pattern was correct on the first run. In this case the operator would mark the gear set -0 to indicate that the spacer thickness does not have to be increased or decreased at assembly to get proper pinion depth and consequently proper gear mesh.

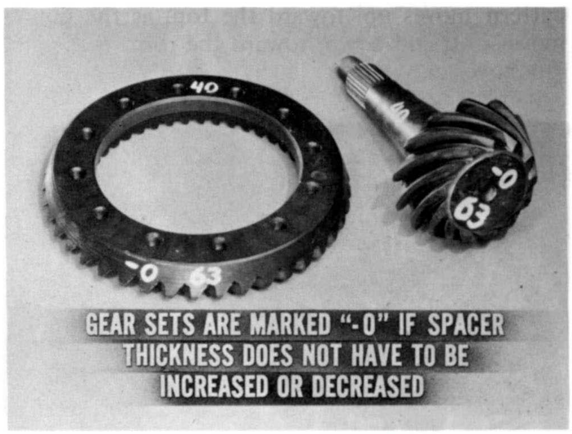

Fig. 29—Pinion depth not corrected on Gleason

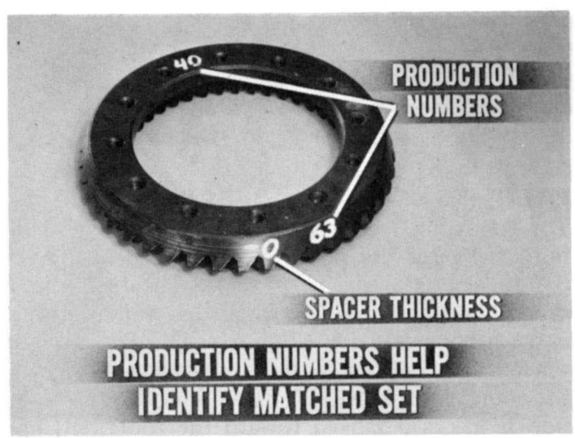

Fig. 30—All three must be the same

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ALL THREE NUMBERS ARE IMPORTANT

Along with the pinion depth spacer thickness are two other numbers that are marked on the gear sets. They have no bearing or relation to the spacer thickness; however they are important to a matched gear set. The other two numbers on the gears are production numbers that are used to help identify the gears as a matched set. Because of strict quality control operations, most gear sets will be marked -0 and the possibility of pinion and drive gears becoming mismatched is great. So, even if the drive and pinion gears are marked with the same spacer thickness, the other two numbers *must be the same* for them to be a matched set.

IT TAKES MORE THAN A "GLEASON"

Actually the Gleason is only one way of determining the proper spacer thickness. After the gears are tested on the Gleason, they move down the assembly line to be assembled in the carrier. The carrier dimension is the other factor that affects the thickness of the pinion depth spacer.

CARRIER DIMENSION WILL VARY

Much the same as the pinion gear, production tolerances will allow the carrier dimensions to vary slightly. Before assembly, the carrier is measured from the center of the cross bores to the bearing shoulder with the bearing cup installed. This dimension is the one that initially determines the thickness of the pinion depth spacer.

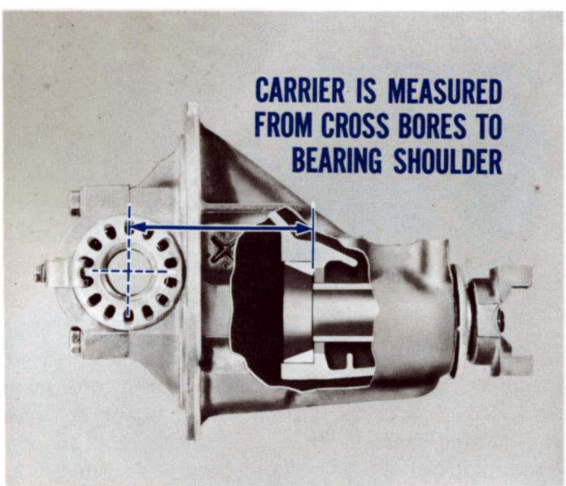

Fig. 31—Carrier dimensions will also vary slightly

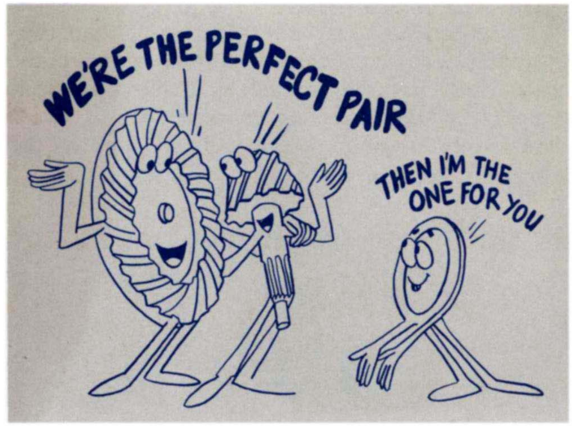

Fig. 32—Spacer size designed for axle is used

EVERYTHING A-OK

If you had an ideal situation where the carrier, pinion head, and bearing were machined right in the middle of the tolerance range, the pinion depth spacer used at assembly would be the size designed for that size axle assembly.

SPACER IS SELECTED

After the carrier is measured, a spacer thickness corresponding to the carrier dimension is selected. This spacer will give proper pinion depth when the axle is assembled *if* the drive and pinion that are to be installed are marked "minus zero", which means that further correction of the pinion depth spacer thickness is not necessary.

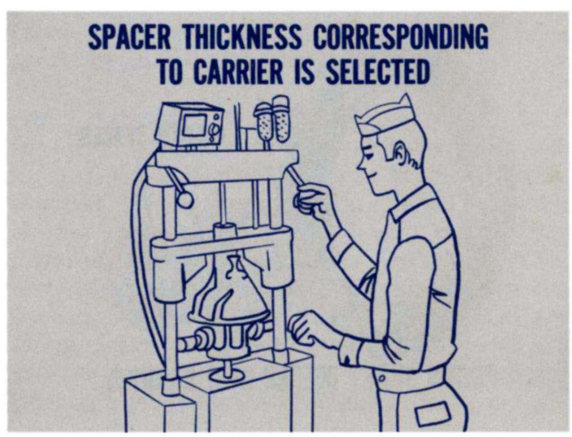

Fig. 33—Spacer is correct for -0 gear set

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PLUS TWO, MINUS TWO

If the gear set is marked "plus two", then two-thousandths of an inch is *subtracted* from the spacer thickness determined by the carrier measurement. If the gears are marked "minus two", then two-thousandths of an inch is *added* to the spacer thickness.

Fig. 34—Spacer size changes opposite of markings

PINION HEAD TOO LONG

A "plus two" marking on the drive and pinion gears means that when the gears were run on the Gleason machine, the pinion gear had to be positioned two-thousandths of an inch *out* of the drive gear for them to mesh properly and have a good tooth contact pattern. What this means is that the overall length of the pinion, including the shaft, is two-thousandths too long for the carrier bore.

PINION INTO CARRIER

By using a spacer that is two-thousandths thinner, the pinion head will go deeper into the carrier the correct distance to line up with the drive gear. This simulates the positioning of the pinion and drive gears on the Gleason gear machine. On a gear set marked "minus two", a thicker spacer is used to move the pinion head toward the drive gear.

IMPROPER PINION DEPTH CREATES NOISE

To restate a fact mentioned earlier in this book, any time you have gears meshing, a certain amount of sound is going to be produced by the gears coming into contact. This sound will increase as the error in pinion depth setting increases. If you recall, these sounds were part of the film. They were actual sounds recorded at the factory as the drive and pinion gears were run at various pinion depth settings.

YOU CAN FORGET THEM NOW

Don't try to use these sounds to diagnose a noisy axle in a car. The sounds that you heard in the film are not the same as those that would be heard inside a car. They were used to demonstrate that improper pinion depth setting will create noise that gets increasingly louder and harsher. If you want the lowdown on axle noise diagnosis, be sure to attend Part II of this session and read the Reference Book.

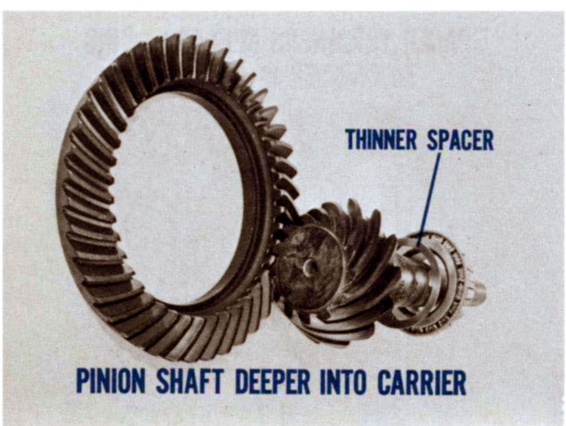

Fig. 35—Pinion lines up with drive gear

Fig. 36—Wrong backlash is another cause of noise

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BACKLASH SETTING

The Gleason gear match tester can also be used to change the position of the gears and simulate different backlash settings. However, it is not used to establish backlash, which of course, is an axle adjustment.

BACKLASH AFFECTS PATTERN AND SOUND

A wrong backlash setting is another common cause of rear axle noise and can be seen in the gear tooth contact pattern. "Backlash" setting is the distance the drive gear is set away from the pinion, which tells you how deep or shallow the teeth of both gears are meshing.

DRIVE GEAR TOO CLOSE

The drive gear can be positioned closer to the pinion gear by adjusting the Gleason machine, and one condition of improper backlash can be simulated. With the drive gear set closer, the pinion gear teeth mesh very deep in the drive gear. The tooth contact pattern that is produced will be very low on the tooth and will have a very sharp line at the root of the tooth.

Fig. 37—Pattern has sharp line at root of tooth

DRIVE GEAR TOO FAR

By positioning the drive gear away from the pinion gear, the opposite conditions will exist. With the drive gear too far from the pinion, the teeth are not fully meshed. The tooth contact pattern naturally moves toward the top of the tooth and produces a distinct line across its top edge.

Fig. 38—Sharp line in pattern at top edge

PATTERNS DIFFERENT IN ASSEMBLED AXLE

Keep in mind that the patterns created on the gears by the Gleason machine are *simulated* patterns. The backlash setting is checked at four points, or every ninety degrees around the circumference of the drive gear. Although the patterns in an assembled axle will have the same characteristics, they more than likely will not be as uniform as those created on the Gleason machine.

SO MUCH FOR PART I

It is hoped that Part I of this double session on rear axles has given you technicians a better understanding of matched gear sets. You should now realize how important pinion depth setting is and how much guesswork is eliminated for you at the factory by determining the thickness of the pinion depth adjusting spacer during production.

PART II IS MORE IMPORTANT TO YOU

Session 71-1, which is Part II, also covers the subjects of pinion depth setting and backlash setting. However, it is much more pertinent and applicable to you as technicians. Part II will explain how pinion and drive gear positions determined at the factory tie in with service procedures. One very important feature of Part II is the diagnosis of gear sounds under actual driving conditions. It also tells how tooth contact patterns can be checked and gears adjusted to eliminate these noises.

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