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AUTOMOTIVE DIESEL MAINTENANCE 2. UNIT VI, AUTOMATIC TRANSMISSIONS--PLANETARY GEARING.

HUMAN ENGINEERING INSTITUTE, CLEVELAND, OHIO

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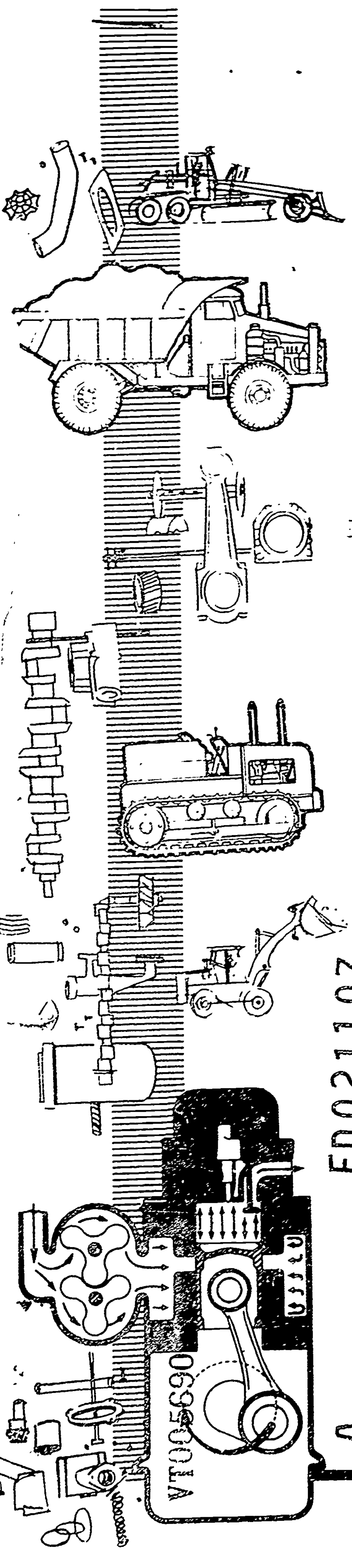
THIS MODULE OF A 25-MODULE COURSE IS DESIGNED TO ACQUAINT THE TRAINEE WITH THE OPERATION OF PLANETARY GEARS IN AUTOMATIC TRANSMISSIONS USED ON DIESEL POWERED VEHICLES. TOPICS ARE (1) PURPOSE OF PLANETARY GEARING, (2) POWER TRANSMISSION THROUGH A PLANETARY SYSTEM, (3) HYDRAMATIC TRANSMISSION, (4) HYDRAULIC SYSTEM, AND (5) GEAR FAILURE AND LUBRICATION. THE MODULE CONSISTS OF A SELF-INSTRUCTIONAL PROGRAMED TRAINING FILM "UNDERSTANDING PLANETARY GEARING IN RELATION TO AUTOMATIC TRANSMISSIONS" AND OTHER MATERIALS. SEE VT 005 685 FOR FURTHER INFORMATION. MODULES IN THIS SERIES ARE AVAILABLE AS VT 005 685 - VT 005 709. MODULES FOR "AUTOMOTIVE DIESEL MAINTENANCE 1" ARE AVAILABLE AS VT 005 655 - VT 005 684. THE 2-YEAR PROGRAM OUTLINE FOR "AUTOMOTIVE DIESEL MAINTENANCE 1 AND 2" IS AVAILABLE AS VT 006 006. THE TEXT MATERIAL, PROGRAMED TRAINING FILM, AND THE ELECTRONIC TUTOR MAY BE RENTED (FOR $1.75 PER WEEK) OR PURCHASED FROM THE HUMAN ENGINEERING INSTITUTE, HEADQUARTERS AND DEVELOPMENT CENTER, 2341 CARNEGIE AVENUE, CLEVELAND, OHIO 44115. (HC)

STUDY AND READING MATERIALS



AUTOMOTIVE DIESEL MAINTENANCE 2

AUTOMATIC TRANSMISSIONS -- PLANETARY GEARING, UNIT VI

SECTION A	PURPOSE OF PLANETARY GEARING
SECTION B	POWER TRANSMISSION THROUGH A PLANETARY SYSTEM
SECTION C	HYDRAMATIC TRANSMISSION
SECTION D	HYDRAULIC SYSTEM
SECTION E	GEAR FAILURE AND LUBRICATION

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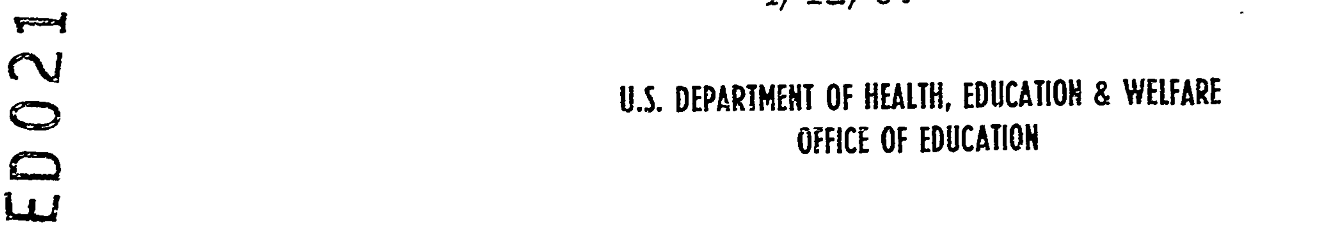


HUMAN ENGINEERING INSTITUTE

SECTION A -- PURPOSE OF PLANETARY GEARING

Some automatic transmissions use a system of planetary gears to enable the torque converter or fluid coupling to be used as efficiently as possible. To help you understand how automatic transmissions operate, planetary gears in a simple planetary system will be explained.

A simple planetary gear system consists of four members: a planetary sun gear, two or more planetary pinions, a planetary ring gear, and a planetary carrier on which the planetary gears are mounted (see Figure 1). The term planetary gears is used because the planetary pinions (planet gears) rotate around the sun gears in the same manner that the planets rotate around the sun in our solar system.

There are several ways that power can be transmitted through planetary gears. The engine may be connected to drive the sun gear, planet carrier, or the ring gear. Also, the propeller shaft (driven member) may be connected to one of the three members and the engine to another. One more condition must exist before power can be transmitted: the other member must be held stationary. Automatic transmissions provide the means for holding the other member through hydraulic servos or spring pressure.

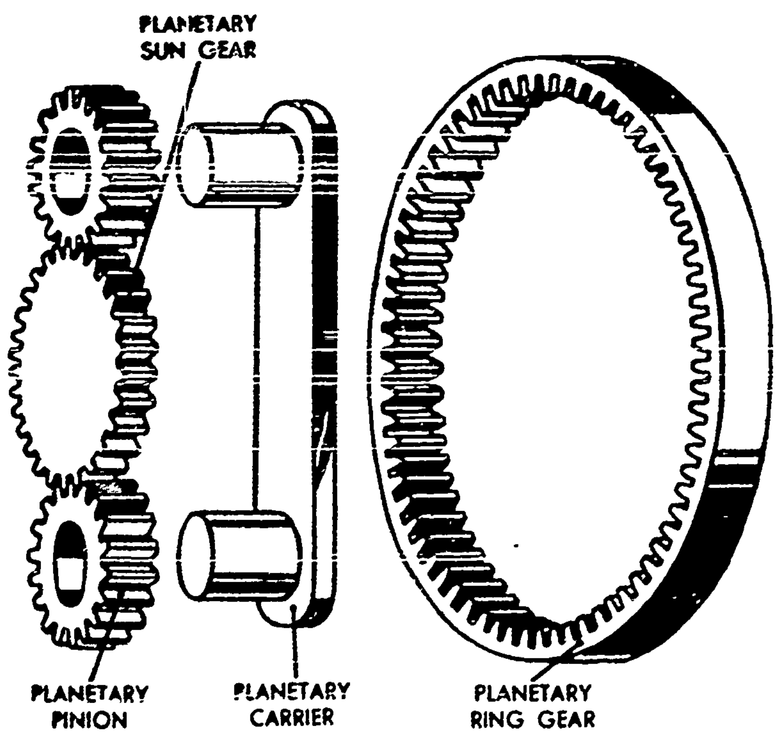


Fig. 1 Planetary gear members

SECTION B -- POWER TRANSMISSION THROUGH A PLANETARY SYSTEM

MAXIMUM REDUCTION -- Maximum reduction from a set of planetary gears is obtained as follows: the engine drives the sun gear; the propeller shaft is hooked to the planet carrier; and the ring gear is held stationary (see Figure 2).

As the sun gear rotates with the engine, the planet gears must rotate on their shafts. Since the ring gear is held stationary, the planet gears will walk around the ring gear, thus rotating the planet carrier and the propeller shaft.

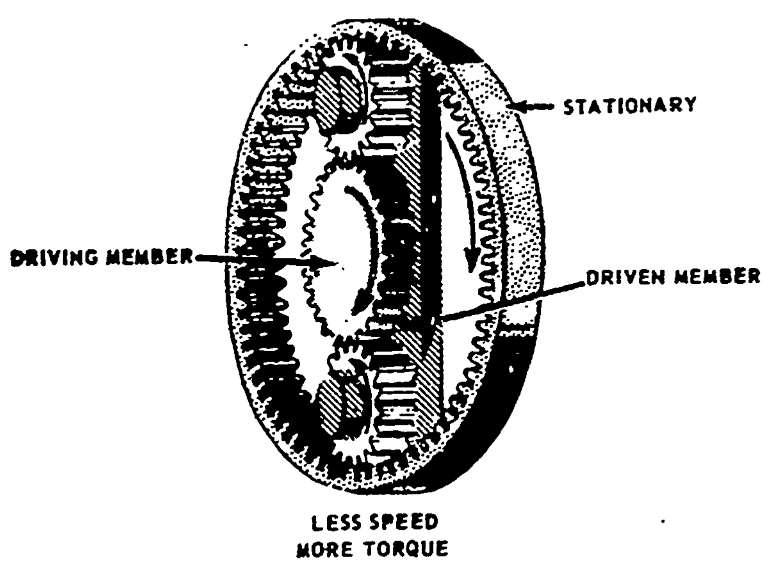
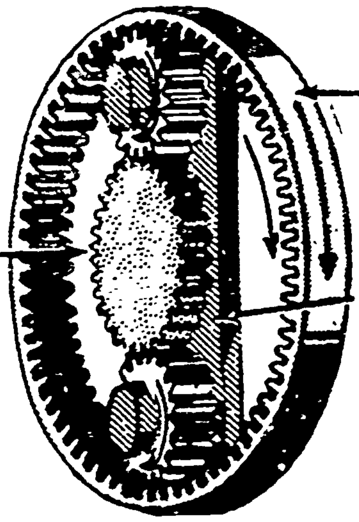


Fig. 2 Maximum reduction

When the above mentioned condition exists, a definite speed reduction ratio is obtained. To find this ratio, add the number of teeth in the sun gear to the number of teeth in the ring gear; then divide the number in the sun gear into the total. For instance, if the sun gear has 18 teeth and the ring gear 36, the total is 54. Divide 18 into 54, and the answer is three. This means the sun gear must rotate three times in order to rotate the planet carrier once.

MINIMUM REDUCTION -- Minimum reduction from a planetary gear train is obtained as follows: the engine drives the ring gear; the propeller shaft is connected to the planet carrier; and the sun gear is held stationary (see Figure 3). The rotation of the ring gear forces the planet gears to walk around the sun gear, causing the planet carrier to rotate in the same direction as the ring gear.



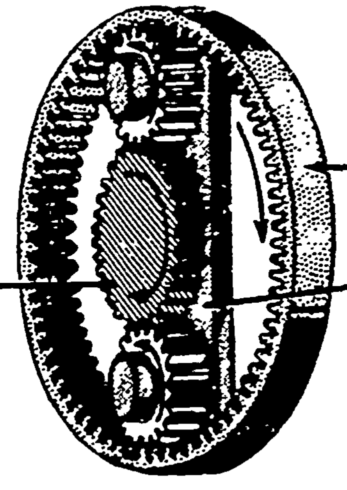


Fig. 3 Minimum reduction

Fig. 4 Maximum overdrive

The speed reduction that takes place can be figured by adding the number of teeth on the sun gear to the number on the ring gear and dividing the number of teeth in the ring gear into the total. For example, if the sun gear has 18 teeth and the ring gear has 36, this would make a total of 54. Divide 36 into 54 and the answer is one and one-half. This means the engine must rotate the ring gear one and one-half times in order to rotate the planet carrier once.

MAXIMUM OVERDRIVE -- Planetary gears may be used to obtain speed advantages, as well as to reduce speed. If the engine is connected to the planet carrier and the sun gear connected to the propeller shaft, a maximum overdrive is accomplished when the ring gear is held stationary (see Figure 4). Here you will notice the hookup of the driving and the driven members is opposite from the way they were when a maximum speed reduction was obtained. The actual speed increase can be found in the same way as the speed reduction was found under maximum speed reduction -- that is by adding the teeth in the sun gear and the ring gear and dividing the total by the number of teeth in the sun gear.

However, the change must be considered an increase in speed rather than a decrease.

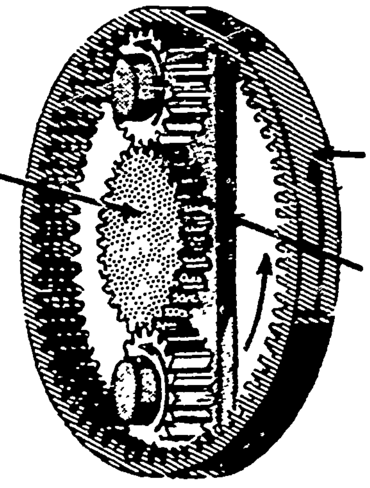


Fig. 5 Minimum overdrive

MINIMUM OVERDRIVE -- A minimum overdrive is the type usually found in automotive equipment that has an overdrive incorporated in the transmission. The hookup of the driving members is opposite to that for a minimum speed reduction (see Figure 5). Because the driving and driven members have changed places, the result will be an increase in speed instead of a decrease. The formula for finding the speed ratio is the same as that for the minimum speed reduction -- that is, by adding the number of teeth in the sun gear into the number of teeth in the ring gear, and dividing the total by the number of teeth in the ring gear.

REVERSE REDUCTION -- So far, we have considered only those setups where the driving and driven members are rotating in the same direction. In planetary gears, reverse direction can be accomplished in a speed reduction, overdrive (speed increase), and direct drive. Since direct drive reverse, and overdrive reverse, are of little practical value in off-highway vehicles, only the reverse reduction will be considered at this time.

When a reverse reduction is desired, the engine is made to drive the sun gear, and the planet carrier is held stationary (see Figure 6). The sun gear is driven in the same direction of rotation as the engine (clockwise), thus causing the planet gears to rotate counterclockwise. Since the planet carrier is held stationary, the planet gears rotate on their shafts and cause the ring gear to rotate in the opposite direction from the sun gear. The gear reduction, in this case, is a direct ratio of the number of teeth on the ring gear to the number of teeth on the sun gear. For example, if the ring gear has 36 teeth and the sun gear has 18, the speed reduction will be two-to-one. The planetary gears merely idle and do not influence the speed ratio.

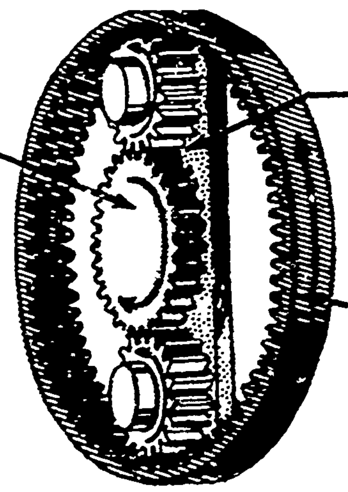


Fig. 6 Reverse reduction

DIRECT DRIVE -- If direct drive is desired, no member of the planetary gears is held to prevent rotation. A direct drive can be obtained regardless of which member is the driving member. As an example, consider the situation where the driving member is the sun gear and the driven member is the planet carrier as in Figure 2. Instead of locking the ring gear, leave it free to rotate and lock the ring to the sun gear. If this condition existed, the entire unit would rotate and, as a result, a one-to-one ratio from the engine to the propeller shaft would exist.

A summary of the possible planetary combinations discussed is shown in Figure 7. As mentioned earlier, disregard the reverse overdrive. The algebraic expressions for the speed of the propeller shaft, where there is a speed reduction or increase,is listed and shown in Figure 8.

In the discussion that follows on automatic transmissions you will be able to see how planetary gears are used singularly or in compound groups to achieve the torque and speed ratios that are desirable to efficiently operate an engine operated torque converter.

CASE	STATIONARY MEMBER	DRIVING MEMBER	DRIVEN MEMBER	RESULT
ONE	RING	SUN	CARRIER	MAXIMUM REDUCTION
TWO	SUN	RING	CARRIER	MINIMUM REDUCTION
THREE	CARRIER	SUN	RING	REVERSE REDUCTION
FOUR	SUN	CARRIER	RING	MINIMUM OVERDRIVE
FIVE	RING	CARRIER	SUN	MAXIMUM OVERDRIVE
SIX	CARRIER	RING	SUN	REVERSE OVERDRIVE
SEVEN	NONE (TWO HELD TOGETHER)	ANY	ANY	DIRECT DRIVE
EIGHT	NONE	ANY	NONE	NEUTRAL

Fig. 7 Summary of possible combinations for planetary gears

PLANETARY GEAR SPEEDS

S = Number of Teeth in Sun Gear = 18

R = Number of Teeth in Ring Gear = 36

C = Planet Carrier

CASE	STATIONARY MEMBER	DRIVING MEMBER	DRIVEN MEMBER	SPEED RATIO ENGINE: PROPELLER		RELATIVE SPEED OF THE DRIVEN MEMBER	
ONE	R	S	C	R + S:S	36 + 18:18 54:18 3:1	S/R + S	1/3
TWO	S	R	C	S + R:R	18 + 36:36 54:36 1 1/2:1	R/S + R	2/3
THREE	C	S	R	R:S	36:18 2:1	S/R	1/2
FOUR	S	C	R	R:R + S	36:36 + 18 36:54 1:1 1/2	R + S/R	3/2
FIVE	R	C	S	S:S + R	18:18 + 36 18:54 1:3	S + R/S	3/1
SIX	C	R	S	S:R	18:36 1:2	R/S	2/1
SEVEN	NONE	ANY	ANY	1:1		1/1	
EIGHT	NONE	ANY	NONE	---		0	

Fig. 8 Algebraic expressions for determining the relative speeds of the planetary gear members

SECTION C -- HYDRAMATIC TRANSMISSION

The hydramatic transmission can be found in both passenger cars and trucks. Its function is to provide suitable gear ratios between the engine and the driving wheels to meet all driving needs (see Figure 9).

From the explanation of planetary gears you can see that a single planetary gear assembly is actually a two-speed transmission. All that is needed to make it operate is a way to hold any one of the members to provide a reduction in speed, or a way to hold any two members for direct drive.

To provide reduction in the front planetary of the hydramatic transmission, a band is wrapped around a drum which is an integral part of the sun gear. When the band is actuated, it stops the sun gear. In this case, the internal gear continues to turn, and the pinion walks around the sun gear, rotating the planet carrier at a speed less than that of the internal gear.

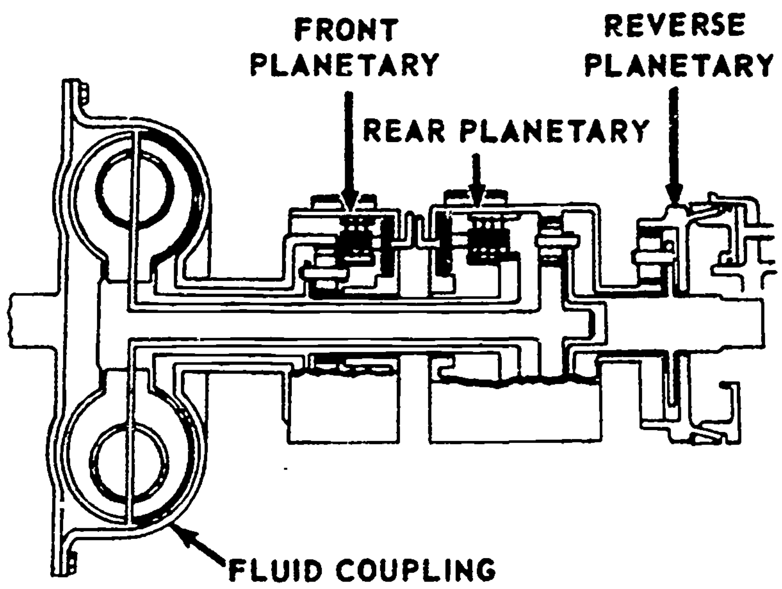


Fig. 9 Drive components of hydramatic transmission

To provide reduction in the rear planetary, a band is wrapped around a drum which is part of the internal gear. When the band is applied, it stops the internal gear. In this case, the sun gear continues to turn and drives the planet carrier and its pinions at a reduced speed.

To provide direct drive, multiple disk clutches or drum bands are used. In the front planetary unit, the clutch disks are alternately attached to the sun gear and the planet carrier. In the rear unit, the disks are alternately attached to the internal gear and to a hub which is splined to a shaft that extends from the front planet carrier. With no pressure applied to a clutch, the two members to which the disks are attached are free to rotate independently. You can see from the foregoing that transmission control depends upon devising a way to apply the clutch disks or the drum bands.

The bands are applied and released hydraulically, by hydraulic servos. The front servo consists of a stem with two pistons installed in a cylinder (servo), which has a wall between the two pistons (see Figure 10). A release spring, installed between the servo body wall and one of the pistons, holds the servo in the released position when no oil pressure is applied.

As mentioned earlier, the clutch disks are attached alternately to the sun gear and the planet carrier, according to the speed range required. The clutch disks are actuated by pistons located within the clutch drum (see Figure 11). When no pressure is applied to the actuating piston, the clutch is released by springs. When hydraulic pressure is applied, the piston is forced against the clutch disks, which slide together, causing the sun gear and planet carrier to lock together.

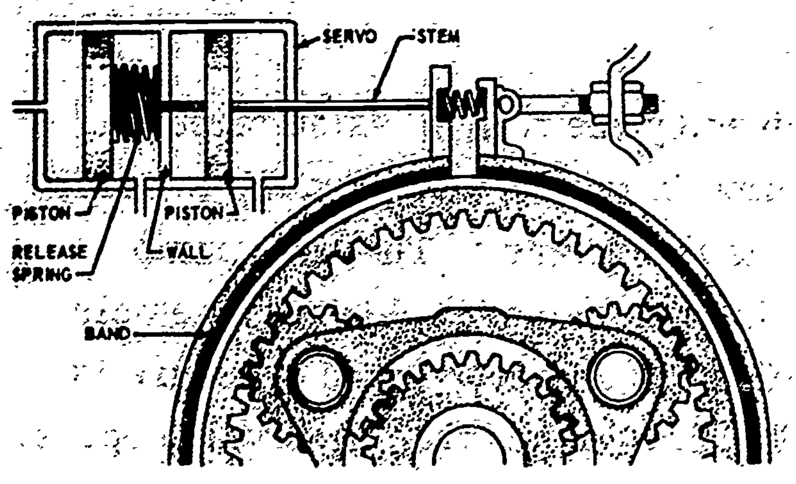


Fig. 10 Band operation in hydramatic transmission

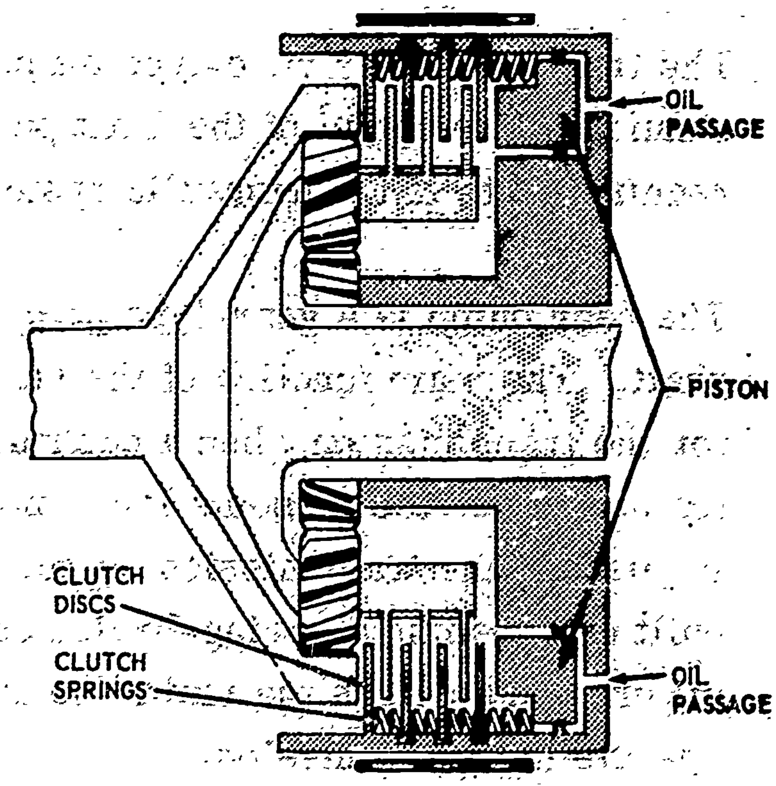


Fig. 11 Clutch disc operation in a hydramatic

The rear servo and planet operate on the same general principle as the front unit. The rear servo, however, is designed somewhat differently, in that it is applied by spring pressure and released by hydraulic pressure.

Precisely timed and coordinated action between the bands and clutches in the two planetaries must take place. With different bands and clutches being applied and released with each shift, the need for exact timing is important. This need is so important that nearly every hydramatic adjustment is directed toward proper band operation. If the bands do not operate properly, rough shifting, slippage and serious damage may result.

SECTION D -- HYDRAULIC SYSTEM

The hydraulic system of the hydramatic transmission provides the automatic shifting control. The system consists of a front and rear oil pump, hydraulic pressure regulator, operating control valve assembly, hydraulic governor, front and rear servos, and the necessary lines and passages for transferring the oil pressure to the required places.

The front pump is a vane-type oil pump that turns when the engine is running. The output of the front pump is regulated in accordance with the requirements of the hydraulic system.

The rear pump is a gear-type pump driven by the transmission output shaft. The main function of the rear pump is to provide hydraulic pressure for the transmission when a push start is necessary. (The rear pump feature is deleted on some later model transmissions.) When the vehicle is pushed, the transmission output shaft turns and rear pump pressure is built up, opening a spring-loaded check valve. When the check valve opens, oil pressure enters the main line and is directed to the servo units to operate the transmission.

The hydraulic control system has two functions. It directs oil to the clutches in the transmission, and it provides a supply of oil to lubricate the gears and bearings of the transmission. In most hydraulically controlled transmissions, two clutches must be applied at one time in order to transmit power through the transmission; otherwise the transmission is in the neutral position.

NEUTRAL -- With the selector level in the neutral position, oil pressure is shut off from all the hydraulically operated pistons, and all multiple plate clutches are disengaged. As no planetary members are held stationary or locked together, all gears are free to rotate; therefore, no drive is transmitted through the planet carrier.

The gears in most automatic transmissions are in mesh at all times but do not transmit power until one of the multiple disc clutches is actuated by the selector valve. In studying the power flow of the various ranges, as mentioned before, it should be remembered that the power flow to the planetary system always enters through the INPUT SUN GEAR; and the power always leaves the planetary system through the OUTPUT PLANETARY CARRIER.

SECTION E -- GEAR FAILURE AND LUBRICATION

When two loaded surfaces slide over each other, as is the case with meshing gear teeth, there always is frictional resistance opposing the motion. Wear and loss of power result unless friction is minimized by a film of lubricating oil between the two sliding surfaces. Such a film substitutes the low fluid friction of the oil for the high metallic friction of dry surfaces. A film of the oil-wedge type may be of sufficient thickness to completely separate rubbing metallic surfaces with a measurable and comparatively thick layer of fluid oil, (hydrodynamic film). With such a film, friction is entirely due to the fluid friction within the oil, which in turn depends on oil body (viscosity).

Gears and their bearings usually are designed to function satisfactorily during the entire life of the machine of which they are a part, and their failure to do this indicates some unusual condition of operation. However, regardless of gear design, size of construction, correct lubrication is essential to assure minimum wear, quiet operation and long service life. During manufacture, tooth shapes are very accurately developed. Nevertheless, no matter how accurately and smoothly the teeth are finished, there always will be microscopic surface irregularities which cause frictional resistance if they are allowed to meet.

With the gears in proper mechanical condition and with correct lubrication, friction is reduced, wear is practically eliminated and gears should operate efficiently for years. However, even with correct lubrication properly applied, certain mechanical or operating conditions can cause wear and destruction of teeth. Destruction seldom takes the form of tooth breakage, but usually shows up as damage to the rubbing surfaces.

Such surface failures may rapidly destroy the original tooth contour, and once this occurs, smooth, quiet operation can no longer be expected. Surface failure may be directly attributed to improper lubrication; but more often lubrication is in no way responsible. In fact, even though the correct lubricant for normal service is in use, tooth surface may still be ruined by overloading, overheating, shock, abrasives, chips, improper alignment, loose bearings or deflection of shafts or housings. These conditions lead to various types of surface failures.

Many terms are employed to describe graphically the appearance of damaged tooth surfaces. Terms such as pitting, abrasion, scratching, spalling, galling, scoring, scuffing, wiping, cutting, gouging, seizing, burning, burnishing, peening, rolling, ridging, rippling, fish-scaling, and flaking, do not readily lend themselves to classification according to the fundamental causes of tooth damage. However, the first five listed above are the major types of failures, under which all of the other failures can be grouped as sub-divisions. Furthermore, it can be shown that these five types of failures have different basic causes. Of course, from the lubrication point of view, the cause of the failure is of major interest, rather than the appearance of the surfaces. For the purpose of this unit, gear-tooth failures are classified under the heading of "pitting","abrasion", "scratching", "spalling" and "galling".

PITTING -- The tooth surfaces of new gears, although smooth to the eye, are actually comparatively rough.

In addition to roughness, there may be variations in the hardness of the surface of the metal. Under conditions of boundary lubrication, both roughness and variations in hardness cause uneven distribution of load across the tooth surfaces. As teeth pass through mesh, the load is concentrated on local high spots or hard spots. The heavy localized stresses are repeated at each turn of the gear, and metal fatigue eventually occurs. As a result, minute particles break away and leave small pits where high points or hard spots had been (see Figure 12).

The type of pitting described ordinarily occurs where there is a low ratio of slide or roll. Therefore, in spur or helical gears, the action occurs at or near the pitch line, where sliding is at a minimum. On other areas of tooth surface the sliding action wears away the high spots before pitting can occur. With worm and most hypoid gears, side slide predominates in all contact areas, and true pitting of the gear teeth does not occur.

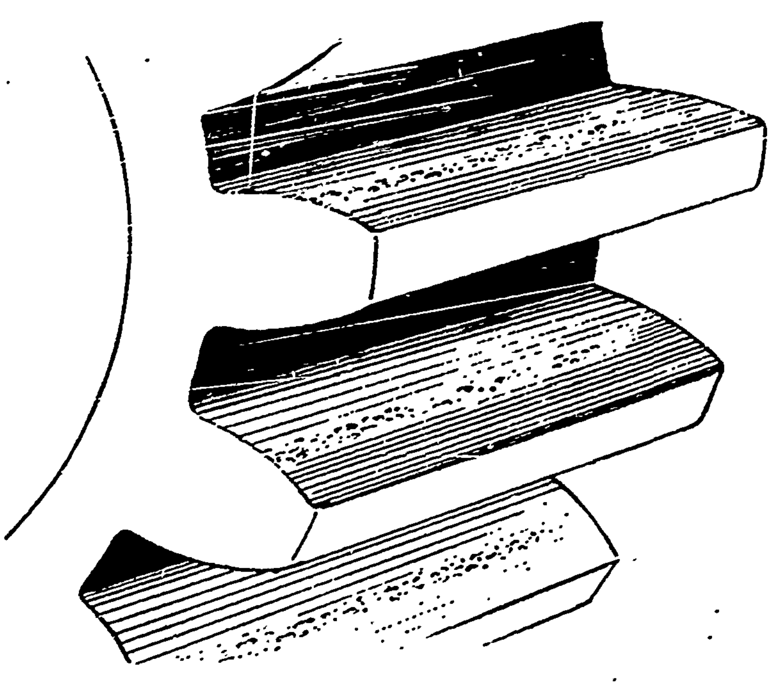


Fig. 12 Incipient pitting

Although pitting is not a lubrication failure, there is some experimental evidence that oil plays a part in the following manner: As a result of fatigue, microscopic surface cracks start. These become filled with oil, and under the contact loads existing between the teeth, hydraulic pressure is developed. The pressure tends to extend the cracks and eventually to push out small particles of metal. This hydraulic action would occur with any fluid.

With spur and bevel gears, as each tooth passes through the center mesh, the entire load is momentarily concentrated on the pitch line. If the area along the pitch line has already started to pit, the load is further concentrated on the remaining undamaged metal, and pitting is likely to increase progressively, until the tooth surfaces are destroyed or severely damaged.

On the other hand, with helical, herringbone and spiral bevel gears, there is less likelihood of destructive pitting. This is because each tooth during mesh makes contact along a slanted line extending from root to tip. This line cuts across the pitch line, and although pitting may have roughened the area along the pitch line, the line contact always extends beyond this roughened surface, and thus the load is carried on undamaged root and tip areas. Under such circumstances, pitting may cease as soon as the few isolated high spots along the pitch line have been removed.

When pitting becomes progressively worse (see Figure 13) a reduction of load on the gears will decrease the localized stresses and may prevent further damage to the tooth surface. Lubricants should not be ex-

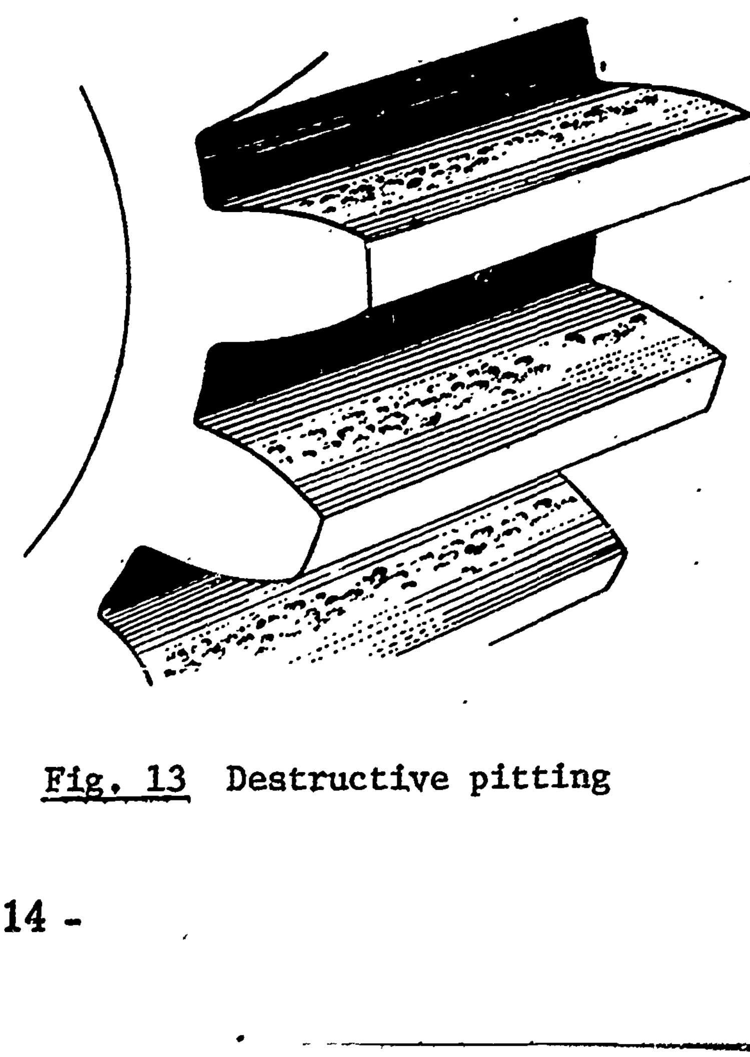


Fig. 13 Destructive pitting

pected to eliminate pitting although, in some instances, a borderline case of pitting may be improved by using a heavier bodied oil.

NORMAL WEAR -- When gears are of proper design, construction and hardness, when they do not operate at excessive loads and when correct lubricants are used, then a condition of normal wear should result. Normal wear over a long period and under conditions of proper lubrication, gradually smooths rubbing surfaces of the teeth and work-hardens them to a polish. As the surfaces become smoother and more work-hardened, friction and wear decrease, until a condition may be reached where further wear practically ceases.

DIDACTOR PLATES FOR AM 2-6D

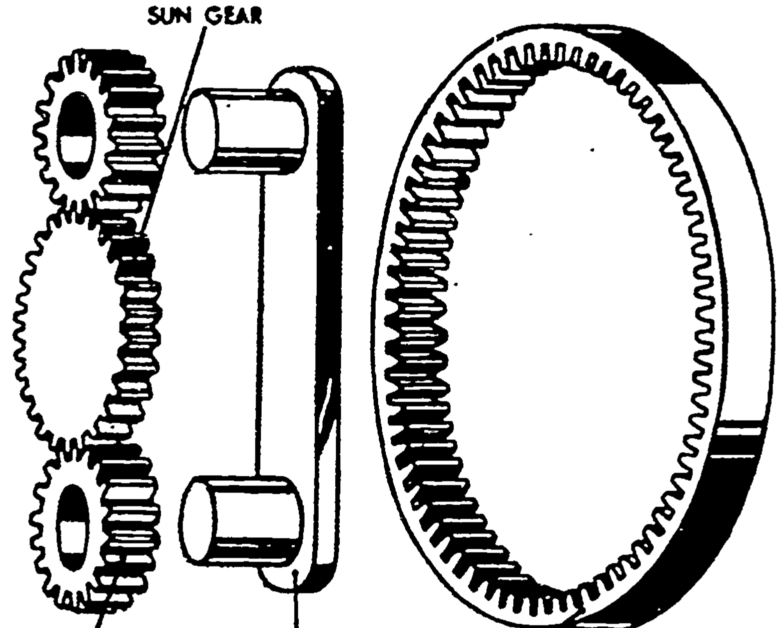


Plate I Planetary gear members

CASE	STATIONARY MEMBER	DRIVING MEMBER	DRIVEN MEMBER	RESULT
ONE	RING	SUN	CARRIER	MAXIMUM REDUCTION
TWO	SUN	RING	CARRIER	MINIMUM REDUCTION
THREE	CARRIER	SUN	RING	REVERSE REDUCTION
FOUR	SUN	CARRIER	RING	MINIMUM OVERDRIVE
FIVE	RING	CARRIER	SUN	MAXIMUM OVERDRIVE
SIX	CARRIER	RING	SUN	REVERSE OVERDRIVE
SEVEN	NONE (TWO HELD TO-GETHER)	ANY	ANY	DIRECT DRIVE
EIGHT	NONE	ANY	NONE	NEUTRAL

Plate II Summary of possible combinations for planetary gears

PLANETARY GEAR SPEEDS

S = Number of teeth in sun gear = 18 (text example)
R = Number of teeth in ring gear = 36 (text example)
C = Planet carrier

CASE	STATIONARY MEMBER	DRIVING MEMBER	DRIVEN MEMBER	SPEED RATIO ENGINE:PROPELLER		RELATIVE SPEED OF THE DRIVEN MEMBER	
ONE	R	S	C	R+S:S	text example 36 + 18:18 54:18 3:1	S/R + S	text ex. 1/3
TWO	S	R	C	S+R:R	18 + 36:36 54:36 1 .1/2:1	R/S + R	2/3
THREE	C	S	R	R:S	36:18 2:1	S/R	1/2
FOUR	S	C	R	R:R + S	36:36 + 18 36:54 1:1 1/2	R + S/R	3/2
FIVE	R	C	S	S:S + R	18:18 + 36 18:54 1:3	S + R/S	3/1
SIX	C	R	S	S:R	18:36 1:2	R/S	2/1
SEVEN	NONE	ANY	ANY	1:1		1/1	
EIGHT	NONE	ANY	NONE	---		0	

Plate III Algebraic expressions for determining the relative speeds of the planetary gear members

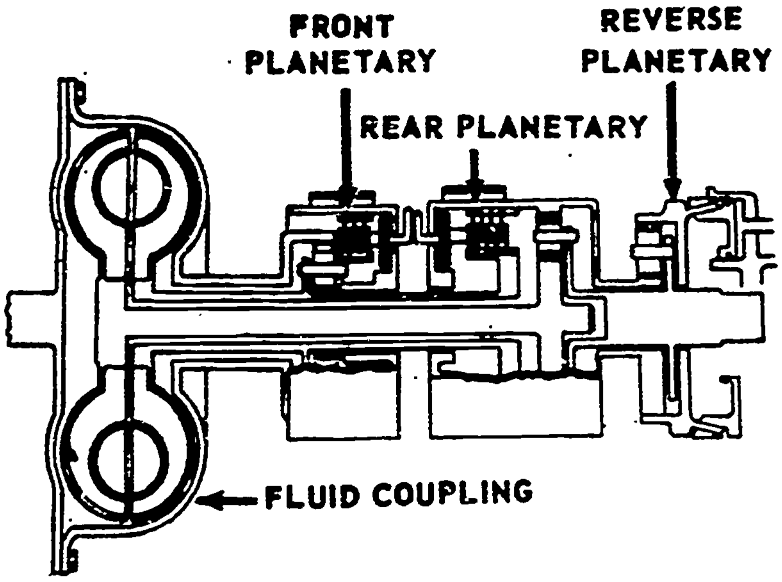


Plate IV Drive components

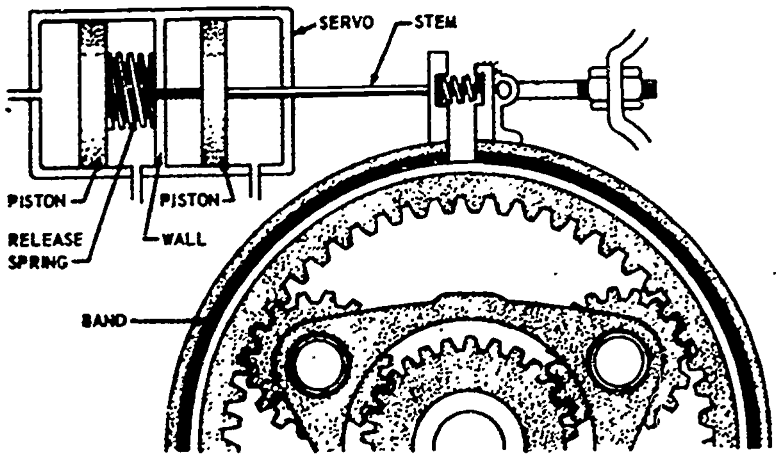


Plate V Band operation

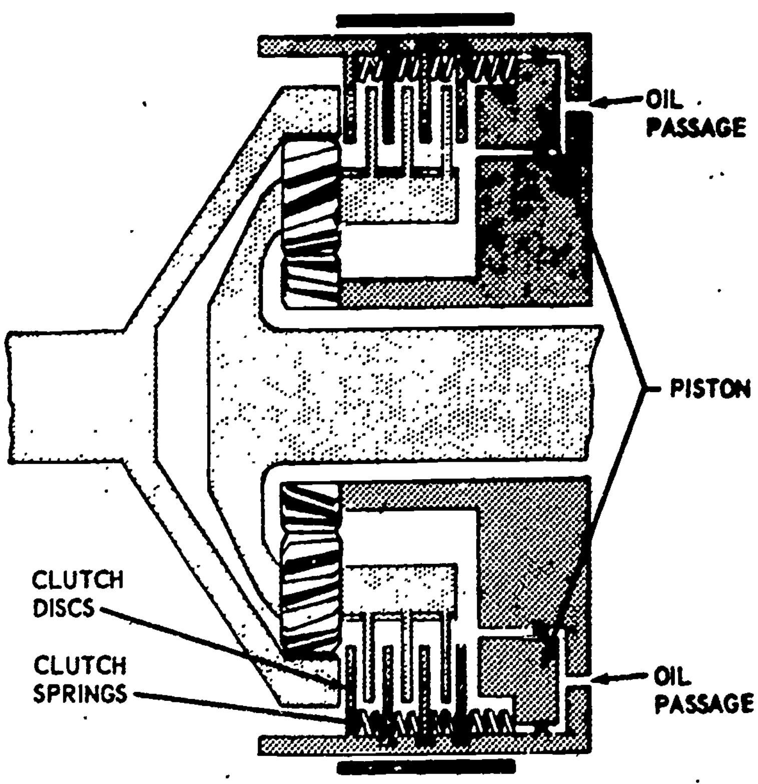


Plate VI Clutch disc operation

1

AM 2-6D
8/18/67

UNDERSTANDING PLANETARY GEARING IN RELATION TO AUTOMATIC TRANSMISSIONS

Human Engineering Institute

Minn. State Dept. of Ed. Vocational Education

Press A 2 Check to see that timer is OFF.

2

Some automatic transmissions use a system of planetary gears to enable the torque converter or fluid coupling to operate as efficiently as possible. If you want to understand how automatic transmissions operate, you must first know some basic facts about planetary gears.

Press A 3

1-2

3

A simple planetary gear system consists of four members: a planetary sun gear, two or more planetary pinions, a planetary ring gear, and a planetary carrier on which the planetary gears are mounted.

The term planetary gears is used because the planetary pinions (planet gears) rotate around the sun gear in the same manner that the planets rotate around ________.

A. the sun 5
B. the moon 4
C. the solar system 4

1-3

4

You are incorrect.

The planets in our solar system rotate around the sun as do the planetary gears around the sun gear in automatic transmissions. (See Plate I)

Press A 5

1-4

5

Correct.
There are several ways that power can be transmitted through planetary gears. Power from the engine may be driving through the sun gear, planet carrier or the ________.

A. planetary pinion 6
B. ring gear 7
C. propeller shaft 6

1-5

6

You are incorrect.

The engine would not be connected directly to the propeller shaft; if so the transmission would be completely bypassed. The engine may be connected to the ring gear or the sun gear, or to the planet carrier.

Press A 7

1-6

7

Correct.
The propeller shaft (driven member) may be connected to one of the three members and the engine to another. One more condition must exist before power can be transmitted -- ________.

A. another member must be held stationary 9
B. two other members must be held stationary 8
C. the other members must be free to rotate 8

1-7

8

You are incorrect.

If two other members were held stationary, there would be no power transmitted; and if all the members were free to rotate there would be no power transmitted, either.

All members free to rotate is the NEUTRAL position.

Try this one again. Press A 7

1-8

9

Correct.
Automatic transmissions provide the means for holding the other member, through hydraulic servos or through spring pressure.

Press A 10

1-9

10

MAXIMUM reduction from a set of planetary gears is obtained as follows: The engine drives the sun gear; the propeller shaft is connected to the planet carrier; and the ring gear is ______________.

A. left free to rotate 11

B. rotated in the opposite direction 11

C. held stationary 12

1-10

11

You are incorrect.

There are no provisions for rotating the other member in the opposite direction; and if left free to rotate, no power would be transmitted to the output shaft. The correct answer is "the ring gear is held stationary".

Press A 12

1-11

12

Correct
As the sun gear rotates with the engine, the planet gears must rotate on their shafts. Since the ring gear is held stationary, the planet gears will walk around the ring gear, thus rotating the ______________.

A. propeller shaft and axle 13
B. planet carrier and propeller shaft 14
C. ring gear and propeller shaft 13

1-12

13

You are incorrect.

When the ring gear is held stationary, the planet gears will walk around the ring gear, thus rotating the planet carrier and propeller shaft.

Press A 14

1-13

14

Correct.
When the above condition exists, a definite speed reduction ratio is obtained; to find this ratio, add the number of teeth in the sun gear to the number of teeth in the ring gear; then divide the number of teeth in the sun gear into the total. For instance, if the sun gear has 18 teeth and the ring gear has 36, the total is 54. This means the sun gear must rotate _____ times in order to rotate the planet carrier once.

A. 4 15
B. 6 15
C. 3 16

1-14

15

You are incorrect.

If the sun gear has 18 teeth and the ring gear 36, the total is 54. Divide 18 into 54 and the answer is 3. This means the sun gear must rotate three times in order to rotate the planet carrier once.

Press A 16

1-15

16

Correct.

MINIMUM reduction from a planetary gear train is obtained as follows: the engine drives the ring gear; the propeller shaft is connected to the planet carrier; and the sun gear is held stationary. The speed reduction that takes place can be figured by adding the number of teeth on the sun gear to the number of teeth on the ring gear and dividing the number of teeth in the ring gear into ______________.

A. one-half the total 17

B. the total 18

C. twice the total 17

1-16

17

You are incorrect.

For minimum reduction, divide the number of teeth in the ring gear into the total number of teeth in the sun gear and the ring gear.

Press A 18

1-17

18

Correct.
To find minimum reduction, divide the number of teeth in the ring gear into the total number of teeth in the sun gear and the ring gear.

Press A 20

X(c)-19

2-18

19

Correct.
For a minimum reduction calculation, divide the number of teeth in the ring gear into the total number of teeth in the sun gear and the ring gear.

You have answered one or more of the questions incorrectly. Let's review this portion. Read carefully and take your time in answering the questions.

Press A 3

1-19

20

MAXIMUM OVERDRIVE -- Planetary gears may be used to obtain speed advantages as well as to reduce speed. If the engine is connected to the planet carrier and the sun gear is connected to the propeller shaft, a maximum overdrive is accomplished when the ________________.

A. ring gear is left free to turn 21
B. ring gear is held stationary 22
C. ring gear is locked to the planet carrier 21

2-20

21

No. You are incorrect. The ring gear must be held stationary for any power to be transmitted through the planetary gear train.

Press A 22

2-21

22

Correct.

The actual speed increase can be found in the same way as the speed reduction was found under maximum speed reduction -- that is by adding the teeth in the sun gear and the ring gear and dividing the total by the number of teeth in the sun gear. However, the change must be considered ________________.

A. a decrease in speed rather than an increase 23
B. neither an increase or a decrease in speed 23
C. an increase in speed rather than a decrease 24

2-22

23

No. You are incorrect. In figuring overdrive the change must be considered as an increase in speed rather than a decrease. Read the questions carefully; take your time in selecting an answer.

Try this one again. Press A 22

2-23

24

Correct.

MINIMUM OVERDRIVE -- A minimum overdrive is the type usually found in automotive equipment that has an overdrive incorporated in the transmission. The hook-up of the driving members is opposite to that for a minimum speed reduction. Because the driving and driven members have changed places, the result will be ________________.

A. an increase in speed instead of a decrease 26
B. a decrease in speed instead of an increase 25
C. neither an increase or a decrease 25

2-24

25

No. You are incorrect. An increase in speed instead of a decrease, is the correct answer.

Press A 26

2-25

26

Correct.

REVERSE REDUCTION -- So far we have considered only those setups where the driving and driven members are rotating in the same direction. In planetary gears, reverse direction can be accomplished in a speed reduction, overdrive and direct drive. When a reverse reduction is desired, the engine is made to drive the sun gear; and the planet carrier ____________.

A. is left free to rotate 27

B. is locked to the planet gears 27

C. is held stationary 28

2-26

27

No, you are incorrect. The planet carrier is held stationary, or no power will be transmitted through the planetary gear train.

Press A 28

2-27

28

Correct.

The sun gear is driven in the same direction as the engine (clockwise), thus causing the planet gears to rotate counterclockwise. Since the planet carrier is held stationary, the planet gears rotate on their shafts and cause the ring gear to rotate ____________.

A. in the same direction as the sun gear 29

B. in the opposite direction from the sun gear 30

C. with the planet carrier 29

2-28

29

No, you are incorrect.

When reverse reduction is desired, the planet carrier is held stationary. The planet gears rotate on their shafts and cause the ring gear to rotate in the opposite direction from the sun gear.

The gear reduction is a direct ratio of the number of the teeth on the ring gear to the number of teeth on the sun gear. The planetary gears merely idle, and do not influence the speed ratio.

Press A 30

2-29

30

Correct.

Direct Drive -- If direct drive is desired ____________ held to prevent rotation.

Direct drive can be obtained regardless of which member is the driving member.

A. no member is 32

B. one member is 31

C. all members are 31

2-30

31

No, you are incorrect.

The correct answer is "no member is held to prevent rotation" to get the desired direct drive.

Press A 32

2-31

32

OK.

An example to consider for direct drive is the situation where the driving member is the sun gear and the driven member is the planet carrier. Instead of locking the ring gear, leave it free to rotate and lock the ring to the sun gear. If this condition existed, the entire unit would rotate and as a result a ____________.

A. two to one ratio from the engine to the propeller shaft would exist 33

B. three to one ratio would exist 33

C. one to one ratio would exist 34

2-32

33

No, you are incorrect. If the condition just described existed, a one to one ratio (direct drive) would be the result.

Press A 34

2-33

34

OK.
A summary of the possible planetary combinations discussed is shown in Plate II: disregard the reverse overdrive. The algebraic expressions for the speed of the propeller shaft where there is a speed reduction or increase are listed and shown in Plate III.

PLANETARY GEAR SPEEDS

S = Number of teeth in sun gear = 18 (unit example)
R = Number of teeth in ring gear = 36 (unit example)
C = Planet carrier.

Press A 35

2-34

35

In the discussion that follows, you will be able to see how planetary gears are used singularly or in compound groups to achieve the torque and speed ratios described to operate an engine operated torque converter.

Press A 36

2-35

36

The HYDRA-MATIC TRANSMISSION can be found in both passenger cars and trucks. The function of the hydra-matic is to provide suitable gear ratios between the engine and the driving wheels to meet all driving needs. See Plate IV.

From the explanation of planetary gears you can see that a single planetary gear assembly, is actually a ____________.

A. three speed transmission XX
B. two speed transmission 38

(Only the correct answer will move the film.)

3-36

X (c) - 37

37

It is evident that you do not have a clear understanding of the planetary gear system or have misunderstood some of the questions. You should have an opportunity to go back for a review. Read the questions carefully; take your time in selecting an answer. Press A

20

2-37

38

OK. Let's go on.

To provide reduction in the front planetary of the hydramatic transmission, a band is wrapped around a drum which is an integral part of the sun gear. When the band is actuated, it stops the sun gear. In this case, the internal gear continues to turn, and the pinion walks around the sun gear, rotating the planet carrier at a speed ____________.

A. greater than that of the internal gear 39
B. the same as that of the internal gear 39
C. less than that of the internal gear 40

3-38

39

No, you are incorrect. The planet carrier would rotate at a speed less than that of the internal gear to obtain a reduction in the front planetary.

Press A 40

3-39

40

OK.
To provide reduction in the rear planetary, a band is wrapped around a drum which is part of the internal gear. When the band is applied, it stops the internal gear. In this case, the sun gear ___(1)___ and drives the planet carrier and its pinions at a ___(2)___ speed.

A. (1) stops turning (2) increased 41
B. (1) continues to turn (2) reduced 42
C. (1) continues to turn (2) increased 41

3-40

41

No, you are incorrect. The sun gear continues to turn, and drives the planet carrier and its pinions at a reduced speed, to provide reduction in the rear planetary.

Press A 42

3-41

42

Correct.
To provide direct drive, multiple clutches or drum bands are used. In the front planetary unit, the clutch discs are alternately attached to the sun gear and the planet carrier.

In the rear unit, the discs are alternately attached to the internal gear and to a hub which is splined to a shaft that extends from the front planet carrier.

Press A 43

3-42

43

With no pressure applied to a clutch, the two members to which the discs are attached are free to rotate independently. You can see from the foregoing that transmission control depends upon devising a way ________________.

A. to release the clutch discs or drum bands 44
B. to apply the clutch discs and release the drum bands 44
C. to apply the clutch discs or the drum bands 45

3-43

44

No, you are incorrect. Transmission control depends upon devising a way to apply the clutch discs or the drum bands.

Press A 45

3-44

45

OK.
The bands are applied and released hydraulically, by hydraulic servos. The front servo consists of a stem with two pistons installed in a cylinder, which has a wall between the two pistons; see Plate V. A release spring installed between the servo body wall and one of the pistons, holds the servo in the released position when ________________.

A. no spring tension is applied 46
B. no oil pressure is applied 47
C. no oil pressure or spring tension is applied 46

3-45

46

No, you are incorrect. No oil pressure is applied, is the correct answer.

Take another look at this one. Press A 45

3-46

47

OK.
As mentioned earlier, the clutch discs are attached alternately to the sun gear and to the planet carrier, according to the speed range required. The clutch discs are actuated by pistons located within the clutch drum; see Plate VI.

When no pressure is applied to the actuating piston, the clutch is released by springs. When pressure is applied, the piston is forced against the clutch discs, which slide together, causing the ________________.

A. sun gear and planet carrier to lock together 49
B. sun gear and planet carrier to turn in opposite directions 48
C. neither of the above 48

3-47

48

No, you are incorrect. The sun gear and planet carrier lock together when pressure is applied.

Press A 49

3-48

49

OK.
The rear servo and planet operate on the same general principle as the front unit. The rear servo, however, is designed somewhat differently, in that it ________ ________.

A. is applied mechanically 50
B. is released by springs 50
C. is applied by spring pressure and released by hydraulic pressure 51

3-49

50

No, you are incorrect. The rear servo is applied by spring pressure and is released by hydraulic pressure.

Press A 51

3-50

51

Correct.
Precisely timed and coordinated action between the bands and clutches in the two planetaries must take place. If bands do not operate properly ________ ________, and serious damage may result.

A. loss of power and torque, rough handling 52
B. rough shifting, slippage 53
C. overheating, power loss 52

3-51

52

No, you are incorrect. If the bands do not operate properly, rough shifting, slippage and serious damage may result.

Press A 53

3-52

53

Correct.
The hydraulic system of the hydra-matic transmission provides the automatic shifting control. The system consists of a front and rear oil pump, pressure regulator, operating control valve assembly, hydraulic governor, front and rear servos, and the necessary lines and passages to the required places.

The front pump is a vane-type that turns when the engine is running. The rear pump is a ___(1)___ and is driven by the ___(2)___ shaft.

A. (1) gear type (2) input 54
B. (1) gear type (2) output 55
C. (1) vane type (2) output 54

3-53

54

No, you are incorrect. The rear pump is a gear-type and is driven by the output shaft.

Press A 55

3-54

55

The hydraulic control system has two functions. It directs oil to the clutches in the transmission, and it provides a supply of oil to lubricate the gears and bearings of the transmission. In most hydraulically controlled transmissions ___(1)___ clutches must be applied at one time in order to transmit power through the transmission; otherwise, the transmission is in the ___(2)___ position.

A. (1) three (2) locked 56
B. (1) two (2) neutral 57
C. (1) two (2) reverse 56

3-55

56

No, you are incorrect. In most hydraulically controlled transmissions, two clutches must be applied at one time in order to transmit power; otherwise the transmission is in the neutral position.

Press A 57

3-56

57

With the selector lever in the neutral position, oil pressure is shut off from all the hydraulically operated clutches, and all multiple plate clutches are disengaged. As no planetary members are ____(1)____, all gears are free to rotate; therefore ____(2)____ is transmitted through the planet carrier.

A. (1) held stationary or locked together 59
(2) no power

B. (1) left free to turn
(2) reverse drive 57.2

X(C)- 58

3-57

57.2

No. You are incorrect. With the selector lever in the neutral position, no planetary members are held stationary or locked together; therefore no drive is transmitted through the planet carrier.

Press A 59

3-57A

58

OK.
Remember, with the selector lever in the neutral position no planetary members are held stationary or locked together; therefore no drive is transmitted through the planet carrier.

You have missed one or more of the questions in this sequence of material and should have the opportunity to review. Read carefully and take your time in answering the questions.

Press A 38

3-58

59

OK.
The gears in most automatic transmissions are in mesh at all times, but do not transmit power until one of the multiple disc clutches is actuated by the selector valve. In studying the power flow of the various ranges as covered before, it should be remembered that the power flow to the planetary system is in most cases through the ____(1)____ and the power leaves the planetary system through the ____(2)____.

A. (1) planetary gear (2) sun gear 60

B. (1) input sun gear (2) output planetary carrier 61

C. neither of the above 60

4-59

60

No. you are incorrect. Power flow in a planetary system is from the input sun gear to the output planetary carrier.

Press A 61

4-60

61

OK.

GEAR FAILURE AND LUBRICATION

When two loaded surfaces slide over each other, as in the case with meshing gear teeth, there always is frictional resistance opposing the motion. ________ results unless friction is minimized by a film of lubricating oil between the two sliding surfaces.

A. Destruction of the gears and contamination of the oil 62

B. Wear and loss of power 62

C. Both of the above 63

4-61

62

No, you are incorrect. Not just wear and loss of power, but destruction of the gears and contamination of the lubricating oil may also occur without proper lubrication.

Press A 63

4-62

63

OK.
Such a film, as mentioned before, substitutes the low fluid friction of the oil for the high metallic friction of dry durfaces. A film of the oil-wedge type may be of sufficient thickness to completely separate rubbing metallic surfaces with a thick layer of fluid oil. With such a film, friction is entirely due to the fluid friction within the oil which in turn depends on ________.

A. the anti-foam quality of the oil 64

B. oil density 64

C. oil body (viscosity) 65

4-63

64

No, you are incorrect. Fluid friction of lubricating oil depends on the oil body (viscosity), its resistance to flow.

Press A 65

4-64

65

Correct.

Gears and their bearings usually are designed to function satisfactorily during the entire life of the machine of which they are a part, and their failure to do this indicates some unusual condition of operation. However, regardless of design, size, etc., ____(1)____ is essential to assure ____(2)____, quiet operation and long service life.

A. (1) correct lubrication (2) minimum wear 67
B. (1) gear design (2) power transfer 66
C. (1) proper meshing of the gear teeth (2) power transfer 66

4-65

66

No, you are incorrect. Correct lubrication is essential to assure minimum wear, quiet operation and long life.

Press A 67

4-66

67

Correct.

During manufacture, tooth shapes are very accurately developed. No matter how accurately and smoothly the teeth are finished, however, there will always be ________ which cause frictional resistance if they are allowed to meet.

A. a few faulty gears 68
B. microscopic surface irregularities 69
C. Both of the above 68

4-67

68

No, you are incorrect. Microscopic surface irregularities is the correct answer.

Press A 69

4-68

69

Correct.

With the gears in proper mechanical condition and with ________, friction is reduced, wear is practically eliminated and gears should operate efficiently for years.

A. proper alignment 70
B. proper break-in procedure 70
C. correct lubrication 71

4-69

70

No, you are incorrect. With the gears in proper mechanical condition and with the correct lubrication, friction is reduced, wear is practically eliminated and the gears should operate efficiently for years.

Press A 71

4-70

71

Correct.

Even with correct lubrication properly applied, ________ can cause wear and destruction of teeth.

A. design features 72
B. certain mechanical or operating conditions 73
C. operating personnel 72

4-71

72

No, you are incorrect. Certain mechanical or operating conditions can cause wear and destruction of teeth, is the correct answer.

Press A 73

4-72

73

Correct.
Destruction seldom takes the form of tooth breakage, but usually shows up as ______________________.

A. damage to the bearings 74
B. damage to the rubbing surfaces 75
C. contamination of the lubricating oil and damage to the gears and bearings 74

4-73

74

No, you are incorrect. Under normal conditions, destruction of the gear teeth usually shows up as damage to the rubbing surfaces.

Press A 75

4-74

75

Correct.
Surface failures may rapidly destroy the original tooth contour, and once this occurs, smooth, quiet operation can no longer be expected. Surface failure may be directly attributed to ___(1)___, but more often ___(2)___ is in no way responsible.

A. (1) bearing alignment (2) alignment 76
B. (1) overheating (2) temperature 76
C. (1) improper lubrication (2) lubrication 77

4-75

76

No. you are incorrect. Bearing alignment may contribute to surface failures, but the correct answer is improper lubrication.

Press A 77

4-76

77

Correct.
In fact, even though the correct lubricant for normal service is used, tooth surface may still be ruined by ______________________.

A. overloading, overheating, shock, abrasives, chips, improper alignment, loose bearings or deflection of shafts or housings 79
B. some of the reasons that are listed in "A" may cause tooth failure, but not all 78
C. the operating personnel 78

4-77

78

No, you are incorrect. The operating personnel may cause all the possible reasons for failure; but the damage is done by one or more of the items listed: overloading, overheating, shock, abrasives, chips, improper alignment, loose bearings, or deflection of shafts or housings.

Press A 79

4-78

79

Correct. Many terms are used to graphically describe the appearance of damaged tooth surfaces. For the purpose of this unit, gear tooth failures are classified under the heading of ______________________.

A. cross-hatch and scratched 80
B. scuffed, wiped and peened 80
C. pitting, abrasion, scratching, spalling and galling 81

4-79

80

No, you are incorrect. The five items listed in "C" are correct: pitting, abrasion, scratching, spalling and galling.

Press A 81

4-80

81

Correct.

PITTING -- The tooth surfaces of new gears, although smooth to the eye ________________.

A. actually are comparatively rough 83

B. actually are smoother than they seem 82

C. need the added roughness of running-in for proper lubrication 82

4-81

82

No, you are incorrect. The tooth surfaces of new gears actually are comparatively rough, and tend to get smooth as running-in progresses, which in turn has little effect on lubrication.

Press A 83

4-82

83

Correct. In addition to roughness, there may be variations in the hardness of the surface of the metal. Under some conditions of lubrication, both roughness and variations in hardness cause uneven distribution of load across the tooth surfaces. The heavy, uneven, localized stresses are repeated at each turn of the gear, and ________________.

A. eventually a smooth gear tooth pattern develops 84

B. metal fatigue eventually occurs 85

C. neither of the above is correct 84

4-83

84

No, you are incorrect. Metal fatigue will result if uneven distribution of load across the gear tooth surfaces is momentarily concentrated in one area.

Press A 85

484

85

Correct.

In the heavy localized stress area just described, minute particles break away and leave small pits where high points or hard spots have been. In other areas of the tooth surface, the sliding action wears away the high spots before pitting can occur. With ________ gears, side slide predominates in all areas, and true pitting of the teeth does not occur.

A. spur and bevel 86

B. herringbone and spur 86

C. worm and hypoid 87

4-85

86

No, you are incorrect. With worm and most hypoid gears, side slide predominates in all contact areas, and true pitting of the gear teeth does not occur.

Press A 87

4-86

87

Correct.

Although pitting is not a lubrication failure, there is some evidence that oil plays a part in the following manner: As a result of fatigue, small surface cracks start; they become filled with oil, and under load ________________ is developed. This tends to extend the cracks and even to push out small particles of metal.

A. overloading 88

B. hydraulic pressure 89

C. heat 88

4-87

88

No, you are incorrect. Hydraulic pressure is developed in the condition just described. This hydraulic action would occur with any fluid.

Press A 89

4-88

89

Correct. With spur and bevel gears, as each tooth passes through the center mesh, the entire load is momentarily concentrated on the pitch line. If the area along the pitch line has already started to pit, the load is further concentrated on the undamaged metal, and ______________________.

A. pitting is likely to increase progressively 91
B. a wiping action may occur resulting in overheating 90
C. both of the above are correct 90

4-89

90

No, you are incorrect. With spur and bevel gears and the condition described, pitting is likely to increase.

Take another look at this one. Press A 89

4-90

91

Correct. With helical, herringbone and spiral bevel gears, there is less likelihood of destructive pitting. This is true because each tooth, during mesh, makes contact along a ___(1)___ line extending from ___(2)___. This line cuts across the pitch line.

A. (1) slanted (2) root to tip 93
B. (1) straight (2) pitch line to base 92
C. (1) curved (2) light contact to heavy contact 92

4-91

92

No, you are incorrect. With the gears just described there is less likelihood of destructive pitting because each tooth, during mesh, makes contact along a slanted line extending from root to tip of the gear tooth.

Take another look at this one.

Press A 91

4-92

93

Correct. Lubricants should not be expected to eliminate pitting although, in some instances, a border-line case of pitting may be improved by using a ______________.

A. lower viscosity lubricant 94
B. non-detergent lubricant 94
C. heavier-bodied oil 95

4-93

94

No, you are incorrect. The use of a heavier-bodied lubricant will sometimes improve a border-line case of pitting.

Press A 95

4-94

95

Correct.

NORMAL WEAR

When gears are of proper design, construction and hardness, when they do not operate at excessive loads, and when correct lubricants are used, then a condition of normal wear should result.

Normal wear over a long period gradually smooths rubbing surfaces of the teeth and work-hardens them to a polish. As the surfaces become smoother and more work-hardened, friction and wear decrease until a condition may be reached where further wear practically ceases.

Press A 97 X(c)-96

4-95

96

OK.
You have answered one or more of the questions in this sequence incorrectly. Review the last few frames. Read carefully and take your time when answering the questions.

Press A 59

4-96

97

Congratulations, you have just finished unit AM 2-6D on PLANETARY GEARING. You will learn more on this subject in later films.

Please press the REWIND button.

4-97

INSTRUCTOR'S GUIDE

Title: AUTOMATIC TRANSMISSIONS -- PLANETARY GEARING

AM 2-6
4/12/67

OBJECTIVES:

1. To help the trainee understand how planetary gears operate in an automatic transmission.
2. To acquaint the student with the reduction created in planetary gears, and how it is accomplished.
3. To familiarize the student with the power flow through a planetary system, in both maximum and minimum reduction; also how direct drive is accomplished.

LEARNING AIDS suggested:

MODELS: Any samples of gear failures that can be brought into class and discussed would be helpful. Also, any parts of a hydramatic transmission (cut-away, etc.) would be of great value in understanding how planetary gear arrangements operate.

QUESTIONS FOR DISCUSSION AND GROUP PARTICIPATION:

1. Why are adjustments so critical in an automatic transmission?
2. Why is cooling transmission oil important?
3. What are some of the signs of low transmission oil?
4. Name some of the advantages of automatic transmissions.
5. Discuss how scheduled maintenance can eliminate some major repairs.
6. Discuss how maximum and minimum reduction and direct drive are accomplished in automatic transmissions (speed reduction ratio etc.).
7. Discuss the use of compound groups, as well as single groups, of planetary gears to achieve torque and speed ratios that are desirable in different applications.

8. Explain the operation of hydraulic servos and their part in controlling the shifting from one speed to another in automatic transmissions.
9. Discuss the pumps used in automatic transmissions, type, capacity, etc.
10. Discuss some of the terms used to describe the appearance of gear tooth surfaces: pitting, abrasions, scratching, etc.