



THE ORDNANCE SERGEANT

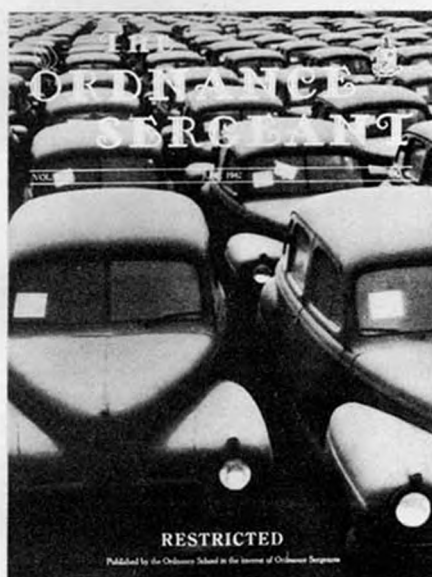
VOL.

JUNE 1942

NO. 6

RESTRICTED

Published by the Ordnance School in the interest of Ordnance Sergeants



HIGHLIGHTS

This is an AUTOMOTIVE ISSUE. Thousands of Ordnance officers and men are and will find a knowledge of the principles of automotive vehicles of constant value to them - in the supervision of transportation, as drivers, and in other capacities as well as in maintenance activities. For the benefit of such personnel "An Introduction to Automotive Theory" is published on pages 475 to 538, inclusive.

The classification and safeguarding of documents is especially important in time of war. Staff Sergeant Arnold discusses this subject on page 472. Be reminded that THE ORDNANCE SERGEANT is now classified as "Restricted".

The discussion of shotguns is concluded in an article by Master Sergeant Dyer beginning on page 459. This will be followed next month by some useful information regarding the "Tommy" gun.

Lieutenant Hampton provides some very useful information, with ample illustrations, on the "Inspection and Adjustment of the 105mm Recoil Mechanism" on page 462.

The discussion of machine shop equipment and operations is continued on page 474 by Technical Sergeants Bingert and Tibbetts; Captain Sylvester adds to his consideration of welding applications on page 541; and forging operations are again discussed by Lieutenant Allen on page 544.

"RESTRICTED"

Restricted military information will not be communicated to the public or to the press but may be given to any person known to be in the service of the United States and to persons of undoubted loyalty and discretion who are co-operating in Government work.

Address all communications to THE ORDNANCE SERGEANT, The Ordnance School, Ordnance Training Center, Aberdeen Proving Ground, Md.

REPRODUCTION PLANT
THE ORDNANCE SCHOOL
ABERDEEN PROVING GROUND
MARYLAND

RESTRICTED

--IN THIS ISSUE

Army Calls for Idle Auto Men.	455
Editorials. "To the Chief".	456
Small Arms.	459
Artillery.	462
Automotive.	468
Fire Control.	470
Administrative.	472
Depot and Supply.	473
Machine Shop.	474

AN INTRODUCTION TO AUTOMOTIVE THEORY.	475-538
---	---------

Welding.	541
Forging.	544
Ammunition.	547
Aviation Ordnance.	549
Ordnance Training Activities.	551
Notes from the Editor.	560



The cover picture is an enlarged Wirephoto by courtesy of the Associated Press.





Automotive Section
The Ordnance School

No man can accurately estimate the future importance of AUTOMOTIVE in our war effort. All estimates of the past have dwindled into insignificance as developments progressed. Estimates of the immediate future are apt to prove as insufficient as those of the past. This issue of THE ORDNANCE SERGEANT places special emphasis upon AUTOMOTIVE subjects, because many thousands of fighting young Americans will want to know just a little more about "what makes it go, and why".

Army Calls For Idle Auto Men

DENVER, April 2—(A. P.).—Out-of-work auto salesmen, idle motor mechanics and war-stymied dealers are going to get a chance to join the Army and work shoulder-to-shoulder at the job they know best—repair and maintenance of motorized equipment.

At the request of the Army Ordnance Department, the National Auto Dealers' Association is organizing two ordnance regiments to be composed mainly of auto industry workers whose jobs vanished when the industry quit making family sedans and began turning out battle-wagons.

The Three Hundred and First Ordnance Regiment will be recruited in the NADA's western region, one battalion each from the Chicago, San Francisco and Denver areas and another battalion from the region at large. The Three Hundred and Second Regiment will be drawn from the association's Eastern region, with battalions from the New York, Atlanta and Dallas areas and one from the region at large.

Herman R. Goodin, Washington, vice-president of the NADA, explained to Rocky Mountain dealers that "this is strictly Army business." To join, a man must first enlist in the Army.

VPB Warn

See pages
475 - 538
inclusive

WAR DEPARTMENT
OFFICE OF THE CHIEF OF ORDNANCE
Washington, D. C., May 31, 1942

ORDNANCE OFFICE MEMORANDUM)
NO.

1. Within the hour after taking the oath of office as Chief of Ordnance four years ago, I sent the following message to all Ordnance personnel — military and civilian:

"The great responsibility which rests upon the Ordnance Department today demands the very best effort of all of us. New developments of a highly technical nature must be completed without delay. Plans for improved maintenance, storage and supply are of paramount importance. New equipment and ammunition must be provided in quantities greater than ever before authorized in the peace-time history of the Army. Ordnance preparedness in all its phases must go forward with renewed vigor. These duties will require our united resolution.

"The Ordnance tradition has three main objectives. First, unfailing service to the fighting forces of the Army; second, reliance upon the professional and industrial resources of our country; third, internal progress and cooperation. To these I dedicate my tenure with abiding faith in the ability, loyalty and devotion to duty of the officers and men and the civilian employees of the Department. I am confident that the high standards of Ordnance will continue to be maintained for the national defense of the United States."

(Continued on page 458)



Major General C. M. Wesson
Retiring Chief of Ordnance

To GENERAL WESSON Our Retiring Chief

AN EDITORIAL

He has retired as our chief. It was his responsibility to guide the destinies of the Ordnance Department during one of the most critical periods in our nation's history.

The vast quantities of munitions now pouring out of the industrial facilities in this arsenal of democracy exceed by far any preconceived plan of national mobilization. This achievement is due in no small part to the foresight and resourcefulness of our retiring chief.

The quality of our products, emerging from these production lines, are in general superior to the munitions being produced in any other country. These are not the result of hasty decisions made in time of emergency but rather the resultant natural development during many years of research. General Wesson's contribution to these achievements dates from many years past during his tours of duty both with the Technical Staff in Washington and in his command of Aberdeen Proving Ground as well as Chief of Ordnance.

In our field forces, similar expansion and progress may be noted during his last four-year tour of duty. Our enlisted strength has increased so rapidly that the Ordnance Training Center, conceived and organized by General Wesson here at Aberdeen Proving Ground, which will soon have capacity for twenty five thousand men, has never been able to meet the ever increasing demand for trained men. The demand for ordnance officers has increased so rapidly that it became necessary for The Ordnance School to increase the Officer Candidate Course to a strength that will produce second lieutenants at a weekly rate nearly equal to the total number of officers authorized for the Ordnance Department during the past twenty years of peace. General Wesson's council and guidance in this expansion at the Ordnance Training Center, from which this fountain of personnel springs, is symbolic of his foresight and ability for accomplishment.

Yes, General Wesson has retired as our chief, but the lessons we have learned in following his leadership in the trail blazing for national security will live on in the hearts and minds of the men who have served under him, and especially those who have been so fortunate as to know him personally and to sit at his council table.

THE ORDNANCE SERGEANT wishes you, General Wesson, "Godspeed" and "Good Luck" in any future assignment, duty, or pleasure you may take.

To GENERAL CAMPBELL Our New Chief

AN EDITORIAL

THE ORDNANCE SERGEANT salutes our new Chief. We have noted with pride the important missions and tasks assigned to prominent ordnance officers by our governing authorities during our present critical period. General Campbell was first selected for the very important and difficult task of obtaining new ordnance facilities for the manufacture of explosives, bombs, tanks and guns, and later placed in charge of the nation's \$30,000,000,000 ordnance procurement program. His selection as the new Chief of Ordnance indicates the high quality of results he has been found capable of producing.

The Ordnance Department is indeed fortunate in having at its head a man with his broad vision. His early schooling with the Navy, his experience with combat branches, his contact with the design and development of materiel during many years following World War I, and his more recent experience in manufacture at two of our large arsenals carefully and amply prepared him for the tasks that lie ahead.

Today, we find the Ordnance Department securely established upon this vast production program. Its success is now assured. The term "too late with too little" can never be applied to this effort. Can we be so sure of our military effort? Supplies will reach the troops as rapidly as shipping will permit and spare parts, in reasonable quantities, can arrive in time. There remains only the personnel problem. Will sufficient ordnance troops be available? Will they possess that high degree of training and skill necessary to keep the materiel functioning on the field of combat?

Ordnance troops, today, can no longer be classed as non-combatant. Their installations are of high value to combat operations and their destruction of great value to the enemy. We must expect the development of ever-increasing methods for their annihilation. The men who operate these installations must be soldiers first, and then mechanics. In each, they must excel if our mission is to be filled.

Yes, General Campbell, THE ORDNANCE SERGEANT is highly pleased with your selection as our Chief. With your knowledge of our field problem as our 'staff' we can face the future with courage and confidence. We shall not fail.

WAR DEPARTMENT
OFFICE OF THE CHIEF OF ORDNANCE
Washington, D. C., June 2, 1942

In assuming my duties as Chief of Ordnance, I take this opportunity to extend my greetings, through THE ORDNANCE SERGEANT, to the Officers and men of The Ordnance Department.

You have done splendid work. You will, I know, continue to do so, as the magnitude of your task increases.

More Ordnance men must be trained to keep pace with the expansion of the Army as a whole. Courses must be changed to keep abreast of improvements resulting from actual field experience. New weapons will have to be maintained.

Modern warfare makes speed essential. To attain this speed, the officers and men of the Ordnance Department must keep them rolling — keep them firing. Modern warfare requires teamwork of the highest degree — we of the Ordnance Department must do our full share.

I am counting on each and every one of you to drive forward ceaselessly until our goal is reached; until victory is won.

LEVIN H. CAMPBELL, JR.
Major General, Chief of Ordnance



Major General Levin H. Campbell, Jr.
Chief of Ordnance

GENERAL WESSON RETIRES

2. Today my task is finished. During these past four years you have never failed me in your support. The Ordnance tradition has been carried on by you with unselfish devotion and stimulating enthusiasm. The Ordnance program underway is the most stupendous ever undertaken by any country at any time, and production is flowing from the lines in amounts never dreamed of until less than one year ago. Our designs compare most favorably to those of other nations, and our provisions for supply and maintenance have kept apace with the march of events.

3. I am justly proud of the Ordnance Department and its achievements and have been signally honored to be its Chief during these four momentous years. To each and every one of you I give my heartfelt thanks for what you have done in preparing for and carrying out the War Effort.

4. To my distinguished successor, General Levin H. Campbell, Jr., you will give, I know, the unflagging support and devotion to duty which, these past four years, you have so freely given me.

5. When peace comes after Victory, may our country say of the Army Ordnance Department — "Well done!"

C. M. WESSON
Major General, Chief of Ordnance

OFFICIAL:

H. C. Minton
Brig. Gen., Ord. Dept.
Executive Officer



NOTICE

A displacement of material in this issue has been deemed advisable. The feature material is devoted entirely to Automotive Theory, and is placed in the center of the issue. This makes it possible to remove this material from the issue, if desired, without disturbing the remainder of the contents. The usual format will be resumed in the next issue.

NEXT MONTH

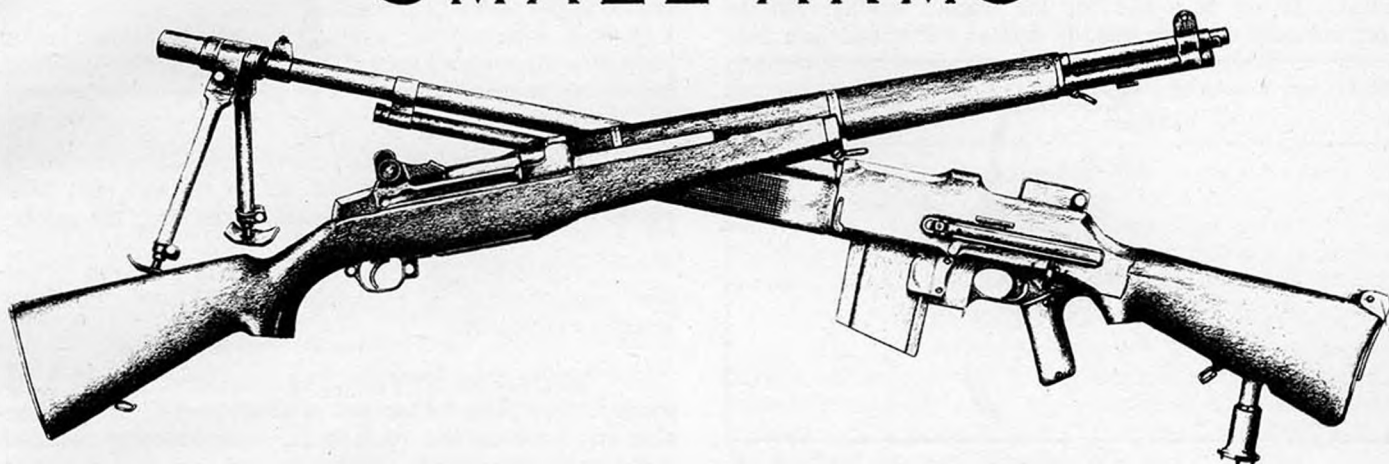
Next month THE ORDNANCE SERGEANT will visit with the Field Artillery. Several excellent articles and



numerous interesting photos will be a part of the July issue. You will know more about Ordnance-Field Artillery problems after you see it.



SMALL ARMS



Conducted by: C. B. Goodman, Capt., Ord. Dept.

SHOTGUN, REMINGTON, 12-GAUGE, M1910, RIOT TYPE

By: Edward Dyer, M. Sgt., Ord. Dept.

DESCRIPTION OF PARTS

EXTRACTOR SPRING. - The extractor spring is a double leaf type spring. Figure 1. This spring is assembled into the receiver seat on top of the breechblock with the loop of the spring to the rear and with the long leaf up.

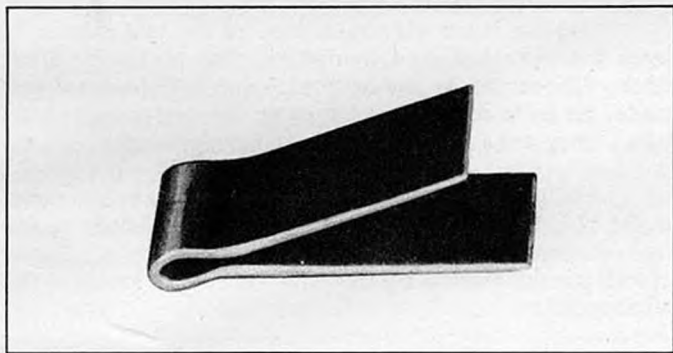


Fig. 1 - Extractor spring.

EJECTOR SPRING. - The ejector spring Figure 2, is also a leaf type spring, and is assembled in the top of the receiver just above the breechblock seat. The rear end of the ejector spring is wider and the edges are beveled to permit assembling it into its seat.

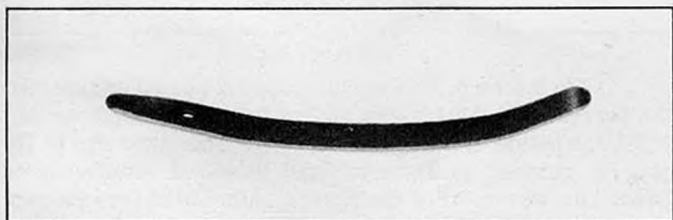


Fig. 2 - Ejector spring.

A hole is drilled in this wider part to enable the use of a drift when assembling and disassembling.

TRIGGER GUARD. - The trigger guard Figure 3, is somewhat "U" shaped with one of its legs longer than the other. The upper or shorter leg *a*, is shaped to fit over the tang of the receiver to which it is fastened by means of the tang screw and tang screw check screw, through the drilled and counterbored holes *b*. The underside of this leg carries two guide ribs *c*, for the receiver tang.

Through the rear end of the trigger guard is drilled the tapped hole *l*, into which is screwed the stock bolt to secure the butt stock to the receiver.

The long leg is considerably wider and thicker at its front end than the remainder of the guard. At the extreme front end is the hole *d*, for the shank of the trigger guard screw. Just to the rear of the trigger guard hole and on both sides of the trigger guard, are formed narrow ribs *e*, which fit into grooves cut in the receiver when the guard is assembled to the receiver. Toward the rear of

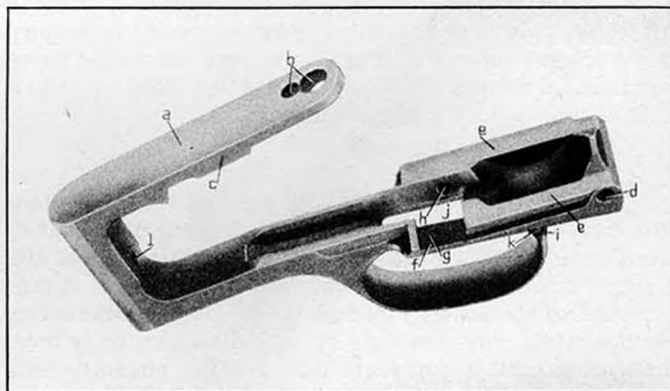


Fig. 3 - Trigger guard.

the right rib, there is a rectangular cut-out *f*, which forms a seat for the base of the upper half of the trigger. In the base of this rectangular cut-out is drilled a shallow blind hole *g*, to act as a seat for the trigger spring. On the left rib near its rear end, is drilled the trigger pin hole

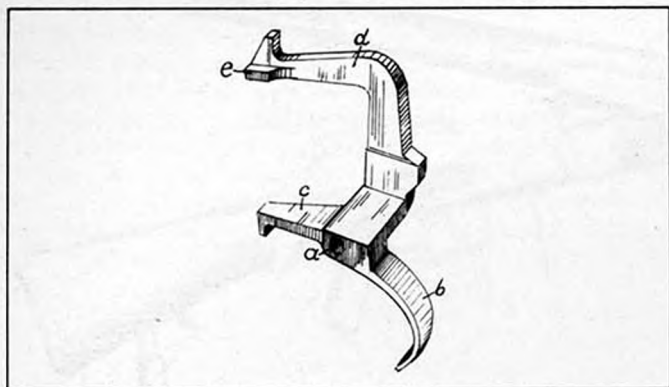


Fig. 4 - Trigger.

The trigger guard bow is formed on the underside of the longer leg of the trigger guard. The upper surface of this leg is cut out, for clearance purposes. Two rectangular openings are cut vertically through this longer leg, with the smaller of the two located near the front of the trigger guard and so cut, that it communicates with the trigger guard bow, with the forward wall of the bow slotted at *i*, to permit this. The second and the larger opening *j*, communicates with approximately the central position of the bow. The smaller opening is the seat for the safety, which is pinned to the walls of the bow, by the safety pin passing through the hole *k*. The larger opening permits the passage of the lower end of the trigger into the guard bow. The same serial number as stamped on the receiver and barrel will be found stamped on the left side of the trigger guard.

TRIGGER. - The trigger, Figure 4, is an irregularly shaped piece, having its pin hole *a*, in a flat base from which extend three projections. One projection curves smoothly downward and forms the trigger bow *b*. Extending forward and inclined slightly downward is a straight arm *c*, with a short stud or leg at a right angle to the arm. This arm is acted on by the safety.

The side of the base opposite the trigger bow is turned through a right angle to form another arm *d*, extending vertically. About three quarters of an inch from the base, this arm too, is bent forward and inclined downward slightly. The extreme end of this arm is flattened on its underside to form the surface *e*, which acts on the sear, while the top part is extended upward to form a lug which serves to prevent excessive upward movement of the trigger when the trigger and sear are in the firing position. On the underside of the base is a blind hole which acts as a seat for the trigger spring.

SAFETY. - The safety, Figure 5, is a small piece with both ends concave and knurled. The top of the safety has a small notch *a* cut near the rear end which mates with a projection on the trigger, when the safety is off. A hole *b*, is drilled horizontally through the side walls of the safety for the safety pin. The hole *c*, is drilled vertically from the bottom until it communicates with the pin hole. Into this vertical hole are assembled the steel ball, spring and plug of the safety.



Fig. 5 - Safety.

The purpose of these parts is to allow the safety to move forward or rearward on its pin and still have spring tension to prevent accidental movement of the safety.

TRIGGER PIN. - The trigger pin is enlarged on one end, necessitating its assembly from the left side of the trigger guard only.

MAGAZINE TUBE. - The magazine, Figure 6, is made from a plain tubing and is about 16-1/2" long. The plug end contains two rectangular diametrically opposed clearance cuts *a*, one slightly longer than the other, to permit passage of the magazine lever in operation. The magazine plug seats inside the tube and is secured in position by means of two flat-head screws inserted through countersunk holes *b*, in the wall of the tube.

In the rear end of the tube is a welded ring *c*, about 3/4 inches wide, which projects from the tube for about 1/2". On the projecting part of the ring, diametrically opposed, are two segments of threads *d*, through the medium of which the magazine group is secured to the receiver. The inside shoulder of the ring forms a stop for the magazine follower.

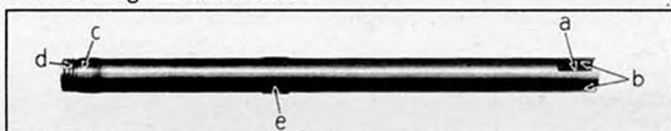


Fig. 6 - Magazine tube.

On the outer circumference of the tube, about 6" from the rear end, are welded two flat pieces *e*, 3/32" thick. These pieces are 5/8" wide and 7/8" long and are made, so as to conform to the outer circumference of the tube. They act as stops for the wooden foreend.

ACTION BAR. - The action bar, Figure 7, is composed of three pieces: the rolled sheet metal body *a*; the foreend cap plug *b*, and the action bar proper *c*. These are all manufacturing components, hence this group is not disassembled.

The body is formed from sheet metal into a cylinder having a 1/2" gap *d*, in the upper part of its circumference to provide clearance for the barrel in the assembled position.

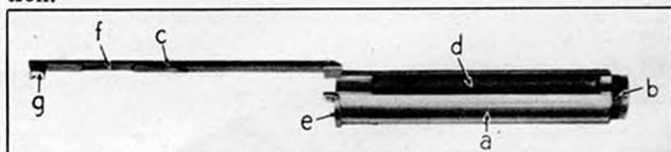


Fig. 7 - Action bar.

To the front end of this body is pinned and welded the foreend cap plug. One end of the plug is cut, so that it fits the inside diameter of the body. The other end of the plug is reduced in diameter and threaded externally to permit the assembly of the internally threaded foreend cap.

The action bar is also pinned and welded to the

opposite end of the body. The action bar proper consists of a wide cylindrical ring e, that is permanently secured to the body and a long narrow rectangular bar extending from the ring for 7-5/8". About one and one-half inches from the extreme end of the bar, on the inner side, is a recess F, which provides clearance between the guide rib on the breechblock and action bar when assembled. At the extreme end, also on the inner side, is the lug g, by means of which the action bar actuates the breechblock.

MAGAZINE PLUG. - The magazine plug, Figure 8, is cylindrical and turned to the inside diameter of the magazine tube. It has rectangular cuts a, conforming to those on the tube. There are two tapped holes b, (one on each side of the plug) mating with those on the tube, to permit insertion of the flat head screws used in securing the plug to the tube.

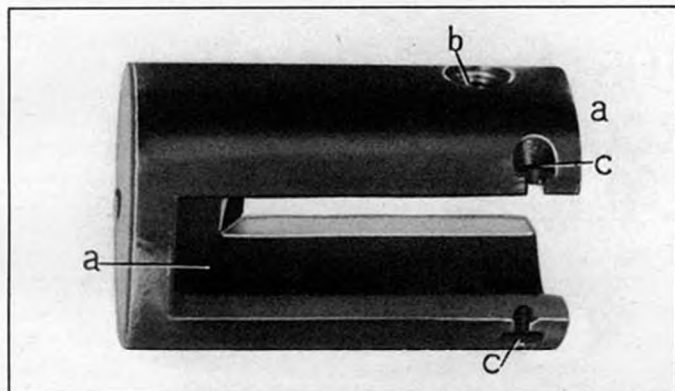


Fig. 8 - Magazine plug.

To the open end of the larger rectangular opening, through the holes c, is pinned the magazine lever assembly. On one side wall of the larger rectangular opening is a small recess terminating in a shoulder. This shoulder acts as a stop for the magazine lever detent.

MAGAZINE LEVER. - The magazine lever, Figure 9, is an irregularly shaped piece assembled to the magazine plug. The lever is the means by which the magazine tube is locked to or unlocked from the barrel lug. In cross section, the lever is "T" shaped. One end of the lever is well rounded while the other is cut at an angle. In the short side of the lever is assembled the spring loaded magazine lever detent a. The detent is secured by the detent pin b.

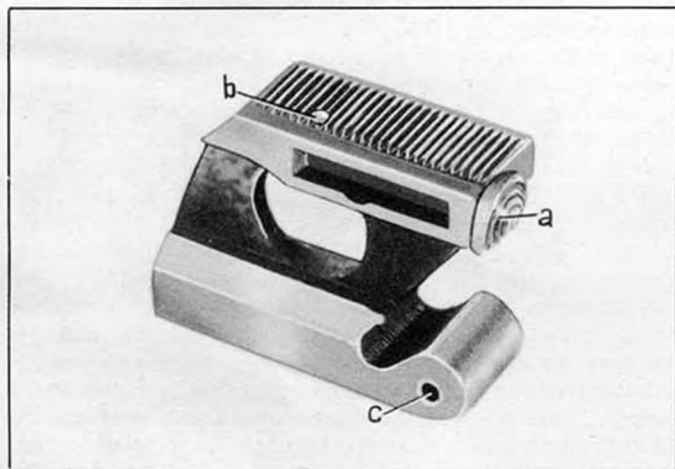


Fig. 9. Magazine lever.

On the longer side of the lever is the hole c, for the magazine lever pin. The outer surfaces of both sides are knurled to provide a better grip.

FOLLOWER. - The follower Figure 10, is a cone shaped sheet metal stamping closed on one end. The other end is open to permit the entrance of one end of the magazine spring.



Fig. 10 - Follower.

The open end of the follower is belled outward to form a shoulder which acting against a shoulder on the inside of the tube, stops the rearward movement of the follower. The large hole drilled on the circumference of the follower permits escape of air during loading.

MAGAZINE SPRING. - The magazine spring is helical, and made of fine gauge wire, the spring is about 20" long.

FOREEND. - The wooden foreend Figure 11, is made cylindrical to assemble over the body of the action bar. The outer circumference is grooved. One end is tenoned to enter the recess in the foreend cap. The other end is mortised to mate with the shoulder, formed by the end of the action bar ring.



Fig. 11 - Foreend.

What is normally the upper side of the foreend when assembled, is cut out to provide clearance for the barrel.

FOREEND CAP. - The foreend cap is internally threaded, to fit over the foreend cap plug. Its purpose, is to secure the foreend to the action bar body. Slots are provided on the face of the cap to facilitate disassembly.

BARREL LUG. - The barrel lug Figure 12, is assembled to the barrel about 2-1/2" from the muzzle. The lug extends downward and forms the front support for the magazine group. A heavy stud a, in conjunction with the

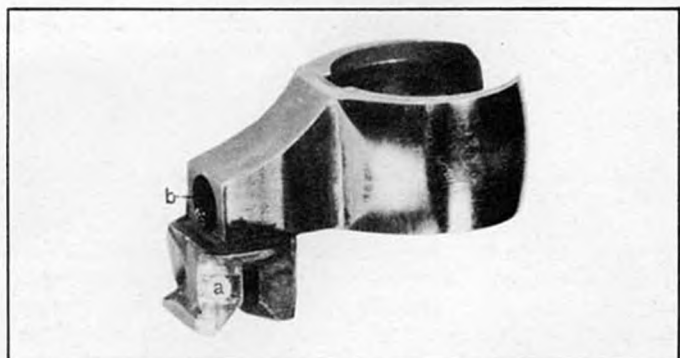
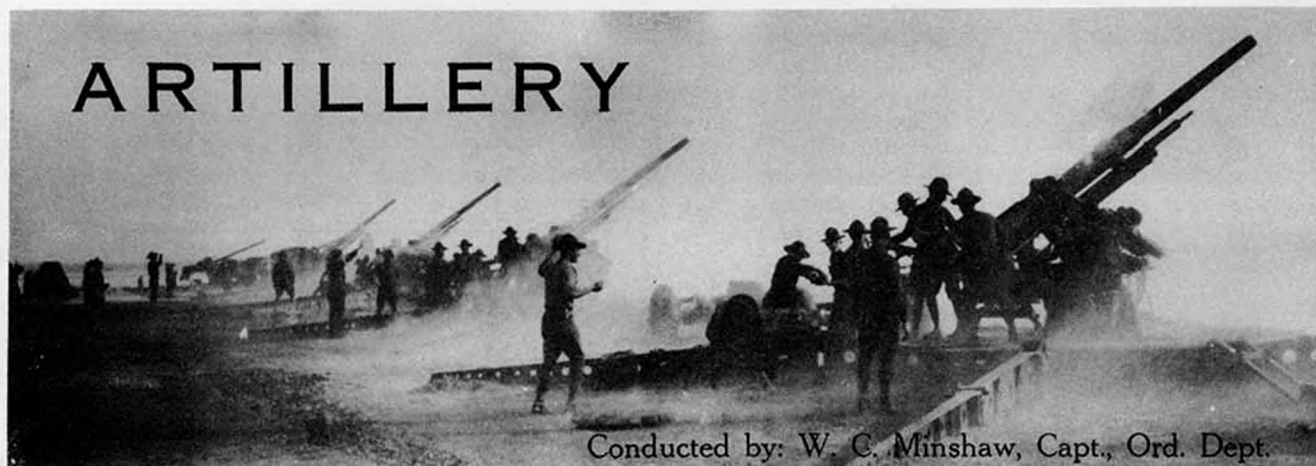


Fig. 12 - Barrel lug.

(Continued on page 554)

ARTILLERY

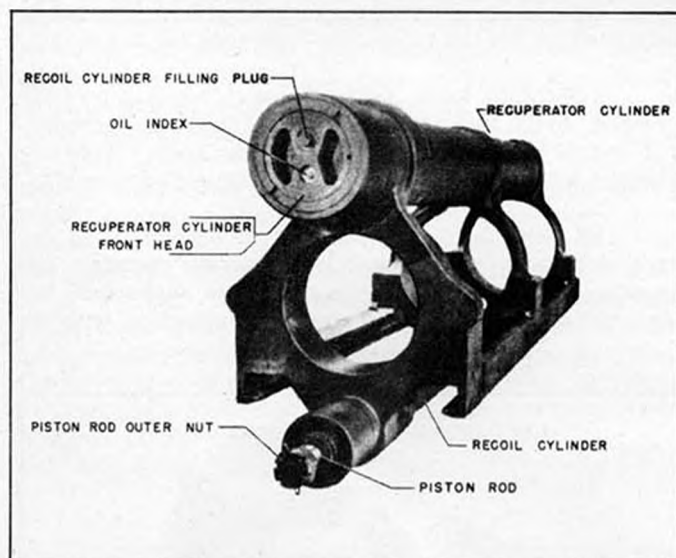


Conducted by: W. C. Minshaw, Capt., Ord. Dept.

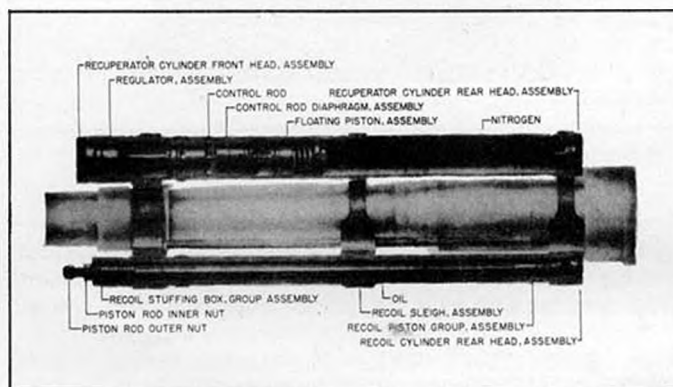
INSPECTION AND ADJUSTMENT OF THE 105mm HOWITZER RECOIL MECHANISM

By: H. D. Hampton, 2nd Lt., Ord. Dept.

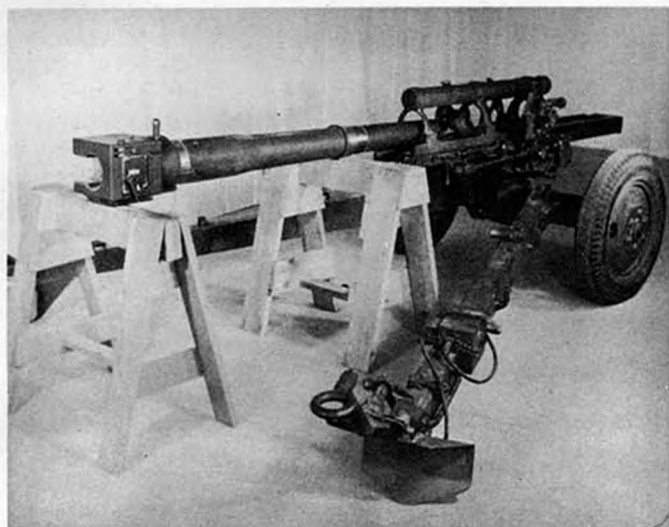
In order to determine the serviceability of the 105mm howitzer carriage, M2, the condition of the recoil mechanism must be carefully and accurately checked. This is accomplished by the artillery mechanic or designated Ordnance machinist under the supervision of the Ordnance officers and/or non-commissioned officers who are thoroughly acquainted with the principles involved. Pending the publication of TM 9-1325, and FS titled, "Howitzer, 105mm, M2A1, and Carriage, howitzer, 105mm, M2", it is believed that the instructions to follow will serve as a satisfactory guide for use in connection with this work in the field.



The 105mm howitzer recoil mechanism, M2, is of the hydro-pneumatic, high pressure type and functions on the same general principle as the Puteaux mechanism found on 75mm gun carriages of the M1897 variety. It may also be classified as being of the constant recoil type. The actions of braking and counterrecoil are dependent, one upon the other.



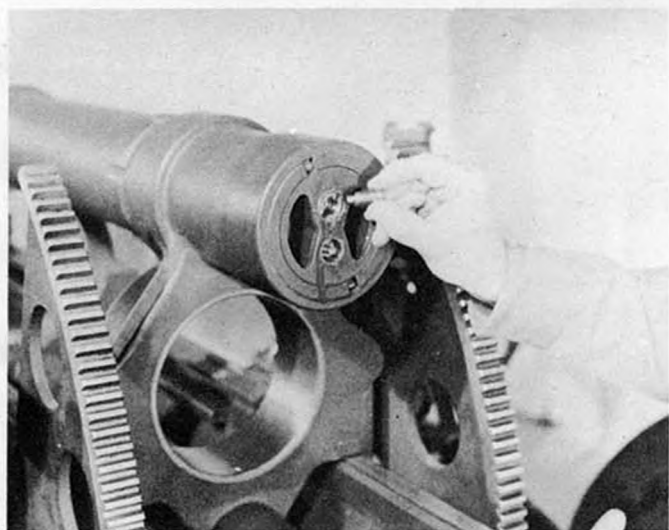
The mechanism consists primarily of (1) a recoil cylinder containing a recoil piston and piston rod and (2) a recuperator cylinder containing a floating piston and oil regulating device, the two being securely joined to a yoke at the front ends. The flow of liquid between the two cylinders is provided for by drilled passages through the body of the front yoke. The unoccupied space in the recoil piston and in the recuperator cylinder in front of the floating piston is filled with heavy recoil oil under pressure. The space in the recuperator cylinder in rear of the floating piston is filled with nitrogen gas under pressure. When the howitzer is fired, oil in front of the recoil piston is forced into the recuperator cylinder where it must pass through controlled orifices in the regulating device and thence force the floating piston toward the rear of the recuperator cylinder, thereby further compressing the nitrogen gas. Thus the energy of recoil is absorbed and the howitzer brought to rest. The highly compressed nitrogen gas acting on the rear of the floating piston then causes the oil to be forced back into the recoil cylinder and the pressure acting on the recoil piston head and recoil cylinder front head causes the howitzer to be returned to battery. Near the end of counter-recoil the passages in the regulating device through which the oil is being forced are restricted so that the howitzer moves into battery without appreciable shock.



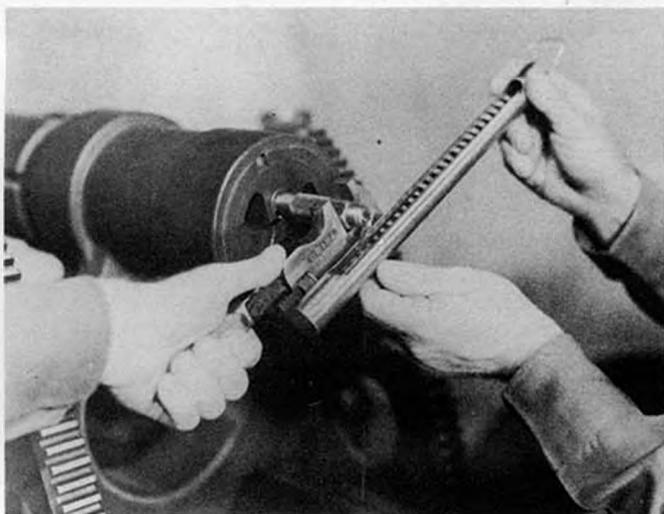
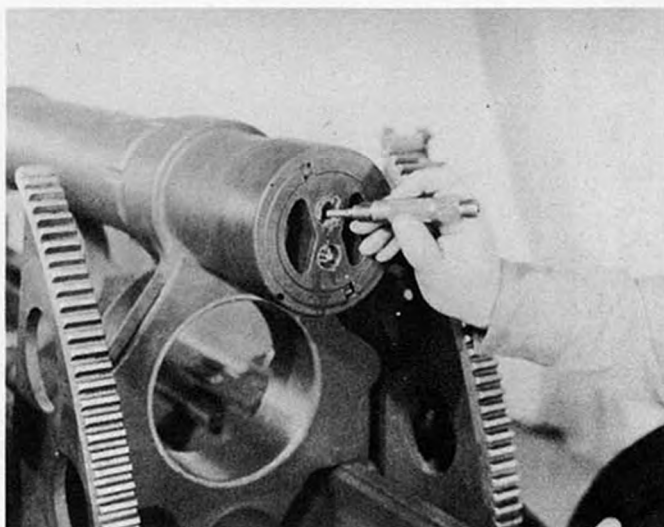
Prior to starting the detailed inspection of the recoil mechanism, the howitzer should be removed from the carriage, the piston rod outer nut removed and the recoil mechanism slid to the rear until the recoil cylinder head is slightly in rear of the end of the cradle.

Beginning the inspection, a careful visual examination of the mechanism should be made, paying particular attention to the possibility of oil leaks at the various cylinder heads and joints and at the filling and drain valve and oil index. The exterior surface of the cylinders should be examined for dents. A dented cylinder would of course render the recoil mechanism unserviceable.

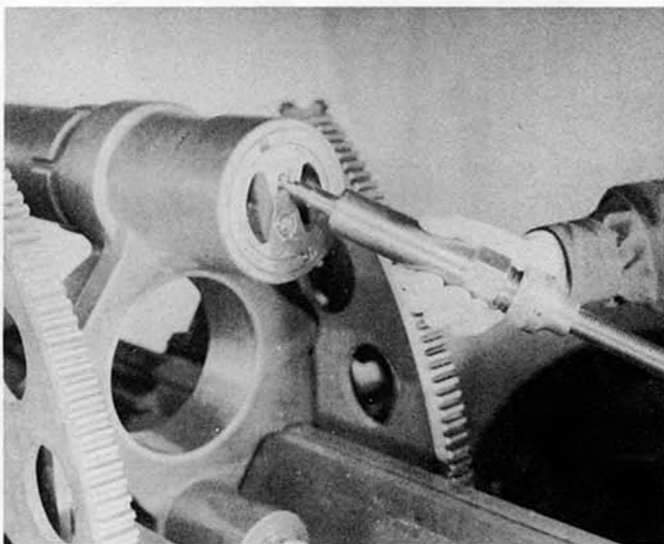
The position of the oil index should next be noted to determine whether proper oil reserve is being maintained. This is indicated if the index is flush with the front face of the cylinder head.



Next, a check should be made on the functioning of the oil index. This is accomplished by first draining off the reserve oil. As the oil is drained off the index should recede to the "in" position. This movement will be gradual and when the oil ceases to flow out under pressure the index should have reached the full "in" position, indicating no oil reserve and that the floating piston is against the regulator. The oil so drained should be caught in the thermometer receptacle, placed out of the sun, and the temperature of the oil recorded after a few minutes.



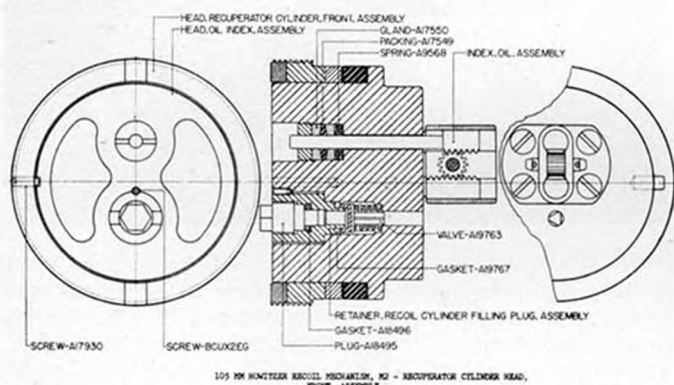
While draining the oil, careful observation should be made to determine whether there is presence of air or nitrogen in the mechanism. In case nitrogen has leaked past the floating piston the oil drained off is likely to be emulsified, milky or grayish in appearance, and a considerable amount of "sputtering" will occur instead of a steady stream of oil. In case of excessive amounts of air in the mechanism, it should be purged. This operation will be explained later.



In case it can be definitely established that a nitrogen leak exists, the mechanism should be removed from service and its condition reported to higher authority.



Establish a full oil reserve by forcing 1-1/2 screw fillers full of heavy recoil oil into the mechanism. If the index is functioning properly it will begin to move out when the force required to operate the screw indicates that there is evident pressure, after five to ten turns on the screw, and will be flush with the front of the cylinder head when approximately 1-1/2 fillers full have been introduced into the mechanism.



Should the oil index fail to function properly, the failure will normally occur on the "out" stroke. This is usually caused by excessive friction of the packing. To correct this condition loosen packing follower slightly. If this does not correct, without creating excessive leakage, it may be necessary to replace the packing. To do this proceed as follows:

a. Remove recoil cylinder rear head and install the piston rod jack. Turn the jack screw until it is firmly seated against the recoil piston head.

b. Drain off the oil reserve.

c. Using the special wrench provided remove the packing follower.

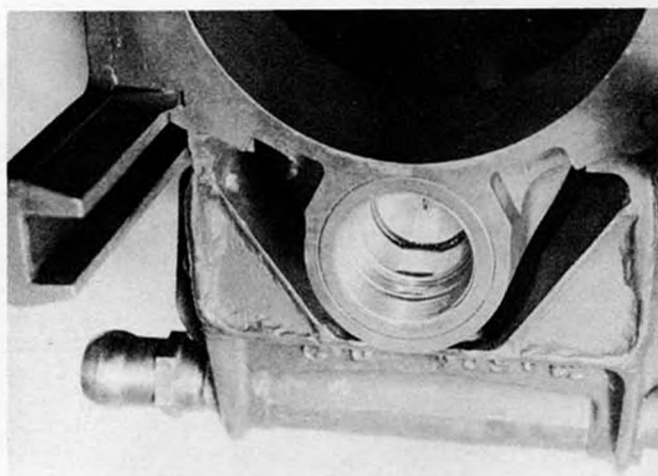
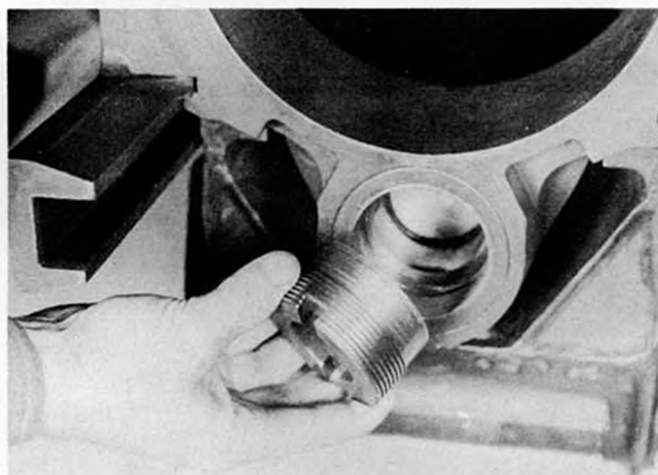
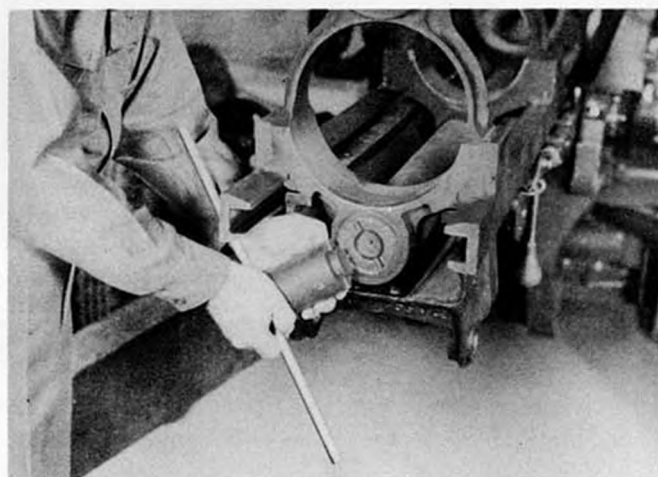
d. Turn the piston and jack rapidly, forcing the recoil piston forward. This will build up pressure in the oil column sufficient to force the packing and glands out.

e. Inspect the three belleville springs which will be found in rear of the rear gland to see that none are cracked or broken.

f. Replace packing and reassemble parts in reverse order of disassembly, tightening the follower only enough to prevent excessive leakage.

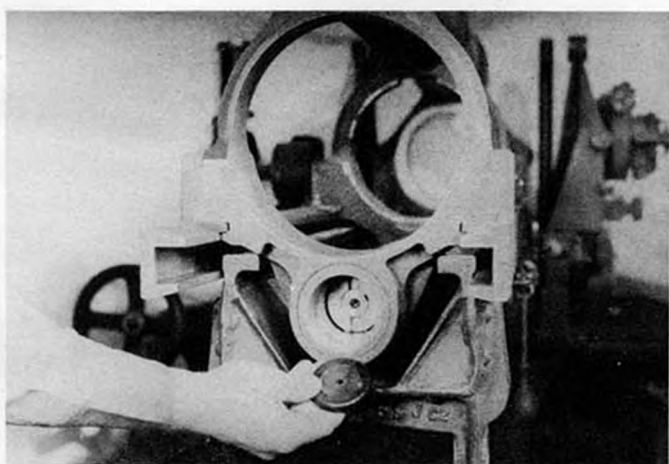
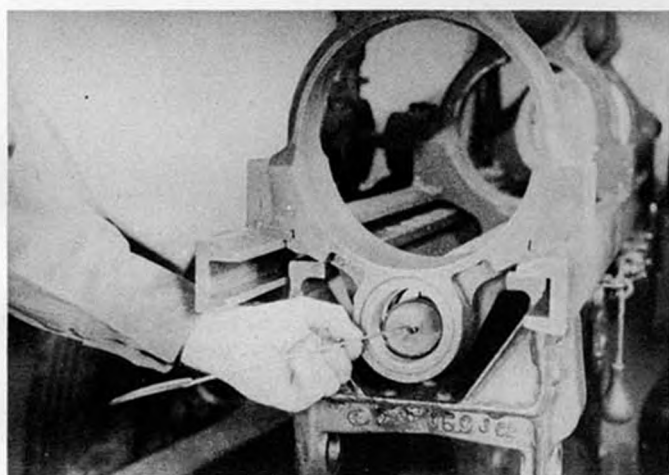
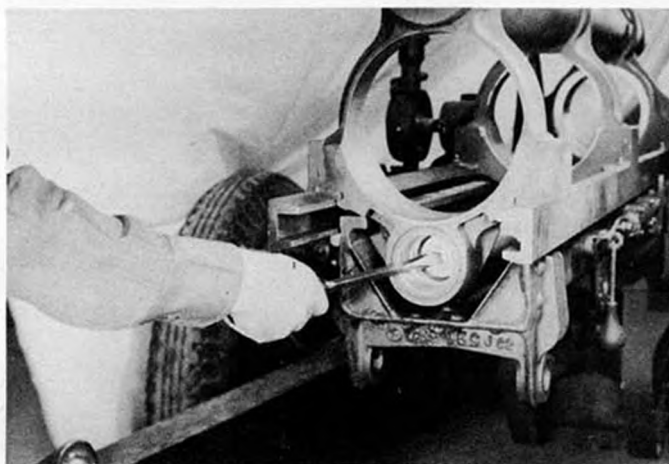
g. Completely retest the functioning of the oil index.

Sometimes it will be found that the index does not function due to rust, excessive paint, or, occasionally, a burr. In this case carefully remove the obstruction. If none of the above measures correct the condition it is indicated that something inside the mechanism is out of order, and the recoil mechanism should be returned to an arsenal or designated base shop for repair.

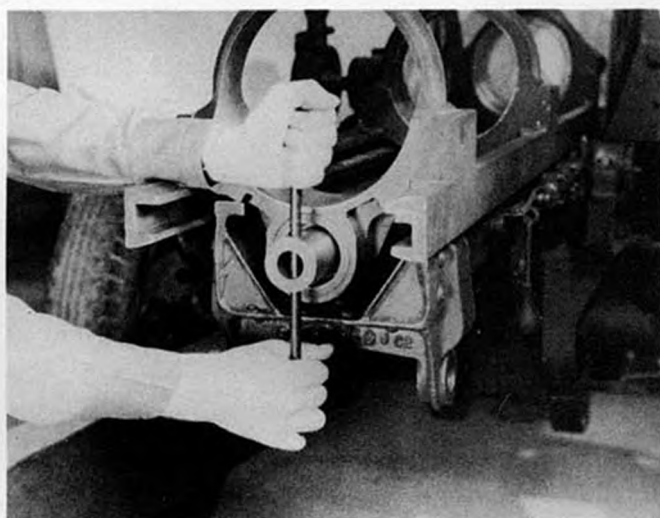
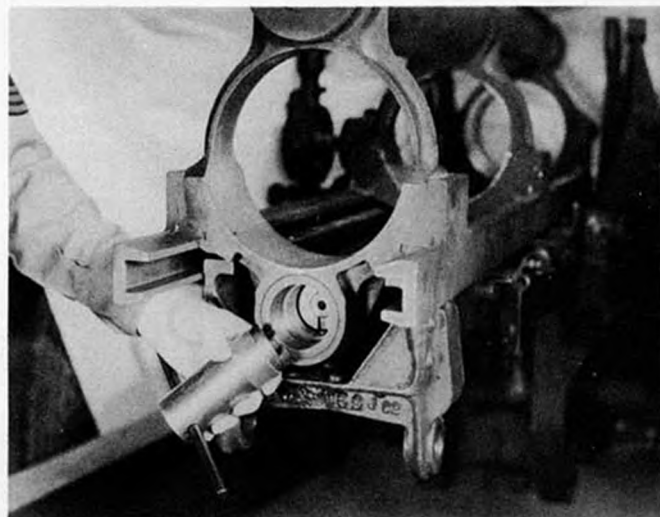


To resume the inspection, remove the recoil cylinder rear head and test the action of the ball valve by pressing the ball with a match stem or other soft material to insure that it opens and closes properly. Examine the rear of the cylinder for excessive oil leakage. This will show up by the presence of a considerable quantity of clean clear oil in rear of the piston head.

NOTE: A certain amount of leakage is to be expected and is perfectly normal, as the piston packing is lubricated by this means.

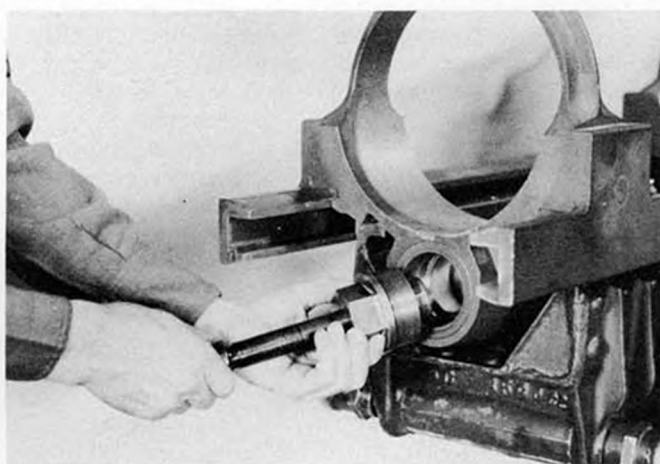


Remove the piston wiper assembly from the piston head and examine the leather to determine whether it has become dirty or glazed. Clean or replace leather if necessary.

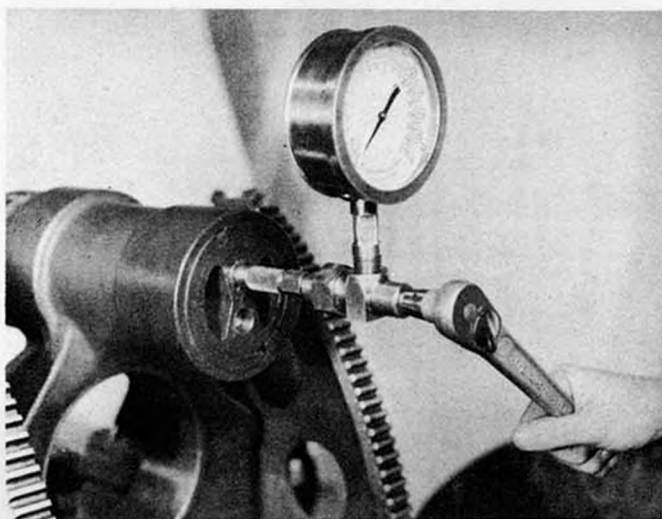
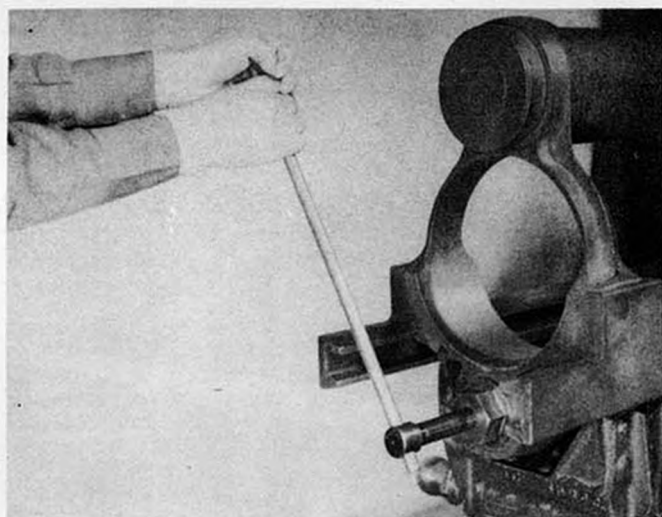
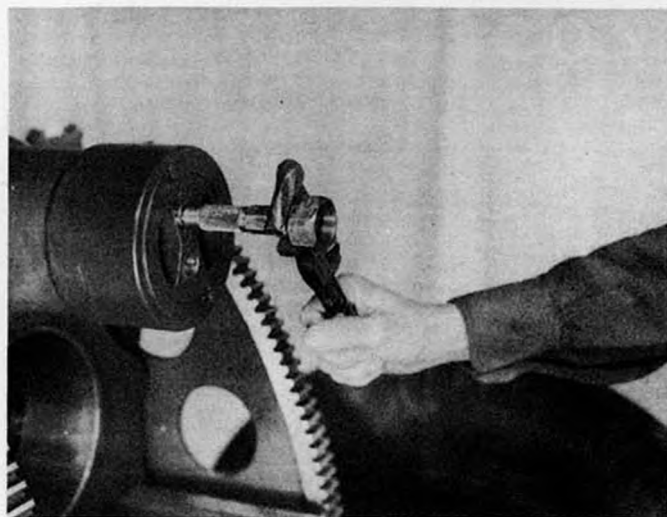


In case of excessive leakage past the recoil piston, tighten the piston head slightly (not to exceed about 1/4 turn), using the special wrench provided for that purpose.

NOTE: If this operation increases the combined friction of the recoil piston and stuffing box packings to exceed the prescribed tolerances it cannot be allowed. Instructions for friction tests will be given later.



Replace the piston wiper assembly and stake the screw. Install the piston rod jack and tighten the nut securely. Turn the jack screw until the head contacts the piston head.



Again drain the oil reserve and connect the pressure gage to the mechanism in the manner shown, being careful that all joints are securely tightened. Before installing the plug into the gage connection turn the piston rod jack enough to expell air from the connection. Start the plug about two or three threads and again turn the jack to completely expell air. Tighten plug securely.

NOTE: The gage used should be carefully checked by comparison with a master gage and the hand reset if necessary to insure accuracy.

Turn the piston rod jack so that the piston moves toward the front of the cylinder. This will create pressure in the oil column and finally start the floating piston moving to the rear. Continue turning until the oil index indicates a full oil reserve. Check all connections for leakage. Examine the stuffing box and note whether there is excessive oil leakage. The same general rule applies in this instance as for leakage past the recoil piston previously discussed. When necessary to correct for excessive leakage, tighten the stuffing box head a small amount (not to exceed approximately 1/10 turn), using the face spanner provided for this purpose.

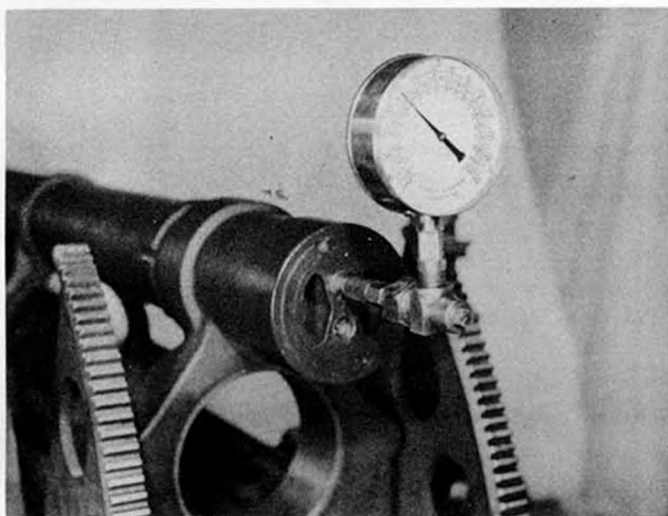
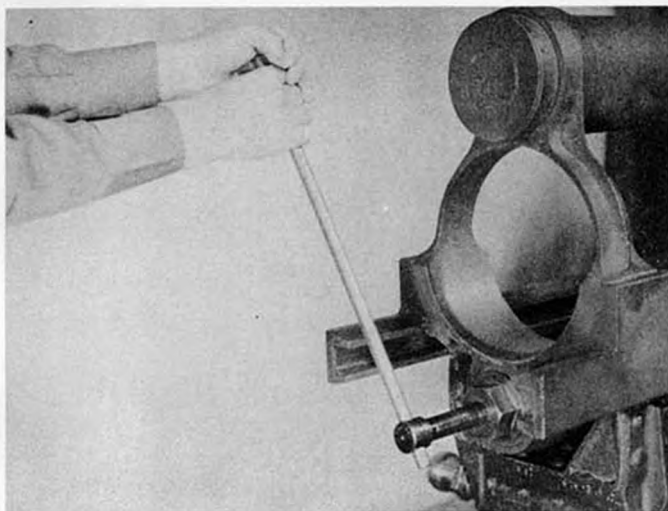
NOTE: Again, if this operation increases the combined friction of the recoil piston and stuffing box packings in excess of the prescribed tolerances it cannot be allowed.

At this time examine the exposed end of the piston rod paying particular attention to the possible presence of scratches or scoring. If either of these conditions exists, drain the reserve oil and, with adapter plug removed, jack the rod to the front so as to expose the front end. Carefully polish the piston rod with crocus cloth, using longitudinal strokes. In case a scored condition exists remove the piston rod inner nut and, using the small face spanner provided, remove the piston rod wiper follower and the leather wiper. Clean or replace the wiper, as necessary. Great care should be taken to insure that the piston rod is not damaged during this operation. Replace all parts in reverse order of disassembly.

NOTE: As a means of safety the piston rod inner nut should not be removed when there is pressure in the oil column nor unless the piston rod jack is installed.

To continue the inspection (the connections all being tight, the piston rod jack having been turned so as to establish a full oil reserve, the oil index then being flush with the front of the cylinder head) continue turning the jack slowly at a rate not to exceed four turns per minute. Read the pressure indicated on the gage and record. This reading is equal to the nitrogen pressure plus the friction of the floating piston (AP + F).

Continue turning the jack for two or three additional



revolutions. Reverse the jack and turn slowly in a counter-clockwise direction. It will be noted that the pressure indicated by the gage will decrease at a fairly uniform rate for a few turns. The gage hand will then pause momentarily while the next few turns are being made. At this point again read the gage and record. This reading is equal to the nitrogen pressure minus the friction of the floating piston (AP - F).

NOTE: It is important that both gage readings above be taken while the floating piston is in motion and it is therefore necessary that the readings be taken while the jack is actually being turned at a uniform rate.

Using the two gage readings above mentioned, it is possible to compute the actual pressure of the nitrogen in the recuperator cylinder, the pressure being equal to the mean of the two readings:

$$\text{Thus, } AP = \frac{(AP + F) + (AP - F)}{2}$$

When AP = Nitrogen pressure.

F = Friction of floating piston.

EXAMPLE: Atmospheric temperature = 70° F.

Gage reading (AP + F) = 1315 pounds per square inch.

Gage reading (AP - F) = 885 pounds per square inch.

Substituting: $AP = \frac{1315 + 885}{2} = 1100$ pounds per square inch, the gas pressure of the mechanism.

NOTE: The above test should not be made if the temperature of the recoil mechanism is lower than 50° F.

The recoil mechanism is charged with nitrogen gas at a pressure of 1100 pounds per square inch at 70° F. temperature. Since it is necessary to test the recoil mechanism at varying temperatures, it will therefore be necessary to make pressure corrections to compensate for this variation. As the gas pressure varies directly proportional to the absolute temperature (volume remaining constant) the following formula may be used:

$$\frac{P_1}{P_2} = \frac{T_1}{T_2}$$

Where, P_1 = initial pounds per square inch absolute pressure.

P_2 = final pounds per square inch absolute pressure

T_1 = initial absolute temperature

T_2 = final absolute temperature

Pounds per square inch absolute = gage pressure + 14.7

Absolute temperature = degrees F. + 460

Since the atmospheric pressure is small compared to the high pressures in the recoil cylinder, gage pressures may be substituted for absolute pressures in this formula without appreciable error. Substituting the initial conditions ($P_1 = 1100$ pounds per square inch and $T_1 = 70 + 460 = 530^\circ \text{ F}$) gives the following:

$$\frac{1100}{P_t} = \frac{530}{550} \text{ or } P_t = \frac{1100 \times 550}{530} = 1100 \text{ lbs per sq. in. where}$$

P_t = gage pressure in pounds per square inch at $t^\circ \text{ F}$.

t = temperature, $^\circ \text{ F}$., of the oil (and recoil mechanism)

EXAMPLE: What is the pressure at 90° F. when the mechanism was originally charged to 1100 pounds per square inch at 70° F.?

$$\frac{1100}{P_t} = \frac{530}{550} \text{ or } P_t = \frac{1100 \times 550}{530} = 1141.5+$$

Therefore, we may consider the correct pressure under the above conditions to be 1142 pounds per square inch.

In order for the recoil mechanism to be serviceable the nitrogen pressure must be 1100 pounds per sq. inch or within the allowable tolerance of $\pm$ (plus or minus) 100 pounds per square inch.

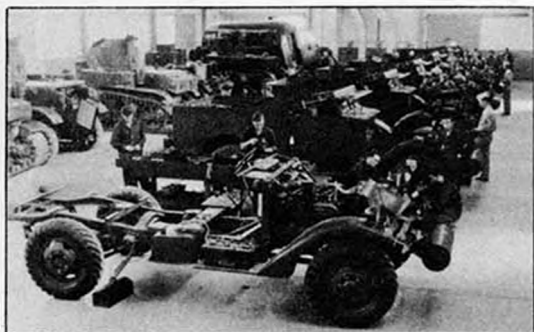
Again using the gage readings obtained above it is possible to determine the friction of the floating piston (F) in terms of gage pressure in pounds per square inch, since F is equal to one-half the difference of these readings:

$$F = \frac{(AP + F) - (AP - F)}{2}$$

Substituting:

$$F = \frac{1315 - 885}{2} = 215 \text{ pounds per square inch; value of the friction of the floating piston.}$$

(Continued on page 555)



Automotive

Conducted by:
J. W. WINSLOW,
M. Sgt., Ord. Dept.

REMOVAL OF BOGIE ROLLERS AND FRAMES WITHOUT REMOVING TRACK ON THE CAR, HALF-TRACK, M2

By: A. L. Hettrich, Capt., Ord. Dept.

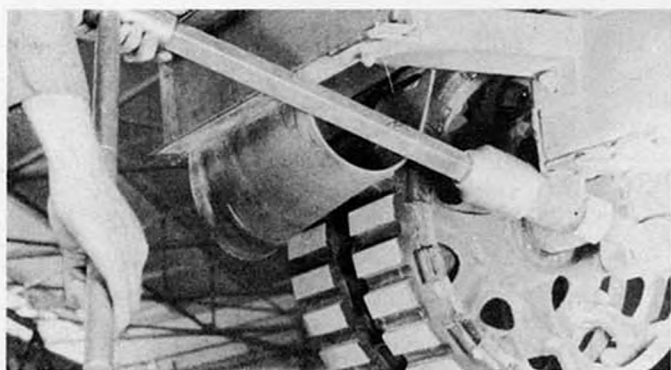


Fig. 1.

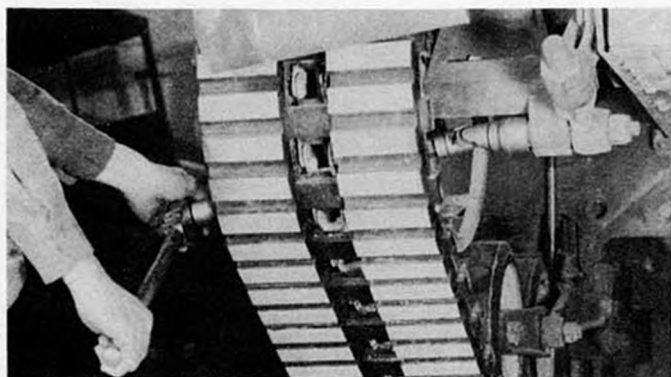


Fig. 2.



Fig. 3.

1. Remove Nut, special bronze (A215323) from end of Rod, idler adjusting (B185117) (Figure 1).

2. Loosen Nut, safety (A215354) a few turns on PIN, idler adjusting rod anchor (A215360) (Figure 2).

3. Bump idler adjusting rod anchor pin with a large hammer, and drift so that idler adjusting rod anchor pin will turn freely as IDLER, track adjusting assembly, (E3858) is pushed forward. (Figure 3).

4. Push idler assembly forward in order to loosen track. (Figure 4).

5. Remove 4 Screws, Cap (BANXIEE) that hold ROLLER, top assembly, (D48424) to BRACKET, bogie frame assembly, (D48423) (Figure 5).

6. Remove top roller assembly from bogie frame bracket assembly. (Figure 6).

7. Place special crab arm assembly hooks (Figure 7), on top of bogie frame bracket assembly so that hooks will hold up CRAB, bogie assembly, (D48407) (Figure 8.) Tighten

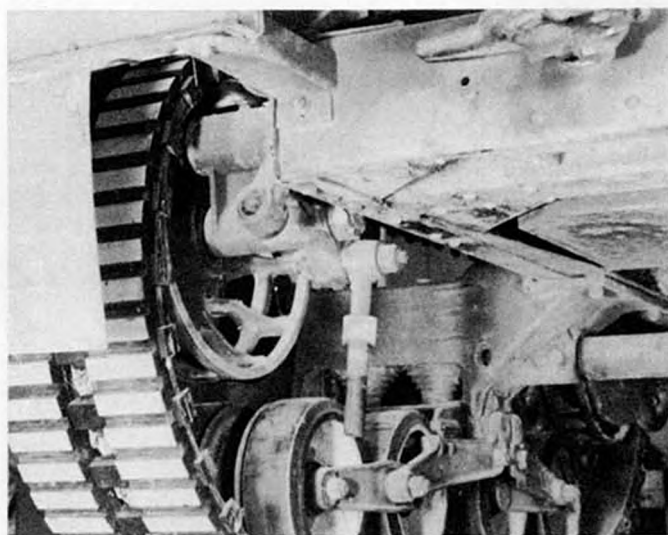
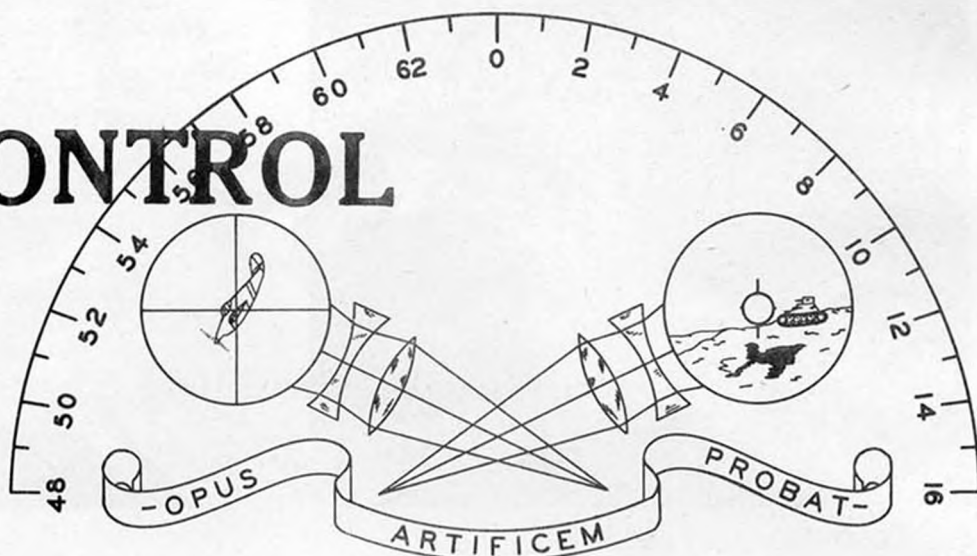


Fig. 4.

FIRE CONTROL

Conducted by:
R. L. JOHNSON,
Captain, Ord. Dept.



BINOCULAR, M3

GENERAL. - The new, standard Binocular, M3, (SNL F-210) is replacing the Glass, field, type EE as fast as manufacturing facilities permit. Ordnance maintenance units may already be encountering this instrument in the field, and in the absence of specific reference material the following information is furnished.

COMPARISON. - The binocular, M3, is lighter and more compact than the older, EE model. These instruments are being manufactured by Bausch and Lomb, and the M3 model is being turned out by other manufacturers as well. This may lead to minor variations between models.

Both the M3 and the EE models are 6-power, 30-mm aperture, binocular instruments, used for observation

and the measurement of small vertical and horizontal angles. Both have a radius of stereoscopic vision of approximately 6,000 yards. In general, the optical systems and mechanical construction are very similar. There are, however, minor variations with which the instrument repairman should be familiar.

The erecting prisms of the M3 model are mounted in a holder and must be considered an assembly for replacement and repair. No attempt should ever be made to replace a porro prism in the M3 Binocular in the field. Rather, the entire erecting system of the telescope (either right or left) should be replaced. This does not hold true with the EE model, where the prisms may be replaced individually.

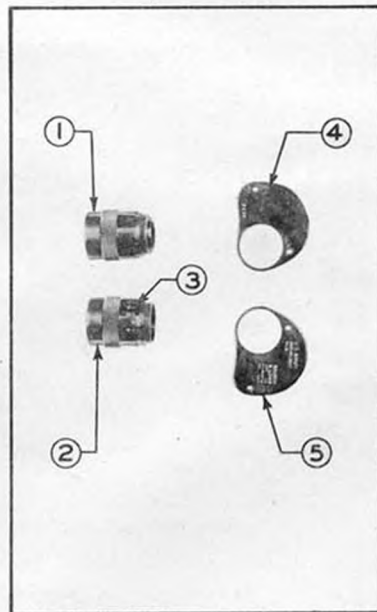
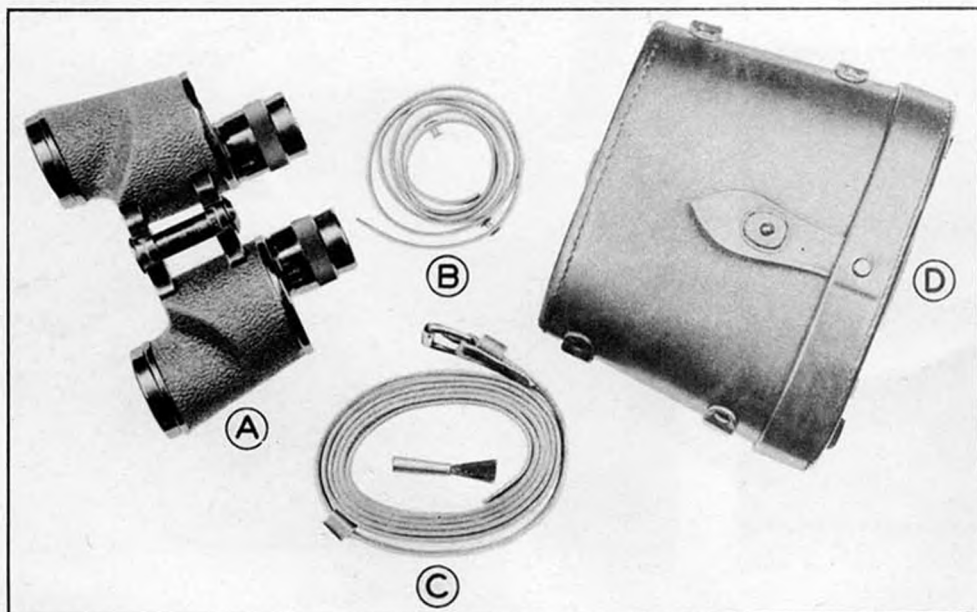
Another important variation, found in the M3 binocular, is the mounting of the objective lenses. They are mounted in eccentric cells capable of being rotated.

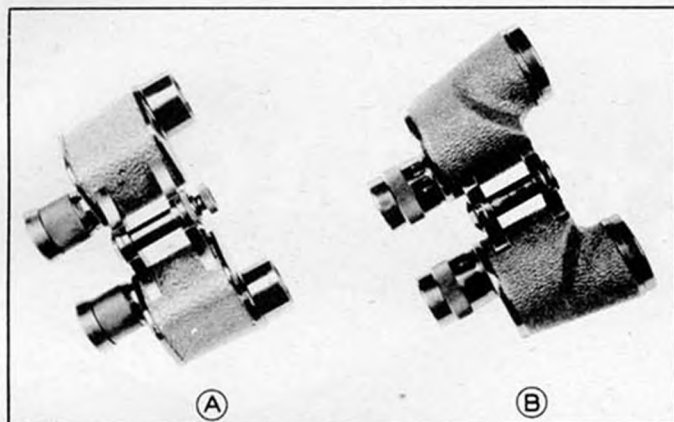
BINOCULAR, M3 (Complete)

- A - Binocular, M3
- B - Neck strap
- C - Carrying strap
- D - Carrying case

BINOCULAR, M3

- 1 - Left eyepiece
- 2 - Right eyepiece
- 3 - Diopter scale
- 4 - Left cover plate
- 5 - Right cover plate





FIELD GLASSES

- A - Glass, Field, Type EE
(Limited standard)
B - Binocular, M3
(New standard)

The importance of this fact will be found in the discussion on adjustment.

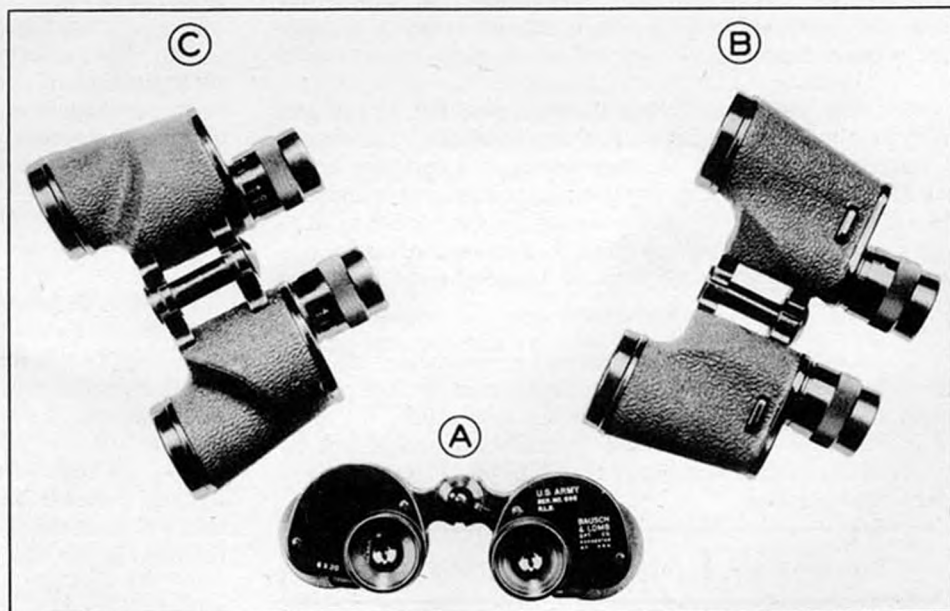
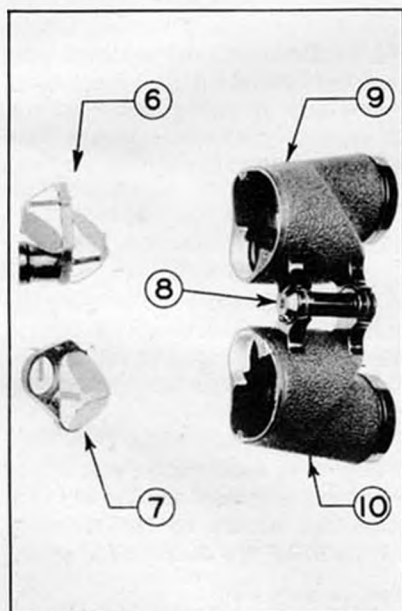
DISASSEMBLY. - When disassembling the M3 Binocular, which should only be done by experienced Ordnance personnel, and then only when absolutely necessary, the same precautions must be exercised as for the EE model. All elements should be carefully marked and wrapped to insure reassembly to the same position they originally occupied. This will simplify final adjustment. Pay particular attention to proper sealing and complete cleanliness of all optical components. Avoid excess lubrication of the focusing movements, and prior to any lubrication refer to OFSB 6-F-1.

REASSEMBLY. - Similar precautions must be observed for reassembly, sealing and cleaning being the two operations which must be strictly supervised. The use of proper metal cleaning solvents, and the cleaning of lenses and prisms, will determine the standard of the finished job.

- 6 - Left prism assembly
(with reticle)
7 - Right prism assembly
8 - Interpupillary scale
9 - Left body
10 - Right body

BINOCULAR, M3

- A - Rear view
B - Bottom view
C - Top view



ADJUSTMENT. - Parallax in the M3 is eliminated in a manner similar to that used in the EE model.

Double vision is eliminated by collimation. This collimation is accomplished by rotation of the eccentric objective cells, rather than by manipulation of the porro prisms as in the EE model. This greatly simplifies the work of the instrument repairman. Formerly, collimation was a tedious job requiring great patience and considerable skill.

Other phases of adjustment, repair and replacement, are similar to the EE glass, and accomplished in the same manner. Replacements of prisms (erecting) must be accomplished by replacing the entire assembly. These assemblies are procured as a unit.

RETICLE. - Great care must be exercised in cleaning the reticle of the M3 Binocular, as the reticle pattern is not etched into the glass. Cleaning the reticle with alcohol in the usual manner will cause the removal of the reticle pattern. This is caused by a new method of manufacturing them. This difficulty, which complicates the cleaning and adjustment of the instrument, will probably be eliminated very shortly. However, it will still be encountered in the earlier models in existence, until this type of reticle has been replaced.

Clean the reticle only as a last resort, and then do it by the application of the air bulb, camels hair brush, or very light polishing with lens tissue, observing the graduations and pattern very closely that they are not damaged.

INSPECTION. - Inspection of the M3 Binocular is identical with the procedure utilized for the glass, field, type EE.

SUMMARY. - Section leaders of instrument sections in the field should acquaint their sections with the precautions applying to the binocular, M3 when the instruments start showing up for repair and adjustment. All personnel in the Ordnance Department engaged in maintenance operations should familiarize themselves with the Binocular M3 at the earliest opportunity since it is very likely that these instruments will be in the field in quantity in a very short time.

Administration

Conducted by: J. E. Dempsey, 1st Lt., Ord. Dept.

The statutory sources for company punishment — A.W. 104 and Chapter XXIV, Manual for Courts-Martial 1928 — are limited in directing a method for maintaining a record of disciplinary action. As a general rule commanding officers use their own discretion in the methods employed in keeping a record. Whether the record is a "black book" or a file, the object of any system is to keep for record the essential facts—the name of the person involved, the manner of the offense, and the punishment imposed.

Provisions of A. W. 104 state that commanding officers of any detachment, company, or higher command may, for a minor offense, and without intervention of a court martial, impose disciplinary punishments upon persons subject to military law, including officers.

In the interests of justice and discipline the cardinal principle employed in imposing company punishment is to make the "punishment fit the crime". The powers outlined under A.W. 104 cannot be delegated to another individual. Whether or not a case will be punished under A. W. 104 depends on whether it is "minor". In determining this commanding officers will take into consideration "the time and place of commission, and the person committing it."

Generally speaking, cases that fall within the jurisdiction of company punishment are instances "not involving moral turpitude." And these derelictions should not be of greater magnitude, seriousness or criminality than are involved in the average offense tried by a summary court martial.

The authority of this Article does not in any way interfere with or overlap nonpunitive measures authorized a commanding officer. In other words, if a company commander employs "administrative admonitions, reprimands, disapprovals, criticisms, censures or reproofs" to discipline his command—these measures are authorized above and beyond the methods delegated as punishment under the Article of War.

As a further consideration commanding officers should exercise great care in determining that cases singled out for punishment clearly are within the pale of A. W. 104. Court martial jurisdiction should not be resorted to when measures provided by the Article clearly serve the purpose.

By: Charles J. Arnold, S. Sgt., Ord. Dept.

COMPANY PUNISHMENT

A. W. 104 punishments which may be imposed are:

1. Admonitions and reprimands.
2. Withholding privileges for not more than one week.
3. Extra fatigue for not more than one week.
4. Restriction to certain limits (generally the confines of the company or the post) for not exceeding one week.
5. Hard labor for not exceeding one week.

Commanding officers are not authorized to impose forfeiture or deduction of pay under A. W. 104; however, the Article also includes the provision that a commanding officer of the grade of brigadier general or higher may impose upon an officer below the grade of major a forfeiture of not more than one half of such officer's pay for one month. With this exception the immediate commanding officer of the accused is charged with imposing punishment.

In imposing company punishment it is noted that hard labor will not be enforced as a punishment against any person of "actual, relative or assimilated rank" above that of private first class in the army. Punishment which tends to degrade the rank of the individual involved is not permitted.

The importance of an offense which requires company punishment should not be handled lightly. Any failure to impose punishment when it is required would have a highly deleterious effect on discipline, even worse than actual condonation of the offense for which punishment was imposed.

PROCEDURE

If a dereliction is punishable under A. W. 104, the immediate commanding officer of the accused will inform such member of his command of the nature of the offense and that punishment will be imposed unless a court martial is demanded.

(In case of an officer this notification will be by written communication through channels and the accused will be directed to acknowledge receipt by indorsement. Included in the indorsement will be any demand for trial.)

(Continued on page 556)



PACKING AND MARKING PROPERTY

By: Jack Hannula, M. Sgt., Ord. Dept.

The packing and marking of property for shipment is one subject that is not given as much thought as should be. If the person making the shipment would stop and give some thought to what the receiving officer has to contend with, it would eliminate a lot of trouble for the personnel having to check the shipment at the other end. Property is sometimes received in an unserviceable or damaged condition due to improper packing, resulting not only in added expense to the Government, but a delay in making the issue to the using arm, or in making the necessary repairs on articles that are in need of repairs before issue. The improper marking of packages for shipment often results in undue delay in the shipment reaching its destination.

There are various publications covering the methods of packing and marking property for shipment. One of the most recent being the ORDNANCE STORAGE and SHIPMENT CHARTS (OSSC). These charts are arranged and divided into groups much the same as Standard Nomenclature Lists, i.e., one for "A" group, one for "B" group, etc. These charts contain valuable information and should be on file in every office concerned with making shipments of property.

In making shipments of property the first step, and also a very important one is the selection of the property to be shipped. Only serviceable property should be selected for shipment. Unserviceable property should be shipped only when specific instructions have been received to do so. The property selected for shipment should be inspected by a person having the ability and knowledge to determine the condition of the property, preferably the property officer.

Articles that might deteriorate should be properly preserved before being packed for shipment. Weapons and other articles that might rust should be slushed, not only that they should reach their destination in good condition, but that if necessary, they can be placed in storage upon arrival at destination without further work in preparing the items for such storage. Articles that are affected by moisture should be wrapped in water proof paper or placed in suitable containers. In packing fire control and sighting equipment for shipment great care should be exercised in the method used in packing; these articles are very expensive and delicate, and can be very easily rendered unserviceable with improper handling. When fire control and sighting equipment is being shipped the instruments should be packed in packing cases provided for that purpose. The cases used to pack these articles are

manufactured so that the instrument can be placed in the case without the use of force if done in the proper manner.

In making shipments of small articles such as spare parts, etc., the articles should be placed in small boxes, tied in bundles, or packed in cloth sacks, and these marked or tagged before being placed in larger boxes for shipment.

At posts, camps, and stations as well as at depots and arsenals, small shipments of miscellaneous articles are packed in one container for convenience in shipment. In doing so it is important that all articles and small packages be marked or tagged to make it possible for the receiving officer to identify the contents of the package. A packing list, or a copy of the tally sheet should be placed in the box. Great difficulty is often experienced by the receiving officer in identifying articles received in shipment that are not tagged or marked in some way. This is especially true in the case of spare parts for weapons and automotive parts, due to the parts being similar in appearance but not being interchangeable in all cases.

In these days with inexperienced personnel and sometimes the lack of publications to identify articles, the improper tagging or marking of the contents of packages results in extra labor and a loss of time in identifying certain items received in shipment.

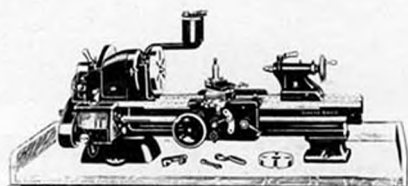
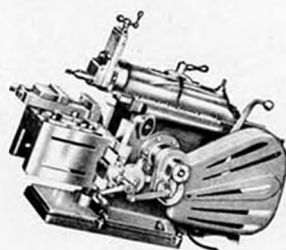
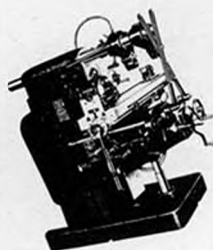
The term package as used herein applies to boxes, barrels, crates, bundles, etc. The marking of packages for shipment depends on the type of package. Due to the various types and shapes of packages it is difficult to lay down a hard and fast rule to follow, however, the principles and the methods outlined can be used as a guide.

If possible only the prescribed material should be used in marking packages for shipment. Standard Specifications 100-2D, lists the type of paint, ink, etc., to be used. Of course it is understood that these prescribed materials are not always available, consequently other material must be used. In no case should lead pencil, writing ink, or chalk be used.

In marking packages for shipment the first step is to remove or deface all old markings neatly. No advertising matter should appear on the packages, except that usually used by manufacturers on their containers. The location of the markings should be such that it will not become obliterated under normal handling. The markings should be placed on one end and on one face of boxes, on one side and on one end of barrels, never on the bulge

(Continued on page 556)

THE MACHINE SHOP



Conducted by: F. P. Bingert, T. Sgt., Ord. Dept.

TRAINING THE ORDNANCE MACHINIST

By

F. P. Bingert and G. E. Tibbetts,
Technical Sergeants, Ord. Dept.

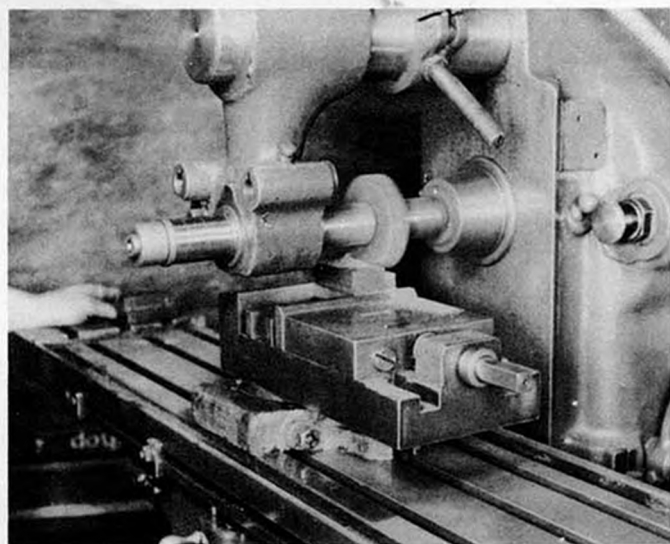
In the May issue we came to that phase of the course which covered the engine lathe. In this article we will cover the Milling Machine, and explain its parts.

As stated previously, when a new machine is being introduced, the students are divided into small groups with an instructor attached to each group. They are then assembled around the machine, and required information imparted to them. In this case, it is as follows:

- a. Nomenclature, capacity, and function of various groups, care and maintenance.
- b. Feeds and speeds.
- c. Attachments and their uses.
- d. Safety precautions toward students and machine.
- e. Care in selection and mounting of cutters.
- f. Mounting of work.
- g. Milling Machine Operations.
 1. Face Milling.
 2. End Milling.

3. Form Milling.
4. Grooves, keyways, and slots.
5. Use of index head.
6. Use of Vertical attachment.

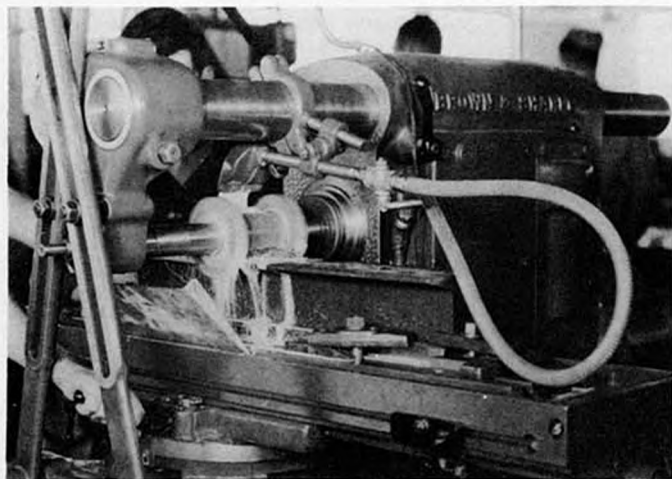
The students are not led to believe that the particular machine we have in the shop is the only type used, but we do stress our particular machine, as it is of the same type being used on our present shop trucks. But regardless of whether a machine is manufactured in, Cincinnati, Ohio, or Providence, R. I., the fact remains that the principles



still remain the same; also, if a man is taught to operate a bench type machine he should have little difficulty in operating a large floor type machine.

The Milling Machines being used for instructional purposes in our machine shop, are Browne and Sharpe, No. 2A Universal Milling Machines. The following is a brief outline, which will explain the Milling Machine in general:

(Continued on page 539)



THE
ORDNANCE SERGEANT

presents

An Introduction

to

Automotive Theory

by

THE AUTOMOTIVE SECTION
OF THE
ORDNANCE SCHOOL

JUNE

ORDNANCE TRAINING CENTER
ABERDEEN PROVING GROUND
MARYLAND

1942

CONTENTS

PART I - THE ENGINE

The internal combustion engine	477	The crankcase	482
The Otto cycle	477	Piston rings	483
Diesel cycles	477	Piston pins	483
Compression ratio	478	Connecting rods	484
Volumetric efficiency	478	Bearings	484
Thermal efficiency	478	Valves and valve seats	484
Power and work	478	Camshafts	485
Torque	479	Valve operating mechanism	486
Valves and valve timing	480	Crankshafts and vibration	486
Classification of engines	480	Cooling systems	488
Method of cooling	480	Air cooling	488
Valve arrangement	480	Water cooling	489
Cylinder arrangement	481	Engine lubrication	490
Cylinders	481		

PART II - FUEL SYSTEMS AND FUELS

Fuel system	492	tion	499
Fuel tanks	492	Intake manifold gasket	499
Gasoline gauges	492	Intake manifold heat riser	499
Electric gauges	492	Carbon intake manifold	499
Hydrostatic gauges	492	Carburetor trouble shooting	499
Fuel pump	492	Circuit Number 1	499
Electric fuel pump	493	Circuit Number 2	499
Carburetion	494	Circuit Number 3	499
Intake manifold pressures	495	Circuit Number 4	500
Carburetor circuits	495	Circuit Number 5	500
Float level	496	Air cleaners	500
Low speed system	496	Governors	500
High speed system	496	Centrifugal governor	500
Pump or accelerating circuit	497	Velocity or vacuum governors	501
Vacuum type accelerating pump	497	Manifold construction	501
Choke system	498	Mufflers	501
Climatic control or automatic choke	498	Muffler trouble	501
Air cleaner	498	Muffler abuse	501
Throttle linkage	498	Gasolines, engine oils, gear oils,	
Gasoline line	499	greases, diesel fuels	502
Exhaust system	499	Gasolines	502
Intake manifold	499	Engine oils	503
Manifold heat control	499	Gear oils	504
Vacuum spark advance connection	499	Greases	504
Windshield wiper hose and connec-	499	Diesel fuels	506

PART III - FUNDAMENTALS OF ELECTRICITY

Basic principles	507	The starting motor	511
Units of measurement	508	The charging circuit	512
Electrical circuits of the automotive		The ignition system	513
vehicle	509	Ignition timing	514
Starting circuit	509	The accessory circuit	515
The storage battery	510		

PART IV - THE POWER TRANSMISSION SYSTEM

Clutches	515	Cam and lever	527
Adjustment for clutch wear	516	Recirculating ball type	527
Tank clutch	516	Steering linkage	527
Transmissions and transfer cases	517	Maintenance	527
Transmissions	517	Brakes	528
Transfer cases	520	Braking requirements	528
Light tank transmission (syncro-		Stopping distance	528
mesh)	521	Maximum retardation	528
Propellor shafts and universal joints	523	Materials used in brakes	528
Propellor shafts	523	Brake classification	528
Universal joints	523	Types of fundamental brakes	528
Final drives	524	Types of brakes	532
Differentials	525	Mechanical	532
Final drive unit (Tank)	525	Hydraulic	532
Controlled differential used in tanks	525	Vacuum	532
Driving axles	526	Electric	533
Steering mechanisms	526	Air	533
Worm and sector	526		

PART I

THE ENGINE

An engine may be described as a machine that produces power to do work, particularly one that converts chemical energy to heat energy to mechanical energy.

THE INTERNAL COMBUSTION ENGINE

An internal combustion engine is one which obtains its power by the combustion or burning of fuel in confining spaces, called cylinders. The operation of all heat engines is based upon the expansion of a burning gas. In this class fall all gasoline and Diesel engines. This shows that an internal combustion engine involves a basic law of physics known as Charles's law, which states that a gas under constant pressure will expand if its temperature is raised.

The operating parts of an internal-combustion engine are shown in Figure 1. A close-fitting piston is free to slide up and down in a

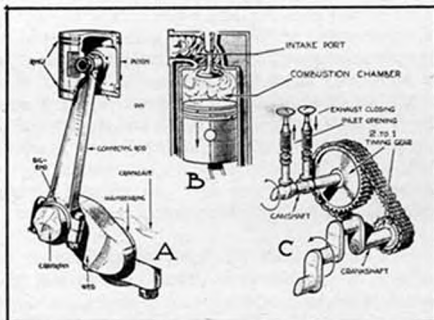


Fig. 1 - The operating parts of a four stroke Otto cycle engine.

cylinder while maintaining a gas-tight seal against the cylinder wall. The cylinder is mounted or built integrally with the crankcase, Figure 2, which contains the crankshaft, Figure 1, carried on the bearings. The connecting rod is joined at its upper end to the piston by means of the piston pin, and at its lower end is attached to one of the crankpins (journals of the crankshaft.) With the piston in the position shown, an expanding gas confined in the upper portion of

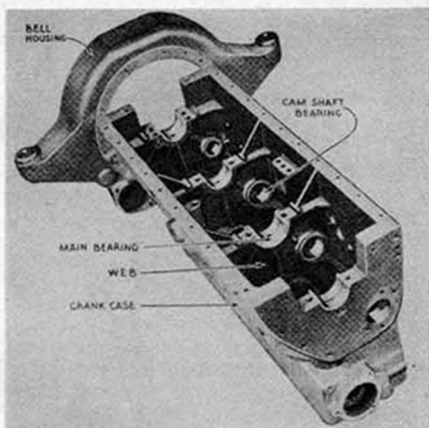


Fig. 2 - Crankcase.

the cylinder will cause the piston to move downward. This motion will be transmitted by the connecting rod to the crankpin, causing the crankshaft and the flywheel to rotate. The momentum of the flywheel will cause the crankshaft to continue its rotation, thus returning the

piston to its former position in the cylinder, provided the pressure of the burned gases in the cylinder is relieved. If the gas in the cylinder is compressed before it is burned, the pressure of expansion is increased. Successive applications of pressure to the piston will serve to repeat this motion of the mechanism thus producing a continuous rotation of the crankshaft.

To make use of the expansion power of burning gases in an internal combustion engine it is necessary that:

- (1) A combustible charge be introduced into the cylinder and the cylinder then sealed.
- (2) The charge be compressed.
- (3) The charge be ignited and burn.
- (4) The expanding gases drive the piston downward.
- (5) The burned gases (exhaust) be expelled.
- (6) There be a means of repeating these events to produce continuous rotary motion from the power strokes of the piston.

In order to continue running and to deliver continuous power, an internal combustion engine must repeat over and over again a certain definite series of operations. Each operation is called an event and a cycle is a succession of events repeated in a regular order.

THE OTTO CYCLE

Any gasoline engine that requires four strokes of the piston, two down and two up (consequently, two complete revolutions of the crankshaft), to complete a cycle of events is called a four-stroke-cycle engine. Since the four-stroke cycle employed in the modern gasoline engine follows closely a thermodynamic principle discovered by Dr. N. A. Otto in 1876, it is referred to as the four-stroke Otto cycle. The operation of this engine is as follows.

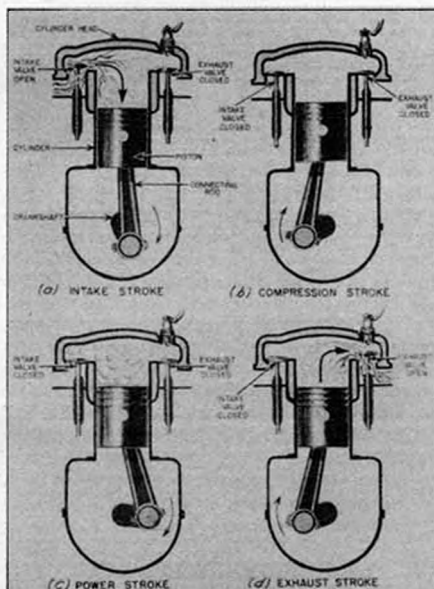


Fig. 3 - Diagram showing the events of one complete cycle of a four stroke Otto cycle internal combustion engine.

(1) Intake stroke, Figure 3a. The piston starts from its topmost position or top dead center (T.D.C.) With the exhaust valve closed and the intake valve open, the piston moves downward, creating a partial vacuum or suction in the cylinder that draws a charge of fuel and air through the intake valve port into the cylinder. When the piston reaches the bottom of its stroke, or bottom dead center (B.D.C.), the intake valve closes and traps the cylinder full of fuel mixture. The intake and exhaust valves are assumed to open and close at top or bottom dead center of the piston for purposes of explanation. The actual points of opening and closing vary widely as will be explained in valve timing.

(2) Compression stroke, Figure 3b. On the second stroke of the piston, the intake valve and exhaust are closed, and the charge is trapped and compressed into the small clearance space (combustion chamber) above the piston. The temperature at the end of the compression stroke will reach from 500 degrees to 600 degrees F., and the pressure will be from 80 to 140 pounds per square inch. Toward the end of this stroke the charge is ignited by an electric spark which is made to jump between the points of a spark plug. Upon completion of this stroke the crankshaft has revolved one complete turn, or 360 degrees, and the piston has made two strokes, down and up.

(3) Power stroke, Figure 3c. The pressure resulting from the expansion of the burning fuel mixture forces the piston downward, turning the crankshaft and thus developing power. Both valves remain closed during this stroke. The highest pressure developed will be approximately four times that at the end of compression, and the temperature of the flame may increase to about 4000 degrees F. The exhaust valve opens when the gases still have a pressure of about 50 pounds per square inch and a remaining temperature of about 2,500 degrees F.

(4) Exhaust stroke, Figure 3d. As the piston reaches bottom dead center position the exhaust valve opens and the pressure on the piston is immediately relieved. The exhaust valve remains open while the piston again moves upward to top dead center, forcing the burned gases out of the cylinder through the exhaust port. The crankshaft has now made two complete revolutions, or 720 degrees of circular movement, and the camshaft has made only one revolution. The intake and the exhaust valve have each opened and closed only once.

DIESEL CYCLES

In general, the events of the four-stroke Diesel cycle are similar to those of the four-stroke Otto cycle. The principle differences are in admitting and igniting the fuel. Air only is drawn into the cylinder on the intake stroke, and compressed to much higher pressure. Compression pressures of 500 pounds per square inch or more are common in Diesel engines. These extremely high pressures raise the air temperature to about 1000 degrees F. Just before the piston reaches top dead center on the compression stroke, a measured quantity of fuel oil is forced into the cylinder through a fuel injection system. The high temperature of the air in the cylinder ignites the injected fuel, and the power stroke follows. This principle of ignition, by taking advantage of the higher temperatures created by the greatly increased compression, eliminates the necessity for an ignition system.

In the two-stroke-cycle Diesel engine the intake and exhaust take place during part of the compression and power strokes. A two-stroke-cycle Diesel engine, therefore, does not function as an air pump, so an external means of supplying the air is provided. A specially designed blower, bolted to the side of the engine, forces air into the cylinders in order to expel the exhaust gases and fill the cylinders with fresh air for combustion, as shown in Figure 4.

A series of ports cut into the circumference of the cylinder wall above the piston, in its lowest position, admit the air from the blower into the cylinder as soon as the top face of the piston uncovers the ports, as shown in Figure 4a. The unidirectional flow of air toward the exhaust valves produces a scavenging effect, leaving the cylinders full of clean air when the piston again covers the inlet ports.

As the piston continues on the upward stroke, the exhaust valves close and the charge of fresh air is subjected to the final compression in Figure 4b.

Shortly before the piston reaches its highest position, the required amount of fuel is sprayed into the combustion space by the unit fuel injector, as shown in Figure 4c. The intense heat generated during the high compression of the air ignites the fine fuel spray immediately, and the combustion continues as long as the fuel spray lasts. The resulting pressure forces the piston downward until the exhaust valves are again opened. As shown in Figure 4d, the burnt gases escape into the exhaust manifold as the downward moving piston is about to uncover the inlet ports. When these ports are uncovered, the cylinder volume is again swept with clean scavenging air, as shown in Figure 4a. This entire combustion is completed in each cylinder for each revolution of the crankshaft, or, in other words, two strokes, hence, the "two-stroke cycle."

From the above explanation the principal difference between the Otto and Diesel cycles are:

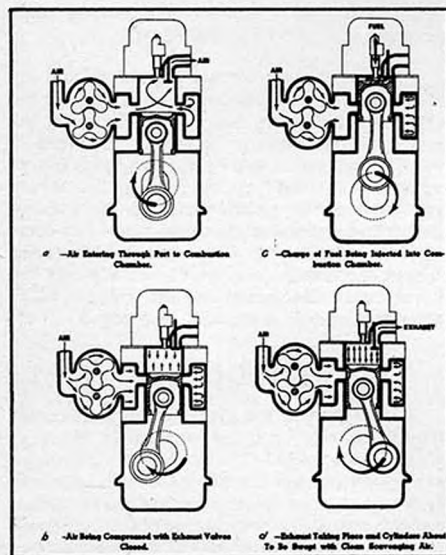


Fig. 4 - Two stroke Diesel cycle.

(1) Fuel is mixed with air after compression in the Diesel and before compression in the Otto cycles.

(2) Much higher compression is used in the Diesel than in the Otto cycle.

(3) The Diesel cycle has approximately constant-pressure combustion while the Otto cycle has approximately constant-volume combustion.

(4) The Diesel cycle requires no source of ignition while the Otto cycle does.

These differences exist in the two-stroke cycle as well as in the four-stroke cycle.

COMPRESSION RATIO

The compression ratio of an engine is the total volume of the cylinder divided by the clearance volume, or

$$\text{Compression ratio} = \frac{\text{Displacement volume plus clearance volume}}{\text{Clearance volume}}$$

A study of Figure 5 shows the relationship of these volumes. The volume above the piston, when it is at top dead center, is the clearance volume (minimum volume). The displacement volume is the increase in volume as the piston moves to bottom dead center. Volumes only should be considered in referring to compression ratio. Pressures are sometimes confused with this term.

Early makes of engines used compression ratios of from 3 to 1 to about 4 to 1, and were known as low compression engines. If higher compression ratios were used at that time the gasoline would cause detonation or pinging because it burned too rapidly. When slower burning gasolines were developed, particularly the ethyl-treated type, it was possible to use higher compression ratios. Modern engines of today

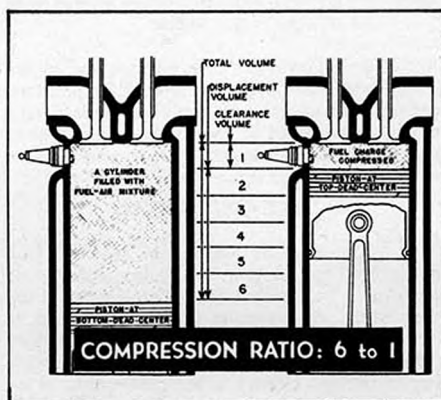


Fig. 5 - Diagram showing compression ratio in terms of total, clearance and displacement volumes.

are built with a compression ratio of at least 5 or 6 to 1 and some go as high as 7.5 or 8 to 1. This results in higher horsepower output and an increase in operating efficiency for any given engine.

This increase in power is principally due to the fact that the pressure existing above the piston at the end of the compression stroke is multiplied approximately four times when the mixture is ignited and the burning gases expand. Thus, an engine using a compression ratio which results in a compression pressure of 100 pounds per square inch would have a combustion pressure of 400 pounds per square inch to work against the piston head. On the other hand, if a higher compression ratio is used so that the compression pressure will be, say, 125 pounds per square inch, then a combustion pressure of 500 pounds per square inch will work against the piston head. Thus, by increasing the compression pressure 25 pounds per square inch, the working pressure was increased 100 pounds per square inch.

VOLUMETRIC EFFICIENCY

The power output of an engine is dependent upon the amount of the fuel mixture drawn into the cylinder. Theoretically, each time the piston goes down on the intake stroke

the space vacated by the piston is filled with a combustible mixture. Unfortunately this is not the case. The ratio between the amount taken in, corrected to standard pressure, and the amount that should have been taken in determines volumetric efficiency. For most modern engines its value equals

$$\frac{\text{Volume of mixture drawn in}}{\text{Displacement per stroke}} \text{ or about } 90\%.$$

THERMAL EFFICIENCY

Thermal efficiency is the ability to convert heat into mechanical energy. About 30% of the heat generated is converted into work, 30% is lost to the cooling system, and 40% is lost to the exhaust system. Thermal efficiency equals

$$\frac{\text{Heat converted into mechanical work}}{\text{Total heat supplied to the engine}}$$

A portion of the power developed by an engine is lost in the engine by performing work necessary to overcome internal friction. Mechanical efficiency equals the ratio of the energy delivered by the engine to the energy put into it. About 85% of the work done on the pistons is delivered to the flywheel.

POWER AND WORK

Until a machine which could compete with a horse had been devised, there was no need of a measurement of power. But with the advent of the steam engine and internal combustion engine a term was needed to express the ability of a machine. It was only natural to turn to the horse for a basis of comparison. It was found that a strong horse hoisting coal from a mine could lift a load of 550 pounds while walking at an average speed of one foot per second during periods of a few minutes each.

James Watt rated his steam engine in terms of horsepower, using this rather unscientific basis of 33,000 foot-pounds of work per minute. This unit of power measurement has been accepted as the basis of power calculations.

It is difficult to associate 33,000 foot-pounds of work per minute with the 90 horsepower engine shown in the motor vehicle specifications, therefore, a detailed review may be of interest.

In Figure 6, the sketch shows a man lifting a 110 pound weight by means of a rope and pulleys suspended from a beam. Neglecting friction, the man must exert a pull, or force, of 110 pounds to keep the weight suspended in mid-air. To raise the weight a distance of three

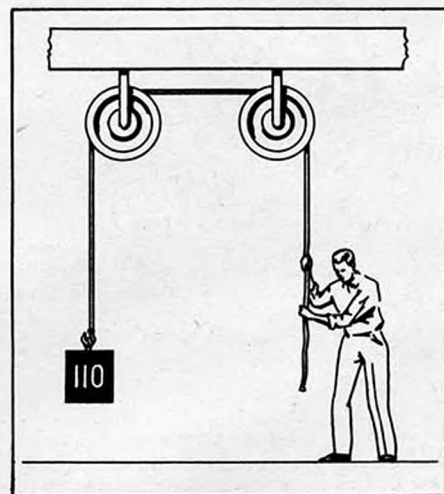


Fig. 6 - Force.

feet, as in Figure 7, the man must exert a 110 pound force on the rope through a distance of

three feet. He now performs work and the quantity of work is expressed in foot-pounds — distance in feet x force in pounds. The quantity of work performed is 3×110 equals 330 foot-pounds.

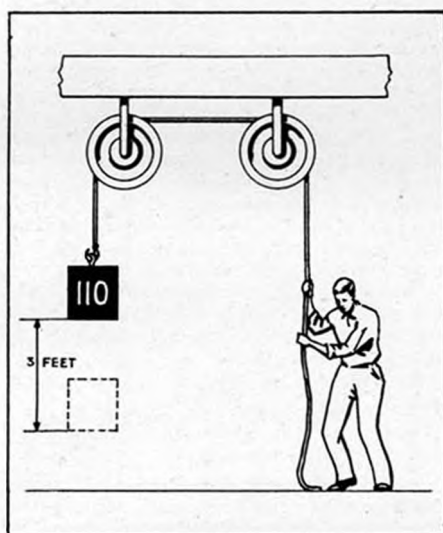


Fig. 7 - Work.

It will be noticed that the time required for the man to pull up the weight was not considered, the quantity of work being the same whether performed quickly or slowly. The rate of doing work is called power. A machine which will do a given amount, or quantity, of work in a short time is said to be more powerful than one that requires a greater time in which to do the same work.

The customary method of expressing power is in units called horse-power and work is done at the rate of one horse-power (abbreviated H.P.) when 33,000 ft. lbs. of work are done in one minute. Therefore (1) H.P. equals

$$(1) \frac{\text{Distance in feet} \times \text{force in pounds}}{33,000}$$

Going back to the man, if he took 1 minute to lift the weight (Figure 7), we find he worked at the rate of

$$(2) \frac{3 \times 110 \times 1}{33,000} = \frac{1}{100} \text{ H.P.}$$

If another man were able to lift the weight of 110 pounds a distance of three feet in 15 seconds, or one-quarter minute, he would have worked at the rate of

$$(3) \frac{3 \times 110 \times 4}{33,000} = \frac{1}{25} \text{ H.P.}$$

The second man would be considered four times more powerful than the first man.

TORQUE

In determining the horsepower developed by a gasoline engine, the factor of distance takes a slightly different form than in Figure 7 because our working member, the crankshaft, rotates. The force is now a twisting or rotating force which engineers like to call torque. The word torque is derived from the Latin word "torqueo," meaning "to twist". When speaking of a certain engine torque, we mean the rotating force exerted by the crankshaft as it revolves at a given speed. Engine torque is usually expressed in terms of pounds-feet and is measured by the pull or force exerted at the end of a one-foot long lever attached to the crankshaft.

Torque is illustrated in Figure 8, where a lever is attached to a shaft which is suitably supported and free to turn. At a lever length of three feet a 110 pound weight is attached. To prevent the shaft from turning a scale is attached at the other end of the lever, one foot from center, and is attached to the floor. The scale indicates a pull of 330 pounds. The torque is 110×3 equals

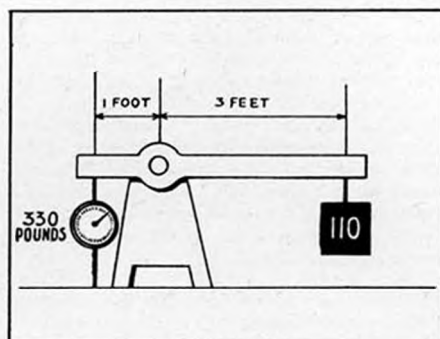


Fig. 8 - Torque.

330 pounds-feet. It is assumed that the lever arms are balanced.

Obviously, the diagram in Figure 8 is explanatory only, because the rotation of the shaft at various speeds renders this method of using a weight scale impractical. This will be considered later.

Substituting the value of torque for force in formula (1) we have yet to determine the distance in feet through which the force acts in one minute. For each revolution of the crankshaft the torque acts through a distance equal to the circumference of a circle having a radius of one foot. Since the circumference of a circle equals $3.1416 \times$ its diameter, we find the distance equals 3.1416×2 equals 6.2832 feet. Knowing the number of revolutions per minute (abbreviated R.P.M.) we can find the distance in feet per minute — $6.2832 \times \text{R.P.M.}$

Referring to Figure 8, if the crankshaft turns at the rate of 100 R.P.M., we find

$$(1) \text{H.P.} = \frac{330 \times 6.2832 \times 100}{33,000} = 6.2832$$

Knowing the engine torque in pounds-feet (abbreviated T) at a given speed, the horsepower at that speed is quickly found from

$$(2) \text{H.P.} = \frac{T \times \text{R.P.M.} \times 6.2832}{33,000}$$

$$= \frac{T \times \text{R.P.M.}}{5252.1}$$

In a like manner, if the horsepower at a given speed is known, the torque may be figured from

$$(3) T = \frac{\text{H.P.} \times 5252.1}{\text{R.P.M.}}$$

Brake Horsepower (abbreviated B.H.P.) is the actual horsepower delivered at the crankshaft and is somewhat less than the theoretical or indicated horsepower, due to unavoidable internal losses caused by friction of moving parts.

One of the simplest ways to measure this power is on the flywheel, or on a pulley, keyed to the crankshaft of the engine, which is arranged

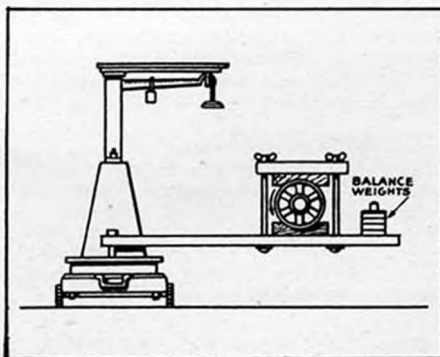


Fig. 9 - Prony brake.

to run against a braking device. One of the earliest of these devices was introduced by Baron Prony, a French engineer, and is known as the Prony Brake. The principles of this device, available in various forms, are indicated by the sketch in Figure 9. The wooden blocks are clamped against the revolving pulley, thus controlling the speed. From the load indicated on the scale, the torque, and then the horsepower, may be calculated. Hence the term "brake horsepower."

The modern method — more practical and more accurate — is to make use of an electrical apparatus called a dynamometer. The dynamometer consists of a stand on which the engine may be securely mounted. The engine is coupled to the armature of an armature and field magnet combination, which may be used as a dynamo for power absorption or as a motor for measuring friction losses in the engine.

The torque produced in the armature, when rotated by the engine, tends to rotate the field magnet frame which "floats" on its own bearing supports. Rotation is prevented by an arrangement of balance arms resting on a suitable weight scale. Very accurate measurement of torque and horsepower, at any engine speed, is thus obtained.

It may be reasonable to assume that the faster the engine runs, the more torque and horsepower is developed, but this is not true. The reason for this is that the driving force of the exploding gases is fairly constant through a considerable range of engine speeds.

At very low speeds the engine cannot draw in full fuel charges and the efficiency of the engine is very low. At high speeds the gas mixture cannot move fast enough to permit full fuel charges and the torque falls off.

This is contrary to the steam engine and electric motor. With these, the starting torque is very high and the torque falls off as the speed

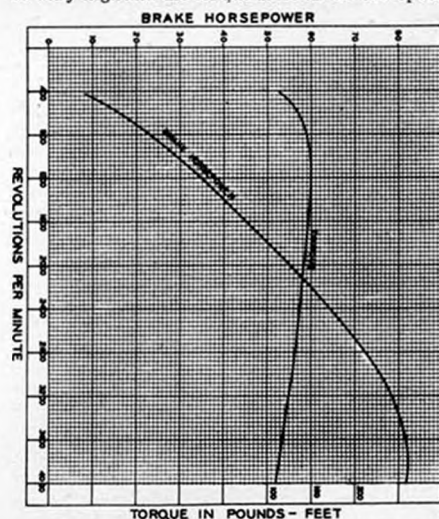


Fig. 10 - Curves showing torque and horsepower of a high-speed engine.

increases. That is why electric motors and steam engines are suited to locomotion, no change speed gears being necessary.

The gasoline engine develops very little torque at low speeds and it is essential to provide a change-speed gear box, called a transmission, to permit stepping up the engine speeds for sufficient torque to start and climb hills.

In Figure 10 are shown the torque and horsepower curves for what may be called a high-speed gasoline engine. Figure 11 shows the horsepower and torque curves of a slightly larger engine of the moderate speed type.

It is evident that both engines develop a torque that varies only slightly over a wide spread range while the brake horsepower increases with the engine speed.

Note that the relation of horsepower to torque at any speed is exactly in accordance with formulas (1) and (2) previously explained.

Engine torque governs the hill-climbing ability of any motor vehicle and horsepower

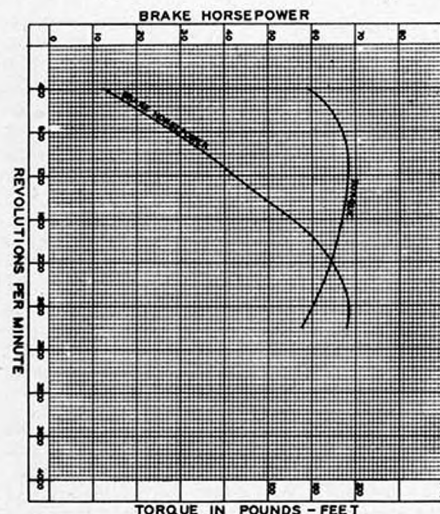


Fig. 11 - Curves showing torque and horsepower of a moderate speed engine.

governs the speed at which the vehicle may travel on the level and on hills.

Always remember that the use of gear reductions back of the engine does not increase its horsepower output. The torque at the wheels can be increased by using gear reductions, but the speed is reduced proportionately and the product of torque $\times$ feet per minute remains the same.

VALVES AND VALVE TIMING

Smooth operation of the internal combustion engine depends upon a fresh charge of fuel mixture entering into and being trapped in the cylinder at the proper time during each cycle. A short time later the products of combustion must be allowed to flow out of the cylinder. Valve timing refers to the exact time in the engine cycle at which the valves open and close. Correct valve timing is obtained by a proper relation between the camshaft and the crankshaft and the setting of specified valve clearances. Should either valve be slightly open during any part of the compression or the power stroke, fuel or power losses will develop. Valves must open and close so that they are constantly in step with the piston movement of the cylinder which they control. In describing the four strokes of an engine it was assumed that a stroke of the cycle began at top or bottom dead center of the piston movement and continued for 180 degrees rotation of the crankshaft. This would indicate that the valves should open or close when the piston is at the top or bottom of its stroke. Actually this does not happen because of other conditions that must be considered.

If the exhaust valve was not opened until bottom dead center, the exhaust would exert considerable pressure at the end of the power stroke. Since it is desired to keep power losses at a minimum the exhaust valve is opened before the flywheel starts to move upward and work against this pressure. Relieving this pressure makes it easier for the flywheel to move the piston up to top dead center. Some power is lost at the end of the power stroke, but the gain is greater than the loss, and a net gain in power results.

When the crankshaft is at top or bottom dead center it is moving almost horizontally and can move 15 or 20 degrees without the piston moving perceptibly. This is called the "rock" position of the piston. When the piston is moving up on its exhaust stroke it has imparted considerable momentum to the exhaust gases as they pass out through the exhaust port. If the exhaust valve closes before top dead center, a small portion of the exhaust gases will be trapped in the combustion chamber and will dilute the incoming fuel charge.

Since it was shown that the piston had little downward motion while in the rock position, the exhaust valve can remain open during this period to allow a more complete scavenging of exhaust gases by taking advantage of their momentum. Figure 12 shows an example of the opening and closing points of the exhaust valve.

Very little suction effect is created in the combustion chamber as the piston passes through the rock position at top dead center because it has moved downward only a very short distance on the intake stroke. The exhaust gases, because of their momentum in passing through the exhaust valve port, have created an air current or turbulence in the combustion chamber. This momentum or air current is sufficient to cause the fuel mixture to move into the combustion

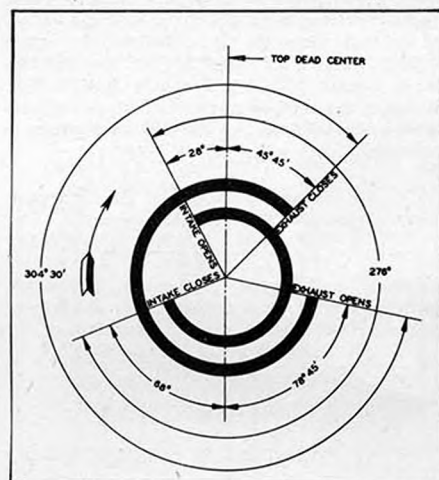


Fig. 12 - Typical valve timing diagram.

chamber if the intake valve is open. For this reason, the intake valve opens slightly before

top dead center. As the piston moves down on the intake stroke the vacuum or suction effect becomes greater and considerable momentum is created in the incoming fuel charge. Full advantage can be taken of this momentum of the incoming fuel mixture if the intake valve is closed after the piston has passed bottom dead center. By this method a maximum fuel charge is obtained in the cylinder. The opening and closing points are shown in Figure 12.

The valve timing of an engine depends on the design of the camshaft, which is based on the design of the crankshaft. Timing gears or timing chains are marked to indicate the proper valve timing when assembled to the engine. The timing gears or sprockets can then be assembled to the camshaft and crankshaft in only one correct position. Manufacturers sometimes place timing marks on the rim of the flywheel, which can be used for valve timing should the timing need be checked. Letters are usually used to indicate the point at which the valves open and close.

In engines that have only top dead center positions marked, the opening and closing points of the valves can be located on the flywheel by calculation and measurement of a distance on the flywheel. Valve operations take place so many degrees before or after top and bottom dead center. This information can be found in the manufacturers' handbook. This distance can be found by multiplying the diameter of the flywheel in inches by the angle in degrees and dividing the answer by 114. To illustrate: Find the opening point on a 20 inch flywheel of an intake valve that should open 10 degrees before top dead center. Multiply 20 by 10 equals 200. Divide 200 by 114 equals 1.75. Hence 10 degrees on this flywheel would be 1-3/4" back from the top dead center mark on the flywheel. Rotate the flywheel to this mark with respect to a fixed pointer and check the intake valve opening.

If the top dead center position of the piston is not marked on the flywheel it can be found by setting a dial indicator so that it will come in contact with the piston at its top position. Rock the flywheel until the indicator shows the same downward movement of the piston in each direction and mark these two positions on the flywheel with respect to a fixed pointer. Make a third mark halfway between these two which will be top dead center position of the flywheel.

CLASSIFICATION OF ENGINES

A number of manufacturers place timing marks on the circumference of the vibration damper or fan drive pulley.

The number of internal combustion engine designs is many and the application by a manufacturer of a particular need or system of manufacturing has caused certain designs to be more common and to be recognized as conventional. There are three general methods of classifying engines:

- (1) Method of cooling.
- (2) Valve arrangement.
- (3) Cylinder arrangement with respect to crankshaft.

METHODS OF COOLING

There are two methods of classifying engines according to cooling:

- (1) Air cooled. (2) Liquid cooled.

The air cooled engine has been most successful in aircraft due to the absence of

water jacket, water pump, and radiator, which save considerable weight, and because of natural air-cooling facilities. Air-cooling is seldom if ever used on large in-line automobile engines. Air-cooling is, however, used considerably in small one and two-cylinder engines such as used on motorcycles. An air cooled radial aircraft engine is used in tanks.

Liquid cooled engines have been adapted for motor vehicle use. This type of engine requires a water jacket around the cylinders, combustion chamber, and valve ports; and a water pump to circulate water through a radiator where the heat is dissipated into the surrounding air.

VALVE ARRANGEMENT

When engines are classified according to valve arrangement there are four typical valve arrangements which will be considered; "L" head, "T" head, "I" head, and "F" head.

The L-head valve arrangement is shown

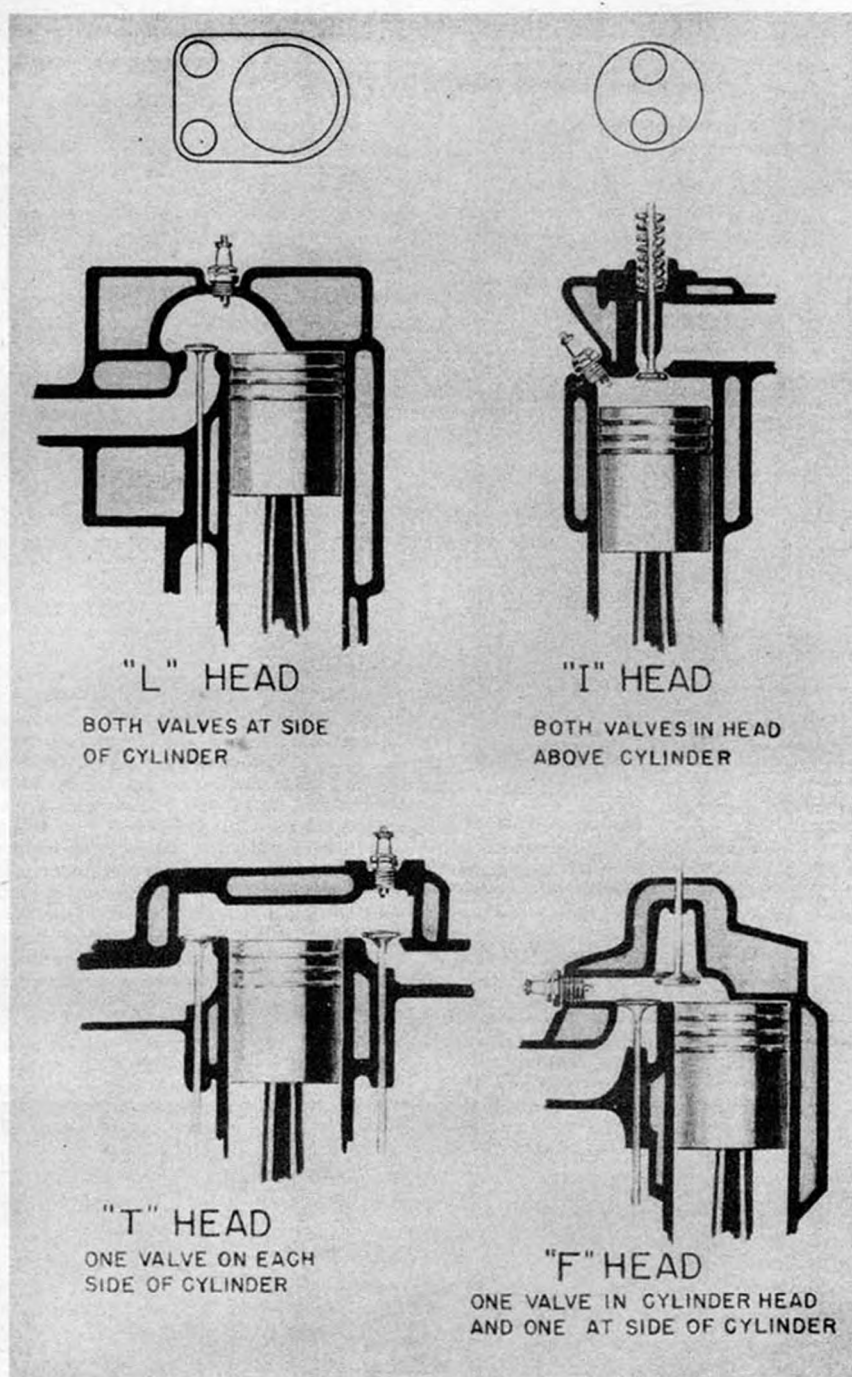


Fig. 13 - Typical valve arrangements in common use.

In Figure 13. In this arrangement the intake and exhaust valves are placed at one side of the cylinder in the cylinder block, and the valve operating mechanism is located directly below the valves in the crankcase.

In the I-head, Figure 13, or more commonly called "overhead valves", the valves are mounted in the cylinder head above the cylinder. This valve arrangement requires some form of valve operating mechanism on the cylinder head.

The T-valve arrangement, Figure 13, has the intake valve placed at one side of the cylinder and the exhaust valve at the other side, both being in the cylinder block. The disadvantage of this arrangement is that two complete valve operating mechanisms are required.

The F-head valve arrangement, Figure 13, has one intake valve in the cylinder head and the exhaust valve at one side of the cylinder in the cylinder block. This arrangement also requires two valve operating mechanisms, one in the cylinder block and one in cylinder head.

There are many variations of these valve arrangements, but the two most commonly used are the L-head and I-head engines. There have also been used various types of rotary, sleeve, and cylinder valves, but the poppet type is the most common.

CYLINDER ARRANGEMENT

The design of any engine depends upon the relationship between the cylinder and the crankshaft. The in-line, V, and radial type are the

most common.

The vertical in-line cylinder arrangement is shown in Figure 14, and is the most common in army vehicles.

The V-type is also shown in Figure 14. In this engine two cylinders or groups of in-line cylinders are mounted above a common crankshaft in a V-shape. The engine is designated by the number of degrees in the angle between the cylinder.

The horizontally opposed engine, Figure 14, has two cylinders or banks of cylinders arranged along the same crankshaft with the cylinders horizontal and the two banks opposite each other. This engine is used primarily in passenger buses where it is mounted under the body of the vehicle because of its low overall height.

The radial engine has its cylinders placed in a circle around the crankshaft which has only one throw. Engines of this type are used primarily in aircraft and military tanks.

There are numerous other arrangements which are not used sufficiently to be discussed here.

CYLINDERS

The cylinder of an automotive internal combustion engine, together with the crankcase, form the framework or main body of the engine about which the other parts of the engine are assembled. The cylinders also provide the combustion spaces in which the burning and expansion of the gases take place, and in which the heat energy of the fuel is transformed into mechanical energy. There are a number of factors that determine the design and construction of the cylinders. The most important of these are the following:

- (1) Piston displacement (bore and stroke.)
- (2) Compression ratio desired.
- (3) Arrangement for cooling the cylinder walls.
- (4) Materials used.
- (5) General form of the cylinder castings (cast singly or in-block with removable or integral heads.)
- (6) General methods of casting, machining, and producing used.

The material used in cylinder castings is a special alloy iron containing nickel, chromium, and molybdenum. Cylinder castings were formerly made of gray cast iron but their wearing qualities were not good enough to warrant their continued use.

The cylinders and crankcase of nearly all in-line and V-type automotive engines are cast in-block, that is, in one piece. Cylinder heads are usually cast separately. In some engines the cylinders are cast singly, in pairs, or quadruple, with the cylinder heads cast separately. As a rule, air cooled automotive engines have the cylinders cast singly with the head cast integrally with the cylinder. The advantages favoring the in-block method of casting cylinders are so great that it has become almost universal. This method produces a more compact, shorter, and more rigid construction at less cost than cylinders cast singly or in pairs. The in-block method also simplifies the assembly of the engine and makes it easier to inclose the valve operating mechanism. The air cooled engine cylinders must be cast singly in order to insure that the maximum outside cylinder wall area is exposed to the cooling air.

The two most widely used materials used in cylinder heads are cast iron or cast aluminum. Cast aluminum has the advantage of being

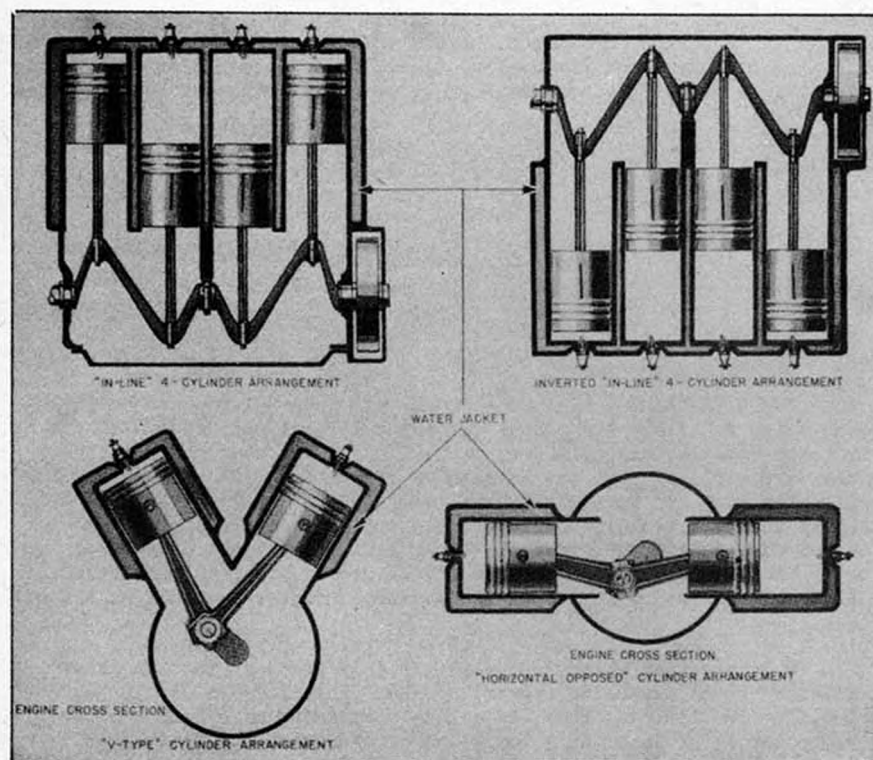


Fig. 14 - Diagrams of cylinder arrangements in common use.

a better conductor of heat and as a result it keeps the walls of the combustion chamber cool enough to avoid hot spots and to permit the use of higher compression pressures.

Due to the seriousness of cylinder distortion, a tension indicating wrench should be used for tightening down the head bolts. In tightening these head bolts, mechanics must follow the procedure indicated in the vehicle manual. Failure to tighten the studs evenly and in the indicated order will distort the block and head and may cause leaks between the cylinders and the water jacket as well as warping of the valve seats and cylinder walls.

The cylinder block and cylinder head contain the water jackets or outside cooling fins necessary to maintain proper operating temperatures within the engine. Water jackets are cast integrally with the block and head as shown in Figure 15. Cylinders cast in-block with removable head have communicating passageways between the block and head to permit the circulation of water between them. The gasket between the block and head has openings corresponding to the openings in the block and the head to allow circulation of the water. Gaskets must maintain watertight and gas tight joints. Outside cooling fins usually are cast only on air cooled cylinders.

Cylinder liners or sleeves are coming into common use in large truck and bus engines. Liners are made of alloys specially treated to give them better wearing qualities than it is possible to obtain from cast iron alloys. They are made with outside diameters as large as the opening into which they fit. They are then forced into the cylinder block, giving a water-tight fit to prevent water from the cooling system leaking into the combustion chamber. Recently liners have been ground two thousandths (.002") to four thousandths (.004") of an inch loose so that the liners can be pushed in the block by hand. This method is used mostly with dry liners. There are two types of liners, known as the wet and dry type liner. The wet type liner

comes in direct contact with the cooling water and is sealed at the bottom and top by some sort of rubber sealing ring. The dry liner is pressed in the block and does not contact the cooling water directly. Liners have two great advantages over conventional cylinder blocks. They usually wear longer, and after they have worn and been

rebored and worn beyond the maximum oversize, they can be replaced with new liners, saving replacement with the more expensive complete block casting.

The cylinder must be absolutely round and true and have a highly finished surface. These surfaces are obtained in manufacturing by boring, grinding, and honing (done in the order given) and the final surface has a mirrorlike finish that offers little resistance and makes a uniform seal between the cylinder surface and the piston.

The oil pump, oil passages, accessory mountings, camshaft bearings, valve lifter brackets, intake and exhaust ports, and suitable bosses for necessary mountings, all form an integral part of the complicated block casting.

THE CRANKCASE

The crankcase is that portion of the engine which supports the crankshaft, provides a tight inclosure for the crankpins, provides a reservoir for the supply of lubricating oil, and acts as a support for a number of auxiliaries. It is common practice at the present time to cast the upper part of the crankcase as part of the cylinder block. The oil pan is made of pressed or cast metal and attached to the crankcase by means of screws. The oil pan contains the lubricating oil and incloses the crankpins. The crankshaft, which is carried in the crankcase, is held in place by bearing caps.

The crankcase also supports the engine on the vehicle frame or on a sub-frame constructed for the purpose. The engine supports are an integral part of the crankcase or bolted to it in such a way that they support the power plant at three or four points. The points of contact with the frame are usually made of rubber. This insulates the frame and body from the engine vibration and noise and prevents damage to the engine supports and transmission resulting from engine twisting and frame distortion.

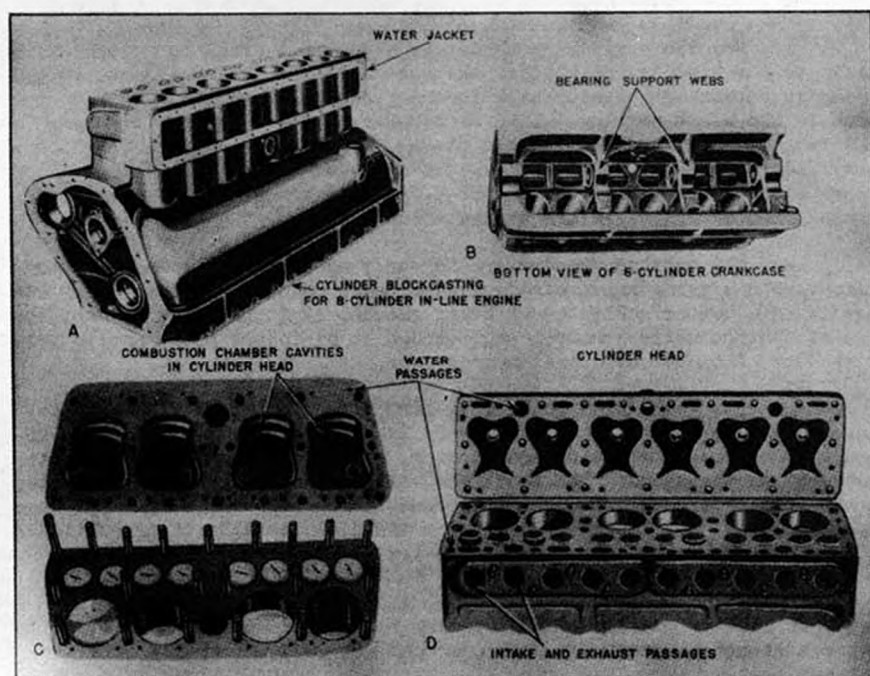


Fig. 15 - Views of cylinder castings for automobile engines; (A) cylinders and crankcase for straight eight engine; (B) Bottom view of cylinder and crankcase casting for 6-cylinder engine; (C) 4-cylinder engine with cylinder head removed; (D) 6-cylinder casting with cylinder head removed, top view of casting shown in (B).

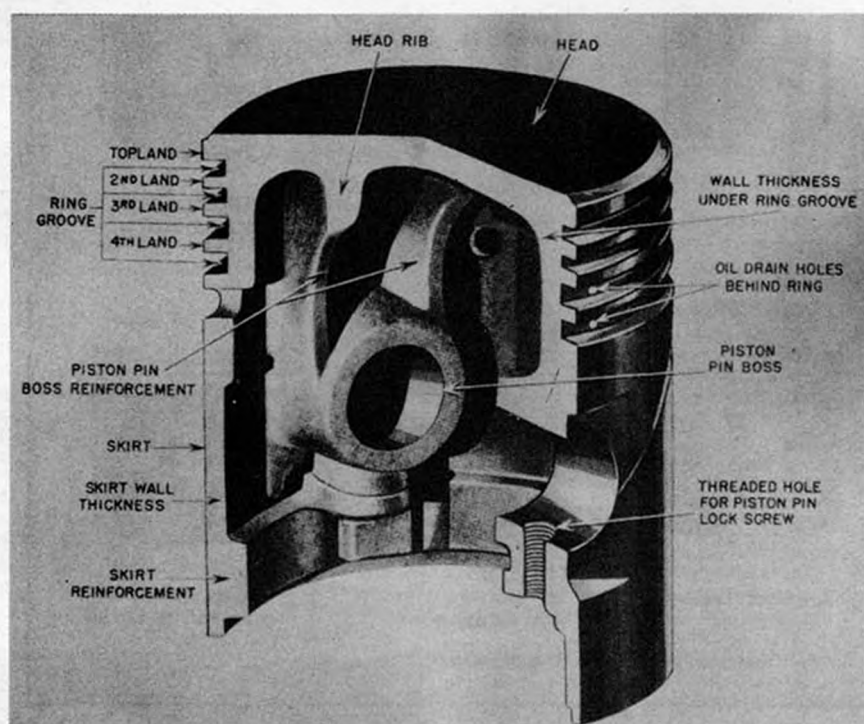


Fig. 16 - Piston nomenclature.

The open end of the cylinder is closed by a movable piston which is kept in proper alignment by the piston skirt, Figure 16. The outer surface of the piston carries ring grooves; it is relieved at the bosses to prevent sticking when the mass of metal at the bosses expands. The piston-pin bosses may or may not be bushed. Piston clearances, specified by the manufacturer, are measured between the cylinder walls and the skirt. It is becoming common practice to make the cross section of the skirt oval rather than round, by cam grinding; the piston becomes round as heat increases the size of the metal mass at the piston bosses. A cam-ground piston can be fitted to close limits on its major diameter when cold. The close fit prevents piston slap during the warming-up period; the oval shape permits expansion without the piston sticking.

Automotive pistons are commonly made of light gray cast iron, semisteel, or aluminum alloy, which are light, wear well, and have high tensile strength. At each end of the strokes of the cycle, a piston must come to a complete stop and start again in a reverse direction. Considerable energy is required to overcome the inertia and momentum of the piston when it stops and starts. With a high speed engine, the subject of piston weight has become more and more important. The head and skirt of a piston are made as thin as possible, consistent with the strength required, in order to reduce weight. Reinforcing ribs are used on the under side of the piston head to assist in conducting heat from the head of the piston to the rings and out through the cylinder walls. Special ribs are also used to reinforce the piston pin bosses.

It is common practice today for some manufacturers to use pistons that have been plated with a soft material, such as tin. The purpose of this is to have the tin work into and fill the pores of the cylinder wall as the engine runs in, providing more perfect fit between the piston and cylinder wall and allowing for a shorter break-in-period. Aluminum pistons are usually treated to give them a thin surface of high resistance to abrasion. Because of the

softness of aluminum, pistons of this material, unless properly treated, might pick up gritty particles which would be imbedded in the piston and cause scratches and wear in the cylinder walls.

PISTON RINGS

Piston rings are used on pistons to maintain gastight joints between the piston and cylinder walls and to assist in cooling the pistons. About one-third of the heat absorbed by the piston passes through the rings to the cylinder wall. All piston rings must be split in order to slip them over the piston lands. When the ring is in place within the cylinder, the ends of the split joint do not form a perfect seal, so it is common practice to use more than one ring and stagger the joints around the piston. Although piston rings have been made from many materials, cast iron has proven the most satisfactory as it withstands the heat, forms a good wearing surface, and retains a greater amount of its original elasticity after considerable use. Steel side pieces are sometimes used on two and three section oil control rings.

There are two types of piston rings used in engines; compression ring and oil control ring. The principal function of the compression ring is to prevent gases leaking past the piston during its compression and power strokes. The principal function of the oil control ring is to assist in lubricating the cylinder walls and to prevent oil from passing into the combustion chamber. Various types of piston ring joints are shown in Figure 17.

Piston rings are made to be the proper diameter when closed to the specified gap that allows for expansion. The gap is about .003 inch for each inch of cylinder diameter. When a ring is fitted within a cylinder of the size for which it is intended, it should have the specified gap or joint clearance, should exert equal pressure at all points against the cylinder, and should fit the cylinder so that no light can be seen between the ring and cylinder wall. In addition to making a gastight fit against the cylinder wall, the ring must also make a gastight fit against the piston land.

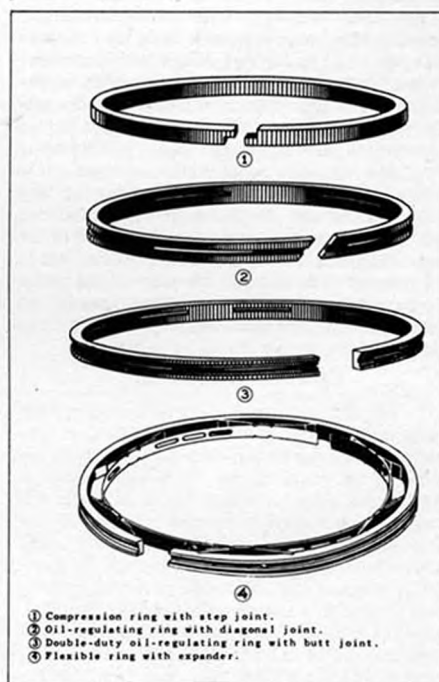


Fig. 17 - Piston rings.

When installing a new set of rings in an engine there are a number of things that should be done to insure a good overhaul job. A ridge or ledge may be found at the top of the ring travel and must be removed to prevent the new ring from striking this ridge and breaking the new ring or breaking the lands between its grooves. A ridge reamer is used to remove the top ridge and in this operation great care must be taken so that the tool does not undercut the cylinder wall below the ledge. When the old rings are removed the piston grooves should be cleaned with a groove cleaning tool. If the carbon found here is not removed, the rings may stick in a very short time. When cleaning the grooves care must be taken so as not to damage the sides of the groove. The ventilating holes, or oil return holes, in the bottom of the ring grooves, should be cleaned out by means of a drill of the size of the hole.

PISTON PINS

The piston is attached to the connecting rod by means of the piston pin. This pin passes through the piston at the piston pin bosses and through the upper end of the connecting rod which rides on the central part of the pin. Piston pins are made of alloy steel with a glass-smooth finish, and are case-hardened to increase

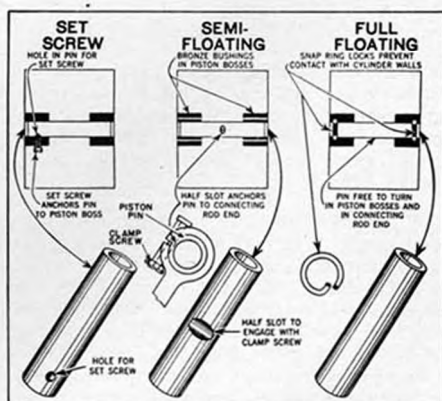


Fig. 18 - Three methods of securing piston pins within the piston or connecting rod.

the wearing qualities. They are made tubular to give them strength with minimum weight. They are lubricated by splash from the connecting rods or by pressure through rifle-bore connecting rods. There are three methods of securing piston pins within the piston and connecting rod, Figure 18. A semifloating pin is anchored to the connecting rod and oscillates in the piston bosses. An anchored or fixed pin is anchored to the piston by a screw through one of the bosses and oscillates in the connecting rod. A full-floating pin is free to rotate in the connecting rod and in the piston bosses but is prevented from bearing on the sides of the cylinder by retainers or plugs. Piston bosses and piston-pin bushings must be honed to very close limits for the proper fitting of piston pins.

CONNECTING RODS

The connecting rod, Figure 19, connects the reciprocating piston with the revolving crankshaft. It must be strong enough to transmit the thrust of the piston to the crankshaft. Since it must be as light as possible, it is generally made with an I-beam section and forged from a steel alloy capable of withstanding heavy loads without deflection (bending or twisting). In automotive engines the connecting rods are roughly drop forged to the desired shape and then machined for the accurate fitting of bearings and bushings. In radial aircraft engines the rods are machined all over to eliminate any unnecessary weight and scratches where failure may begin. In machining or reaming of the two end holes of the connecting rod it is very important that the two holes are parallel.

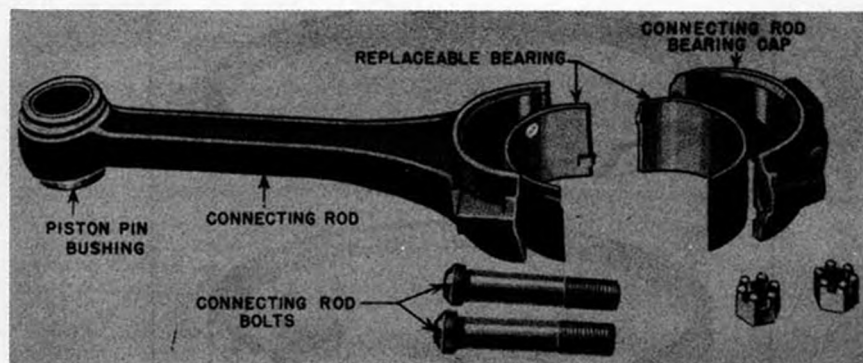


Fig. 19 - Connecting rod assembly showing interchangeable crank pin bearing.

The upper or piston pin end of the connecting rod is connected to the piston by the piston pin. If the piston pin is locked in the piston bosses or floats in both piston and connecting rod, the upper end of the connecting rod is equipped with a bushing of bronze or similar material. As the lower end of the connecting rod revolves with the crankshaft, the upper is forced to oscillate back and forth on the piston pin bushings. Although the movement of the piston pin bearing is not great, the unit pressures exerted are extremely high and the temperatures are quite high. For these reasons correct lubrication of the piston pin is extremely difficult.

The lower end of the connecting rod bears on the crank pin through a suitable bearing. As a general practice the bottom portion or cap of the rod is made of the same material as the rod and machined at the same time. The cap is attached to the rod by two or more connecting rod bolts. The actual bearing surface may be in the form of a special two part bronze shell, the upper half being assembled in the rod and the lower half in the cap. The shells are held in place and prevented from turning by the use of dowel pins, projections, or short

brass screws. The connecting rod bearing is sometimes formed by spinning babbitt metal onto the rod and cap assembled as a unit and then machining the babbitt down to the required dimensions and finish. The advantage of this



Fig. 20 - Bearing which has been badly wiped and scored because of lacking proper oil clearance.

type of construction is that bonding the bearing metal to the metal of the rod assists in conducting heat away from the bearing.

Connecting rod assemblies are weighted and matched in sets for each engine in order to

fatigue, and the bond with the backing metal loosened, allowing the babbitt to break and the pieces to drop out. In order to overcome this, quite satisfactory lining materials were developed. A lining of bronze with high lead content produces a bearing with fairly low coefficient of friction, high load capacity, and long wearing life. An alloy of cadmium, silver, and copper has proven extremely satisfactory as a bearing-lining material. It melts at a higher temperature than babbitt, can be fitted with the same clearance, and holds readily to the shell material.

Most modern bearings for the connecting rods and main journals of the crankshaft consist of precision steel shells lined with a suitable lining material to withstand the high unit loads, high speeds, and high temperatures encountered in this type of service. This type of bearing is highly desirable because it can be replaced without scraping and fitting.

Split bearings used in automotive engines with splash lubricating systems require diagonal or lateral oil grooves so the oil can find its way over the entire friction surface. The oil is

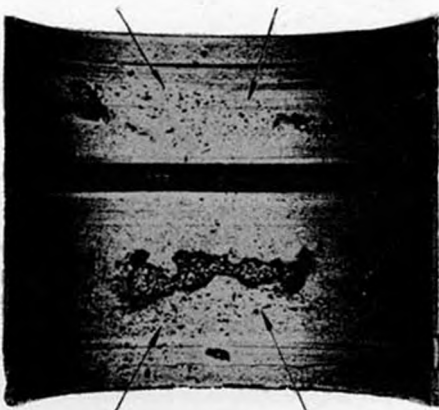


Fig. 21 - Copper-lead bearing which failed because of corrosion.

introduced at the point of least pressure and the grooves act as reservoirs, carrying the oil to points of high bearing pressure. Joints between the bearing valves should be chamfered (beveled) to prevent the oil from being wiped away from the journal.

Bearings for force feed lubricating systems have grooves cut into them to carry the oil around the bearing. The oil is then forced out on the surfaces in contact by pressure from an oil pump. Usually when a spun or bonded babbitt bearing is used with a pressure lubricating system no grooves are used.

Bearing failures can be divided into approximately two types; those due to abrasive action and those due to corrosion. Figure 20 and Figure 21 are examples of these types of failures.

The two main causes of bearing failures are lack of lubricating oil and dirty lubricating oil. If these two points are watched, bearing failure will give little trouble in a modern engine.

VALVES AND VALVE SEATS

The internal combustion engine operating on the four-stroke cycle requires a passageway and opening into the cylinder from the carburetor to draw in fuel-air mixture on the intake stroke, and a passageway and opening for the burnt gases to escape from the cylinder out into the exhaust system on the exhaust stroke. These openings are controlled by valves. Each cylinder

assure a better balance of the reciprocating parts. When installing a new rod the weight should be checked against the weight of one of the old connecting rods.

BEARINGS

The large end of the connecting rods are generally supported on plain bearings with the journals turning within a bearing of anti-friction metal such as babbitt, bronze or special alloy. Babbitt has a very low coefficient of friction, but is too soft to withstand high pressures. Bronze has a high compressive strength and a higher coefficient of friction than babbitt. In order to combine the advantages of these two metals, the bronze backed babbitt bearing was developed, having a thin layer of babbitt on the inside surface of a bronze body. This bearing is made by undercutting the bronze body or by drilling holes through the shell and die-casting the babbitt into the shell. Another method of securing the babbitt to the shell is to coat the shell with a thin layer of solder before the babbitt is cast in place.

In high speed engines, with increased horsepower output which produces heavy loads and high temperatures, the babbitt failed due to

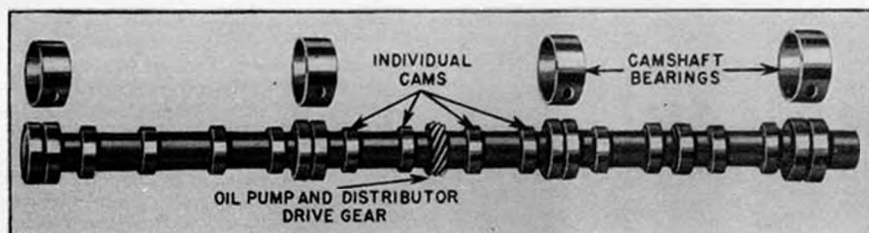


Fig. 22 - One piece camshaft with camshaft bearings. The distributor and the oil pump drive gear in the center of the shaft are integral with it.

must have at least one intake valve and one exhaust valve if the engine is to operate properly.

The type usually used in automobile engines is called a poppet or mushroom valve. The word "poppet" is derived from the popping action of the valve and the word "mushroom" from its general shape. The valves are usually made in one piece from special alloy steels. The intake valves are usually made from chromium-nickel alloy and the exhaust valves use a silchrome alloy because of the extremely high temperatures the exhaust valve must withstand. In some engines, especially aircraft, the exhaust valve and stem is hollow and filled with sodium which is a good conductor of heat and carries away heat much faster than a solid metal valve.

The temperature at which the exhaust valve operates is 900 to 1400 degrees F., depending on the conditions of operation. The intake valve runs much cooler, around 500 degrees F., due to the cooling effect the intake gases have on the valve.

The valve seat is the face of a circular opening leading into the combustion chamber of the cylinder. There are two such openings or valve ports in each cylinder, to which are connected the intake and exhaust manifolds. The valve seat must be of a material that can be ground to make a tight-fitting leak-proof joint with the valve. It must resist corrosion and pitting over long operating periods in order to insure a gastight joint, to withstand wear, the high stresses imposed by the burning fuel, and the constant opening and closing action of the valve spring. The valve seats, especially of the exhaust valves, are subjected to intense heat, pitting, burning, and pounding, with resulting wear and leakage. This necessitates valve grindings and reseatings to renew the seating surfaces. This is minimized in some cases by using nickel-chrome-hard cast iron in the cylinder castings, while in others valve seat inserts are used. These inserts are rings of special alloy steel machined and pressed into place in the cylinder block or cylinder head to serve as valve seats. The use of valve inserts lessens the frequency of valve grinding. Inserts can be used in either exhaust or intake, but are more frequently used in the exhaust.

Valve stems are ground to fit the guides in which they operate. The reamed hole in the guide must be concentric with the valve seat to insure proper alignment of the valve face. The guides may be integral parts of the cylinder block or head, or they may be removed and replaced when worn. Removable valve guides are for the most part made of cast iron. Valve heads are cooled solely by the contact of the stem with the guide and by contact of the valve face with its seat. Valve seats are cooled by the transfer of heat to adjacent metals which are cooled by the water surrounding them.

CAMSHAFTS

All mechanisms of mechanical linkages for operating valves begin with the camshaft. The valves are opened by positive mechanical action

working against the tension of the valve springs which close the valves. The simplest form of cam is a wheel that revolves off-center. In actual practice the outside of the cam or its "profile" is shaped to give the valve a calculated speed or action. The camshaft has a cam for each intake and each exhaust valve. The cams are either made integrally with the shaft, or are made separately and pinned or keyed to it. The integral type is more commonly used because it is impossible for the cams to become loose on the shaft or shift out of correct position, and thereby throw the valve action of the engine out of line. Camshafts with integral cams must have bearings of larger diameter than the highest

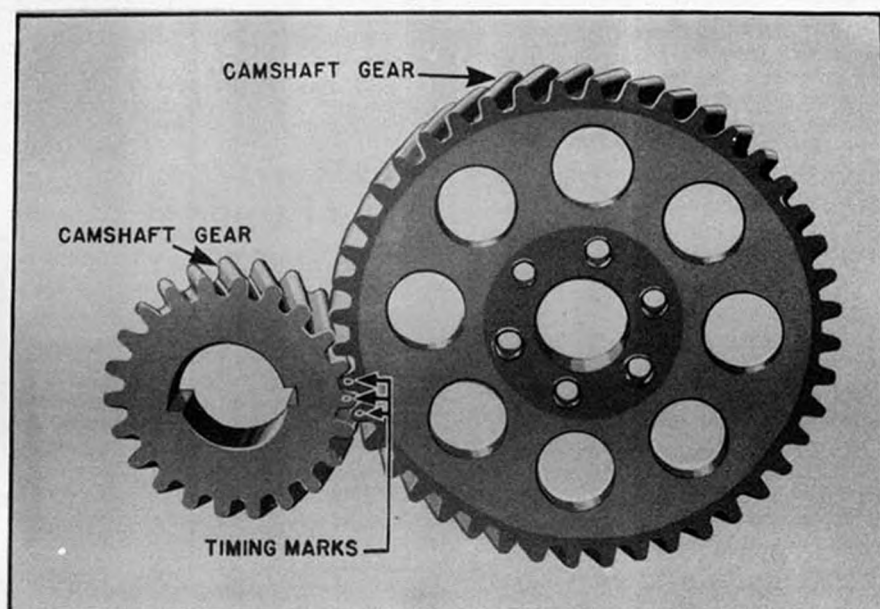


Fig. 23 - Timing gears. The method of marking for proper assembly is indicated.

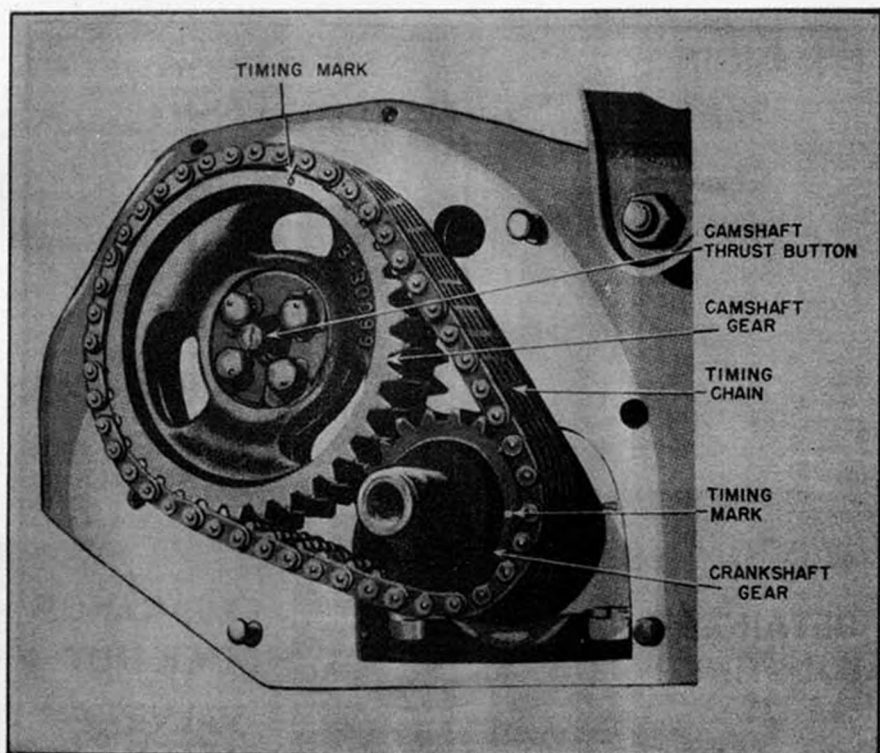


Fig. 24 - Camshaft driven by timing chain.

point on the cams so the shaft can be assembled in the engine by sliding it through the bearing shells in the cylinder block. A one-piece camshaft with its bearing shells is shown in Figure 22. This illustration also shows a gear near the center of the shaft for driving the ignition distributor and oil pump. Although the drop forged steel camshaft has been the prevailing type for a number of years, the chilled cast-iron camshaft is now being considerably used.

Since the valve is opened and closed only once for each complete cycle or for each two revolutions of the crankshaft, the camshaft is required to make only one-half the number of revolutions that the crankshaft makes. It revolves at only half crankshaft speed. This applies only to four-stroke-cycle engines.

The camshaft is driven directly from the crankshaft by means of timing gears or timing chain and timing chain sprockets. A conventional timing gear set is shown in Figure 23. The small gear (marked 0) is the crankshaft gear. It is provided with keyways that permit its assembly on the crankshaft in only one position. The camshaft or large gear (marked 00) is assembled to the end of the camshaft by means of studs or capscrews, also arranged to permit its assembly in only one position. If the gears are always assembled with the tooth marked 0 between the two teeth marked 00, the camshaft will always be in a 1 to 2 relation with the camshaft, and all events controlled by the camshaft will occur at the proper time with respect to the position of the crankshaft or pistons. When a timing chain is used for camshaft drive, Figure 24, the action is substantially the same as that when timing gears are used. The sprockets, by means of a linked chain, act as gears in maintaining the 1 to 2 relation between the two shafts. Here again certain teeth are marked and set with a certain number of chain links between them or with the marked teeth set on a line extending between the centers of the two shafts. In order to produce a camshaft drive that will operate quietly, several arrangements have been used. The silent chain or link belt type of drive has long been considered the quietest type, but with the development of helical gears and special molded material for camshaft gears, the gear drive has become equally quiet.

VALVE OPERATING MECHANISM

The complete valve operating mechanism for the valve of an L-head engine is shown in Figure 25. This is the simplest of all valve mechanisms, inasmuch as it requires a minimum number of parts. A valve lifter having a mushroom type head is mounted immediately above the camshaft in a lifter bushing or guide. It is raised by the cam action against its lower face. The top end of the lifter has an adjusting screw and lock nut assembly which pushes against the reaction of the valve spring. Some engines are equipped with automatic hydraulic valve lifters which have no clearance between the valve lifter and the valve stem, making clearance adjustments unnecessary. This type of lifter is shown in Figure 26.

Oil under pressure from the lubricating system of the engine is supplied to the reservoir back of the valve lifter guide. The oil under pressure from the lubricating oil pump flows under pressure through the port into the supply chamber each time the valve lifter body moves past a hole in the valve lifter guide.

With the face of the lifter on the base circle of the cam and the engine valve seated as shown in Figure 26, the light spring lifts the plunger so that its upper end touches the valve stem, giving zero valve lifter clearance. As the plunger moves upward, increasing the volume of the pressure chamber under the plunger, the ball check valve moves off its seat and the pressure

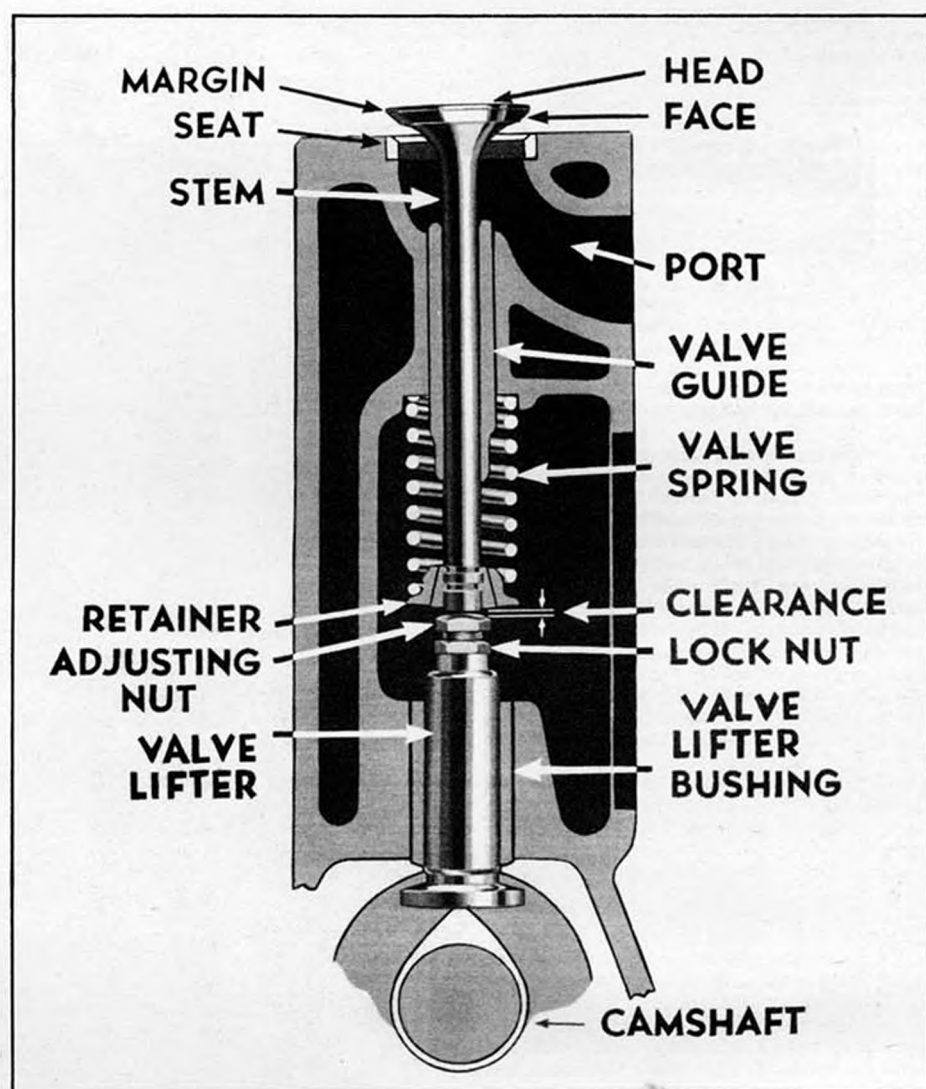


Fig. 25 - Poppet type valve and related parts used in an L-head engine.

chamber is filled with oil from the supply chamber.

As the camshaft rotates, it raises the lifter body, increasing the pressure in the pressure chamber which forces the ball check valve to its seat. Further rotation of the camshaft moves the valve lifter upward, and the confined body of oil in the pressure chamber acts as a rigid unit of the valve-operating mechanism. The valve is lifted and cushioned by this column of oil, which carries the load as long as the engine valve is off its seat. During this period a predetermined quantity of oil leaks from the pressure chamber between the plunger and the cylinder bore. This is necessary in order to provide space so that enough oil to fill the pressure chamber can enter it as soon as the lifter body leaves the receding flank of the cam and comes in contact with the base circle. This maintains the lifter clearance at zero during the next cycle.

In other words, the hydraulic lifter provides a column of oil between the cam and the valve stem which carries the load while the engine valve is off its seat. The length of the column is automatically adjusted with each revolution of the camshaft.

This lifter is self-adjusting when either a warm or a cold engine is being started, because the supply chamber in the body of the lifter remains filled with oil from the previous operation of the engine.

It is impossible for the lifter to hold the

valve open when it should be closed, the principal force tending to open it is the spring action on the plunger, and it is much lighter than the valve spring which closes the valve. An additional force which tends to push the plunger upward and open the valve is the pressure of the oil in the supply chamber. The effect from this source is negligible.

Figure 27 shows the addition of a push rod and rocker arm arrangement for operating the valves in a cylinder head. The I-head engine, which has the intake and exhaust valves in the head, requires two push rods and rocker arms per cylinder.

CRANKSHAFTS AND VIBRATION

The crankshaft might well be called the backbone of the engine, since it acts to tie all the pistons together and transmits their power to the flywheel. In addition to this, it is subjected to all the forces of the power developed by the engine. It transforms the reciprocating motion of the piston and connecting rod into rotary power, and transmits it to the flywheel or clutch. The crankshaft, as the name implies, is a shaft which has one or more cranks along its length. The cranks or throws are formed by forging offsets into the shaft before it is machined. The arrangement of the cranks along the crankshaft influences the firing order of the engine for which it is designed. Actually, the relationship of the camshaft to the crankshaft establishes the firing order for any given engine.

Crankshafts are generally forged from an alloy of steel and nickel. This material is very strong and durable yet soft enough to be machined on a lathe. Some crankshafts have their pins or bearing surface hardened by a special process which case hardens only the bearing journals and not the whole shaft. Such crankshafts are case hardened after being rough ground and cannot be reconditioned by ordinary methods. The case hardening should never be penetrated when reconditioning or finish grinding.

Most crankshafts are similar in design.

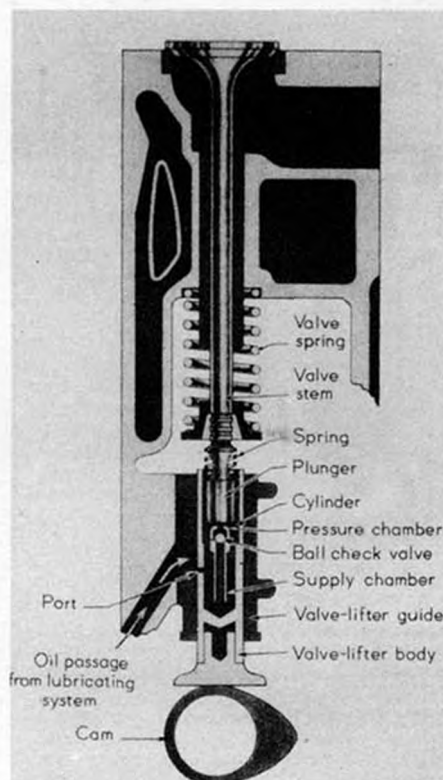


Fig. 26 - Automatic hydraulic valve lifter.

(See Figure 28.) Crankshafts for four-cylinder engines have either three or five main or support bearings and four throws in one plane, with the throws for Nos. 1 and 4 cylinders 180° from those for Nos. 2 and 3. A crankshaft for an eight-cylinder V-type engine would be of the same basic design. One design for V-type eight-cylinder crankshafts has one set (two) of throws advanced 90° over the other for better balance and smoother operation.

The eight-cylinder in-line crankshafts follow two general designs. The first is to have two identical four-cylinder crank arrangements set end to end with one advanced 90° over the other. This is known as a 4-4 shaft. In the other design, the 2-4-2 shaft, one four-cylinder crankshaft is used in the center and another, cut in half, is placed at each end of the first crankshaft. Each two cylinders are advanced 90° or one quarter turn, with relation to the center four.

Crankshafts for six cylinders have either 3, 4, or 7 main bearings. The throws for the connecting rod bearings are forged in three planes 120° apart with two bearings per plane. Cylinders Nos. 1 and 6 are in the first plane, Nos. 2 and 5 in the second, and Nos. 3 and 4 in the third. (See Figure 29.) Shafts for twelve-cylinder V-type engines have these same general characteristics.

Every piece of revolving machinery has a

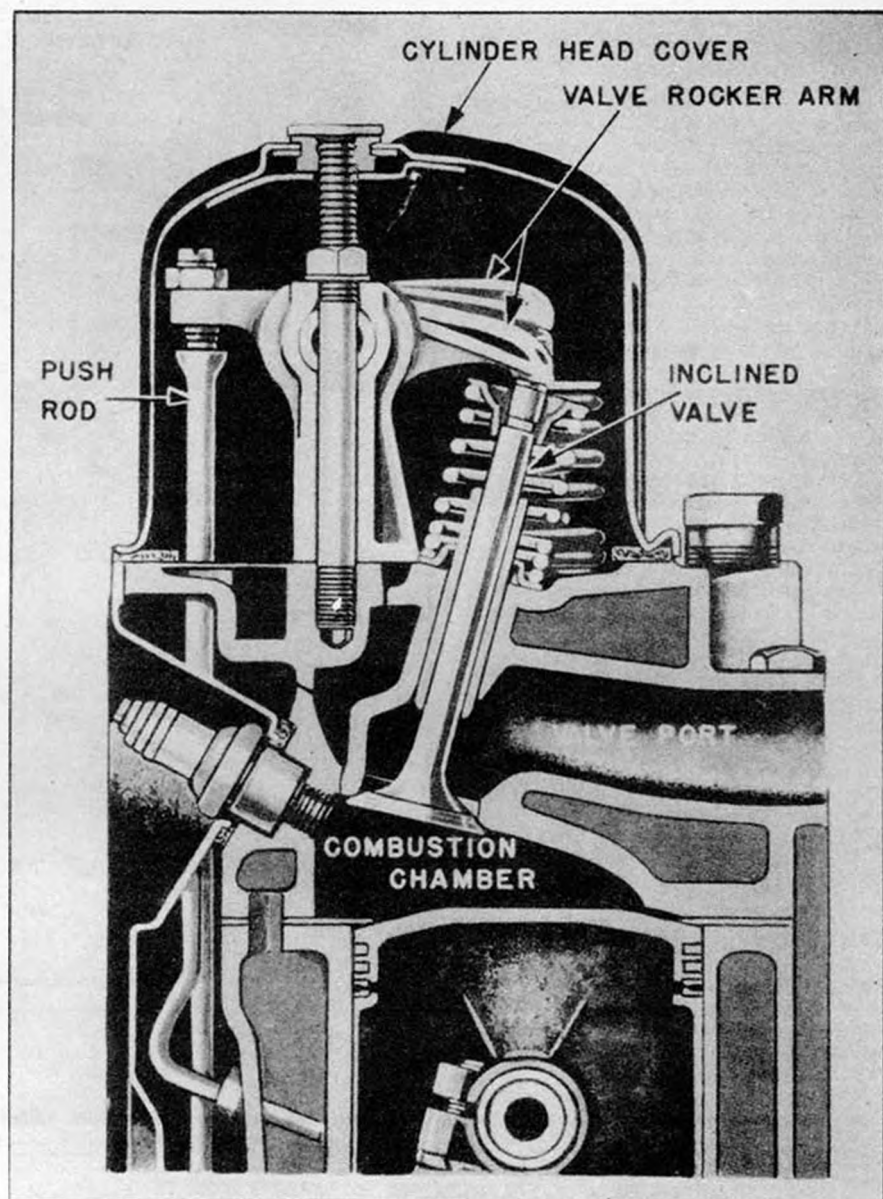


Fig. 27 - Overhead valve design with inclined valves.

certain definite speed at which a vibration is set up in the revolving mass. In designing a crankshaft, it is sometime possible to place this critical speed outside the speed range of the engine. If not, the crankshaft must be heavy enough to withstand the vibration. In severe cases of vibration the crankshaft may break. In order to run smoothly, a crankshaft must be balanced for static balance while at rest and for dynamic balance while running at low and high speeds. Deflection in the crankshaft caused by load stresses will quite often throw a shaft out of balance, especially at high speed. Crankshafts are balanced by use of weights to overcome vibration, load deflection, and uneven balance. These may be forged as part of the shaft, as in Figure 30, or they may be bolted on. If balance weights are removed and replaced in the servicing of an engine, they should be marked before removing and replaced in the same position.

Torsional vibrations set up in crankshafts, due to twists in the shaft as loads are applied, are dampened by a small unit in the front end of the crank, known as a vibration damper, Figure 31. The application of the inertia weight of this

unit is released to counteract the twisting actions of the crankshaft. This unit usually carries a V-type pulley for driving cooling fans and other units.

The front end of the crankshaft also carries a keyed gear or chain sprocket for driving the camshaft and perhaps other units, such as ignition distributors, generators, and water and oil pumps. A notched nut for engaging a starting crank is often screwed into the front end of the crankshaft and usually acts as a retainer for the vibration damper assembly and the crankshaft timing gear.

The rear end of the crankshaft is provided with a flange to which the flywheel is bolted, Figure 32, and a recessed center which receives the small ball or roller pilot bearing that carries the forward end of the clutch shaft. The flywheel rim carries a ring gear, either integrally machined with the flywheel or shrunk on, which is engaged with the starter drive for cranking the engine. The rear face of the flywheel is usually machined and ground and acts as one of the pressure surfaces for the clutch, becoming part of the clutch assembly.

Most engine manufacturers place dead center and timing marks on or near the edge of the rim of the flywheel.

The crankshaft rotates in main bearings mounted in the crankcase. Main bearings are placed at both ends of the crankcase and at one or more intermediate points in the main bearing trusses or webs, depending on the number of main bearings used. The main bearings of most high speed automotive engines are usually of the thin shell bronze or steel backed type, in which one half of the bearing shell is secured to the crankcase and the other half is fastened in the cap part of the bearing. This latter half is sometimes "poured" in the cap without the harder metal backing shell. The principle load on the main bearings of an engine is radial. The small end-thrust load on the crankshaft is usually taken by the rear main bearing which is provided with a rather broad thrust face, and acts as a combination radial and thrust bearing. The main bearings are often channelled for oil distribution and may be lubricated by pressure or by splash from the crankcase.

Oil seals, as a rule, are placed at both ends of the crankshaft where it extends through the crankcase to prevent loss of the engine lubricating oil.

COOLING SYSTEMS

Because of the great amount of heat generated within, all internal combustion engines of the gasoline or Diesel type are provided with some form of cooling system which carries away the unused heat before it can damage the engine. There are two major forms of cooling systems: The air cooled type and the liquid cooled type; air being used to cool airplane and tank engines, and liquid being used to cool most automobile and truck engines.

AIR COOLING

Engines of the air cooling variety have separate exposed cylinders which are covered with fins all over the head section and cylinder barrel proper. (See Figure 33.) This finning provides the cylinder with enough surface or area to transfer all of the rejected heat to the stream of air which is pumped over the cylinder. No matter how well finned a cylinder might be, it would run too hot if some means of pumping

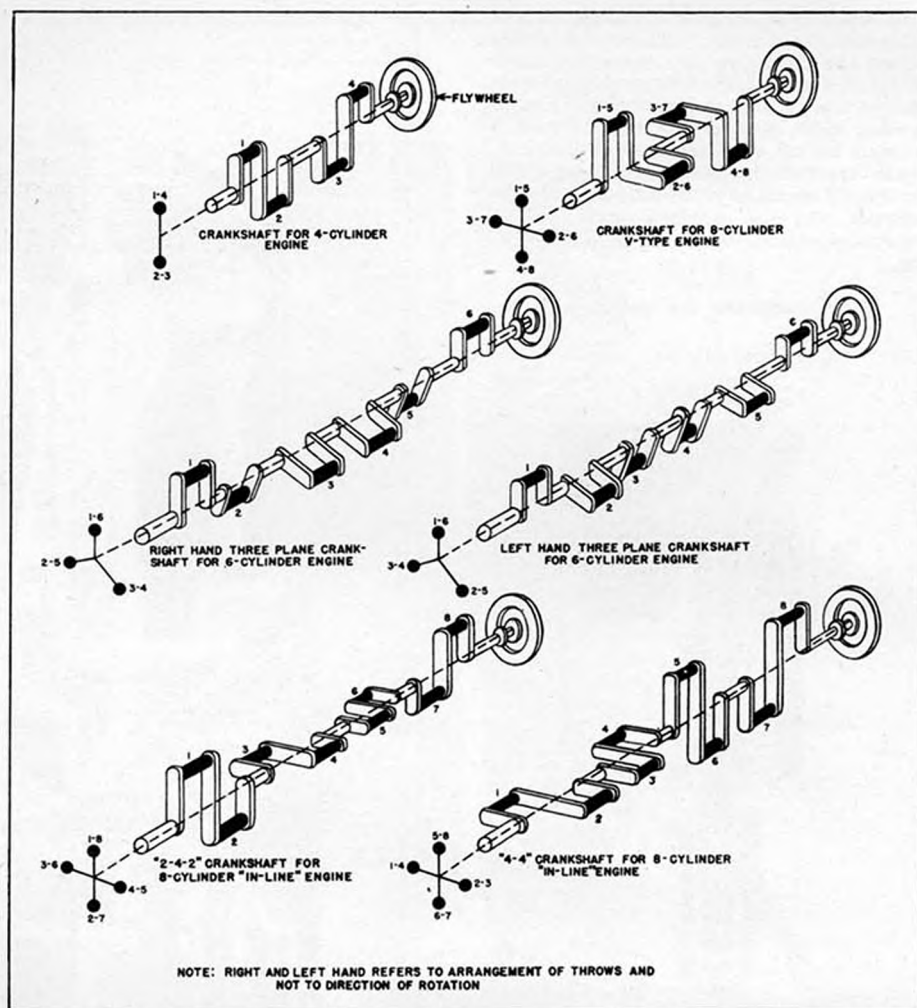


Fig. 28 - Diagrams of crankshafts showing the crank throw arrangements most commonly used.

air over it were not provided, for in stagnant air the cylinder would build up a layer of very

hot air between and around its fins and the heat transfer from the engine to the surrounding air would be almost stopped. In order to facilitate proper heat dissipation and insure adequate cooling, air cooled tank engines are equipped with a large fan built into the flywheel of the unit; thus the engine can not run without rotating the fan and pumping cooling air over the cylinders and other parts to be cooled. Air is taken in the front of the fan and led through baffles and shrouds which are designed to pass the air over the cylinders in such a directed manner that sides, front, and back of the cylinders are cooled evenly. If baffles and shrouds were not used to direct the air flow, the cylinders would heat up unevenly and thermal "growth" would cause out-of-roundness. Air cooling is not merely a process of blowing air over cylinders in a slipshod manner. In a well designed air-cooled engine, all fins are carefully placed and the air stream from the fan is directed over them in such a manner that it will carry away with it a maximum of waste heat. Standard practice on air-cooled tank engines, for instance, is to use fins in such a manner that there will be 0.25 square feet of area of cooling surface on each cylinder for each horsepower developed therein.

Air cooling has an advantage over water cooling in that plumbing and piping are done away with, thus easing the problem of installation and maintenance. An air-cooled engine is generally less vulnerable to bullets than a water-cooled engine, since there is no water to leak out of a punctured radiator or water jacket; it has no passages or pipes to become clogged

FIRING ORDER OF CYLINDERS	ONE COMPLETE CYCLE											
	2 - REVOLUTIONS OF CRANKSHAFT - 720°											
	1-REVOLUTION - 360°						1-REVOLUTION - 360°					
	1/2 REV. 180°			1/2 REV. 180°			1/2 REV. 180°			1/2 REV. 180°		
	1st STROKE DOWN			2nd STROKE UP			3rd STROKE DOWN			4th STROKE UP		
	60	60	60	60	60	60	60	60	60	60	60	60
1	P	P	P	E	E	E	I	I	I	C	C	C
5	G	C	P	P	P	E	E	E	I	I	I	C
3	I	C	C	C	P	P	P	E	E	E	I	I
6	I	I	I	C	C	C	P	P	P	E	E	E
2	E	E	I	I	I	C	C	C	P	P	P	E
4	P	E	E	E	I	I	I	C	C	C	P	P

P-POWER; E-EXHAUST; I-INTAKE; C-COMPRESSION.

Fig. 29 - Events of a cycle in a 6-cylinder in-line engine showing occurrence and relation of power strokes.



Fig. 30 - Crankshaft with integrally forged counterweights.

with dirt or sludge and, finally, it has the advantage that it will never freeze up in winter. But air cooling has some disadvantages, too. One disadvantage lies in its inability to control temperature to within as close limits as a water-cooled motor. And another drawback is that a considerable amount of power must be expended to drive the cooling fan or pump; power which must be subtracted from the output of the engine.

The care and maintenance of an air cooling system is simple, and under ordinary conditions requires very little attention. The system should be kept free of dirt and obstruction, and the cylinder fins must be kept clean so that air passage will be unhampered. The baffles and shrouds must be securely locked in place as designed so that the air stream will be guided correctly and no hot spots will develop on the cylinders. The fan must be correctly mounted and kept in perfect balance. On the tank engine cooling fans, no attempt must be made to alter or change one blade of the fan, since the whole unit is put in balance at the factory and any tampering will make it vibrate.

WATER COOLING

For general use, water-cooled engines are, of course, used a great deal more than air-cooled units. A simple water cooling system for a gasoline or Diesel engine consists of a radiator, a pump, some piping, and a system of water passages and jackets throughout the engine. The pump, Figure 34, sucks water from the bottom of the radiator, forces it through

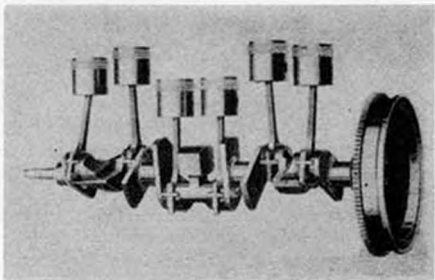


Fig. 32 - Crankshaft, connecting rod and piston assembly.

the jackets and cored holes in the engine and then ejects it to the small tank on top of the radiator. The water is cooled in the radiator, passes through a set of tubes to the bottom of the radiator, and is again put through its paces by the action of the pump. An engine-driven fan draws air over the outside of the tubes in the radiator and the water gives up its heat to the circulated air. Thus, a radiator is a form of heat exchanger in which water passes its heat to air and the air is blown away, carrying waste heat with it.

It is to be noted that water is pumped through the radiator from the top down. That is, water is pumped from the head of the engine to a small tank at the top of the radiator and it passes through cores or tubes to the bottom of the radiator. The reason for this direction of flow is that thermosyphon action aids the pump

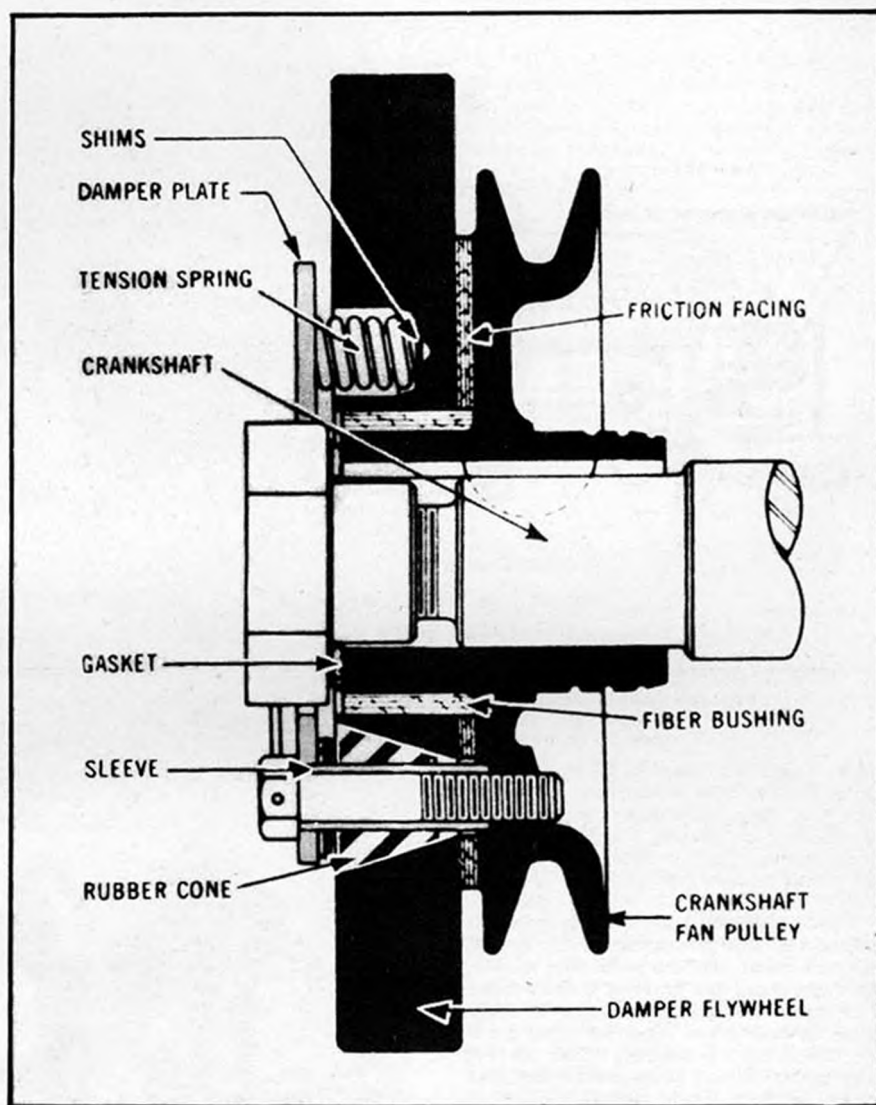


Fig. 31 - Torsional vibration damper of the friction type mounted at the fan pulley drive end of the crankshaft.

to circulate the coolant. The water is heated in the jackets of the engine, Figure 35, this expands it and causes it to become lighter and to flow upward to the top of the radiator. Cooling then takes place as the water enters the cores of the radiator and the water once again becomes heavier and sinks to the bottom of the tubes. This desirable thermosyphon action can not take place if the water level becomes low, and it is for this reason that the level of coolant should be checked often, and additional water added as needed.

The most common type of water circulating pump is the centrifugal pump as shown in Figure 34. The general practice is to drive the pump and the fan both at the same speed with a common V belt — the V belt picking up its power at the forward end of the engine crankshaft. The centrifugal pump is a desirable water circulator since it is relatively inexpensive, can circulate great quantities of water with a small pump, is not clogged by small particles of dirt and permits limited circulation by thermosyphon action even after the engine has stopped.

Since the pump starts the coolant circulating through the system as soon as the engine is started, no matter how cold the system, a thermostat must be installed to assure quick warm-up and to prevent over-cooling in cold

weather. One common type of thermostat consists of an accordion shaped flexible metal chamber attached to a valve. (See Figure 36.) The expandable chamber is filled with a highly volatile liquid when cold; when heated, the liquid passes off into a gas and creates a pressure which pushes out on the walls of the extendable chamber and causes it to grow longer. This "growing" action causes the attached valve to open. When placed in the cooling system, the thermostat reduces the flow of water through the radiator when the water is cold. As warming up takes place, the thermostat valve opens and brings the radiator into play for normal cooling. Thermostats are generally set to open at about 140 degrees F. and maintain the coolant at a temperature between 140 deg. F. and 180 deg. F. Radiator shutters are devices attached to the outside of the radiator to control the amount of air passing through the radiator. They are sometimes used to supplement or replace the action of a thermostat, and are operated either by hand or by an automatic thermostatic device.

Proper care and maintenance of a water cooling system is necessary if proper temperature control is to be had. The following hints will be of value as regards this maintenance:

EVERY DAY. - Check level of water in

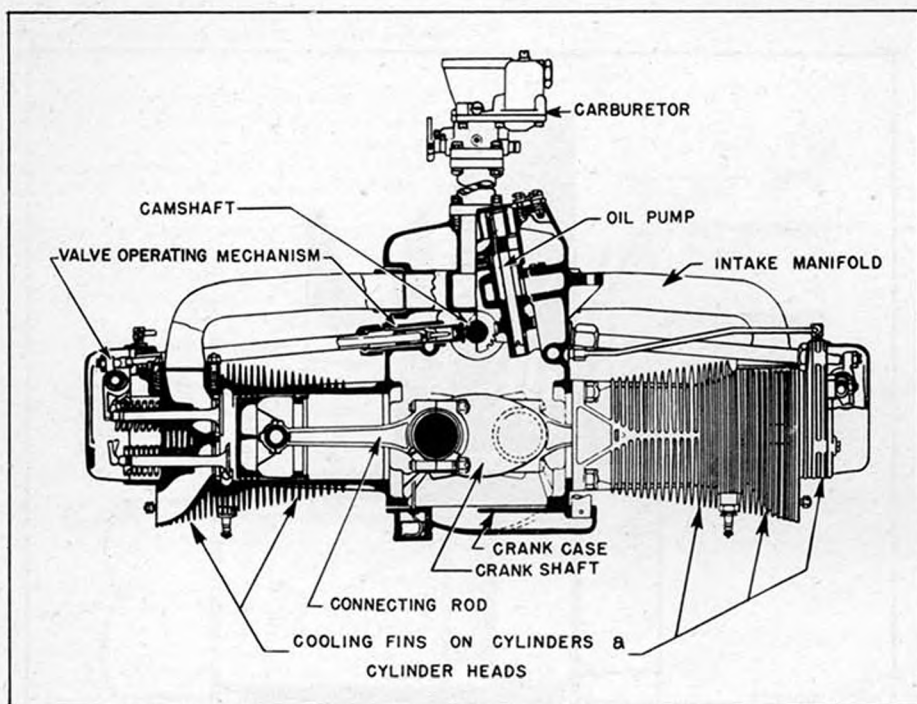


Fig. 33 - Small air-cooled automotive engine of the 4-cycle horizontal-opposed type. The right hand front cylinder is cut away to show the cylinder wall construction.

radiator. Look for leaks in the water pump packing. Check hose connections for leaks. Watch your temperature gauge while driving; if overheating is indicated, find the cause before driving on. Check hose clamps. Look for leaks around cylinder head gasket.

ONCE A MONTH. - Clean dirt from outside of radiator to allow free passage of air. Inspect hoses for condition; if chafed or thin, replace. Open drain cocks and drain off a small quantity of water; look for oil and dirt in water. Tighten all connections. See that filling cap is tight. Check, and if necessary, tighten fan belt; a slipping fan belt will cause overheating since it drives the fan and water pump.

TWICE A YEAR. - Carry out complete monthly check and back-flush radiator; drain, fill with clean water. Replace fan belt if wear or fraying is seen. Check packing on water pump.

IN FREEZING WEATHER. - Be SURE that the system is protected with plenty of antifreeze. Check to be sure that the thermostat is working properly. If necessary, place it in a pan of slowly heating water with a thermometer immersed and note the opening temperature of the valve; it should not be less than 140 deg. F. If no antifreeze is used, the whole system must be drained, making sure that all drain cocks are open and left open.

WHEN ENGINE OVERHEATS. - Check water level. Check fan belt tension. Look for dirt in radiator, both outside and inside cores. Check engine timing; retarded spark causes overheating. Look at thermostat; it may be stuck. Check hoses for clogging. Was engine just overhauled? It may be tight; incorrect gasket may have been used. Is oil level OK? Low oil causes the worst kind of overheating.

ENGINE LUBRICATION

For smooth engine performance and long life, nothing is quite as important as proper un-interrupted lubrication of all moving engine parts. The function of lubricating oils, and the reason for success or failure of any lubricating system, is of importance to all who use and

severe at some localized points; namely, under the rubbing surfaces of the piston rings where they contact the cylinder. At first glance it would appear that the ring pressures should be low, not being any greater than the spring tension of the rings themselves - a few pounds per square inch. This would be a sound assumption if it were not for the fact that the pressure of the gases in the combustion chamber exerts an equal pressure on the rings, forcing them out against the cylinder walls.

While it is true that crankshaft bearings, connecting rod bearings, wrist pin bushings, and surfaces of the pistons and rings must receive first attention as regards lubrication, still it is true that there are many more minor parts which need lubrication also. For instance, valve stems work under severe conditions and changing temperatures for long periods of time, and yet must receive lubrication every minute. Valve followers and cams must be lubricated. All gear bearings, gear trains and accessory drives must be kept in a bath of oil, as must every other moving part subject to friction.

There are two general methods in use by means of which the moving parts of an engine are supplied with oil when the motor is running. In the more simple of the two, the splash system, Figure 37, oil is splashed by moving parts of the engine throughout its interior, creating an oil mist which reaches all bearing surfaces. In the other method, oil is forced under pressure directly to the principal bearings; the excess oil from these bearings is thrown by centrifugal force to the other bearing surfaces.

The combination splash and forced feed lubrication system, Figure 38, employs a pump to deliver oil to important bearings of the engine. The pump, equipped with a screen, Figure 39, to exclude particles of matter, is located below the oil level in the crank case. The pump sucks oil from the crank pan and forces it through tubes or pipes to the main bearings, whence the oil flows through the bearings, runs around the journals and drips out the ends and back into the oil pan. Oil troughs under each connecting rod bearing are kept filled by the pump; any excess oil flowing back to the pan. Each connecting rod bearing is provided with a dipper or scoop which picks up a quantity of oil and feeds it to the bearing. The force of impact of the rotation of the crankshaft drives oil from the trough through a drilled hole to the connecting rod journal; some of the rest of the oil from the trough is thrown from the scoop to the cylinder wall and to the interior of the piston where it lubricates the piston pin. The rapidly rotating parts of the engine dipping in the oil generate an oil mist within the interior of the crankcase and cylinders, thus lubricating the camshaft bearings and other parts. Oil is generally pumped through another tube to the timing gears and valve mechanism.

The need for a more positive circulation of oil to the bearings, both to insure a proper lubricating film and to assist in carrying away excess heat, has led to the almost general adoption of pressure lubricating systems. In these systems, oil is supplied under pressure to the rubbing surfaces and is constantly being renewed and cooled by circulation. In practice, it is customary to classify pressure lubricating systems as forced-feed and full-forced-feed.

In the forced-feed system an oil pump is located in the crankcase and forces oil through the pipes to the main crankshaft bearings. Thence the oil passes through drilled passages in the crankshaft to the connecting rod bearings, Figure 40, from which the overflow is thrown by centrifugal force to the piston pins and cylinder walls. In some systems oil is also delivered to the camshaft bearings under pressure from

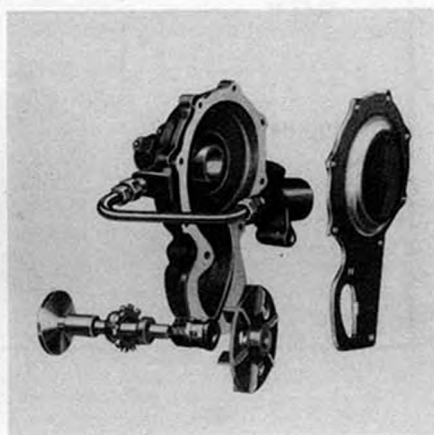


Fig. 34 - Water pump details.

maintain gasoline and Diesel engines. Correct adjustment and care of the lubricating system is a great help in forestalling troubles of the worst sort; troubles which may crop up when the engine is needed most.

The primary function of all engine lubrication is to reduce friction between moving parts. Oils are used to reduce friction not only because friction uses up power that would otherwise be available to drive the vehicle, but also because friction is destructive and creates disintegrating heat. It is well to remember that all energy that goes into the overcoming of friction in a bearing or other part, is turned into heat. In other words: The more friction in a bearing, no matter what its nature, the more energy required to overcome the friction and the more heat that will be generated in the bearing. A bearing which has become deprived of all lubrication may melt out, fuse, or seize up if conditions permit. It is lubrication alone which makes the use of journal bearings possible in a modern engine.

In the case of cylinders and pistons, lubrication must be effective in preventing burning or seizure of either of the parts as they move in relation to one another, for friction here is rather

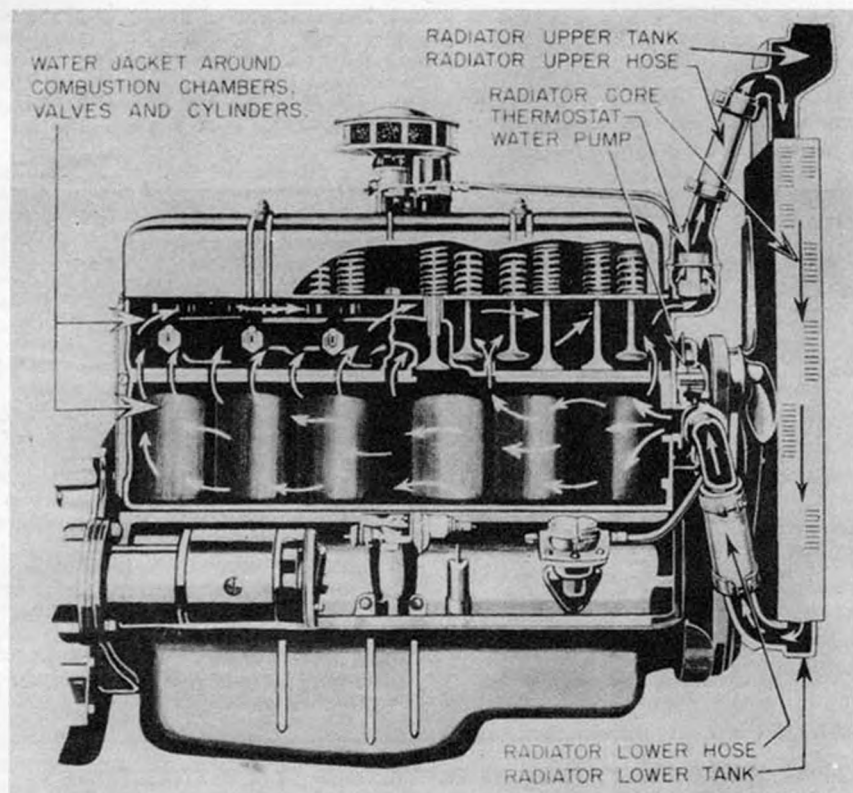


Fig. 35 - The circulation of the cooling liquid and the parts of the cooling system of a water cooled engine.

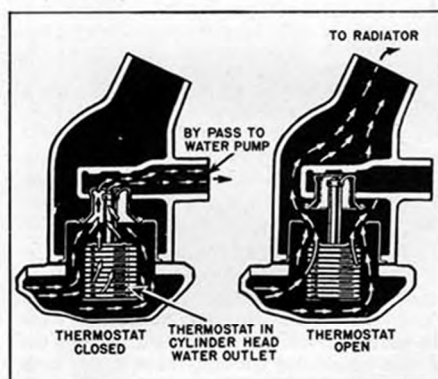


Fig. 36 - Left: Thermostat valve closed, preventing water circulation through radiator. Right: Valve open, permitting water to circulate through cooling system.

the pump. A passage or oil line carries oil to the timing gears and their bearings.

The full-forced-feed system is similar to the forced-feed system in that oil under pressure is supplied to the main bearings, Figure 41, connecting rod bearings, camshaft bearings, rocker arms and timing gears. In addition, a portion of the oil which is delivered to the connecting rod bearings is forced to the piston pins through holes in the upper halves of the connecting rod bearings and passages drilled the entire length of the connecting rods.

The gear type of oil pump, Figure 42, is used a great deal on modern engines because of its positive action, simplicity and reliability. It consists of two meshing spur gears mounted on shafts in a housing. The housing closely fits the two gears. One of the gears is driven

by the engine accessory drive and its rotation drives the other gear. The direction of rotation is such that oil enters the inlet, is carried around the housing in spaces between gear teeth, is discharged through the outlet and forced through pipe connections to the bearings.

Pressure gauges are employed to indicate the amount of pressure present in the lubricating system. The pressure gauge is mounted on the instrument panel and connected by a small tube to the main oil supply line. It must be remembered that the gauge reading represents pressure, not the quantity of oil in the crank case.

The speed of the engine determines the speed, and consequently the pressure, developed by the pump, as well as the quantity of oil delivered by it. In engines employing splash lubrication, the quantity of oil circulated must be sufficiently great to fill the splash troughs; excess oil runs back to the pump. In forced feed systems, however, it may be possible at high speeds to over-supply the system with oil at excessive pressure. For this reason pumps in these systems are supplied with a relief valve which opens when the pressure in the line reaches a certain value. (See Figure 42.) Opening the valve allows a part of the oil to be recirculated through the pump or returned to the oil pan. The relief valve is a simple spring-loaded check valve which opens when the pressure of the oil exceeds that of the spring.

In the combination splash-and-forced-feed system, the gauge registers oil pressure to the main bearings and sometimes to the valve operating mechanism. The reading on the gauge in a forced-feed system should not exceed the pressure setting of the relief valve. Small variations from specified operating pressure in either system may be disregarded, but the cause of extremely low or high pressure should be investigated immediately. Low pressure is usually

traceable to worn or loose bearings, broken oil lines, faulty oil pump, dirty screens, stuck relief valve, or very thin oil.

The driver is responsible that the engine is always supplied with the proper quantity of oil. However, a problem requiring much more care is that of maintaining the proper quality of lubricant. A suitable oil having been chosen,

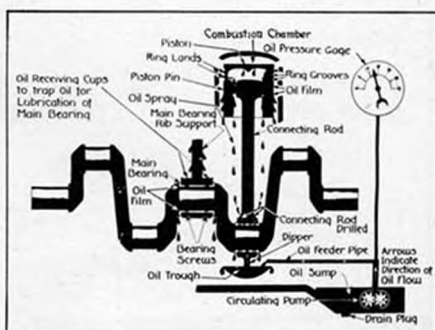


Fig. 37 - Splash lubricating system with circulating pump.

all refills should be of the same brand and grade, because the mixing of oils, even of good grade, may produce unsatisfactory results. Oil does not wear out through friction; it loses its lubricating qualities through contamination or dilution.

It must be remembered that the oil pressure gauge does not register the amount of oil in the crankcase; it indicates pressure only. Because of this, and because it is vitally important that the engine operator know the oil level in his engine, a separate oil level indicator is provided. The most common type is a removable rod or bayonet gauge which is a strip of metal extending into the oil pan through a tube at the side of the crankcase. When this type of "dip-stick" is used to measure oil quantity, the engine must not be running since a reading taken on an engine in operation will not be accurate. For a reading, the gauge should be removed and wiped clear of oil and reinserted; then when the gauge is again pulled out the oil "wet" mark on it will indicate the level.

As mentioned before, oil does not wear

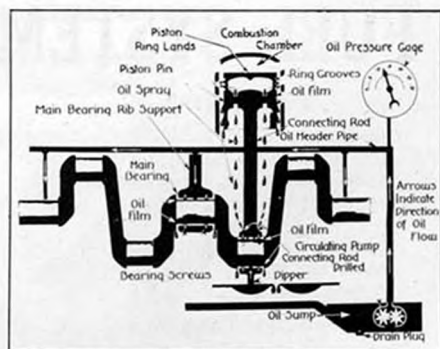


Fig. 38 - Combination splash and force feed lubricating systems.

out, but it becomes contaminated with outside matter and unburned fuel. Dust entering through the air intake of the carburetor mixes with carbon and half-burned lubricating oil and a gummy binder from incombustible parts of the gasoline to form deposits in the combustion chamber. Some of the dust passes the piston rings and gets down into the crankcase. This dirt, together with dirt entering through the crankcase breather, mixes with oil and causes excessive engine wear. Water (a product of

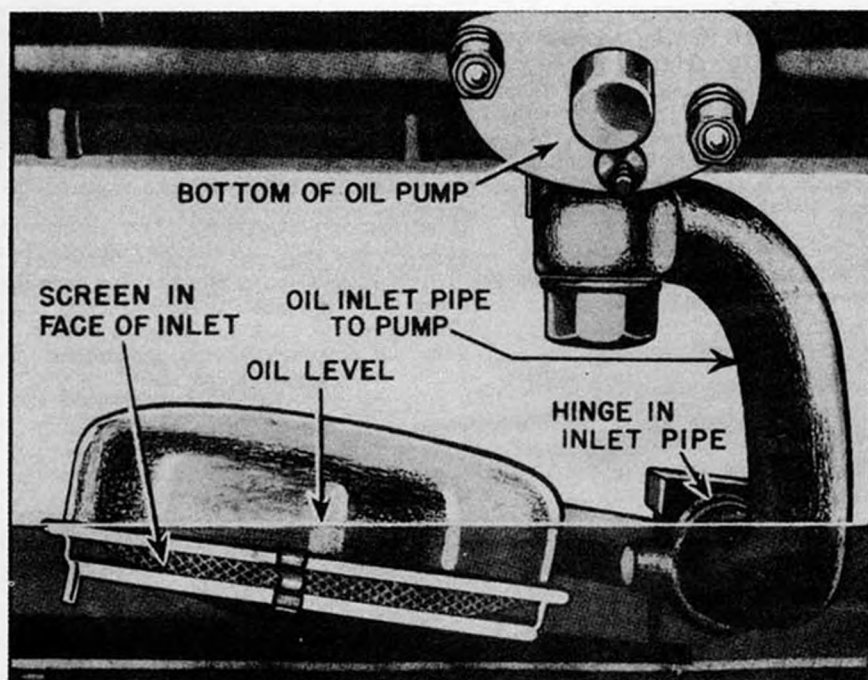


Fig. 39 - Floating type oil strainer on oil pump intake.

combustion) will, especially in cold weather, pass the piston rings as steam and condense in the crankcase. This is emulsified with the oil, and, especially in the presence of dirt and other foreign matter, forms a thick sludge which is of no value as a lubricant and clogs up oil pipes and passages. Oil contamination and sludge is suppressed by the use of thermostats in the cooling system, air cleaners on the carburetor air intake, air filters for the crankcase breather, oil and gasoline filters, and by controlled crankcase ventilation.

When lubricating oil becomes diluted with gasoline it loses its viscosity and some of its

lubricating qualities. Therefore, such dilution must be avoided by all possible means. Excessive use of the choke causes an over-rich mixture to be drawn into the cylinders; some of the fuel thus inducted condenses and drains past the rings into the crankcase. Operating the engine with too low a water temperature produces the same effect to a lesser degree. Many cold starts and short runs in cool weather will have the effect of promoting crankcase oil dilution; this dilution may maintain the oil level at the correct point or even higher, but the lubricating quality of the oil is definitely reduced. Dilution, then, is minimized by correct carburetion, efficient operating and mechanical condition of the engine, and by crankcase ventilation.

PART II

FUEL SYSTEMS AND FUELS

FUEL SYSTEM

This discussion will include the following parts which make up the fuel system: The fuel tank, gasoline gauges, fuel pumps, carburetion, governors, manifolds, and mufflers.

No adjustments are covered here as they are too numerous to list. Always check manufacturers specifications.

FUEL TANKS

The main fuel tanks in vehicles are generally in the rear of the chassis although they may be mounted under the drivers seat, on the sides, or at any convenient place on the vehicle. Most modern vehicles have fuel pumps, consequently the position of the tank has little effect upon its mounting or upon the fuel it supplies to the carburetor.

The tank is usually made of a thin gauge tinned metal or of lead and tin alloy covered sheet steel known as "terne plate". It has an inlet, or filler pipe, and an outlet. (See Figure 43.) The outlet, with a fitting for the fuel line connection, may be placed in the top or side of the tank. The lower end of the outlet pipe, however,

is placed about one-half inch from the bottom of the tank so that any sediment which collects in the tank will not be carried to the carburetor. Baffle plates may be placed inside the tank to reinforce the sides and bottom, and to prevent the fuel from surging or splashing. The baffle plates are welded to the sides and bottom and are notched or perforated so that the fuel can flow freely from one section to another. A drain plug is placed in the bottom, so that the tank can be drained and cleaned.

Fuel tanks give little or no trouble, and require no servicing other than an occasional cleaning. If they are punctured, they should not be welded with an open flame until all traces of fuel and fuel vapors have been entirely removed.

GASOLINE GAUGES

Two types of gasoline gauges are used for indicating to the driver the level of the gasoline in the supply tank. Both are of the dash board type: The electric gauge, which is most commonly used, and the hydrostatic gauge.

ELECTRIC GAUGES

The electric gasoline gauge, Figure 44, consists of two units: a dash unit and a tank

unit. They are electrically connected by running a wire from the ignition switch to the edge terminal of the dash unit, and another from the center terminal of the dash unit to the terminal of the tank unit. The return circuit is through ground connections on the two units.

The circuit and operation of the gauge can be understood from a study of the diagrams in Figure 45. The dash unit consists essentially of two coils spaced 90-degrees apart, with an armature and pointer assembly being swung at the intersection of the coil axes. The coils are wound in such a manner that the faces adjacent to the armature present like polarity.

The tank unit comprises a resistance coil and brush, the latter being driven by a float to take up a position on the resistance proportional to float position. The brush is grounded.

The diagram (a) shows the fundamental circuit, while diagram (b) shows the same circuit with one wire replaced by a "ground" return.

In diagram (c) the float arm is moved so that all the resistance of the tank unit is cut out. In this position it is seen that the right coil is completely shorted out and the left coil alone attracts the armature. The field of the left coil is parallel to its axis and consequently causes the armature to take up a similar position.

In diagram (d) the float has moved the brush to the center of the resistance. In this position the current after flowing through the left coil divides, part flowing through the right coil and part through the resistance.

Both the left coil and the right coil have the same polarity, so that the resultant field is no longer parallel to the axis of the left coil, but is shifted clockwise so that the pointer takes up the position indicating the half mark on the dial.

Diagram (e) shows the brush in such a position that all resistance is in the circuit. Here a still greater proportion of the current flow is through the right coil, shifting the axis of the resultant field still farther, and causing the pointer to indicate a full tank. The effect of the right coil is increased by a pole piece.

HYDROSTATIC GAUGE

The hydrostatic gasoline gauge consists of a dash unit and a tank unit connected by a tube of air, Figure 46. In operating condition the air tube and the air chamber of the tank unit and the air tube connecting the tank unit with the dash unit are filled with air. The gasoline level tries to rise to the same level in the tank unit as it is in the tank, but this is impossible because of the air trapped between the bottom of the tank unit and the liquid in the dash unit. The pressure is thus transmitted by means of the air column in the air tube to the dash unit, where it forces the liquid of the dash unit down in the brass tube and up in the glass indicating tube. The cup and the air delivery tube mounted in the tank take no part in the reading of the gauge, but act only as a means of supplying air to the air chamber to keep it full of air.

FUEL PUMP

OPERATION OF FUEL PUMP AND THE VACUUM SECTION OF COMBINATION FUEL AND VACUUM PUMP

The operation described below is basically the same on all Fuel Pumps of the mechanized and vacuum type, Figure 47.

The rotation of the camshaft eccentric actuates rocker arm (A) pivoted at (B) which pulls the link (C) and diaphragm (D) upward against spring pressure (E) which creates a vacuum in the pump chamber (F).

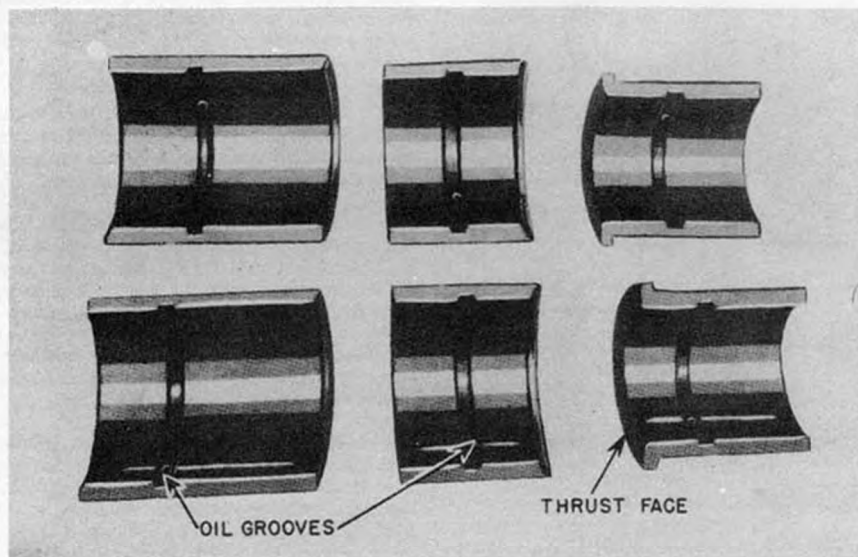


Fig. 40 - Types of grooving in connecting rod bearings for use with force feed lubricating systems.

On the suction stroke of the pump, fuel from the rear enters through the inlet (C) into the sediment bowl (H) and passes through the strainer (I) and then through the inlet valve into the pump chamber (F).

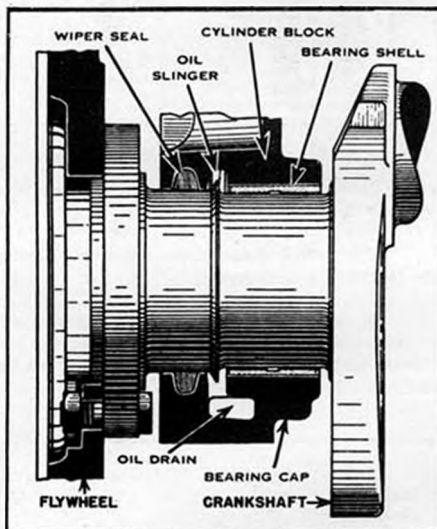


Fig. 41 - Rear main bearing oil seal and drain.

On the return stroke, spring pressure (E) pushes the diaphragm (D) downward, forcing fuel from the chamber (F) through the outlet valve (J) and out through (K) to the carburetor.

When the carburetor bowl is filled, the float in the carburetor will shut off the float valve, thus creating a pressure in the pump chamber (F). This pressure will hold the diaphragm (D) upward against spring pressure (E) where it will remain inoperative in the upward position until the carburetor requires more fuel and the float valve opens. The spring (L) is merely for the purpose of keeping the rocker arm in constant contact with the camshaft eccentric.

The rotation of the camshaft eccentric actuates the rocker arm (A) pivoted at (B) which pushes the link (M) and in turn the diaphragm (N) upward, expelling the air in the chamber (O) through the exhaust valve (P) and out the open-

ing (Q) to the intake manifold.

On the return stroke of the rocker arm (A), the spring (R) moves the diaphragm (N), downward, creating a suction in the chamber (O) opening the intake valve, and drawing air through the inlet passage (S) from the windshield wiper.

When the windshield wiper is not being used, the manifold vacuum holds the diaphragm (N) upward against spring pressure (R) so that the diaphragm does not make a complete stroke for every stroke of the rocker arm (A).

When the manifold vacuum is greater than the vacuum created by the pump, the air will flow from the windshield wiper through both valves of the pump, and the operation of the wiper will be

the same as if the pump were not installed.

However, when the intake manifold vacuum is low — that is, when the car is accelerating or pumping at high speed — the vacuum created by the pump will be greater and will operate the wiper.

The fuel section of the combination pump supplies an adequate amount of fuel from the rear tank to the carburetor to meet engine requirements at all speeds.

The vacuum section of this pump acts as a booster to the intake manifold suction in improving the operation of the windshield wiper at all engine speeds.

The following relates to service operations on these fuel pumps.

In some instances trouble is attributed to the fuel pump which in reality is caused by some other condition. These should be carefully checked to avoid the needless replacement of fuel pumps.

Lack of Fuel at the Carburetor

1. Gasoline tank empty.
2. Leaky tubing or connections.
3. Bent or kinked tubing.
4. Dirty screen.
5. Loose cover plate cap.
6. Worn or punctured diaphragm.
7. Loose cover screws.
8. Carburetor needle valve not seating.

The above can be checked without removing the fuel pump from the engine.

The charts in Figures 48 and 49 can be used in the servicing of both the single fuel pump and the combination fuel and vacuum pump.

ELECTRICAL FUEL PUMPS

Electrical fuel pumps, Figure 50, are designed to supply fuel to the carburetor regardless

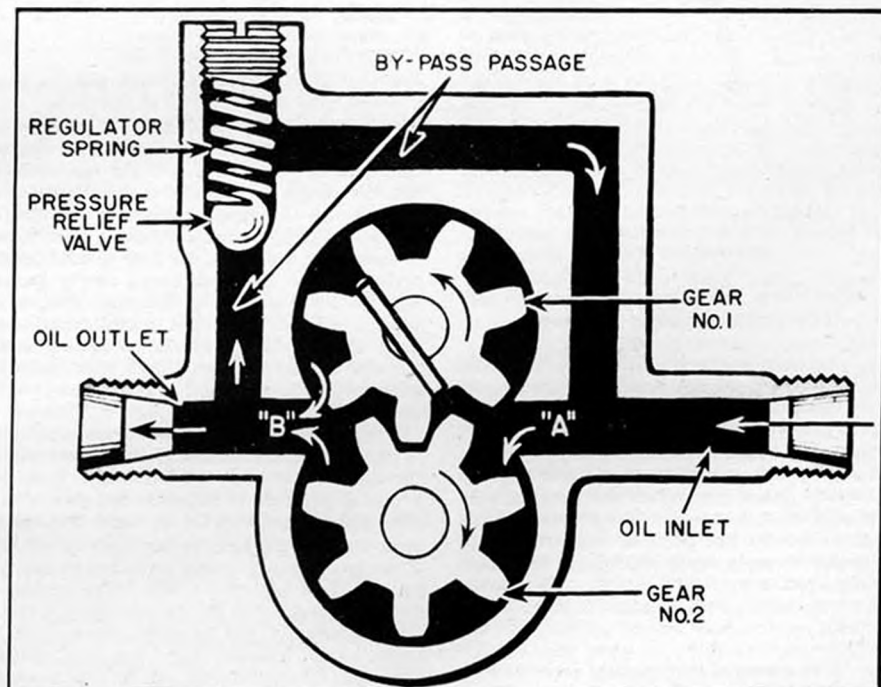


Fig. 42 - Gear type oil pump with cover removed, showing oil passage and pressure relief valve.

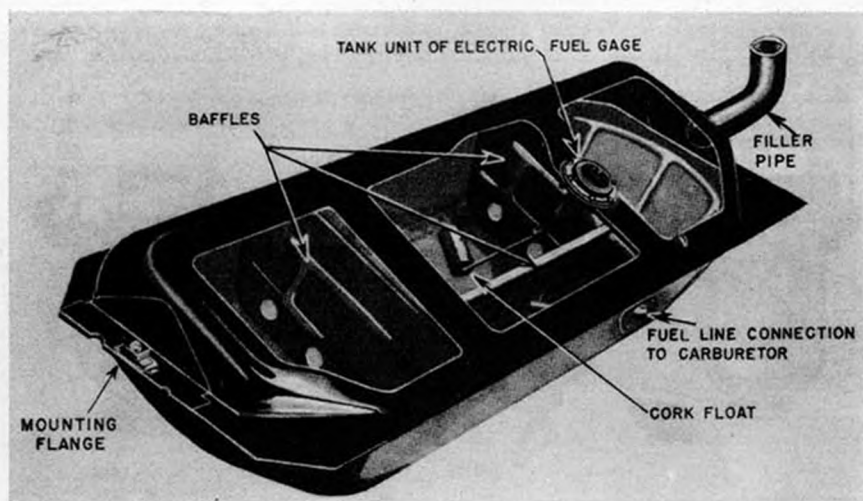


Fig. 43 - Construction of fuel tank.

of the climate, terrain, speed, or location of the fuel tank. This type of fuel pump operates independently of any vacuum in the intake manifold.

The pump is connected between the carburetor and the fuel tank. Operation of the pump depends upon electric current controlled from the coil side of the ignition switch. When the ignition is turned on, the pump will operate before

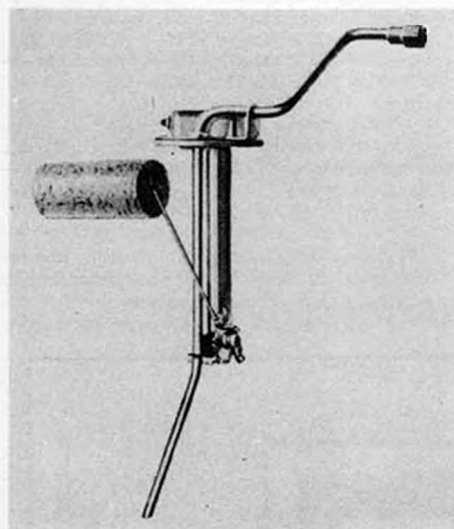


Fig. 44 - Electric gasoline gauge tank unit assembly with feed line.

the engine starts, drawing gasoline from the fuel tank into the carburetor under pressure.

As soon as the carburetor is filled with gasoline to the correct level, the carburetor needle valve closes and pressure is built up, preventing further pumping by holding the electric contact points apart. This action prevents current from flowing and, therefore, there is no drain on the battery. When the level of the gasoline falls the needle valve is unseated and pressure is relieved, so that the fuel pump again operates until the needle valve is again seated by the rising gasoline level in the float chamber. The suction in this type pump is very great and it rarely needs priming.

It is essential that the fuel pump deliver sufficient fuel to supply the needs of the engine under all operating conditions and that it maintain proper pressure in the line between the fuel

pump and carburetor in order to keep the fuel from boiling and to prevent vapor lock. Excessive fuel pump pressure will hold the carburetor float needle valve off its seat, causing a high fuel level in the float chamber, which in turn results in high gasoline consumption.

Ordinarily the fuel pump output is a minimum of ten (10) gallons of fuel per hour at top engine speed, under operating pressure of one (1) to three (3) pounds. Highest operating pressure will be attained at idling speed and the lowest at top speed.

CARBURETION

The internal combustion engine derives

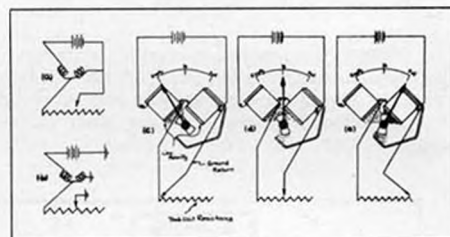


Fig. 45 - Circuit diagram of electric gasoline gauge.

its power from the combustion of gasoline and air. Ordinarily, combustion is the burning of a fuel, such as gasoline, in air. The fuel combines with the oxygen in the air in such a way that heat is produced. Everyone is familiar with the fact that when a lump of coal is burned in a stove, heat is developed and given off over a considerable period of time. The coal burns slowly, because only the outer surface is in contact with the air supply. We also know that in coal mines where there are often large quantities of coal dust in the air, explosions sometimes take place. In this case, each particle of coal is in contact with the air, and burning takes place so fast that we call it an explosion. The heat of the combustion is liberated almost instantly, and is most intense. Gasoline acts in much the same way. If we light a pan of gasoline, it will burn and give off heat over a fairly long period of time, because the outer surface only is in contact with the air, and, if we ignite "gasoline dust" it burns so fast that we call it an explosion. With more surface in contact with the air, the heat is again given off almost instantly and is most intense. If we break up the "gasoline dust" into even smaller particles, the combustion will be still more intense and more complete.

When gasoline and oxygen join in the

cylinder of the automobile engine, certain new gases are formed. The heat of the combustion expands these gases tremendously and the expansion creates terrific pressure. This pressure drives the piston down the cylinder.

In general, then, it is desirable to obtain all the heat possible from the mixture as quickly as possible, because this will give the greatest expansion and pressure from the gases.

Therefore, in the engine, we want to burn the smallest possible particles of gasoline, not even "gasoline dust". This "gasoline dust" is what we call atomized gasoline, and it is made up of very tiny little drops of gasoline, perhaps too small to be seen. But going a step farther, the smallest possible particles of gasoline are available only when the liquid gasoline has been changed into vapor.

The most successful method of getting gasoline vapor for an internal combustion engine is to atomize the gasoline first. This breaks up the liquid into a very fine mist, or "gasoline dust" then, this mist can be easily vaporized.

For the internal combustion engine, we must not only atomize and vaporize the gasoline,

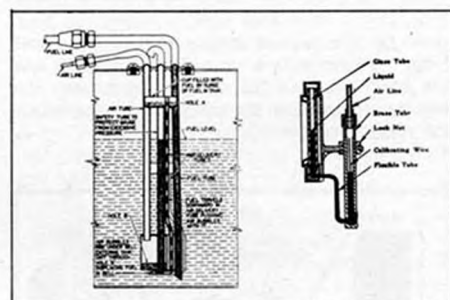


Fig. 46 - Hydrostatic gasoline gauge.

but we must also mix it with air to obtain the oxygen necessary for combustion.

The device which is employed to do these jobs is called a carburetor.

In this discussion of the carburetor, we are not interested so much in the details of individual design, as in the underlying principles as used in all designs.

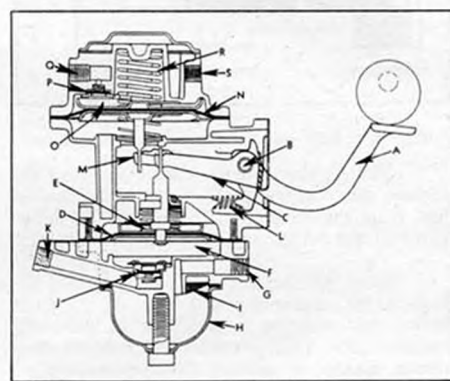


Fig. 47 - Fuel pump.

One of the duties of a carburetor is to feed the gasoline in as finely a divided state as possible. The ideal state would be complete vaporization; however, this is not reached in practice, especially with the present day heavy fuels, as must be evident from the various auxiliary devices that have been provided, such as heated manifolds and hot spots which are employed to vaporize the atomized fuel before it reaches

FUEL PUMP TROUBLE CHART		
TROUBLE	EVIDENCED BY	REMEDY
Broken rocker arm.	Visible.	Replace rocker arm.
Broken rocker arm spring.	Visible.	Replace rocker arm spring.
Defective or worn links.	Fuel pump does not supply sufficient fuel	Replace links. Also check for air leaks.
Full rod oil seal leaking		
Broken diaphragm return spring.	Does not supply fuel to carburetor.	Replace spring.
Punctured or worn-out fuel pump diaphragm.	Fuel leaking through vent hole in body.	Replace complete diaphragm.
Leakage at diaphragm flange.	Visible.	Tighten cover screws evenly and securely.

IMPORTANT: Mark top and bottom covers and body before disassembling so that in re-assembling they are replaced in the same relative position.

Fig. 48

the cylinders.

Even with these devices, at best the fuel will reach the cylinders partly vaporized and partly as mist.

Pure gasoline vapor will not burn. It will only burn when mixed with air within certain limits.

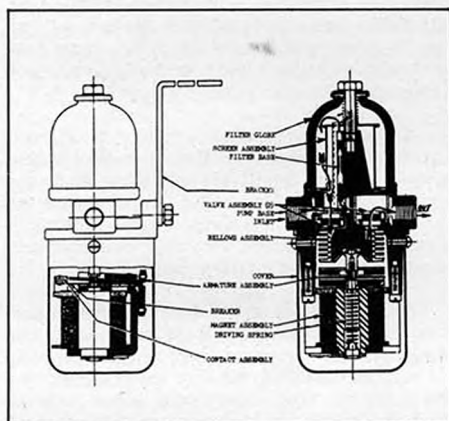


Fig. 50 - Electric fuel pump.

It requires from about 13 to 17 times as much air (by weight) as gasoline to give a proper mixture for varying conditions of engine operation.

Accordingly, a carburetor must automatically vary the proportion of air to meet the ever changing conditions under which the engine operates. Mixtures may be classed as rich, medium, and lean.

The proportion of air to gasoline (by weight) for gas engine operations under different running conditions may be said to have a range of from 12 to 17, approximately. Hence, the average of these, say 15 to 1, may be called a medium mixture, and on the basis of this a rich mixture may be defined as one having a proportion of air less than 15 to 1, while a lean mixture may be considered as having a proportion of air greater than 15 to 1.

In practical operation the characteristics of various mixtures are as follows:

- 18.0 to 1 Severe missing.
- 16.1 to 1 True firing mixture in hot engine giving most miles per gallon but poor power.
- 13.5 to 1 Best compromise between maximum power and maximum economy.
- 8.0 to 1 Richest mixture that will fire regularly in average engine.

those existing in the intake manifold before the distribution pipes are tapped off. In this portion of the manifold the surges due to individual intake valve action are minimized.

First, there are several scales by which intake manifold pressures are measured. A few simple rules will be necessary. All absolute pressures are measured from zero pressure. All gage pressures are measured from a zero set at normal sea-level atmospheric pressure. For example, zero gage pressure represents 15 lbs. per sq. in. absolute. It is the common practice of the aircraft industry to measure manifold pressures on the absolute scale. But in automotive practice the common term is manifold vacuum. This is negative measurement on the gage pressure scale with the minus sign omitted, being understood in the term manifold vacuum.

There are also two common sizes of units of pressure. These are pounds per square inch and inches of mercury. ("Hg). Often the

VACUUM PUMP TROUBLE CHART		
TROUBLE	EVIDENCED BY	REMEDY
Vacuum pump not operating	Slow action of windshield wiper at high speed or when accelerating.	Check wiper lines and fittings. If trouble is not located, disassemble vacuum pump and diaphragm.
Punctured vacuum pump diaphragm.	Oil smoke in engine exhaust-disconnect line between pump and manifold, at pump, and hold paper in front of pump opening and check for oil spray in exhaust from pump.	Replace vacuum pump diaphragm.
Noise.	Worn vacuum pump link and rocker arm pin.	Replace link and rocker arm pin.

CAUTION: Never operate the pump with the outlet passage of the vacuum pump unit closed with a plug of any sort. The downward or exhaust stroke of the pump, is positive and the mechanism may be damaged if this caution be neglected.

Fig. 49

8.0 to 1). Between these two ranges the engine seems to give perfect performance to the driver but will cause excessive carbon, frequent valve grinding, oil dilution, and poor gasoline economy.

12.8 to 1) to The richest end of these two ranges gives maximum power; the lean end gives maximum economy.

It is well to remember that any change in carburetion action will come gradually. Therefore, if the carburetor operated properly when last used, and engine difficulties are encountered, it is reasonable to assume that some other part of the engine is at fault, and the trouble should be located and corrected before attempting alterations on the carburetor.

Dirt is a great enemy to good carburetion; it not only fills up the air bleeds and gasoline passages, but it also accelerates the wear of the delicate parts. How often a carburetor should be cleaned depends upon the conditions under which it is used. In dusty areas the carburetor should get more attention than in parts of the country where this condition is not prevalent.

The carburetor delivers the proper gasoline and air ratios for all speeds of the particular engine for which it is designed.

INTAKE MANIFOLD PRESSURES

A knowledge of intake manifold pressures is most useful in understanding carburetor action, fuel vaporization, and vacuum spark advance mechanisms. By "intake manifold" is meant that portion of the intake system on the engine side of the throttle plate and extending to the intake valves. The pressures spoken of in this discussion are

terms are abused and shortened to pounds and inches, the real meaning supposedly being conveyed by the context. In aircraft engine practice the manifold pressures are in inches of mercury absolute. In automotive engines manifold pressures are in inches of mercury vacuum. For quick calculation it is very nearly true that 30 inches of mercury are equivalent to 15 pounds per square inch. Therefore any pressure in pounds per square inch can be converted to inches of mercury by multiplying by 2. For example: the pressure in a supercharged aircraft engine at takeoff is 25 pounds per square inch absolute. This is equivalent to 25 times 2 or 50 inches of mercury absolute. The chart, Figure 64, shows the several scales and careful study will clear up any confusion.

Here are some useful rules concerning manifold pressure:

(1) For constant throttle plate position, the manifold vacuum increases as engine speed increases, engine power increases and torque decreases.

(2) As the throttle plate opens, manifold vacuum decreases. This action starts at the nearly closed throttle position for idling (18 to 21 inches vacuum) and continues to wide open throttle at maximum power (less than one inch vacuum) on unsupercharged gasoline engines. (This should not be confused with the manifold vacuum obtained by slowly opening the throttle with no load and bringing the engine to maximum speed, the throttle plate being open only a little at maximum speed with no load).

CARBURETOR CIRCUITS

In discussing the carburetor, it is well to divide the unit into its various systems or cir-

cuits. These circuits are: float or gasoline level system, low speed or idle system, high speed system, pump or acceleration system and the choke system.

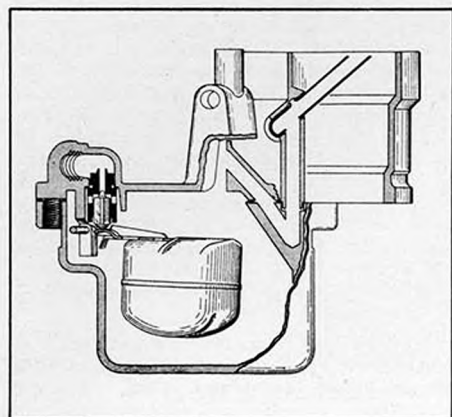


Fig. 51 - The float circuit.

The float system, Figure 51, consists of a needle valve and its seat, needle seat gasket, float and lever assembly, float bowl, bowl cover and gasket, and vent.

The float system controls the gasoline level in the float bowl and also in the high speed nozzle and low speed jet. A gasoline level which is too low or too high will cause trouble in both the low and high speed systems.

The float bowl acts as a reservoir to hold a supply of gasoline throughout the entire range of performance of the engine.

FLOAT LEVEL. - A high float level can be determined by looking down through the throat of the carburetor with a FLASHLIGHT while the engine is idling. If the end of the main nozzle flushes alternately wet and dry, it is a sure indication of a high liquid level in the float bowl. This must be corrected before the engine will idle smoothly.

Always consult the manufacturer's specification sheet before attempting to adjust float level. See Figures 52 and 53.

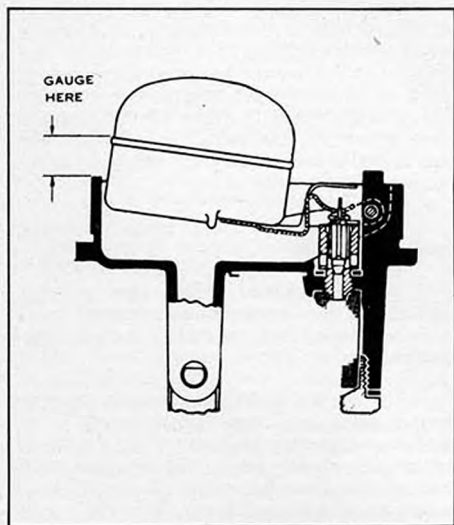


Fig. 52 - Float level setting.

If the float is loaded with gasoline, damaged, or if the holes for the float pin are worn egg-shaped, the carburetor will flood or leak. In this case, replace the assembly. Poor action of the intake needle will result if the lip of the float bracket is ridged. If this is the case, it can be

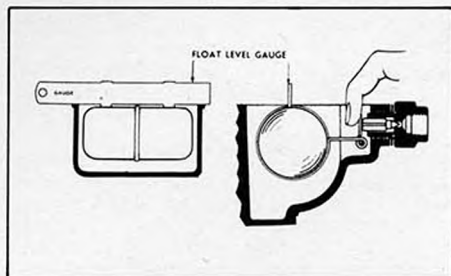


Fig. 53 - Proper method for checking float level.

smoothed with a piece of emery cloth; never use a file. If the float pin, or the hole in the float pin bracket, is worn, it will cause erratic action of the float, and will have the same effect as a high float level.

If the needle is worn so that you can feel or see a ridge, or if the needle and seat leaks or is damaged, or sticks in the seat, the carburetor will flood or leak; replace both the needle and seat, as they are sold in matched sets.

If the fuel pump pressure is too high, the carburetor will flood. If this condition is found, it can sometimes be corrected by adding one or two gaskets under the fuel pump mounting flange. This gives the fuel pump arm a shorter stroke. If the fuel pump pressure is too low, insufficient fuel will be supplied at top speed. In either case, the fuel pump should be repaired. Standard pump

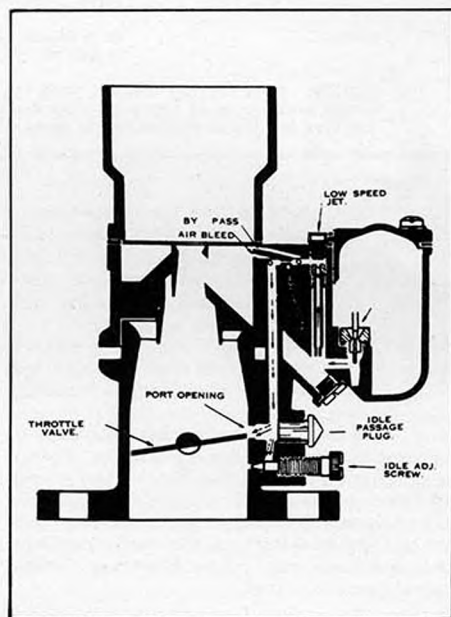


Fig. 54 - Low speed circuit.

pressures vary from 1-1/2 to 4-1/2 pounds, according to the model of the pump.

LOW SPEED SYSTEM. - The idle or low speed system, Figure 54, completely controls the supply of fuel during the idle and light load speeds up to approximately 20 MPH, and it partially controls the light load speeds between 20 and 30 MPH.

During idle and low speed operation of the engine, gasoline flows from the float bowl through the low speed jet to the point where it is combined with a stream of air coming in through the by-pass. The combining of the air and gasoline tends to atomize or break up the gasoline into a vapor.

This mixture of gasoline and air then passes through the economizer, where it is metered and broken up even finer. It then passes

down the low speed passage where more air strikes the mixture and breaks it up even more.

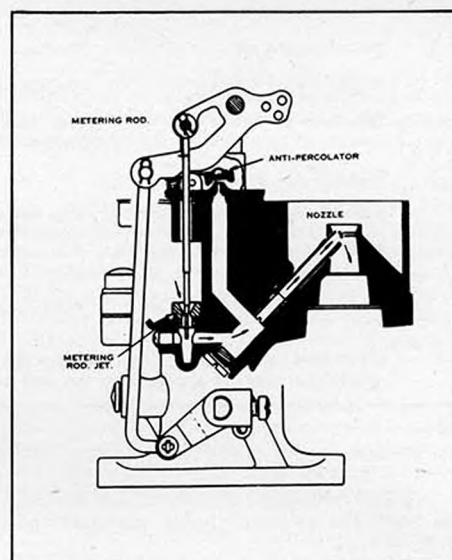


Fig. 55 - High speed circuit.

The gasoline and air mixture flowing downward in the passage from the lower air bleed, is still richer than an idle mixture needs to be, but when it mixes with the air which has come past the throttle valve, it forms a combustible mixture of the right proportions for idle speed.

Idle ports are made in a variety of different shaped slots and holes so that when the throttle valve is opened, it will not only allow more air to come in past the valve, but will also uncover more of the idle port, allowing a greater quantity of gasoline and air mixture to enter the carburetor throat from the idle mixture passage.

The position of the throttle is set so that at an idle speed of 6 MPH, it leaves enough of the idle port open to cover the range in speed between idle and the time when the high speed circuit begins to cut in. The idle adjusting screw controls either the gasoline air mixture or the amount of air. This depends on the location of the idle adjusting screw.

HIGH SPEED SYSTEM. - All gasoline flowing from the float bowl during the idle period and at no load speeds up to 20 MPH, flows from the high speed well through the small metering

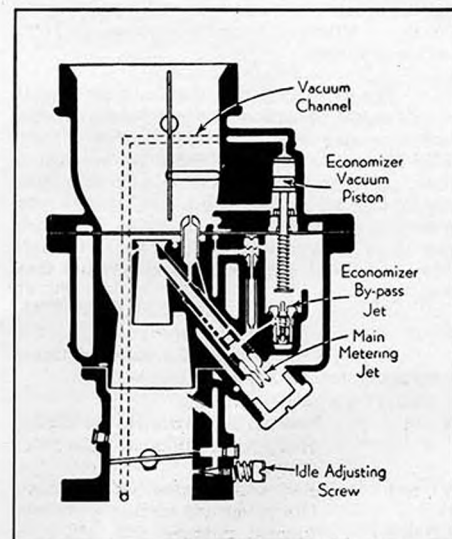


Fig. 56 - Vacuum control.

hole in the low speed jet. As the throttle is opened wide enough for a speed of a little more than 20 MPH, the velocity of air flowing down through the carburetor throat creates a pressure slightly less than atmospheric at the tip of the main nozzle. Since the gasoline in the float bowl is acted upon by atmospheric pressure, the difference in pressure between the two points causes gasoline to flow from the float bowl, through the metering jet, and out at the main nozzle into the throat of the carburetor.

As the speed increases from 20 MPH, the high speed system, Figure 55, continues to cut in more and more, and the idle or low speed system to cut out until the high speed system is carrying the entire load and the idle system is carrying none of the load.

If the carburetor has a metering rod, at higher speeds the area of the opening between the metering jet and the metering rod governs the amount of gasoline going into the engine. At top speed the smallest section of the metering rod is in the jet.

If using a vacuum controlled power step-up system, under part throttle acceleration and for hard pulling at part throttle, the power mixture is required for a short time. This requirement always coincides with a drop in manifold vacuum.

The vacuum control, Figure 56, consists of a small brass piston which has a spring either above or below the piston (depending on the type of carburetor), and is fitted into a cylinder bored into the carburetor casting. The cylinder has a drilled passage, opening into the carburetor throat below the throttle valve. The vacuum acting upon the piston through this passage holds the piston up or down, as the case may be, as long as the vacuum is stronger than the spring. At high speeds, or under a load, when the vacuum

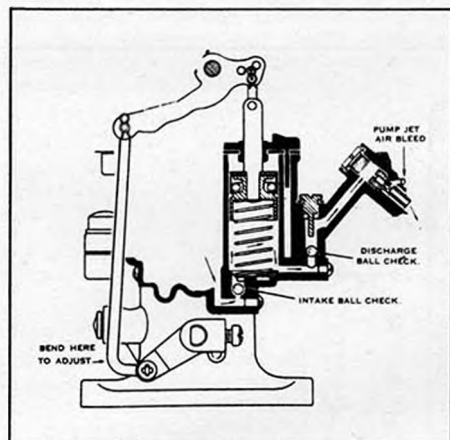


Fig. 57 - Pump circuit.

drops off, the spring acts upon the piston, moving it up or down opening a check valve, which allows more gasoline to flow into the high speed circuit. As the manifold vacuum again increases, the vacuum overcomes the spring tension and the piston moves; shutting off the extra supply of gasoline from the high speed circuit. At speeds above 45 MPH, the throttle valve is so far open that the manifold pressure has dropped enough to allow the spring to overcome the manifold pressure and open the power step-up jet, so as to allow more gasoline to enter the high speed circuit for high speed operation.

PUMP OR ACCELERATION SYSTEM.

The pump system, Figure 57, consists of a pump cylinder, pump arm assembly, connector link, pump plunger and rod assembly, plunger leather, spring, intake valve, discharge valve, pump strainer screen, pump jet, connector rod and pump spring.

When the pump plunger and leather are first installed in the pump cylinder, a small amount of air is trapped between the piston and the top of the liquid gasoline. As the accelerator pedal is depressed, the pump plunger and leather are forced downward. This compresses the trapped air, closes the inlet valve, opens the discharge valve, and discharges gasoline into the carburetor throat. The discharge is prolonged, since the hole in the tip of the pump jet is small enough to restrict the flow as long as it is being forced out by the pump travel, plus the expanding of the trapped air. The prolonging of the pump discharge gives the gasoline in the high speed system sufficient time to increase the gasoline flow enough to satisfy the demands of the engine.

As the accelerator pedal is allowed to return to its original position, the accelerating pump plunger is lifted upward by the link. This creates a partial vacuum in the pump cylinder, which opens the inlet valve, closes the discharge valve, and draws in a charge of gasoline.

Since the discharge valve is below the gasoline level of the carburetor, gasoline would be drawn into the throat of the carburetor through the pump jet from the acceleration system during fixed throttle intermediate speeds and high speeds if it were not for the pump disc check valve, Figure 58, or air bleeds to the outside air. This breaks up the vacuum of the accelerating system by bleeding air.

Pump jets are made in three types: One type is vented by means of the disc check valve,

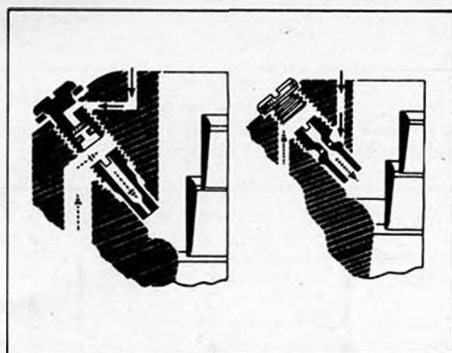


Fig. 58 - Pump disc check valve and pump vent.

one type is vented directly to the outside air, while some other units are not vented and the carburetor is calibrated accordingly.

Where they are vented to the air, the system is known as pump relief, and where they are not vented to the air, the system is called pump pull over, supplying more fuel for high speed operation.

The accelerating pump explained above is operated through linkage connected to the accelerator foot pedal, and operates directly off the throttle connector link to the pump arm. This type of pump has a pump adjustment which is adjusted for pump stroke. If a metering rod is used, the pump stroke is adjusted at the same time the metering rod adjustment is made. When setting metering rod adjustment the pump stroke is automatically adjusted. The adjustment, Figure 59, is made by using a metering rod gauge, and bending the throttle connector link until there is no more than .005 inch clearance between the gauge and the post which holds the metering rod.

On other types of carburetors, the pump adjustment can be made by the use of a pump travel gauge, Figure 60, and it is best to check manufacturer's specifications before attempting to set the pump stroke. If the pump stroke is short, a flat spot will result, and if the pump

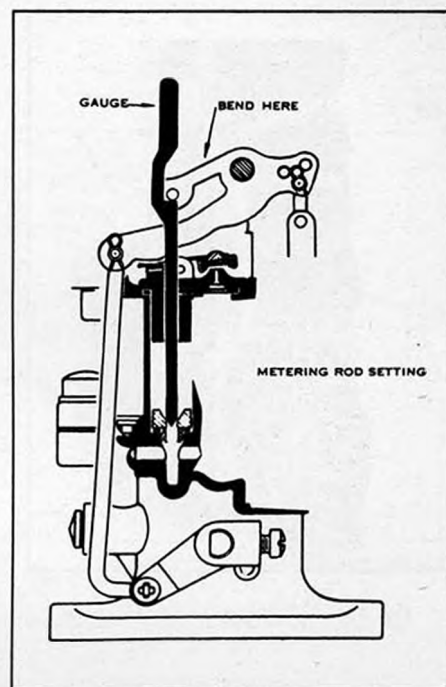


Fig. 59 - Adjustment of pump stroke.

stroke is too long, it will cause loading up, or too rich a mixture.

VACUUM TYPE ACCELERATING PUMP.

This system, Figure 61, supplies the extra fuel required for maximum power or acceleration. When the manifold vacuum is low, as when the throttle is opened quickly, when high engine speed is reached, or under heavy load with the throttle wide open but with low engine speed, the vacuum piston assembly is pushed down its cylinder by the spring above the pump plunger. As it starts its downward stroke, the inlet check valve closes, and fuel is forced through the power jet valve in the bottom of the pump cylinder through the passage to the power and accelerating jet, where it is then discharged into the carburetor throat.

As the vacuum again builds up, it pulls the pump piston back up into its cylinder, stopping the extra supply of fuel which is not needed.

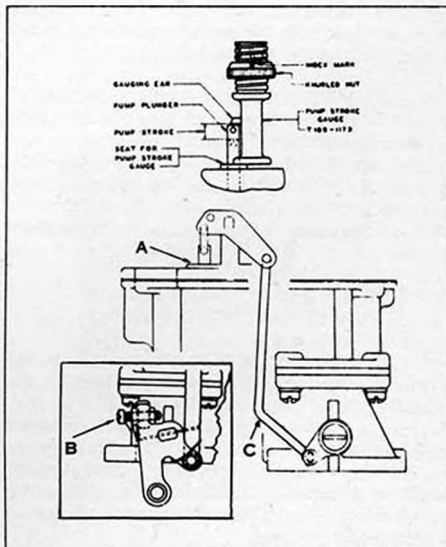


Fig. 60 - Use of pump travel gauge.

Be sure pump link is in setting given in specification sheet. Throttle lever adjusting screw (B) backed away from its seat and throttle valve closed tight. Set gauge on seat (A) and adjust gauging ear to top of pump shaft. Read gauge. Open throttle wide and again set gauging ear on same spot as before. Read gauge again. Deduct second reading from first reading. The gauge reads in 64ths of an inch. To adjust pump stroke, bend at (C).

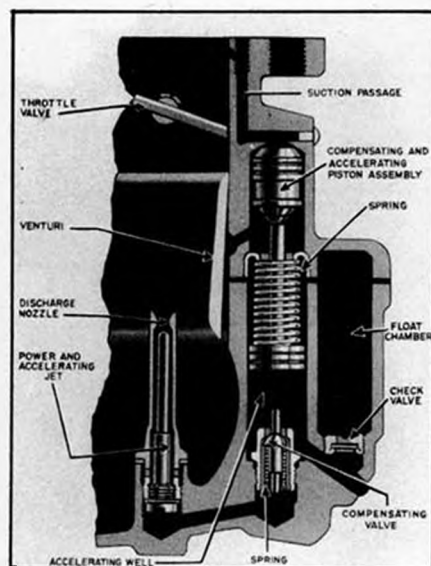


Fig. 61 - Vacuum type accelerating pump.

CHOKE SYSTEM. - This circuit, Figure 62, is used only for starting and warming the engine; its purpose being to supply a rich mixture for starting when the engine is cold. With the choke valve closed, a high vacuum is formed beneath it, resulting in a very rich mixture.

The choke circuit consists of a choker shaft and lever assembly, choker valve, and

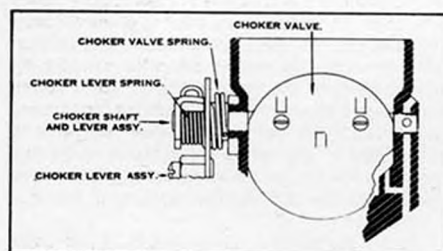


Fig. 62 - Choke system.

means of controlling the valve. In the manual choke, a wire from the dash is connected to the choker shaft and lever assembly.

CLIMATIC CONTROL OR AUTOMATIC CHOKE. - There are several methods employed to operate automatic chokes. Among them are exhaust manifold heat, intake manifold vacuum, carburetor air velocities, and electricity. Some may use only one of these methods while others use a combination of them together. All of them use thermostats. See Figure 63.

OTHER PARTS THAT AFFECT PERFORMANCE-ECONOMY

1. **CARBURETOR FLANGE.** - Which may be loose on the manifold. If either nut of the manifold flange studs is loose as much as one-half turn, a sufficient amount of air will enter the intake manifold below the throttle to destroy the idle and all engine performance. If a tight fit cannot be obtained by tightening the nuts, a new gasket should be installed. Be sure the old gasket is completely removed.

2. **AIR CLEANER.** - Which may be restricted with dirt or have the silencer tube misaligned. Either trouble will cause a restriction of the flow of air into the carburetor, resulting in a partial choking action of the carburetor. This

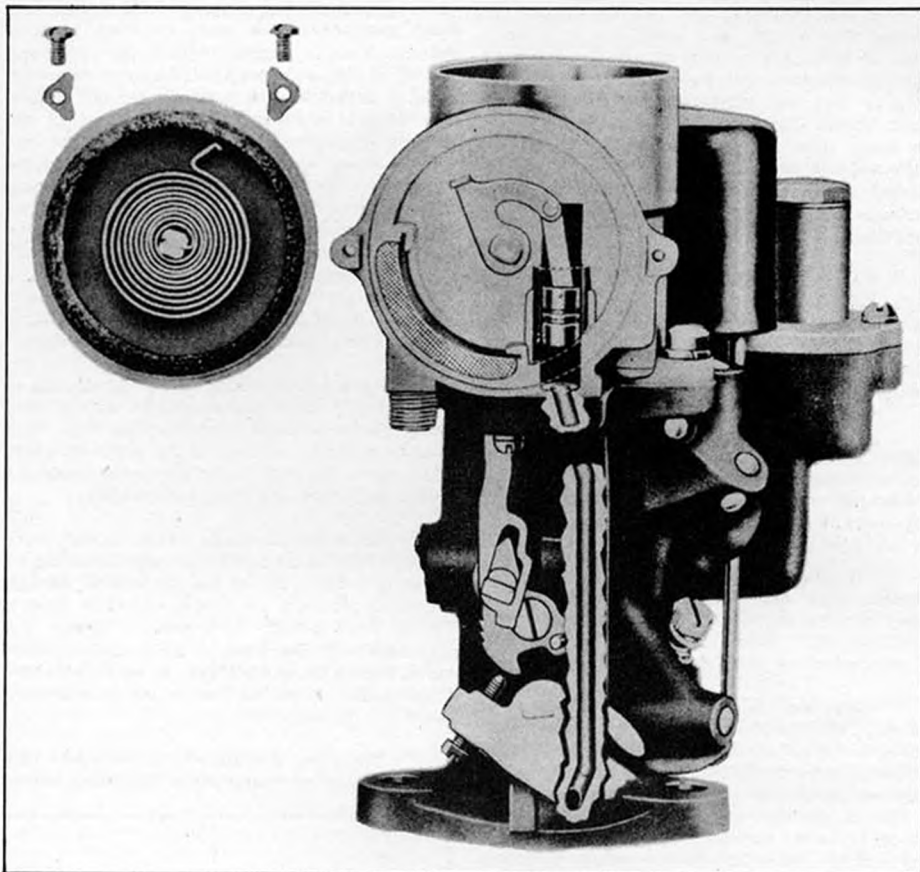


Fig. 63 - Climatic control circuit.

will cause poor engine performance and poor gasoline mileage.

3. **THROTTLE LINKAGE.** - Which may be improperly adjusted. If the linkage is adjusted so

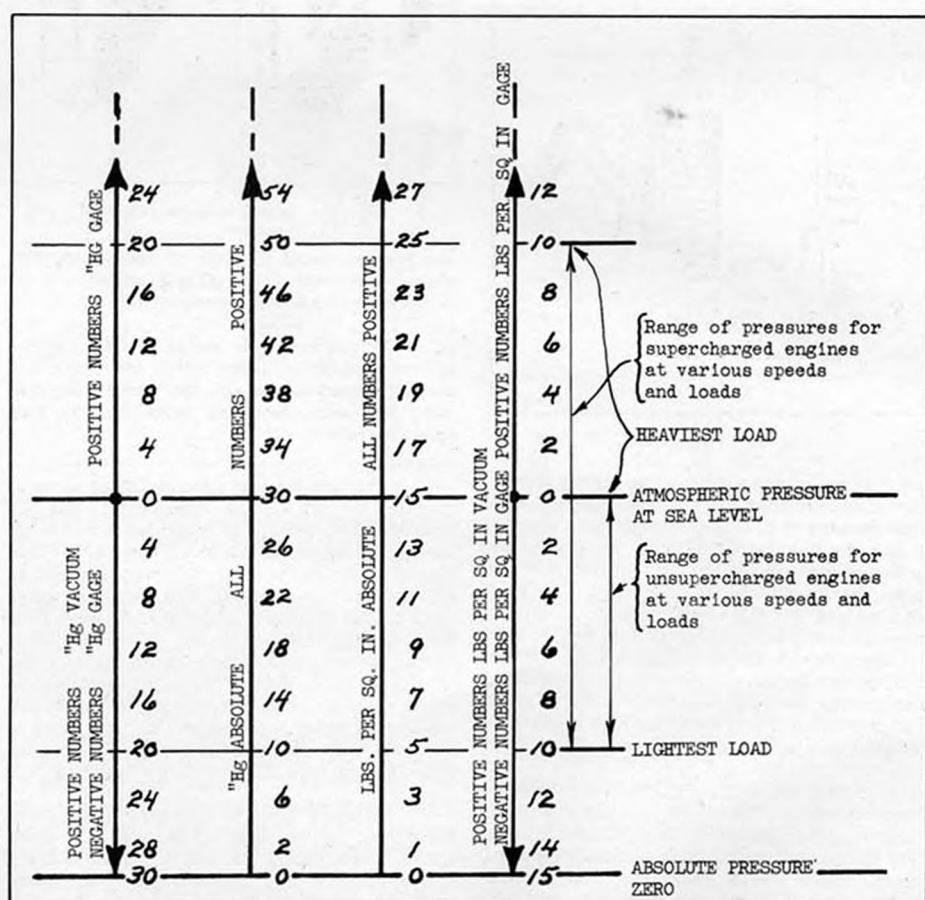


Fig. 64 - Intake manifold pressures for gasoline engines.

that the accelerator pedal will strike the floor board before the valve is opened, it will result in low top speed.

4. **GASOLINE LINE.** - Which may be restricted. A restriction of the gasoline line will likely result in an apparent vapor lock action, or a definite cut-off in the supply of gasoline. This can generally be corrected by blowing out the line with compressed air, but in some cases the line must be replaced.

5. **EXHAUST SYSTEM.** - Which may be restricted. Quite often a tail pipe is found to be partially plugged by dirt or some other foreign substance. This is generally caused by backing into a dirt bank at the side of a road. Such a restriction in the exhaust system will affect all engine performance.

6. **INTAKE MANIFOLD.** - Which may be restricted by gum from gasoline. A deposit of gasoline gum in the intake manifold will restrict the flow of air and gasoline into the engine, affecting all engine performance with a definite loss in power. In some cases, the manifold can be cleaned by using Acetone or a half and half mixture of Benzol and denatured alcohol. In some cases it is necessary to replace the manifold.

7. **MANIFOLD HEAT CONTROL.** - Which may be improperly adjusted, or the thermostatic spring may be allowed to become disconnected during a tappet adjustment and not be properly reconnected. If the heat control is adjusted to where it holds too much heat in the intake manifold, the engine will ping upon acceleration, even though the ignition is timed properly and will have an apparent flat spot because of over-expansion of the fuel and air in the intake manifold. If the control valve is adjusted to open too early, insufficient heat is retained in the intake manifold, and will result in slow warm up, causing poor gasoline economy on short trips. If the thermostat spring happens to become disengaged and is not reinstalled, the entire heat control system is destroyed, causing a decided loss in engine performance and gasoline economy.

8. **VACUUM SPARK ADVANCE CONNECTION.** - Which may be leaking. This will allow air to enter the throat in excess of that considered in the calibration of the carburetor and may result in poor gasoline economy through fixed throttle intermediate speeds because of incorrect operation of the vacuum spark advance. Lower suction on spark advance will cause rough idle.

9. **WINDSHIELD WIPER HOSE AND CONNECTION.** - Which may be leaking. This condition will result in leanness on some cylinders and poor gasoline economy in all speeds. Generally it is necessary to replace the hose to stop the leak.

10. **INTAKE MANIFOLD GASKET.** - Which may be leaking. This is indicated by a very poor idle and will affect all engine performance and gasoline economy. The manifold bolts should either be tightened or the gasket replaced.

11. **INTAKE MANIFOLD HEAT RISER.** - Which may be leaking or coated with carbon. A leaking riser can be identified with a vacuum gauge while cranking the engine with the starter, as it will only show about seven inches of vacuum.

12. **CARBON IN INTAKE MANIFOLD.** - A sluggish engine caused by slow "warm-up" may be due to an accumulation of carbon in the carburetor heat riser section of the intake manifold. If this condition exists, poor acceleration will be noticed even after the engine is well warmed up. To correct this condition, proceed as follows.

Remove the carburetor and intake manifold and unbolt the heat control assembly. Place the manifold upside down on a bench, insert and ignite

a piece of paper in the heat outlet (narrow) opening of the riser. With a torch, using oxygen only, it will be possible to burn and completely oxidize the carbon deposit. Better result will be obtained if part of the opening through which the torch is inserted is covered with a heavy piece of metal after the carbon starts to turn.

CAUTION:

Do not put kerosene in the riser to facilitate burning the carbon, or use acetylene in this operation, as a cracked manifold or burned riser may result.

13. **LEAKING DIAPHRAGM ON A "FUEL-VAC" PUMP.** - When the diaphragm on the vacuum pump is leaking, oil is drawn from the crankcase causing high oil consumption and ignition miss due to fouling of the plugs. With a small hole the trouble first encountered may be a partial miss on the two cylinders adjacent to the spot where the vacuum line taps into the manifold. This condition may be checked by the action of the windshield wiper on acceleration, with the vacuum gauge, or by disconnecting the line on the manifold side of the vacuum and inspecting for oil.

14. **PLUGGED MUFFLER.** - Caused by carbon deposits. This can be detected by means of the vacuum gauge.

15. **OIL TOO HIGH IN OIL BATH AIR CLEANER.** - This will restrict the flow of air.

CARBURETOR TROUBLE SHOOTING

CIRCUIT NUMBER ONE Gasoline Level in Carburetor

FLOODING OR LEAKING

Causes:

1. High fuel pump pressure. Test fuel pump.
2. Leaking gas line, or at connections.
3. High float level. Check with specifications.
4. Stopped up vent hole. Some have vent in cover, others in air horn leading into bowl chamber.
5. Gas line connections cross threaded or loose in bowl cover.
6. Bowl cover not sealing or poor bowl gasket. (Bowl cover warped or bent.)
7. Poor gasket on needle seat or needle seat loose in carburetor. Anything under needle seat gasket preventing seal at bowl cover.
8. Worn needle and seat where you can see or feel a ridge on needle valve.
9. Sticky needle valve. Needle valves and seats come in matched pairs and are tested. DO NOT TAP ON NEEDLE AND SEAT.
10. Gum, dirt, or foreign matter between needle and seat not letting needle valve seat.
11. Wrong needle and seat.
12. Ridge worn in the float lip causing needle valve to bind. This ridge can be smoothed off by using a piece of sandpaper or emery cloth. DO NOT USE A FILE FOR THIS OPERATION.
13. Float pin worn or holes in float pin worn egg shaped. This will cause float to bobble and cause loaded condition. REPLACE BOTH.
14. Check to be sure float does not bind in casting.
15. Cracked casting, passage plugs or parts not sealing gasoline tight in casting.
16. Dirt or paint under copper washers preventing a gasoline tight seal in casting.
17. Gasoline leak at nozzle where it seats in casting due to poor gasket or nozzle not seated tight.

CIRCUIT NUMBER TWO

Low Speed System

LEAN ON IDLE

Causes:

1. Restricted metering hole in low speed jet. Replace.
2. Air by-pass or bleed holes in casting oversized.
3. Economizer hole in casting restricted.
4. Restriction in passage in casting from low speed jet to port hole and idle screw.
5. Port opening too small.
6. Port hole restricted.
7. Hole restricted in casting where idle screw seats.
8. Threads in casting carbonized not letting idle adjusting screw regulate the amount of air needed to adjust the carburetor.
9. Air leak at flange gasket.
10. Idle screw burred.
11. Port plug loose, or not seated in casting.
12. If lever is loose on throttle shaft, it is hard to get idle adjustment.

RICH ON IDLE

Causes:

1. Worn or too large metering hole in low speed jet.
2. Upper end of low speed jet not seated in casting.
3. Air bleed or by-pass hole in casting restricted with dirt or carbon.
4. Economizer in casting too large.
5. Idle port damaged.
6. Gasoline leak at nozzle where it seats in casting.
7. Idle screw damaged so as to prevent adjustment.
8. Carbon around bore where throttle valve seats, causing a rich port opening.
9. Throttle valve installed wrong.

CIRCUIT NUMBER THREE High Speed System

LEAN CONDITION

Causes:

1. Low fuel pump pressure.
2. Restriction in gas line connection to needle seat. This does not allow sufficient gasoline to enter bowl for high speed driving.
3. Low float level.
4. Opening in needle seat too small (the wrong needle and seat.)
5. Restricted outside vent hole.
6. Restriction between metering rod and jet.
7. Improper metering rod setting or parts that operate metering rod worn. (Bowl cover, pump arm, throttle rod, throttle shaft arm.)
8. If the above parts are worn, the different steps of the metering rod will not pull out at the proper time.
9. Wrong metering rod (too large in diameter), or metering hole too small in metering rod jet. (WRONG PARTS).
10. Restriction in casting from metering rod jet to nozzle.
11. Damaged nozzle.
12. Screw nozzle fails to seat in slip nozzle. (Air bleed nozzle.)
13. Two nozzle gaskets installed on nozzles that should have only one nozzle gasket.
14. Air horn assembly loose on casting.
15. Worn throttle shaft.

RICH CONDITION

Causes:

1. High fuel pump pressure.
2. High float level.
3. Warped or bent bowl cover allowing an

air leak at the gasket.

4. Metering rod spring disconnected from metering rod.

5. Metering rod not gauged properly.

6. Worn metering rod and jet. (Replace)

7. Metering rod jet loose in casting.

8. Bent metering rod. (Replace)

9. Damaged nozzle. (Replace)

10. Nozzle installed without nozzle gasket (when one is required).

11. Air bleed nozzles have to be installed with the air bleed hole up.

12. A bowl cover with a vent hole, if installed on a balance vent carburetor, will cause a rich condition.

13. If a relief check is stuck closed on carburetors that have relief check for accelerating pump or if pump vent to the bowl is stopped up, the motor will draw gasoline through the pump system and the carburetor will run rich.

14. If the pumpbushing is missing, it will let gasoline splash from the bowl over on top of plunger causing pump to give high pressure.

15. Choker valve hinge stuck in air horn causing carburetor to be partly choked.

16. Dirty air cleaner.

17. Choke not operating properly.

18. Air bleed in air bleed nozzles stopped up.

CIRCUIT NUMBER FOUR

Accelerating Pump.

LEAN ON ACCELERATION

Causes:

1. Weak plunger spring. (Replace)

2. Worn or dried out plunger leather or weak pump spring. (Replace)

3. Leather loose, not installed tight on plunger.

4. Worn plunger assembly. (Replace)

5. Intake or discharge check not seated in casting.

6. Leaking or sticking intake or discharge check. (Replace)

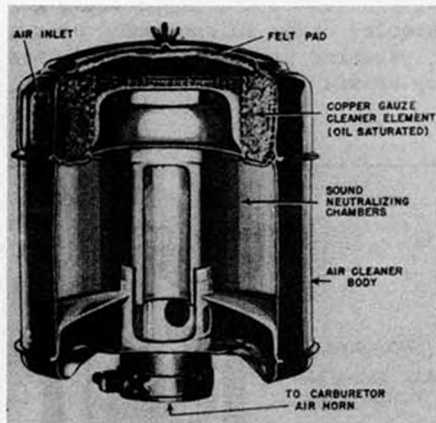


Fig. 65 - Dry type air cleaner.

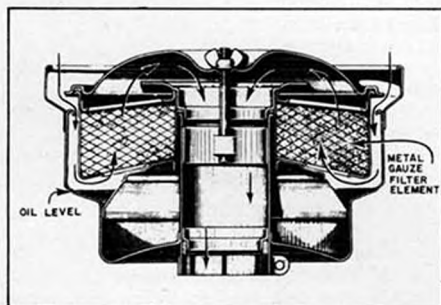


Fig. 66 - Wet type air cleaner.

7. Passages in casting for pump restricted.

8. Pump jet restricted or not seating in casting.

9. Pump disc check sticking or leaking. (Replace)

10. Pump not adjusted properly.

11. Wrong parts.

12. If linkage from throttle to accelerating pump is worn, the mixture will be lean. When throttle is moved open from the closed position, the pump jet should start to discharge instantly. Therefore, there should be little play in these parts.

CIRCUIT NUMBER FIVE

Choke System

TOO RICH

Causes:

1. Choker shaft binds.

2. Choke piston binds or is stuck.

3. Air strainer gauze covered with dirt.

4. Leak in choke gaskets. (Replace)

5. Choke valve binds in air horn.

6. Tube leaking from stove to climatic control.

7. Cork disc in thermostat housing warped.

8. Cork strip shrunk or interfering with operation of the thermostatic coil.

AIR CLEANERS

One of the greatest causes of engine wear in the past has been the large amount of road dust inhaled through the carburetor. This dust is very abrasive, and consequently causes considerable wear on the cylinder walls. At the same time it increases the carbon deposits. Air cleaners are provided to prevent the dust and dirt from entering. An air cleaner is attached to the carburetor air horn and removes the dust and dirt by centrifugal action or by a filtering process. Air cleaners, in addition to removing the dust and dirt, are designed to silence the unpleasant buzzing noise made by the air entering the carburetor, and some are arranged to arrest the flame caused by any backfires which may come from the carburetor.

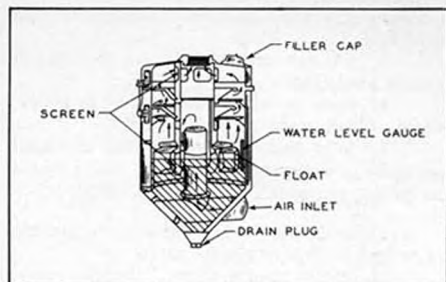


Fig. 67 - Cross section of air washer.

Three types of air cleaners are in general use; the dry type, the wet type, and the air wash type.

The dry type cleaner, Figure 65, consists of the air cleaner body, with baffle plates to silence the incoming air, loosely knitted copper ribbon, or fibrous gauze, and a cover plate which has a felt pad. The copper gauze may operate wet or dry. The incoming air passes through the gauze where the dust or dirt is removed, and the clean air passes down through the air cleaner into the carburetor. In case of a backfire, the flame is snuffed out by the felt pad and the incoming air before any damage can result.

The wet type air cleaner, Figure 66, consists of a main body, a unit filled with copper gauze, and a cover plate with a felt pad. Air entering this cleaner has to pass through small

ports at the top of the main body, and down between the main body and the unit filled with copper gauze. Here it has to make a 180 degree turn where it passes over a bath of oil. The heavy particles, due to their velocity, are caught in the oil. The air then passes up through the copper gauze, where the fine particles are filtered out by the gauze, which is oil soaked due to the air picking it up as it passes over. As the air passes through the copper gauze it hits the cover and is deflected down through the passage leading to the carburetor.

The air wash cleaner, Figure 67, consists of a main body with baffle plates for silencing the air, an inlet passage, and a float. The action of the air passing through the water, or oil, filters out any dust or dirt, and as well as filtering the air, the air will carry with it quite a percentage of moisture, so that the washing is an advantage for motors requiring cooling when using kerosene for fuel.

The air wash cleaner is used mostly in tractors.

GOVERNORS

Governors are used on motor vehicle engines to limit their speed to some predetermined figure. The governor is placed between the carburetor and intake manifold, and is then set at whatever maximum speed desired and sealed.

Engine governors commonly used are of two types; the centrifugal type, which is mechanically driven, and the velocity or vacuum type, operated by vacuum.

CENTRIFUGAL TYPE GOVERNOR. - In its simplest form such a governor consists of

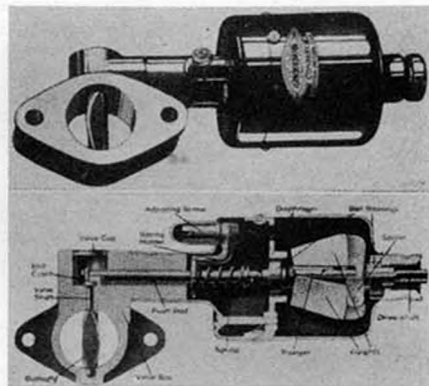


Fig. 68 - Pierce governor.

two weights on the end of two arms which are pivoted on a spindle connected to the throttle valve, either directly or through suitable linkage, so that any movement of the weights operates directly on the throttle. A flexible drive shaft, driven from the rear of the transmission and connected to the spindle which holds the two weights, controls the governor. The Pierce governor, Figure 68, operates a butterfly valve such as used in carburetors. This valve is shown at the left, while the weights and the driving attachment are at the right. Between the two is a spring against which the centrifugal force of the weights must act to close the throttle. Just above this spring will be noted a screw adjustment by means of which the speed for which the governor is set may be altered. Increasing the tension of the spring, by screwing it in, permits an increase in the speed of the motor, since the weights must then revolve at a higher speed in order to overcome the pull of the spring. This is the principle upon which the adjustment of all centrifugal governors is based.

VELOCITY OR VACUUM GOVERNORS. - These governors, Figure 69, are operated by the

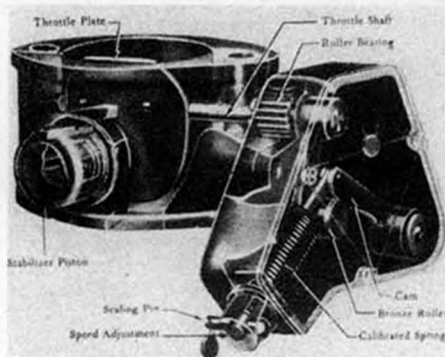


Fig. 69 - Speed limiting governor.

velocity of the fuel mixture and manifold vacuum. The throttle shaft is slightly offset from the center line of the throat, and operates the throttle plate of the governor. The throttle plate is set at such an angle that the flowing fuel mixture will move it. The faster the fuel mixture flows, the harder it strikes the throttle plate. This starts moving the plate, with the aid of the vacuum working on the outside of the piston which acts as a stabilizer. The spring attached to the throttle shaft is adjusted so that it equals the force of the fuel mixture on the throttle at the maximum engine speed desired.

MANIFOLD CONSTRUCTION

Intake manifold. - The design of the manifold has a great deal to do with the efficient operation of the engine. For smooth and even running, the charge taken into the cylinders should be of the same strength and quality. In other words, the charge taken into one cylinder should not be richer or in a better state of vaporization than the charge taken into another cylinder. The distribution of the fuel to the cylinder should, therefore, be as even as possible. This depends greatly on the design of the intake manifold.

The ideal form of charge is one that consists of dry gas, but the present day fuels prevent such a charge unless the mixture is subjected to a high temperature. If the charge is too highly heated, the volumetric efficiency is destroyed and the power output of the engine drops off. A compromise between these two mixtures is used, and the charge is introduced into the cylinder in the form of a gasoline fog. Even this has its disadvantages, as some of the fuel will be deposited on the walls of the manifold and cylinders.

The manifold should, therefore, be designed so that the condensation is reduced as much as possible. If condensation does occur, each cylinder should receive its equal share of the wet mixture which is taken up by the incoming charge.

The firing order and the valve timing also have something to do with the design of the manifold. When two cylinders in the same block next to each other fire one after the other and the intake valve opens a little before the previous intake valve closes, there is a possibility of a supply of gas to the next cylinder being cut off by the suction of the second cylinder.

The inside of the intake manifold should be smooth, and the passage should be large enough so that there is no obstruction to the flow of gases. The bends in the manifold should be so designed that the movement of the gases will prevent any fuel accumulating on the walls of the manifold through condensation. The flat bottom manifold is well adapted for heat application and quick vaporization of condensed fuel moisture on

its wall. As the drops of moisture fall to the floor the mixture is vaporized at once. This applies to all manifolds, whether for four, six, or more cylinders. See Figures 70 and 71.

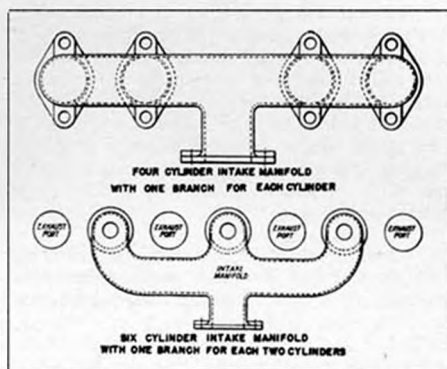


Fig. 70 - Intake manifolds.

Exhaust Manifold. - The object of the exhaust manifold is to carry away the hot burned gases from the cylinders, and to do this with as little back-pressure as possible. These manifolds may be single iron castings, or may be built up units. They should have smooth interior surfaces and no abrupt changes in size. The shape of the manifold, by its influence on the inertia of the hot gases, has an appreciable effect on the scavenging of the engine, and for best results not more than three cylinders should be connected to any manifold.

Hot Spot Manifold. - It is very desirable

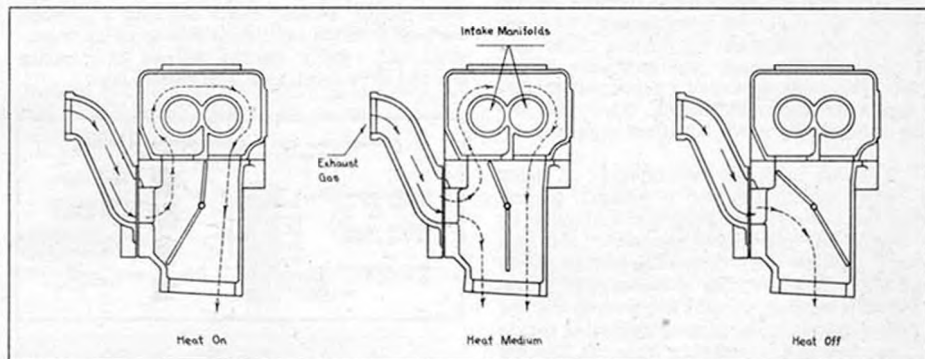


Fig. 72 - Heat control valve operation.

to place the carburetor close to the cylinders so that there will not be a great deal of condensation in the lower part of the intake manifold. It is so constructed that a portion of it, consisting of solid metal, is in constant contact with the exhaust manifold, so that with continuous running this solid metal in the intake manifold becomes heated, perhaps to a high degree. This "hot spot" is located in the inlet passages so that all fuel must pass over it before passing to the cylinders. The result is that any unvaporized particles remaining in the fuel gas are thrown against this highly heated spot and vaporized instead of being carried into the cylinders as liquid particles, as would be the case without this heated spot. See Figure 72.

MUFFLERS

MUFFLER. - The purpose of the muffler is to reduce the pressure of the gases by expansion to a point where they will emerge into the atmosphere without noise. This is generally done by providing a number of concentric chambers. The gas is allowed to expand from the first passage into the much larger second one, then into the still larger third one, and so on, to the final and largest passage which is connected to the pipe leading out into the atmosphere. This is not

as simple as it sounds, for if it is not well and wisely done, there will be a back pressure which will reduce the power and speed of the engine, causing heating trouble, and possibly causing the motor to stop.

DUAL MUFFLERS. - It will be noted that these mufflers are of the straight-through type, Figure 73, being provided with a central tube

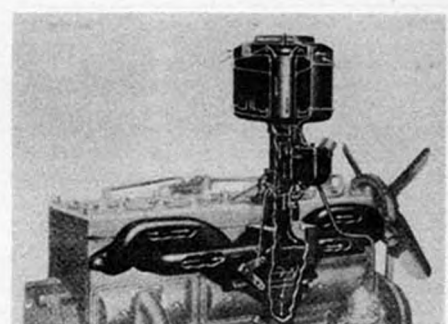


Fig. 71 - Intake manifold in place.

perforated with many openings into the outside chamber. The expansion of exhaust gases through these openings into the outer chamber results in their coming in contact with the outer wall, which is constructed of several thicknesses of sheet metal with asbestos between each. Practically all exhaust noises are eliminated by using two of these mufflers and allowing the gases from the larger one to flow through a tail pipe into the smaller one, and from it through a tail pipe into the open atmosphere.

MUFFLER TROUBLES. - When the engine mysteriously loses power, it is well to look at the muffler. A dirty muffler filled up with oil and carbon, which results from the use of too much oil in the motor, will choke up the passages so that considerable back pressure is created. When

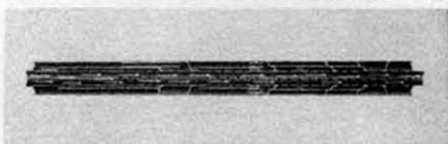


Fig. 73 - Straight-through exhaust silencer.

this is suspected, tap the muffler all over lightly with a wooden mallet, and the exhaust gases will blow the sooty accumulations out.

On six-cylinder motors, and particularly motors with more than six cylinders, the sound of the exhaust is not an accurate guide to the firing of the cylinders.

MUFFLER ABUSE. - Abuse of the muffler is dangerous to the muffler, to the car, and to the public. The practice of running an engine and

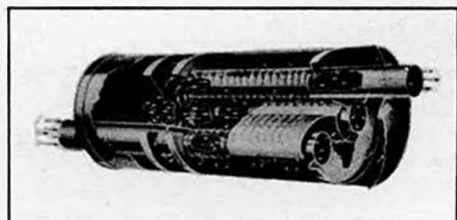


Fig. 74 - Reversing chamber muffler.

turning off the ignition to allow the muffler to "load", and then turn on the ignition to "shoot", is to be discouraged by all first class mechanics. It may result in the loss of life. Instances are on record where mufflers have been blown off for many yards with disastrous results. Figures 74 and 75 illustrate other types of mufflers.

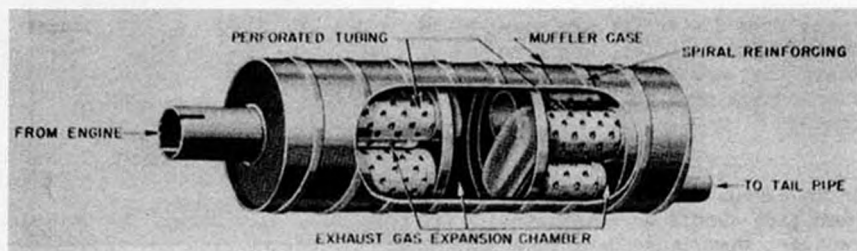


Fig. 75 - Muffler.

GASOLINES, ENGINE OILS, GEAR OILS, GREASES, DIESEL FUELS

Our common fuels and lubricants are all contained in crude oil (petroleum). Because crude oils are different, the derived fuels and lubricants are different. The difference is not as that between an apple and a potato; rather that between a McIntosh and Baldwin. All crudes are in the same family group but differ in behavior.

Crudes from the Pennsylvania oil fields are called "paraffinic", and in general, moving across the country from northeast to southwest, the crudes become more "naphthenic" and less "paraffinic". West Coast crudes are predominantly "naphthenic". When speaking of the "base" of an oil, as "paraffin base" the thought is conveyed that the oil comes from a crude largely containing paraffinic compounds and probably from the Eastern oil fields. It is evident, then, that we can have Eastern paraffinic base oils, Mid-continent mixed base oils, and Western naphthenic base oils.

What are "paraffines" and "naphthenes"? Since all the matter in petroleum is formed of carbon and hydrogen (thus — hydro-carbons) the distinction between "paraffines" and "naphthenes" must be one of structure. To draw an analogy — a Tinker Toy set is made up of "joining blocks" and "connecting sticks". A wide variety of structures may be formed by employing different combinations of joints and sticks.

How are the various parts of the crude oil separated? This can be compared to separating a solution of salt, water, and alcohol in a teakettle. As the solution is heated the alcohol boils off first; then at a higher temperature the water boils off. When all the water has boiled away the residue left in the kettle is salt. This is simple distillation. In refinery practice the crude is distilled by gradually condensing the vapors that rise to the various levels in a fractionating tower. The parts of the crude that boil and condense at the lowest temperatures rise to the top (coolest) part of the tower where they are tapped off as they are condensed. The portion that boils off between the temperatures 85 and 400 degrees Fahrenheit (approximately) is called gasoline. The parts that boil off at lower temperatures are not suitable as

motor fuels because they boil off or evaporate too rapidly at ordinary atmospheric temperatures. The general action of the fractionating tower is shown in Figure 76.

The fractionating tower is a device which allows reasonably good selection of the parts of the crude oil as they boil off. It is evident that the parts called gasolines overlap the parts called naphthas and solvents and so on. This leads to the conclusion that the technique of refining crude oils is far from simple. This discussion is meant simply to indicate to you how the several members of the petroleum family with which we are familiar are related.

Now let's look at the products derived from crude oil that find the most use in automotive equipment. It is such a common thing to associate

petroleum derivatives with the automobile that in "normal" times no one ever considers any other possibilities. But when men began to construct internal combustion engines, petroleum products were hardly known; crude oil was a curious seepage from the earth sometimes sold as "medicinal oil". Early engines burned illuminating gas and were lubricated with animal fats.

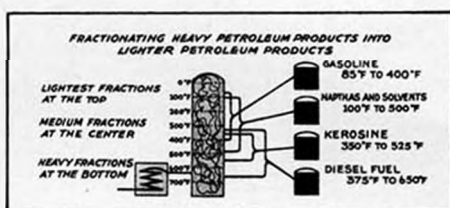


Fig. 76

Last year this country alone had in use some 33 million automotive vehicles. This amounts to about 2,300,000,000 (two billion, three hundred million) available automotive horsepower. And all this power and useful carrying capacity depend on crude oil for fuel and lubrication; requiring gasoline, engine oil, gear oil, greases, and for Diesel's — Diesel fuel.

GASOLINES

To dispose of qualities necessary but receiving little notice in gasolines the following partial list will serve:

Smell — must be inoffensive both as a liquid and when burned.

Non-corrosive, free of acid and acid forming matter, dirt and water.

Stability in storage — will not form gum or lose anti-knock quality over a protracted period.

Distillation curve — relative amounts of low, medium and high boiling point compounds must be suited to the carburetor system of fuel induction.

Two other qualities are of more interest. They are volatility and anti-knock quality. Volatility is especially important if the gasoline used is of the wrong volatility. For example, if a gasoline for winter use has poor volatility the en-

gine will start hard or perhaps not at all. A gasoline of low volatility will not form vapor rapidly enough at low temperature to supply the engine with a combustible mixture. On the other hand, in hot weather a gasoline of high volatility makes trouble by causing vapor lock. A bad case of vapor lock is baffling to the average good natured motorist; but in combat it can immobilize a unit at a critical time, resulting in a serious loss of life and materiel. If the fuel vaporizes too rapidly, the fuel system is troubled and sometimes rendered inoperative. The fuel pump, normally engaged in supplying liquid fuel to the carburetor bowl, will pump more than enough to give the proper mixture in the carburetor barrel. But the pump delivers a certain volume of fluid per stroke. If that fluid is vaporized fuel instead of liquid fuel, then the engine is starved and will quit. This is vapor lock. The engine will quit, too, if there is too rapid formation of vapor in the float bowl of the carburetor itself. There are two remedies: (1) obtain a fuel of lower volatility (2) allow the fuel system to cool off to such a lower temperature as will prevent the formation of excessive gasoline vapor. The second remedy is the one used by spluttering motorists stalled at intersections on hot summer days.

The most interesting quality of gasolines is its anti-knock value (or lack of it). Associate anti-knock value with compression ratio, for these two factors always impose limitations on each other. To get oriented in this subject, realize that high anti-knock value, high octane number, and high octane rating all mean the same thing. Also that "knock", "ping", and "detonation" are similar expressions. Also, that destructive, power-losing knock can occur with varying intensities from slight, almost inaudible "trace" knock to terrific, loud, sledge hammer blows on the piston top and the walls of the combustion space. Any form of knock is bad for the engine. See Figure 77.

In the illustration of normal combustion, Figure 78, four pictures are shown from a film taken through a quartz window on an L-head engine. The full series of pictures shows the



Fig. 77 - Effect of detonation on aluminum piston. Piston of aircraft engine showing the effect of severe and prolonged detonation through the use of improper fuel.

black area grow steadily smaller as the flame moves across the combustion space, burning the mixture smoothly.

As the fuel mixture is burned a large amount of heat is released and raises the temperature and pressure of gases formed during burning. These gases expand rapidly, thus compressing the remaining unburned portion of the mixture. If the remaining unburned fuel is heated to a high enough temperature (due to being compressed by the burned gases) the whole mass will ignite and release its energy of combustion almost

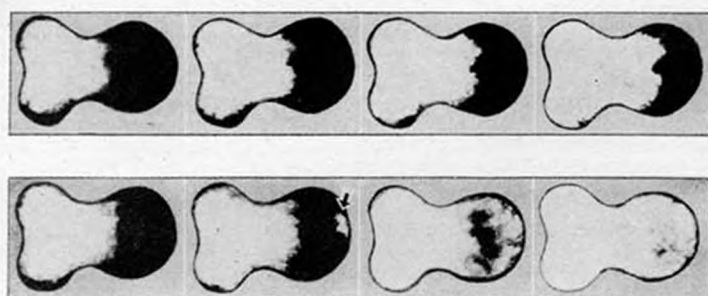


Fig. 78 - Combustion.

Instantaneously. Such rapid release of energy has all the shattering effect of H.E. shell.

The stresses imposed on the surrounding metal parts are large. The energy released in knocking combustion appears as sound and heat. High rates of heat transfer occur resulting in local hot spots in the portions of the cylinder wall, cylinder head and piston top about the knock area. The normal load on the piston top of a three inch cylinder is about one and one half tons. A shock load of three to five tons is imposed on the piston top during severe knocking.

Knocking can be overcome in several ways. In design, by reducing the compression ratio, by securing proper shape of combustion space, by proper distribution of the air-fuel mixture to the several cylinders, and by dual ignition. In an engine of fixed design there are three means of controlling knocking: (1) use a better fuel, (2) reduce the peak pressure and temperature in the cylinders (close the throttle a little or retard the spark), (3) use a richer air-fuel mixture.

Better fuels can be obtained by using better raw gasolines, by adding fuels of very high octane value to the base gasoline, or by adding anti-knock agents such as ETHYL FLUID.

Octane number deserves a little explanation. It is based on a scale from zero to one hundred. In the same way the temperature scale is based on the freezing temperature of water (32 degrees F.) and the boiling temperature of water (212 degrees F.), so also is octane number based on the behavior of two special fuels under particular engine conditions. The pure hydrocarbon gasoline, normal heptane, is known to knock severely. Another pure hydrocarbon gasoline, iso-octane, under the same engine conditions is an excellent fuel. Indeed, with iso-octane the compression ratio of the test engine can be raised considerably before it knocks with the same intensity as normal heptane. So normal heptane is used for the zero and iso-octane for the one hundred on the octane scale. If an unknown fuel is tested in an engine equipped to show knock intensity the intensity can be measured for particular engine conditions. If under the same engine conditions a blend of 70% iso-octane and 30% normal heptane gives the same knock intensity it is established by this comparison that the unknown fuel is equivalent to the 70-30 blend. The unknown fuel can now be assigned the octane number 70. Do not consider iso-octane as a perfect fuel or a knockless fuel. Certainly it is a very good fuel, but under rigorous conditions (high pressures and temperatures such as are obtained with high compression ratios) it too, will knock badly.

In army maintenance nothing can be done toward getting a fuel of higher octane number than the present contracts demand. Also, carburetor jets should not be inordinately enlarged to get richer mixtures in order to reduce knock. The only ready means at hand is reducing the peak pressures and temperatures in the cylinders. As stated before, this can be done by closing the throttle a little or by retarding the spark. Much

destructive knocking can be avoided by insisting that drivers shift to a higher gear ratio (a lower "gear" — as from 3rd or high gear to second) rather than lug the engine under low speed, wide open throttle, high peak cylinder pressure and temperature conditions.

The refiners add some anti-knock fluid to almost all gasolines. The limit is set at 3 cubic centimeters per gallon by law. It should be appreciated that the full strength anti-knock fluid is a powerful, though slow, poison. Both the vapor breathed into the lungs and the liquid on the skin are dangerous. Its effect is cumulative and therefore continued exposure to small concentrations (as in using a loaded gasoline as a solvent) will ultimately cause death. Leaded fuel accidentally spilled on the skin should be washed off immediately and thoroughly with G.I. soap.

Some useful characteristics of an average automotive gasoline follow:

Weight per gallon	6.0 pounds
Heat units per gallon	119,000 Btu
Octane number	75

Aviation gasoline differs from automotive gasoline by being less volatile and having an octane number of 100.

ENGINE OILS

The next fraction of crude oil to claim interest in automotive work is engine oil. The progress made in improving engine oils has paralleled the development of the internal combustion engine. Some questions that should be answered are:

1. What is in engine oil?
2. Why does engine oil wear out, requiring change?
3. What do oil numbers (SAE numbers) mean?
4. What is viscosity index (V.I.)?
5. What engine oils are used on Army vehicles?

Engine oils are composed of hydrocarbon compounds built of carbon and hydrogen, just as gasoline. The difference is again one of structure since the engine oil hydrocarbons are much larger and heavier than the gasolines. For example, the unit structure (molecule) of an average gasoline has 8 carbon pieces (atoms); but the unit structure of an average engine oil has 1000 carbon pieces. It is not known just which hydrocarbons are the best for lubrication. Indeed, the problem of separating out a pure lubricating hydrocarbon is of vast difficulty. But it is known that certain qualities are inherent in oils extracted from particular regions. The oils from Pennsylvania crudes (paraffinic) have a naturally high viscosity index. Oils from Southern and Western crudes have a natural low viscosity index. This quality of oil will be discussed later. The myth that Pennsylvania engine oils are better than any other properly refined oils should be discounted. At the present time there is no foundation for this belief. Refining oils is a complex procedure which must accomplish these things:

All water, solids and oil-soluble material is removed from the oil up to the limit imposed by the high cost of further refining. Acids and alkalies and any unstable compounds are removed. Wax (particularly with crude containing large amounts of paraffines) must be removed to such a degree that the oil will not solidify at the lower temperatures encountered where it is used. Color can be removed to water clearness by sufficient filtering through decolorizing agents. Also the natural color of the oil can be altered by adding dyes. This points out that the color of oil is meaningless.

The processing described above results in a reasonably pure mineral (hydrocarbon) oil. But now most refineries improve engine oils with "addition agents" (also called "additives" or "dopes"). The discussion of additives will serve to a degree to outline the answer to the second question above. The oil is improved to make it last longer in

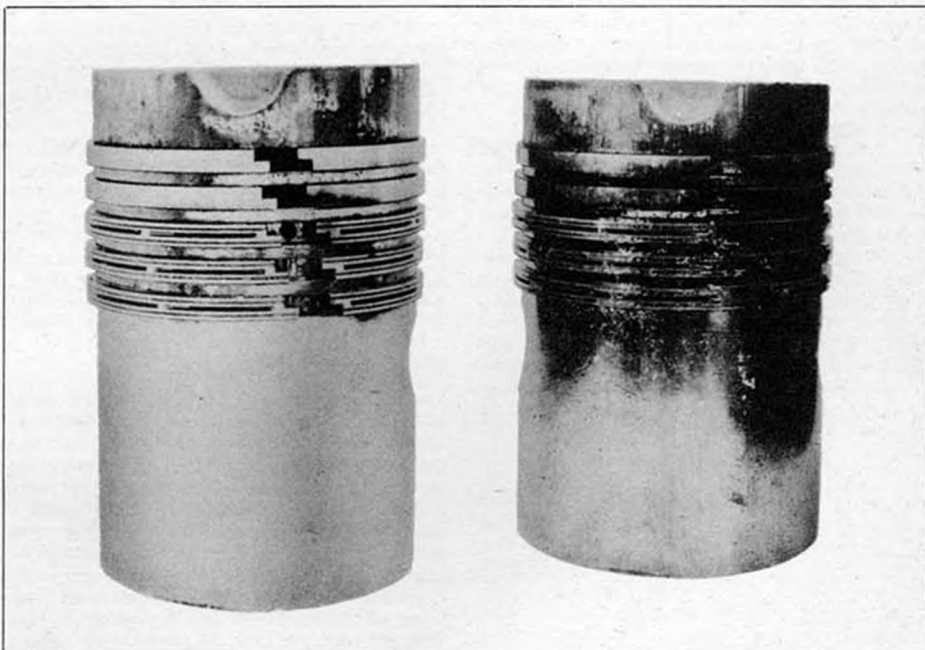


Fig. 79 - Left: With oxidation inhibitor. Right: Without oxidation inhibitor.

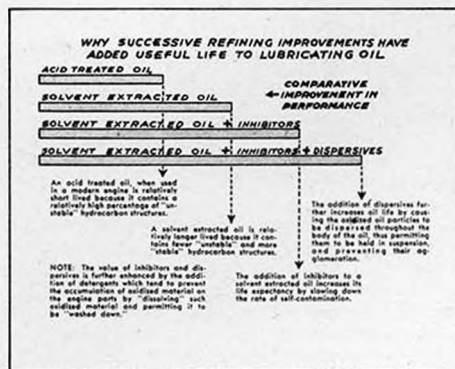


Fig. 80

service and to help it do a better job of lubricating. Here are four types of additives used and their purposes (the list does not include all types of additives):

1. Corrosion inhibitors — to slow down the formation of corrosive compounds and to neutralize (render harmless) such compounds when formed during service.
2. Oxidation inhibitors — to slow down the rate at which the oil would oxidize at crankcase temperatures. This helps prevent sludge. See Figure 79.
3. Compounds to improve the viscosity index.
4. Detergents — to "clean" the engine. See Figure 80.

Although additives increase the useful life of oil, it still must be changed frequently. The interval between changes depends on the use (abuse) the oil gets. Dust entering with the intake air mixes with carbon (from burned engine oil) and a gummy binder from the incombustible part of the gasoline to form deposits in the combustion chamber. Some dust passes the piston rings and, with the dust entering the crankcase through the breather, mixes with oil and causes excessive engine wear. Water will pass the piston rings as steam (from the combustion of the hydrogen in the gasoline) and condense in the crankcase. This water will emulsify with contaminated oil (dirt, acid from blow-by, oxidation products of oil) to form thick sludge which clogs the oil distribution system. Thermostats, radiator shutters, air cleaners, crankcase breather filters, and oil and gasoline filters minimize contamination but will never substitute for oil change at proper intervals.

The third question, concerning SAE numbers, involves a physical property of oil; viscosity. Viscosity in oils is due to the difficulty the hydrocarbon structures (molecules) encounter in sliding past one another. See Figure 81. As generally understood it is a measure of the relative fluidity at the temperature of observation. Viscosity varies inversely with temperature. SAE numbers assigned to oils do not indicate the true viscosity but are reasonable indications. A high viscosity oil has a high SAE number and shows a high resistance to flow and vice-versa. A careful consideration of Figure 82 will show how the several aircraft and automotive engine oils behave.

(Relative viscosity is expressed as the number of seconds required to collect a given volume of oil flowing through a small tube at a given temperature. The apparatus was designed by Mr. Saybolt. Thus the given volume of SAE 30 oil can be collected at 100 degrees F. in about 500 seconds.)

Notice on the chart that viscosity changes as the temperature changes. The perfect oil, as

far as viscosity is concerned, would be one that has the same viscosity at all temperatures. Unfortunately no such oil exists. But changes in viscosity with temperature variations are not the same for all lubricants; some may thin out rapidly or thicken quickly, others relatively slowly. Viscosity Index, or V.I., as it is generally known, is a term invented to show the relationship between these viscosity changes of various oils with given changes in temperature.

A high rating in V.I. means the oil changes less in viscosity with temperature changes than would a corresponding oil of lower V.I.

In an automobile motor high V.I. is most necessary, as the oil may experience temperatures below zero and as high as 400 or 500 degrees F. in the cylinders. The motor oil must not be so thick under winter's cold that the starter cannot turn the engine over, nor so thick that the oil does not flow to the bearings. Neither can the oil become so watery in the cylinders that it fails to lubricate. The oil with the highest viscosity index fulfills these conditions best.

It has long been known that oils differ widely in V.I. Finding a numerical value for this difference has been somewhat of a problem. Oils poorest in V.I., naphthenic (Coastal) oils, are given a zero rating. At the time of making the scale paraffinic (Pennsylvania) oils were the best in V.I. and thus were rated at 100 V.I. Far higher viscosity index oils are now available commercially. To determine the viscosity index of an oil the viscosity at two standard temperatures (100 and 210 degrees F.) must be known. Tables have been prepared from which the V.I. may be calculated, and these are the result of a large number of inspections of reference oils. The improvement of oils by additives to increase V.I. is a rather recent and most successful one.

Detergent oils are cleansing oils. They perform the normal functions of lubrication, cooling and sealing; but the addition agents add the property of dissolving gums, lacquers, and sludges and maintain the minute carbon particles in suspension in the oil. For this reason a clear detergent oil will darken very quickly in service. When drained out the oil will seem to be dirty. See Figure 83. Remember that the oil is taking out of the engine the deposits an ordinary oil would leave behind. Strongly detergent oils are generally available for use in Diesel engines. Some well known brands of engine oil on the market for gasoline engine use have a mild detergent action.

In a practical sense the fourth question requires the most useful information. To give a thorough answer would require too much space. To properly execute lubrication see the maintenance manuals and the WAR DEPARTMENT LUBRICATION GUIDE for the vehicle concerned, Figure 84. Right now movements are afoot to simplify the petroleum product schedule for Army automotive maintenance. On the next page is a table of essential lubricating materials.

GEAR OILS

Gear oils have developed with progress in design of gearing and power transmission systems. When low rotative speeds and low tooth pressures were used, straight mineral oils were satisfactory lubricants. Then spiral, bevel, and helical gears were developed for quieter operation and more compact design. These gear trains required compounded mineral oils. The latest development is the hypoid gear requiring an oil of the extreme pressure type. An insufficient knowledge of the behavior and character of these products may lead to misapplication, resulting in damage to equipment.

Straight mineral gear oils need no explanation.

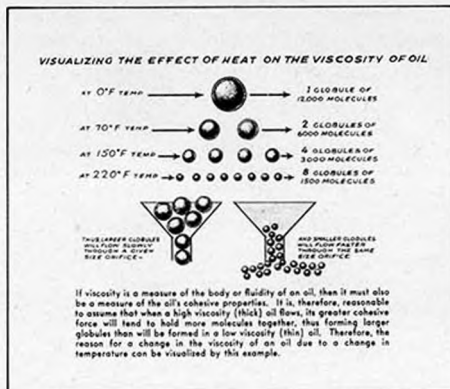


Fig. 81

tion. Compounded gear oils have soaps added to the mineral oil to enable the oil to better resist the wiping action of worm drives in which such oils are commonly used.

Extreme pressure lubricants are mineral oils with soaps and sulfur or chlorine compounds added. Their application is in spiral bevel gears for "mild" EP oils and in hypoid gears for "powerful" EP oils. The EP oils react with the metal of the wearing surface of the gears to give an anti-welding coating which will withstand the extremely high tooth pressures. Both "mild" and "powerful" EP oils are giving way to UNIVERSAL gear oils which are satisfactory in any situation requiring gear lubrication. Gear cases containing powerful EP oils must be drained and refilled with fresh oil at proper intervals, as the active agents in the oil disappear in use. Such gear cases should never have the proper oil level re-established by adding fresh oil to old oil.

The following is quoted from letter SPAG 412.27 dated 4/10/42 paragraph 3:

"Universal Gear Lubricant, as covered by Federal Specification VV-L-761, will be used in all enclosed gear boxes (transmissions, transfer cases, front and rear axles, steering gears, etc.) except the power transmission systems on tanks procured by the Ordnance Department. Gear Lubricants which meet Federal Specification VV-L-761 will be the only general purpose gear lubricant stocked by supply agencies or issued to using services."

This directive simplifies the proper lubrication of gearing. For tank lubrication the manuals and War Department Lubrication Guide charts show that tank power trains are lubricated with engine oil, aircraft grade 100 (SAE 50).

Viscosity specifications for gear oils depend on the temperature range encountered as well as tooth pressures, rotative speeds, and gear types. Particularly at low temperatures the oil must not get so viscous as to "channel" as the gears revolve, thus allowing the gears to become dry. Gear oils are often of the same stock as engine oils. It is reasonable to assume that for VISCOSITY ALONE the following comparison is valid:

GEAR OIL	ENGINE OIL
SAE 80	SAE 40
SAE 90	SAE 50
SAE 140	SAE 70

The comparison does NOT indicate that gear oils are in any way interchangeable with engine oils.

GREASES

The general availability of information on greases is poor, hence there is much confusion of facts concerning the use of greases. The basis of grease making is the addition of metallic soaps to suitable oils. The soap holds the oil quite like a sponge. Heat causes the oil to run out on the

AUTOMOTIVE LUBRICANTS

U. S. Army Standard Nomenclature

ENGINE OIL SAE 10	Gasoline, inline, winter
ENGINE OIL SAE 30	Gasoline, inline, summer
ENGINE OIL SAE 50	Gasoline and Diesel, radial, summer and winter
DIESEL ENGINE OIL SAE 10	Diesel, inline, winter
DIESEL ENGINE OIL SAE 30	Diesel, inline, summer
UNIVERSAL GEAR LUBRICANT (SAE 80)	All enclosed gear boxes, except the power transmission systems on tanks procured by the Ordnance Department and motorcycles. *
CHASSIS GREASE No. 0	Winter
CHASSIS GREASE No. 1	Summer
WHEEL BEARING GREASE No. 2	Winter and summer
WATERPROOF GREASE No. 4	Winter and summer
HYDRAULIC BRAKE FLUID	
SHOCK ABSORBER FLUID	

* For climates where air temperature is constantly above 95 degrees F. during daytime use UNIVERSAL GEAR LUBRICANT SAE 140 (if not available use UNIVERSAL GEAR LUBRICANT SAE 90).

surfaces requiring lubrication and it is the oil which lubricates.

The common soap bases used in grease making are sodium (soda), calcium (lime), and aluminum. The character of the grease is determined by the soap base used. Greases of the sodium base type are good for high (up to 400 degrees F.) temperature operation, they will dissolve in water and the grease has a fibrous texture. Calcium greases will not stand high temperature (will fail at temperatures above 175 to 200 degrees F.), are highly water resistant and have a smooth, buttery texture. Aluminum greases are almost as good as sodium greases with respect to temperature, are resistant to water and have textures from smooth to granular to stringy. All these greases are made by boiling the ingredients together and cooling. Another type of grease, insoluble in boiling water and having a melting point above 212 degrees F. is used in water pumps. This is a calcium base "cold-set" grease made by mixing the ingredients together without cooking. Its use is decreasing

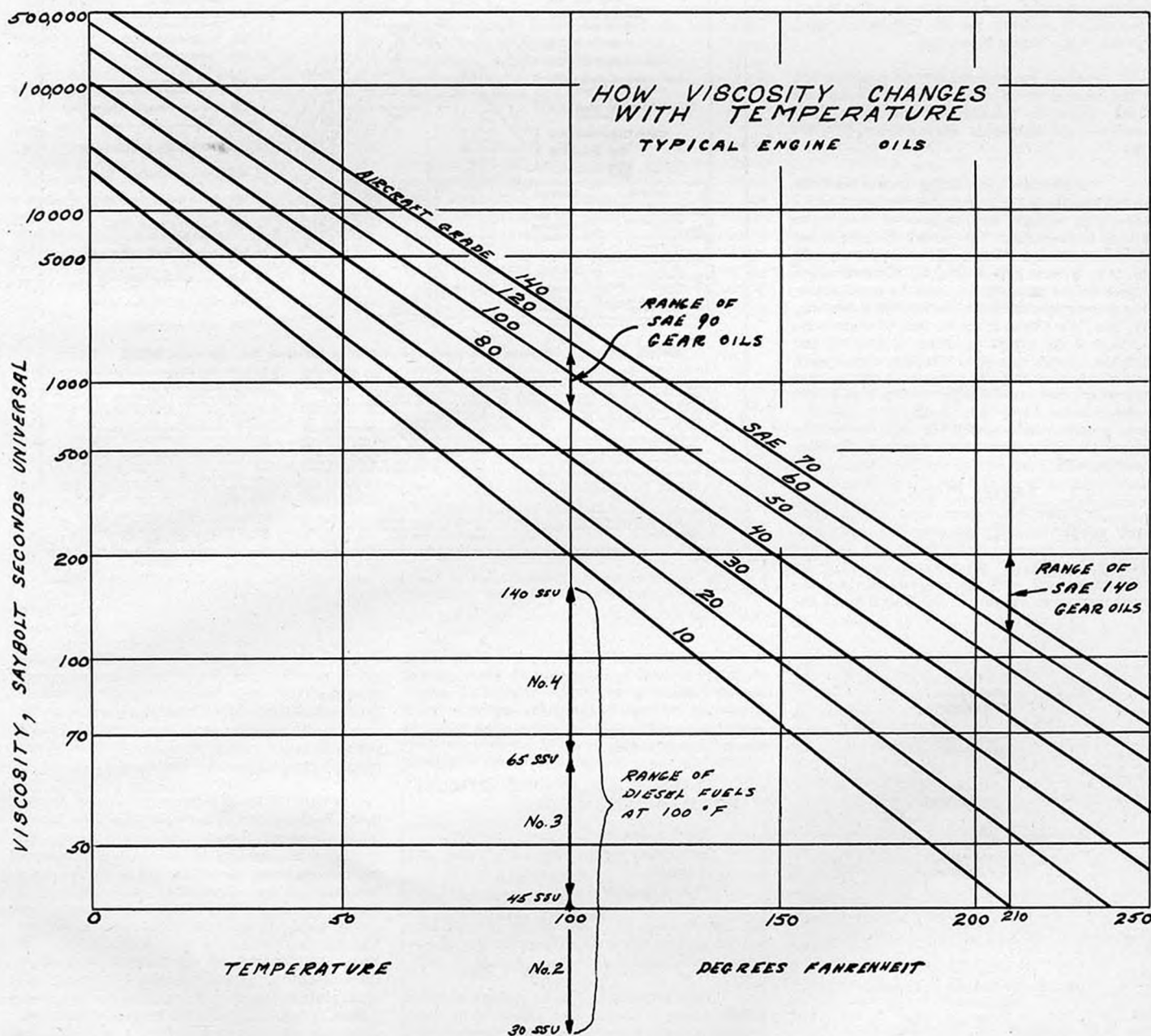


Fig. 82

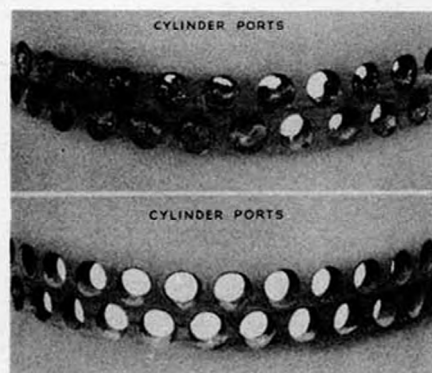


Fig. 83 - Above: With use of straight mineral oil. Below: With use of detergent oil. 2-cycle Diesel engine; 200 hours of operation.

since factory sealed water pumps have been adopted on most vehicles. Greases of intermediate character may be made by using two or more kinds of soap with the oil. These are cooked greases of the "mixed base" type.

Greases grow harder at room temperature as the amount of oil decreases and the amount of soap added to the mixture increases. The quantity of oil increases varies from 60% to 90%.

The National Lubricating Grease Institute has set standards for greases and assigned numbers which indicate the hardness of the grease at room temperature. The harder the grease the higher the number. The range is from very soft (No. 0) to a hard grease (No. 6). Classification of greases is sometimes done by application. Thus greases are known as chassis, wheel bearing, cap, gun, etc. This is apt to lead to vague conceptions of the actual qualities of greases and establish notions that all of a certain consistency and texture serve only one purpose; or worse, that any greases that look the same are the same. The tendency in the Army is to standardize on two or three greases that will fill all requirements in conjunction with a rigorous maintenance schedule. See Figure 85.

DIESEL FUELS

In Diesel fuels there are points of similarity and dissimilarity with respect to gasolines. First let us recognize that in the Diesel field are monsters of 2500 HP which run at speeds below 300 RPM and use very viscous fuel oils, and intermediate types ranging to the Diesel truck en-

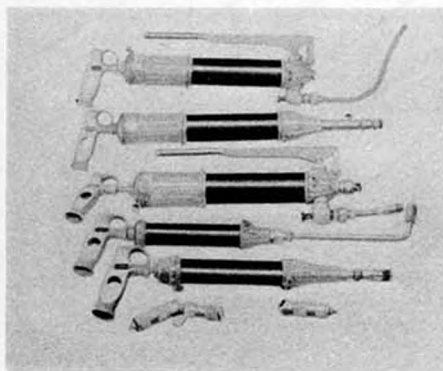


Fig. 85 - Second echelon handgun equipment.

gine of 65 to 250 HP at 2200 RPM, which burns fuels as light as kerosene. It is the latter type that finds a place in automotive use. The fuel for

such an engine must meet certain requirements which are broader in range than for gasolines but equally demanding in quality. It must be understood that the high speed Diesel is much more sensitive to fuel condition and quality than the larger, slower engines.

In common with gasolines, Diesel fuels are defined by:

Specific gravity
Impurities (water, dirt, sulfur, gum, etc.)
Volatility
Cetane number

But Diesel fuels are also defined by pour point and viscosity — two properties given no consideration in gasolines.

As mentioned before, an average gasoline weighs about 6 pounds per gallon. The same volume (one gallon) of Diesel fuel weighs from six and three quarters to eight and one quarter pounds. The energy per pound is about the same

for gasoline and fuel oil, hence fuel oil per gallon contains from 12 to 37 percent more energy than gasoline. In a practical sense, as with a light tank of limited fuel capacity (54 gallons), the maximum distance the tank can travel on Diesel power is much larger than on gasoline power (without replenishing fuel tanks).

DIRT is the great enemy of Diesel operation. Because dirt can render injection pumps inoperative, and because dirt does not settle out of Diesel oil rapidly, every precaution must be taken in supplying the engine and in the fuel system itself to keep dirt out or catch it before it gets to the pumps. This problem, given secondary consideration in gasoline engines, is of PARAMOUNT IMPORTANCE in Diesels. Water or other corrosive liquids in the fuel will cause quick failure of the fuel injection system. In addition, water causes rough engine performance, misfiring, and will "kill" the engine if sufficient quantities enter the fuel system.

Volatility is of little concern in the operat-

WAR DEPARTMENT LUBRICATION GUIDE

CARRIER, MORTAR, 81 mm, HALF TRACK, M4

MFR'S STARTING SERIAL No. 4312.
Located on plate on instrument panel.

TABLE OF CAPACITIES AND RECOMMENDATIONS

SNL G-102 Excerpt from TM 9-710.

	Capacity	Above 90°	Lowest Expected Atmospheric Temperature			
			+32°	+10°	-10°	-30°
Crankcase	12 qt.	140	140	90	80	
Trans. and Transfer Case	2 1/2 qt.					
Differential (Front)	2 1/2 qt.					
Differential (Rear)	6 qt.					

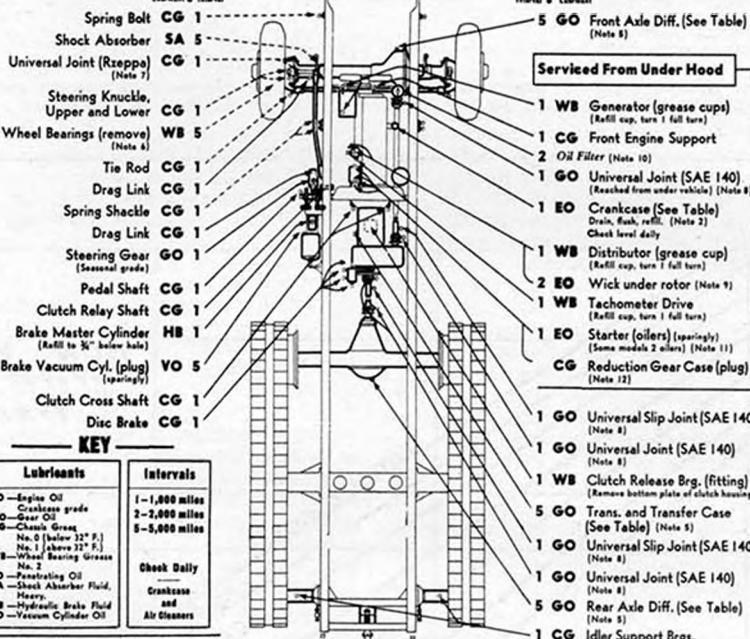
For operation in these temperature ranges, refer to OFS 8-G-3.

CAUTION

Lubricate Dotted Arrow Points on BOTH SIDES

NOTE

See Reverse Side for Lubrication of Track Suspension System



NOTES

- AIR CLEANERS**—(Engines) Check level and refill oil cup to head level daily with EO. Drain, clean and refill every 100 to 1,000 miles, depending on operating conditions. Every 2,000 miles, also remove air cleaner and wash all parts. (Brake Vacuum Cylinder) Every 3 months remove brake vacuum cylinder air cleaner, located under hood, clean and refill with EO.
- CRANKCASE**—Drain only when engine is hot. Flush with 8 qt. SAE 10, idle engine 5 minutes and drain. Refill to FULL mark on gage. CAUTION: Be sure pressure gage indicates oil is circulating. See Table.
- INTERVALS** indicated are for normal service. For extreme conditions of speed, heat, water, mud, snow, rough roads, dust, etc., change crankcase oil and lubricate more frequently.
- FITTINGS**—Clean before applying lubricant. Lubricate until new grease extrudes from the bearing. CAUTION: Always lubricate check points after washing vehicle.
- GEAR CASES**—Check level every 1,000 miles, add lubricant if necessary. Drain, flush and refill at end of first 1,000 miles; thereafter as indicated on guide. Check with vehicle on level ground.
- FRONT WHEEL BEARINGS**—Remove wheel, clean and repack bearings, also remove, clean and lubricate spindle housing with WB.
- REAR WHEEL BEARINGS**—Remove wheel, clean and repack bearings, also remove, clean and lubricate spindle housing with WB.
- UNIVERSAL JOINTS AND SLIP JOINTS**—Apply lubricant to joint until it overflows at relief valve and to slip joint until lubricant extrudes from vent at universal joint end of spline.
- DISTRIBUTOR**—Wipe distributor breaker cam lightly with CG and lubricate breaker arm pivot with EO sparingly every 2,000 miles.
- OIL FILTER**—Remove filter element every 2,000 miles of operation. After removing element, refill crankcase to FULL mark on gage.
- STARTER**—Remove starter every 5,000 miles, clean and lubricate Bendix drive sparingly with PO. Lubricate Bendix drive shaft outer bearing through oiler with EO.
- STARTER REDUCTION GEAR CASE**—Every 4 months remove plug in top of housing and refill with EO.
- OIL CAN POINTS**—Lubricate throttle ends, clutches, hinges, linkages, vacuum cylinder valve and power lever linkage, bumper roller slides and bushings and pin with EO every 1,000 miles.
- POINTS REQUIRING NO LUBRICATION**—Springs, Shock Absorber Link, Bumper Roller Brgs., Water Pump and Fan.
- POINTS TO BE LUBRICATED BY ORDNANCE MAINTENANCE PERSONNEL AT TIME OF GENERAL OVERHAUL**—Clutch Foot Bearing, Speedometer Cable (See OFS 8-G-102).

Fig. 84 - Reproduction (reduced size) of War Department lubrication guide, showing Ordnance Department recommendations and instructions for each lubrication point.

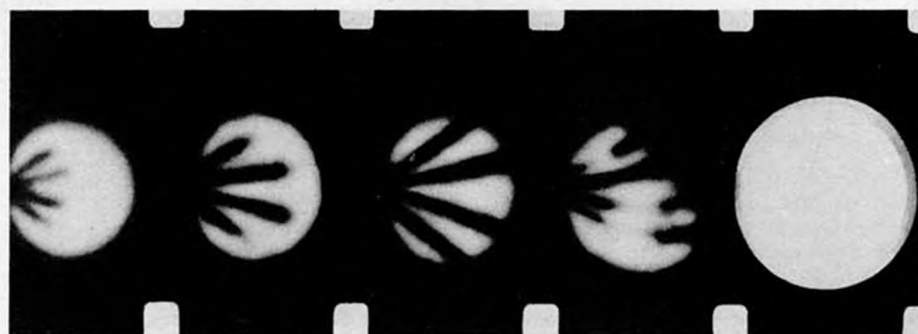


Fig. 86 - Motion pictures taken at the rate of 2500 a second showing the injection and combustion of four fuel sprays in a high-speed Diesel engine. The first picture shows the four sprays entering the engine cylinder. By the third picture they have penetrated to the far side of the chamber. The fourth picture shows three of them on fire. The second from the top has not yet ignited. In the fifth picture, four ten-thousandths of a second later the flame fills the cylinder head.

ing characteristics of Diesel fuel. However, it is an important factor in reducing the fire hazard; volatility being so low that explosive mixtures are not normally formed by evaporation of fuel.

Cetane number corresponds to octane number in gasoline. But the two numbers have entirely different meanings. Careful comparison shows that in the gasoline engine the fuel must be able to withstand high pressures and temperatures without igniting spontaneously, whereas the Diesel fuel must ignite spontaneously at temperatures and pressures easily obtainable by compressing a charge of air. Thus octane number measures "anti-knock quality" and cetane number measures "ignition quality". As with gasolines, two reference fuels are used; alpha-methyl-naphthalene, which will hardly ignite when used alone, and cetane, which ignites readily. The range of cetane numbers for all types of Diesels varies from 30 to 60. Automotive (high speed) Diesels require cetane numbers from 45 to 60.

It has often been observed that Diesels "knock", particularly at light loads. For this the fuel may be held partly responsible. If the cetane number is too low the fuel may not ignite quickly enough. The following sequence accounts for the knock: (1) the ignition delay is too long, (2) too much fuel enters the combustion space before any of it burns, (3) when ignition is finally initiated this large quantity of fuel burns quickly, causing very rapid increase in pressure accompanied by a distinct audible knock. See Figure 86.

It should be remembered that the Diesel depends on high pressure and temperature for ignition, but that all the fuel charge is not present when combustion is initiated. Then, as the fuel continues to enter the combustion space from the injector, the pressure is maintained by continued combustion. This "maintained pressure" (obtained by injecting fuel over a larger crank angle) accounts for the "lugging ability" for which the Diesel is so famous. Except for severe overloads there

is more than enough air in the Diesel cylinder to burn the fuel injected. This partly accounts for the good fuel economy (miles per gallon) of Diesel engines in normal use. Excessive smoking at the exhaust of the engine is evidence of overloading.

The two other properties of Diesel fuels affect the mechanical operation of the fuel system. Pour point is the lowest temperature at which the fuel will flow when not stirred. This property is important when starting the engine at low temperatures. The viscosity of the fuel must be low enough to secure proper atomization of the oil sprays leaving the injector. The range is large for most injection pumps; being from 30 to 300 Saybolt Seconds Universal at 100 degrees F. (These points can be found on the chart, Figure 82.) However, the fuel filter systems require that oils of not more than 200 SSU at the temperature at which the filter operates be used. Higher viscosities flow through the filter system too slowly.

One other factor, "oiliness", must be considered. There is no measure of oiliness, but if the fuel oil does not have sufficient lubricating ability the pump and injector parts will wear rapidly or seize.

IN THE OPERATION OF ANY DIESEL ENGINE, THE MOST IMPORTANT SINGLE ITEM IN MAINTENANCE IS THE USE OF FUEL THAT IS CLEAN. THE MOST PROLIFIC SOURCE OF TROUBLE IN DIESEL ENGINES IS THE USE OF DIRTY FUELS. AND BY THIS IS MEANT THE INTRODUCTION OF SOLID MATTER AFTER SHIPMENT FROM THE REFINER. BY FAR THE GREATEST CAUSE OF THIS CONTAMINATION IS CARELESS HANDLING IN THE FIELD. GREATER CARE MUST BE TAKEN WITH DIESEL FUEL THAN WITH GASOLINE.

A WORD TO THE WISE -----

PART III FUNDAMENTALS OF ELECTRICITY

On the modern gasoline engine electricity performs many functions. It furnishes power for starting the engine, the spark to ignite the air-fuel mixture that keeps the engine running, the current that makes the lights glow, and numerous other applications.

As practically all the appliances connected with the generation, transmission and utilization of electricity use a magnet or utilize the effects of magnetism, "magnetism" must be studied in order to understand many of the electrical units on the automotive vehicle.

There are two types of magnets - one is a permanent magnet, the other is a temporary magnet. With the exception of magneto magnets, practically all magnets used in automotive electricity are temporary magnets.

If electric current is passed through a wire or any other conductor a magnetic field is built up around that wire or conductor. If the wire is straight, then the magnetic field composed of lines of force is circular around the wire, as in Figure 87.

The flow of these lines of force is either clockwise or counter-clockwise, dependent on the direction the current is flowing in the wire. If the direction of current flow is known, the direction of movement of the magnetic field about the wire can be determined by grasping the wire with the right hand with the thumb pointing in the direction of current flow. The fingers will point in the

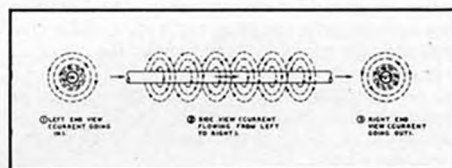


Fig. 87 - Magnetic field surrounding an electrical conductor

direction of flow of the magnetic lines of force.

The magnetic field about a single wire is relatively weak. In electrical equipment, when a magnetic field is wanted, it usually must be strong and concentrated, with very definite polarity. To attain this the wire is usually wound in the form

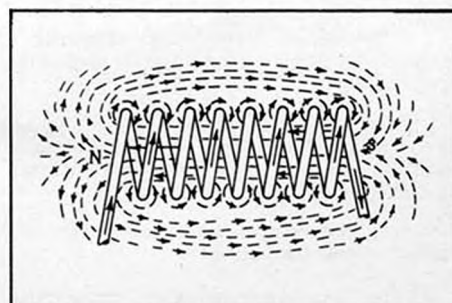


Fig. 88 - Magnetic field produced by current flowing through a coil or solenoid.

of helical coil known as a "solenoid". The magnetic field of each turn of wire will combine with those of the other turns of wire to form a strong field. In the center of the coil the magnetic field will be flowing similar to a stream of current. The magnetic lines of force do not cross each other but combine and flow together, even though the path is longer. See Figure 88.

It may be noted that the solenoid also has definite polarity. That is, one end is marked N, and the other S. The magnetic lines of force, moving like a current, flow out of what is called the North Pole of the solenoid and around into what is called the South Pole, and back through the center of the solenoid from S to N to complete the circuit. A North pole can, then, be defined as that portion of a solenoid out of which lines of force flow, and a South pole, that portion into which they enter. (This is equally true of permanent and electro magnets).

Air, however, is not a good conductor of magnetic lines of force; therefore some conductor that offers less resistance to the flow of magnetic lines of force is used to concentrate them and give them an easy path through which to flow. Either iron or steel is used in the form of a core to do this. It is not necessary for this core to be solid iron or steel. Very often it is constructed of a bundle of soft iron wires or sheet metal laminations. When electric current is passed through the coil of wire wrapped around this core, the core will then attract iron or steel in the same manner as a permanent magnet. Such

a magnet is known as an "electro-magnet". See Figure 89.

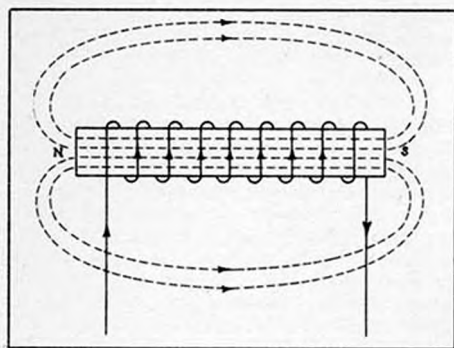


Fig. 89 - The magnetic field of the electro-magnet.

The strength of the magnetic field in an electromagnet is proportional to the strength of the current flowing in the surrounding wire, and the direction of the lines of force in the magnetic field always holds the same relation to the direction of the current flowing in the wire. A change in the direction of the current flow changes the polarity of the electromagnet. The polarity of the electro-magnet is said to "reverse".

Any change in the flow of current tends to produce a corresponding change in the magnetic field. If the flow of current in the wire is stopped by opening the circuit, the magnetic field dies down: in fact it very quickly ceases to exist for all practical purposes. The field is said to "collapse". The more sharply and quickly the electrical circuit around the core can be opened or "broken", the quicker the collapse will be.

The core will, however, retain some of its magnetic effect indefinitely, dependent upon its structure. Temporary magnets, which for all practical purposes are magnets only when under magnetic influence, almost always retain a little of this property. This is called "residual" magnetism. It is an important factor in generator operation.

Solenoids and electro-magnets are used extensively on the modern automotive vehicle. Solenoids are used to do work, as, for instance, engaging the starter pinion in the flywheel on some types of starters. On other types of starters, as, for instance, on the Half Track Scout Car, a solenoid is used only to close the starter switch.

Solenoids take advantage of the attraction that a magnetic field has for iron or steel. When current is passed through the wire of a solenoid, a bar of iron or steel that is in the right position, and near enough to the magnetic field, will be "sucked" into the magnetic field of the solenoid. See Figure 90. Again it is the magnetic field attempting to find an easier path through which to flow, so it just sucks in the nearby path. If this bar of iron or steel is attached to a mechanical linkage, work can be accomplished by the

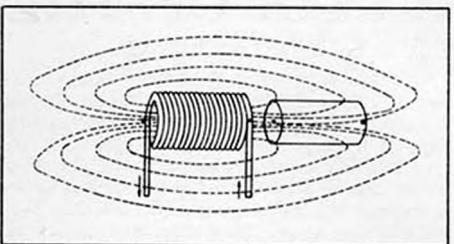


Fig. 90 - Into the magnetic field of the solenoid.

movement of the bar as it is sucked into the field of the solenoid.

The magnetic field and resulting magnetic strength of the solenoid depends upon:

1. The rate of current flow (in amperes.)
2. The number of turns of wire.

The stronger the current flow, and the greater the number of turns of wire, the stronger will be the magnetic field.

This ability of a solenoid or electro-magnet to attract iron or steel is used in many places on the automotive vehicle. In light and horn relays it is used to close a set of points which, acting like an intermediate switch, allows the horn to blow or the lights to burn. See Figure 91. In the reverse-current-relay (cut-out) it is used to close and open the charging circuit. In voltage and current regulators it is used to open the field circuit, thereby causing the field current to take another path through a resistance unit or units.

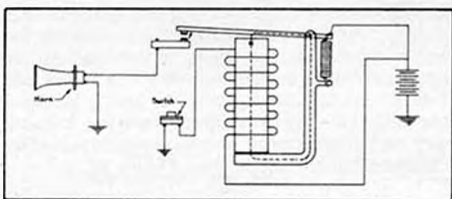


Fig. 91 - Use of the solenoid.

So far, the explanation has dealt with setting up a magnetic field by means of an electric current. In turn, a magnetic field can be used to set up the flow of an electric current. This is done by having conductors, usually wire, cut across a magnetic field. If the conductors are moved across a magnetic field, an induced pressure, called "voltage", is set up that will cause current to flow in a closed circuit connected to these conductors. This voltage is proportional to the rate of speed with which the conductors "cut" across the magnetic field and the strength of the field crossed. (When a steady flow of current is passing through an electric circuit, a certain definite pressure, called voltage, is required to keep the current flowing. The pressure required depends upon the resistance of the circuit and upon the work to be done by the current.)

Basically, it can be said that voltage, or pressure that causes current to flow, can be generated by either of two methods or by a combination of both:

1. By moving a conductor across a magnetic field.
2. By moving a magnetic field across a conductor.

Each of these methods is used in automotive electrical units. The automotive generator uses the first method, that of moving a conductor across a magnetic field.

The second method, that of moving a magnetic field across a conductor, is used in the ignition coil.

The value of the voltage induced by either, or by a combination of these methods, (resistance remaining the same at all times), is determined by the following factors:

1. The strength of the magnetic field that is "cut" or does the "cutting".
2. The speed of movement, cutting of the field, or the speed of change of the field cutting across the conductor.

3. The length of number of turns of conductor cutting through the magnetic field or being cut by the magnetic field.

The value of the voltage induced is directly affected by any change in these factors. The stronger the magnetic field, the faster the movement, or the greater the number of turns of the conductor affected by the field, the stronger will be the induced voltage. Thus, if the speed of movement of the conductors cutting the magnetic field is doubled, the induced voltage will be doubled. If the speed of movement is doubled, and the strength of the magnetic field is reduced one-half, then there will be no change in the voltage induced.

Advantage of the above factors is taken in controlling the voltage and current flow of the generator. By reducing the amount of current flowing around the temporary magnets which set up the magnetic field within the generator, the strength of the magnetic field set up is reduced proportionately.

UNITS OF MEASUREMENT

No knowledge of electrical fundamentals is complete without a knowledge of the units of measurement used in electricity. Such units of measurement have been established so that the relationship between pressure and current flow, and the effects of resistance in the circuit upon either or both of them, can be studied and applied.

Voltage is electrical pressure, and the unit of measurement is the "volt". It may be compared to pounds per square inch of water pressure.

Amperage is rate of current flow, and the unit is the "ampere". It may be compared to gallons per minute of water flow. It is a certain quantity in a certain time. The rate of movement is important, not the total quantity moved. In the case of the starting motor, a high rate of current flow, amperage, is desired for a short cranking time. Since a high rate of flow is desired, a large cable must be used to carry the current. To move 1000 gallons of water in five minutes under a certain fixed pressure would require a pipe that would permit the flow of 200 gallons per minute at that pressure. Had we desired to move the 1000 gallons in twenty minutes, a smaller pipe could have been used. (No change in pressure.)

On automotive vehicles, where a six-volt system is used, the voltage is quite uniform, varying between 6 and 8 volts. So, if more amperage is desired in a circuit, the wiring must be larger to carry that amperage. If not so large a rate of flow or amperage is desired, as for instance, in the ignition circuit, a much smaller wire can be used.

The "ohm" is the unit of electrical resistance, or opposition to the flow of current.

All materials offer some resistance to the flow of electric current. Insulators are merely those materials which have extremely high resistance. The degree to which a conductor will permit electricity to flow is called "conductivity". Conductivity is the exact opposite of resistance.

Four factors control the resistance of a conductor:

1. Length: the longer the conductor, the greater the resistance. Doubling the length doubles the resistance.
2. Cross-sectional area; the greater the cross-sectional area, the lower the resistance.
3. Material; the resistance varies with the material. Iron has about six and one-half times as much resistance as copper. Silver has less resistance than copper.

4. Temperature; most materials offer greater resistance as the temperature of the material increases, and less as the temperature of the material decreases.

From the standpoint of both conductivity and cost, copper has been used almost exclusively for the wire conducting the current in the electrical circuits of the automotive vehicle.

Electrical energy is lost in overcoming the resistance of a conductor, being dissipated in the form of heat. When excessive current is forced through a small wire that wire will become quite hot.

Some safe amperage carrying capacities and melting capacities are:

No. 18 copper wire, 5 amperes safe — 82 amperes to melt.

No. 14 copper wire, 20 amperes safe — 118 amperes to melt.

No. 10 copper wire, 30 amperes safe — 330 amperes to melt.

Fuses are often placed in circuits so that they will melt and open the circuit when the safe load of the circuit is exceeded.

The vehicle engine and frame offer very little resistance to the flow of current. They are therefore used as part of the electrical circuits of the automotive vehicle. They are the ground side of the electrical circuits. If we follow the flow of current in the starting circuit, we will find the current starting at the battery as we close the switch, going from there through the starter cable, through the switch, and through the starter to ground. On the ground side the current returns by way of the engine and frame to the battery ground strap, and by way of that strap back into the battery, completing the circuit. See Figure 92.

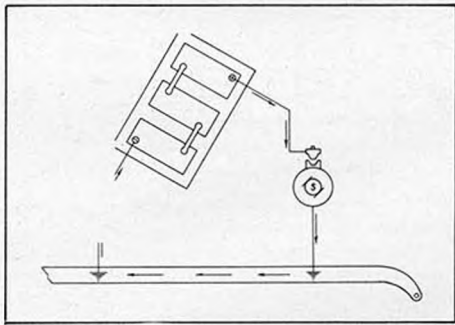


Fig. 92 - The starting circuit.

Resistance in some form is present in all circuits. If it were not for the resistance offered to the flow of current by the filament in the light bulbs, the lights would not burn. Resistance is necessary there to cause the filament to get white hot. This may be called "wanted resistance". Any unnecessary or "unwanted resistance", however, would affect the proper functioning of the unit or units in that circuit.

In an electrical circuit, given a certain amount of voltage and a circuit of a definite resistance, there will be a definite rate of current flow. Increasing the voltage without changing the resistance increases the rate of current flow or amperage. Decreasing the voltage without changing the resistance decreases the amperage. Increasing or decreasing the resistance without changing the voltage decreases or increases the amperage respectively. A definite relationship therefore exists between voltage, amperage and resistance. This is expressed by Ohm's law.

Expressed as an equation in the terms of

E (volts), I (amperes) and R (resistance) it is:

E equals I times R Voltage is amperage multiplied by resistance.

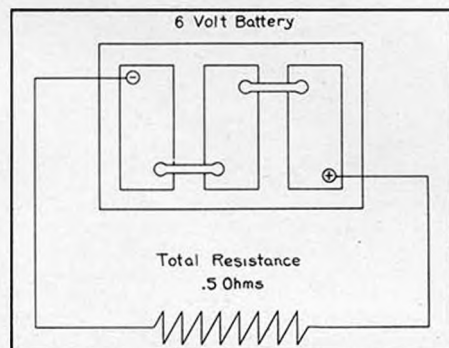


Fig. 93

I equals $\frac{E}{R}$
R equals $\frac{E}{I}$

Amperage is voltage divided by resistance.
Resistance is voltage divided by amperage.

What amperage would flow in a wire having a resistance of .5 ohm if this wire was connected across the positive and negative terminals (posts) of a six-volt battery? (As in Figure 93.)

According to Ohm's law:

$\frac{6}{.5}$ equals I (amperage in amperes)
 $\frac{6}{.5}$ equals 12 amperes

12 amperes, according to Ohm's law, is the rate of current flow in this wire.

There are two kinds of circuits, series and parallel. In the series circuit there is a single path for the current to follow, and the current that flows through one part must flow through all other parts. In the parallel circuit, there are two or more paths, so that the current divides, and the greater portion of it follows the path that offers the least resistance.

Adding units in a series circuit increases the resistance, and therefore reduces the total current flow. The circuit is made longer by addition of units, the units themselves offer resistance, therefore, the total resistance in the circuit will be greater by that much. If there is no increase in voltage to overcome the added resistance, then the total current flow will be reduced.

For instance, if in Figure 94 an additional unit having a resistance of 1.5 ohm is added in series, then instead of a 12 ampere current flow the current flow would be reduced to 3 amperes.

$\frac{6}{2}$ equals I (amperage in amperes)

$\frac{6}{2}$ equals 3 amperes.

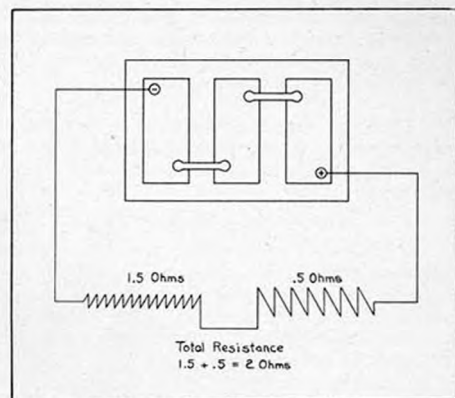


Fig. 94

Connecting batteries or any other source of current in series increases the effective voltage to an amount equal to the sum of all units. For example, if three 6-volt batteries are connected in series, the resulting voltage is 18 volts. The current flow in amperes is approximately that of any one of the batteries.

Connecting units in parallel decreases the resistance, because it gives the current more paths through which to flow. It therefore increases the current flow in the main circuit. The total resistance is less than the resistance of any one unit connected in parallel. Consider Figure 95.

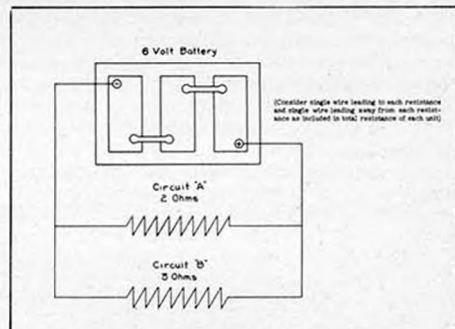


Fig. 95

$\frac{6}{3}$ equals 2 amperes flowing in Circuit B

$\frac{6}{2}$ equals 3 amperes flowing in Circuit A

Total amperage flowing is 2 plus 3 amperes or 5 amperes.

$\frac{6}{5}$ equals 1.2 ohms

5

The total resistance in the circuit is therefore 1.2 ohms, which is less than either resistance unit connected in parallel.

Almost all the circuits in the automotive vehicle are connected in parallel to each other, and often some of the units within each circuit are connected in parallel with each other.

ELECTRICAL CIRCUITS OF THE AUTOMOTIVE VEHICLE

It is not within the scope of this discussion to cover the exact details of construction and operation of the various units that are a part of each separate circuit. The same unit on one make of vehicle very often differs in construction with the same unit on another make of vehicle. Therefore, for the purposes of this discussion, the function, construction and operation of each major unit will only be briefly covered, since basically each unit operates because of certain definite electrical principles. The generator on the Half Track Scout Car differs in construction with the generator on

the Wheeled Scout Car but both generate current by reason of electrical principles previously explained.

The various circuits can be conveniently separated by function into four circuits, the starting, the charging, the ignition, and the accessory circuit.

STARTING CIRCUIT

The first of the circuits with which we have contact is the starting circuit. It is neces-

sary to have some means of cranking the engine without resorting to the strong arm method of days gone by, which sometimes resulted in a broken arm for the unwary cranker.

In the starting circuit we have the battery, starter cable, starter switch, starter, frame of the vehicle, and battery ground cable. See Figure 92.

THE STORAGE BATTERY

The lead acid storage battery is an electro-chemical device for converting chemical energy into electrical energy, and for converting electrical energy into chemical energy. A six-volt battery consists of three cells of two volts each, connected in series by means of lead straps. Each cell consists of an even number of positive plates nested in an uneven number of negative plates. The positive and negative plates are separated from each other, to prevent internal short circuits, by separators made of wood, spun glass, or rubber. The plates and separators in each cell are immersed in a solution known as an "electrolyte". This solution is a mixture of sulphuric acid and water. When the battery is fully charged the specific gravity of this solution, which is the weight of the solution compared to the weight of an equivalent volume of water, is between 1.275 and 1.300 at 80 degrees F. (This varies according to make and age of the battery.) Full strength sulphuric acid has a specific gravity of 1.835, but it is not suitable for use as an electrolyte. It is therefore mixed with distilled water so that the specific gravity will be reduced to about 1.300. This gives best battery operation. See Figure 96.

The specific gravity reading of the electrolyte is taken with a hydrometer. See Figure 97.

In a fully charged battery, when a circuit is completed between the positive and negative posts, chemical action within each cell produces

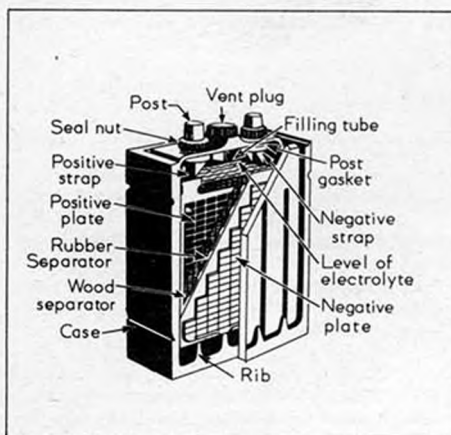


Fig. 96 - Sectional view of a storage battery cell.

an electrical current that will flow through this circuit. During this chemical action, the acid in the electrolyte combines with the porous active material of the plates to form another chemical compound known as lead sulphate. As the battery gradually or quickly discharges, there is a loss of acid in the electrolyte, and it approaches the specific gravity of water, which is 1.000. The electrolyte never completely loses all its acid, since the lead sulphate on the plates, as it builds up, offers more and more resistance to penetration by the acid. The internal resistance of the battery to the flow of current also increases, so that when a battery discharges to a point where the specific gravity reading is less than 1.150, then for all practical purposes on the automotive vehicle it is "dead" and will produce very little current.

The nearer the electrolyte is to the spe-

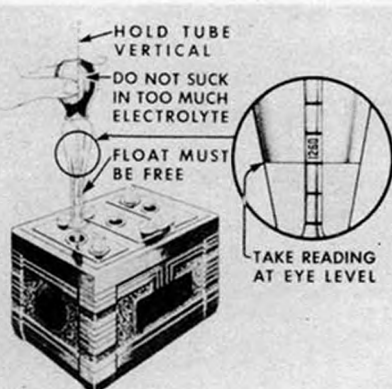


Fig. 97 - Taking specific gravity reading with a hydrometer.

cific gravity of water, the easier it will freeze. A "dead" battery will therefore freeze at temperatures above zero, Fahrenheit, whereas a battery that is fully charged will not freeze unless the temperature is about 90 degrees below zero F. See Figure 98.

For instance, a battery with an S.G. read-

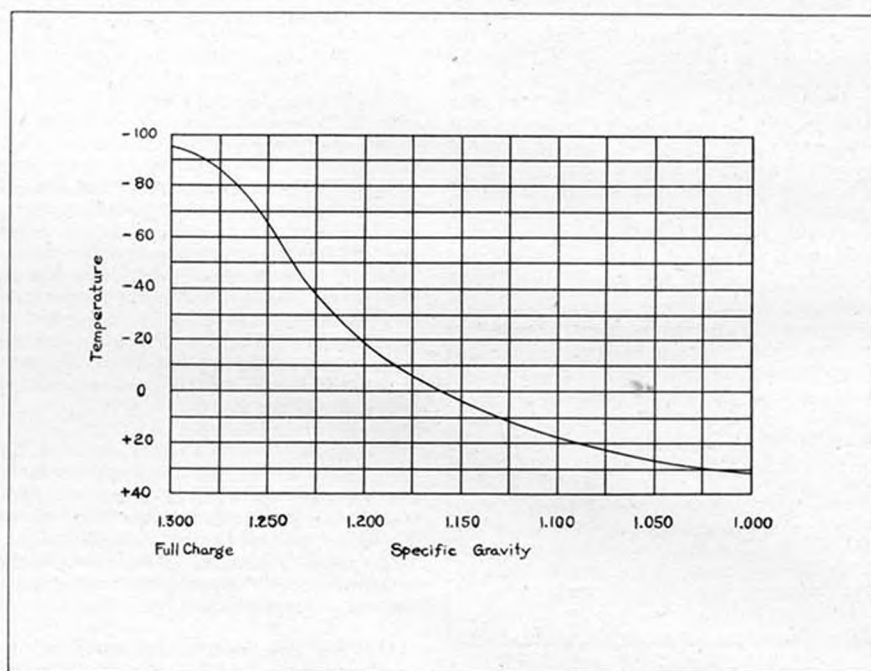


Fig. 98 - As specific gravity falls the battery freezes at a higher temperature.

ing of 1.250 will freeze at about 65 degrees F. below zero, whereas a battery that is as low as 1.175 will freeze at about 12 degrees F. above zero.

In order to recharge the battery, direct current must be passed through the cells in the direction opposite to that of discharge. This current reverses the action which took place in the cells during discharge. The lead sulphate on each plate is transformed back into the original chemical on each plate, lead peroxide on the positive and spongy lead on the negative. As the acid gradually returns into the solution, the specific gravity of the solution also gradually rises. The voltage across the battery terminals also rises, since the battery is getting stronger, electrically speaking, and resists being charged. The energy being stored up in the battery in a chemical form tends to push back the current coming in. It actually is a counter voltage that

tries to push the current back out into the circuit in opposition to the current coming in. The generator compensates for this by increasing its own voltage.

The often repeated cycle of discharging and charging a battery in time causes the active material to shed from the grid in the plates. This material falls down into the spaces at the bottom of the plates, where it accumulates. The positive plates shed faster than the negative plates. Because of this, and because most of the chemical activity takes place next to the positive plates, the grooved side of the separators is placed next to the positive plate.

Excessive shedding of active material is caused by continued overcharging of the battery. Any losses of active material reduces the ability of the battery to produce current for a sustained period of time.

The ability of the battery to produce more or less current for a sustained period of time is dependent on plate area and thickness. By increasing the number of plates, this current producing ability, or rating of the battery measured in ampere hours, can be increased. In other words, a seventeen-plate-per-cell battery with a 100-ampere-hour capacity has less ability to

produce current for a sustained period of time than a nineteen-plate-per-cell battery with a 120-ampere-hour capacity. The first battery will produce only 5 amperes per hour for 20 hours, whereas the second will produce 6 amperes per hour for 20 hours. Theoretically, the second battery should be able to produce 120 amperes for one hour, but this is not true. Battery capacity decreases very rapidly as the discharge rate increases, due to increased losses caused by internal heating of the battery and the inability of the acid to combine quickly with the active material of the plates at the more rapid rate of discharge. The battery is, however, designed to produce four or five hundred amperes for a very short period of time, as in cranking the engine.

The actual ability of the battery to force current through a definite size wire or cable is not increased by changing either the total plate area or thickness. The voltage of a 3-cell six-

volt battery remains the same, no matter how many plates there are in each cell. It is only by adding more cells in series that we can increase the total voltage of the battery. A 12-volt battery is nothing more than 6 two-volt cells in series.

Excessive current draw has the same effect on the voltage of a battery as it has on the amperage. That is why resistance in the starting circuit must be kept at a minimum to insure maximum available voltage at the starter. Unless the necessary voltage is available in the starting circuit at the starter, or in the ignition circuit at the coil, then difficulty in starting will be the rule, not the exception, particularly on cold mornings.

Temperature plays an important part in affecting the capacity of a battery. The colder the temperature — the lower the battery capacity. Even a fully charged battery is only partially efficient at sub-zero temperatures. This fact, coupled with the condition which may exist in a poorly maintained engine, may seriously reduce the cranking ability of the battery.

It is particularly important in the winter time to:

1. Keep the battery Specific gravity above 1.250.
2. Use lubricating oil with the correct winter service body.
3. Maintain circuit breaker points in good condition, and with the proper clearance.
4. Keep spark plug electrodes clean and with correct gap.
5. Have good engine compression.
6. Maintain all joints and connections between the carburetor manifolds and engine, in gas tight condition.
7. Check the operation of the carburetor choke.
8. Check all connections in the starting circuit for condition, and check that all are securely fastened to clean connections. This includes the battery ground connection.

In addition to the above, the following points to remember about year around battery care are:

1. That the electrolyte level should be checked weekly and kept up to 3/8" to 1/2" above the top of the plates.
2. That excessive evaporation of the electrolyte usually indicates overcharging.
3. That too frequent removal of the battery for a charge on an external charger indicates that the battery, regulator settings, generator, and charging circuit connections and wiring should be checked thoroughly to determine why the battery does not fully charge while on the vehicle.
4. That the specific gravity of the electrolyte determines the temperature at which a battery will be damaged by freezing.
5. To add nothing but distilled water or water that is known to be chemically pure to a storage battery.
6. To use a strong solution of soda and hot water for removing terminal corrosion and cleaning the battery.
7. To prevent corrosion by applying vaseline to terminal connections.
8. To keep connections to battery clean and tight.
9. To keep battery securely fastened in its carrier.
10. To keep vents in caps clean.

THE STARTING MOTOR

The automotive type of starting motor is a special overload motor capable of delivering high horsepower for its size for short periods of time. In order to obtain this power from the unit without increasing its size, it is necessary to build the starting motor with a minimum of

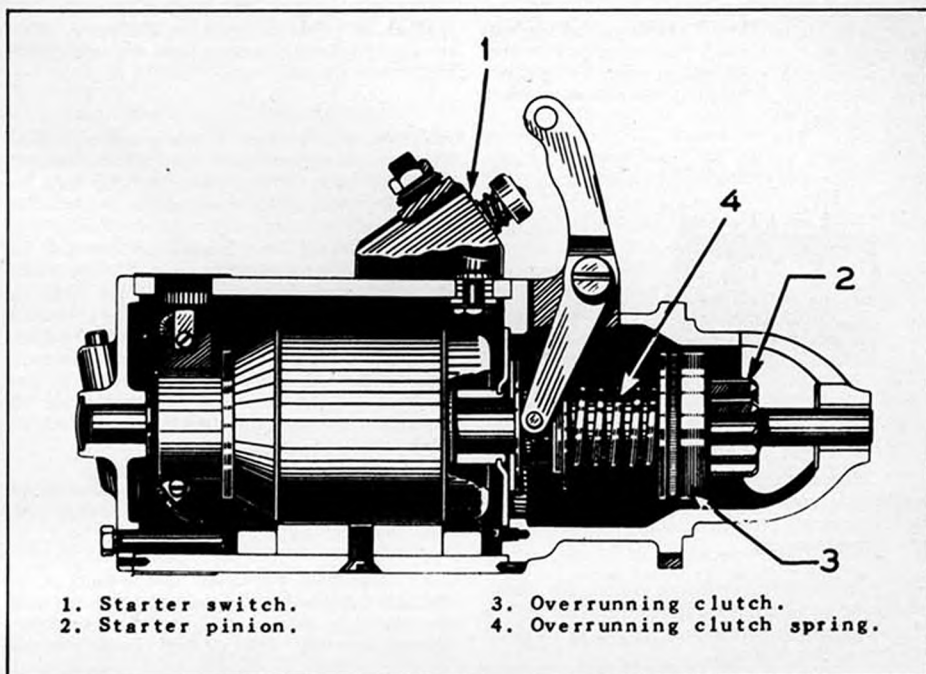


Fig. 99 - Sectional view of starting motor with overrunning clutch drive.

resistance so that a large current may flow through it while cranking.

Because of the high current flow from the battery to the starting motor during cranking, some positive means of connecting and disconnecting the battery and the starting motor must be used, and the switch used must have contacts of adequate size to carry the current without burning. The manually operated switch mounted either on the floor board or the starting motor frame is the simplest type of switch, and the one in most universal use.

A solenoid switch that closes the starting circuit is used on many vehicles. This switch on some applications also shifts the starter pinion into mesh with the flywheel.

Without going into detail about the electrical principles of starting motor operation, it can be said briefly that the starting motor is a machine so designed and constructed that the electrical current applied to it will be changed into mechanical power. When electric current from a battery is allowed to flow to a starting motor, it causes the armature within the starting motor to revolve. The armature in revolving, when finally geared to the flywheel by the starter pinion gear performs the mechanical work of cranking the engine.

The starting motor drive is the vital part of the starting motor, since it is through the drive that the pinion on the starting motor is meshed with the flywheel on the engine, and through which the actual cranking occurs. The action of the drive must be positive so that the engagement and disengagement with the flywheel is certain, and it must be strong enough to withstand the torque of cranking.

Two types of drives are in widespread use, the Bendix and the overrunning clutch, although there is a third type, the Dyer drive, in use on heavier duty applications.

In the overrunning clutch drive, a manually or solenoid operated shift lever moves the starter clutch assembly along a splined starter shaft and shifts the pinion into mesh with the flywheel teeth. As the shift lever reaches its limit of travel, it closes the starting-motor switch contacts. Oc-

casionally the pinion teeth and the flywheel teeth butt together instead of meshing. When this happens, the clutch spring is depressed, and when the switch contacts close, the starting motor armature turns only enough to align the teeth before full meshing takes place and cranking is accomplished. See Figure 99.

After the engine begins to operate, and before the pinion can be withdrawn from the flywheel teeth, the overrunning clutch, Figure 100, permits

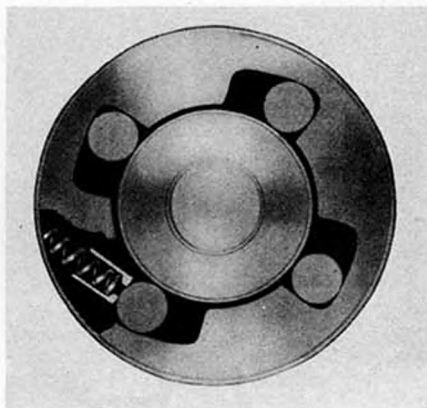


Fig. 100 - Overrunning clutch.

the pinion to overrun the starting motor armature, thus preventing the armature from being driven at excessive speed. The overrunning clutch consists of a pinion and collar assembly, and an outer shell with four rollers which tighten between the pinion collar and shell as cranking torque is transmitted, but loosen to permit the pinion to overrun the shell when the torque is in the opposite direction.

In the starter using the Bendix drive, the pinion gear is mounted on a spiral threaded sleeve (connected to the armature shaft through the Bendix spring) in such a manner that when the armature revolves, the spiral threaded sleeve turns within the pinion gear, moving it endwise, and causing it to mesh with the flywheel and crank the engine. When the engine runs under its own power, the flywheel drives the pinion gear at a

higher speed than that of the threaded sleeve, causing the pinion gear to be turned in the opposite direction on the sleeve. The pinion gear, therefore, automatically disengages from the flywheel. The Bendix spring takes up the sudden shock of meshing. See Figure 101.

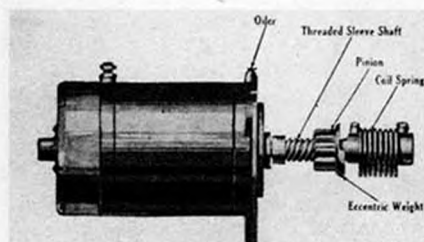


Fig. 101 - Bendix drive starter.

The spiral threaded sleeve upon which the pinion gear moves in and out of mesh should be kept free of oil, grease, or dirt, in order to permit free movement.

If the starting motor cranks the engine slowly, or not at all, some indication of the source of trouble may be gathered by turning on the lights and attempting to crank.

1. If the lights go out as the starting motor switch is closed, it is probable that a poor connection exists at the battery terminals or elsewhere in the starting circuit.
2. If the lights dim considerably, but still burn, it is likely that the battery is at fault. It may be almost totally discharged, or have very little capacity. Or possibly there may be some mechanical trouble in the starting motor or in the engine, which makes it difficult for cranking to take place, and resulting in an excessively high current drain from the battery.
3. If the lights do not dim, it indicates that there is no current flowing to the starting motor, due either to the internal circuits in the motor being open or the starting motor switch being open.

The above checks give only an approximate idea of the source of trouble, so that in an emergency it might be possible to effect a temporary repair.

In any systematic analysis of the starting motor circuit, the first step would be to check the battery specific gravity. A battery with a specific gravity reading of less than 1.225 cannot be expected to crank an engine effectively, and must be brought up to at least 1.225 for best starter operation. Then the battery connections and cables should be checked along with the starter switch. The next step would be to thoroughly check the starter itself, and this should be done by a man experienced in doing this type of work.

THE CHARGING CIRCUIT

The basic charging circuit in the modern automotive vehicle consists of the generator, what is often called the control box or voltage regulator, the ammeter, and the battery. The necessary wiring connecting all these units together provides the path for the flow of current through the circuit from the generator through the control box, to the ammeter, to the terminal on the starter, through the starter cable, to the battery terminal or post, through the battery, to the frame by way of the battery ground cable, and from there back to the generator.

Earlier in this discussion when fundamental electricity was covered, the method by which the generator produces current was mentioned briefly.

It may be said that the generator is a device which transforms mechanical energy into

electrical energy. The engine furnishes the mechanical power to drive the generator. This is usually done by belt drive from the same pulley that drives the fan.

The generator consists of field coils (electromagnets) which create a magnetic field as current flows through them, an armature which, as it revolves, carries conductors through the magnetic field, and a commutator and brushes to carry off the current induced in the conductors. The output of any generator is dependent upon the strength of the magnetic field and the speed with which the conductors cut through the magnetic field. Where the possible output of the generator is greater than needed by the connected load and condition of charge of the battery, some means of output regulation is required. In automotive type generators this is accomplished by varying the strength of the magnetic field by means of regulators.

The magnetic field of the generator varies directly with the amount of current flowing in the field coils.

The most commonly used method of reducing the strength of the field, and thus reducing the generator output, is to insert a resistance into the generator field circuit. In the past this

at the switch, resulting in an increased generator output. With this device, there were, in effect, two generators, a low output generator when the resistance was in the field circuit, and a normal output generator when the resistance was shorted out of the generator field circuit.

This same operation is now accomplished automatically by means of a magnetic switch; one which is nothing more than an electromagnet operating a hinged armature which opens and closes the field circuit. The field circuit, when closed, flows through a pair of contacts. When opened, the contacts separating, the circuit must take another path through a resistance unit or units.

The contact points can be arranged to either close or open as the armature moves down toward the winding core. When the arrangement is such that the points come together, the mechanism has the essentials of a relay. See Figure 91.

Contained within the modern control box are the units that control the generator output. Here are the magnetically operated switches, the voltage regulator, and the current regulator, units which automatically do what was once done by thermostats, resistance units at the lamp switch

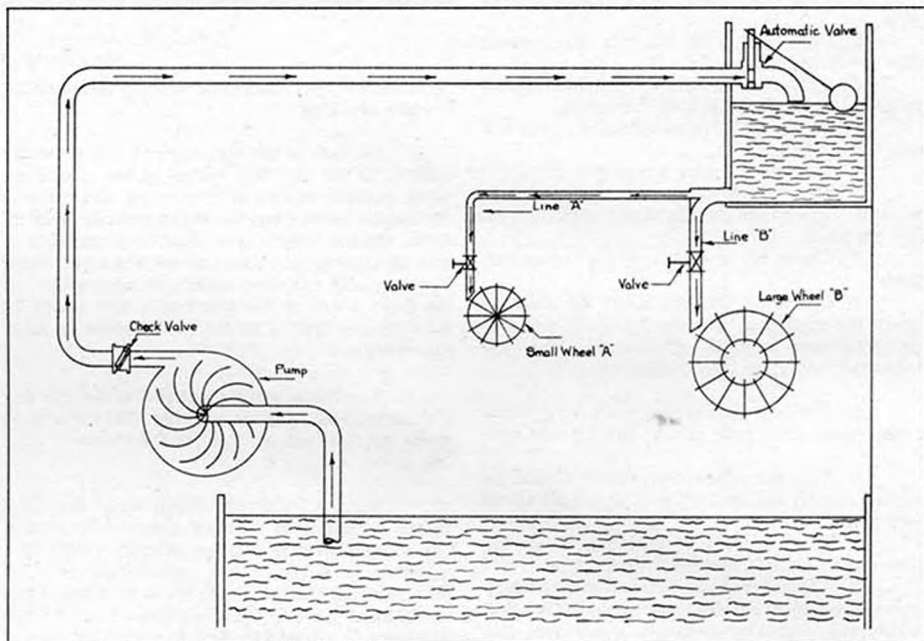


Fig. 102 - An analogy.

was accomplished by means of a thermostat placed inside the generator. When the generator output continued high for a sufficient length of time, the generator would heat internally, causing the points of the thermostat to open. A resistance unit was placed in parallel with, or across, these points, and the field current which otherwise went to ground through the points would be forced to flow through the resistance, causing a reduced generator output. This method was not entirely satisfactory since generator output regulation was dependent on generator temperature, and not on the condition of charge of the battery and the connected electrical load. This form of control served as a protection to the generator only. Inserting a resistance into the generator field circuit by means of a manual switch arrangement was used on some applications. This consisted of a resistance placed in the light switch so that when the switch knob was pushed all the way in, the resistance would be in the generator field circuit and the generator would have a reduced output. At other positions of the switch, the generator field circuit would be grounded directly

etc.

The voltage and current regulator are the means of regulation that control or regulate the generator at those times when the possible output of the generator would be greater than needed by the connected load and condition of charge of the battery.

If the generator output was not controlled high voltage would result. This voltage is a direct result of the generator's ability to more than overcome battery resistance (battery voltage when fully charged), and any other resistance up to a certain point would be forced up to 8.5 or even 9.0 volts in a six-volt system, or 17 to 18 in a 12-volt system. This high voltage would cause the battery to gas and overheat because of excess amperage flow through it. It would also greatly shorten lamp bulb, radio tube, ignition coil, and circuit breaker point life.

An analogy is drawn comparing the functioning of the charging circuit, ignition circuit and starting circuit with that of a water pump,

reservoir and water wheels. See Figure 102.

If we compare the pump to the generator, the spring loaded check valve to the cut-out relay, the automatic valve to the voltage and current regulator, and the tank to the battery, we have an analogy of the charging circuit. When the vanes in the pump start to turn, and enough pressure is built up against the spring loaded check valve, this valve opens. When the pump pressure falls off the valve closes. The action of the cut-out relay is similar to this in that by its action it establishes and stops the current flow from the generator to the battery.

When the water level in the tank is low the ball on the automatic check valve allows maximum flow of water through the valve. As the water level rises in the tank the ball rises also, and gradually shuts off the flow of water. In a similar manner, as the battery rises in charge the voltage and current regulators reduce the rate of current flow to the battery. As the water level drops off the automatic check valve allows more water to flow until the tank is full again. In a similar manner, after having drained the battery somewhat when we start the vehicle the voltage and current regulator allow an increased rate of current flow until the battery reaches the fully charged state again.

Now we may also note that we have one large water wheel and one small wheel connected to the tank. We also have a valve in each water line. The pressure in each line is the same, that is, the pounds per square inch pressure is the same. But since pipe "B" is larger, the volume of water flowing will be greater than in pipe "A". The work that can be accomplished by water wheel "B" is therefore greater than can be accomplished by water wheel "A". If the starting circuit is like line "B" and the ignition circuit like line "A", even though each has a different function, then it is obvious that the rate of current flow with the same pressure, and what that current may do functionally, is dependent on the size of the wire, as in our lines it is dependent on the size of the pipes.

In order to thoroughly check the charging circuit for malfunctioning, it is necessary to have reliable test equipment. It must be done only by competent personnel. The voltage and current regulators, particularly, must never be tampered with by inexperienced personnel. An exact setting is specified by the manufacturer and just any setting will not do. Only the exact setting will control the generator output and protect the electrical units of the automotive vehicle.

The ammeter is usually connected in all circuits except the starting and horn circuits. The ammeter is an electrical device designed to measure the rate of current flow of electricity. On most vehicles the ammeter scale only shows plus or minus, which indicates whether the battery is being charged or is discharging. The ammeter, when working properly, is an instrument of considerable value to the driver. It affords the driver a means of making a quick check of the charging circuit by watching its dial for indications as to whether the battery is being charged or whether it is handling the entire electrical load of the vehicle.

THE IGNITION SYSTEM

It has been explained that the ordinary gasoline engine is operated by means of the combustion and expansion of a gasoline and air mixture within the cylinder. The proper firing of this mixture at the correct instant is the function of the ignition system. The power, as well as the efficiency, of the engine are dependent upon the correct operation of the ignition system units.

The fundamental parts of the ignition system are:

1. Source of current. (Battery or generator.)
2. A transforming device. (Coil aided by the condenser.)
3. A primary circuit breaker to open the primary circuit in order to cause a spark to occur, and at the correct instant.
4. A distributor to direct the spark to the different cylinders in the proper order and at the proper time.
5. The spark plug serves as a means of setting a spark gap into each cylinder.
6. The necessary wiring to carry the current, and other units such as switches, ammeter, fuses, etc.

The ignition system may be divided into two separate circuits for identification as to function and operation.

These two circuits are normally called the primary and secondary circuits. See Figure 103. In the primary circuit the current flows from

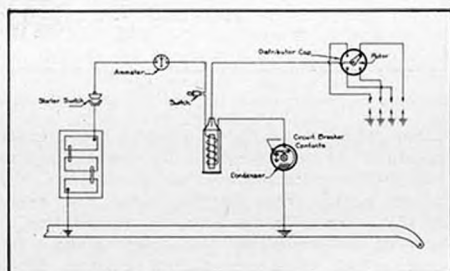


Fig. 103 - Primary and secondary circuits.

the battery to the terminal on the starter switch, to the primary winding of the ignition coil, through the circuit breaker points to ground, returning to the source of power through the frame. Basically, the above circuit is the same in all automotive vehicles. In the secondary (high voltage) circuit, current flows from the secondary windings in the ignition coil to the distributor cap, to the rotor, to the spark plug terminals in the distributor cap, to the spark plug terminals on the spark plugs by way of the secondary wires and across the spark plug gap from the center electrode to the side electrode, where the current is grounded, and from there completes the circuit through the frame of the vehicle.

Each separate unit plays an important part in the two circuits. The battery or generator, as stated, is the source of current. When the engine is first started by means of the starter or by hand cranking, the battery supplies the current for the primary circuit. Until such time as the generator produces enough current to close the cut-out relay, the battery continues to supply the current. Whenever the cut-out points are open, or whenever the charging circuit becomes inoperative due to defective parts, the battery supplies the current for the primary circuit.

The coil, Figure 104, is constructed of a core, primary winding, insulators, secondary winding, sealing compound, bakelite cap or tower, the outside case and the necessary terminals for the primary and secondary windings. Both terminals of the primary winding are exposed. Only one terminal of the secondary winding is exposed. The other end is connected internally to the primary.

The core of the coil is made up of a bundle of wires and laminations, around which is wound the secondary, consisting of approximately 21,000 turns of fine copper wire. The primary, consisting of approximately 250 turns of comparatively much heavier copper wire, is wound around the secondary and is insulated from it.

The function of the coil is to step up the

voltage of the battery or generator to an average that may be as high as 20,000 volts at times. This depends on the type and manufacturer of the coil. The final result desired of this step-up is to raise the voltage of the coil high enough to force the current across the gap of the spark plug in the cylinder. The voltage of this current must of necessity be very high in order to force the current across the gap when the pressure is at its maximum in the cylinder. (High compression pressure causes and increases the resistance to the flow of current between the spark plug electrodes.)

The coil accomplishes this by "mutual induction". Briefly, this is described as "inducing a high voltage in the secondary by the inductive effect of the magnetism produced by the current in the primary winding. When current flows through the primary winding (circuit breaker points closed) a magnetic field is built up in the coil. We know that a voltage and current can be induced in a closed circuit when a wire is moved through a magnetic field, and also that a voltage and current can be induced in a wire by moving the magnetic field across the wire. In the coil it is obviously impossible to move the wire across the magnetic field set up by the primary so the field itself is moved. By opening the primary circuit by mechanical means, (opening the circuit breaker points), the primary current flow is suddenly stopped. This quickly demagnetizes the coil, and the core in particular, which in turn breaks down the magnetic field built up in the coil. The field is said to "collapse", that is, the lines of force snap toward the core like rubber bands. As they collapse the lines of force cut across the secondary, inducing a high voltage in it. When the voltage is of sufficient value to break down the resistance of the air-fuel mixture that exists between the spark plug electrodes, a current is forced across the gap, igniting the mixture.

The value of the induced current will depend upon:

1. The number of turns in the secondary winding. Voltage (electrical pressure) is induced in each turn of the secondary winding. As these turns are connected in series, the total voltage of the induced current will be the sum of the voltages induced in all secondary windings.
2. The size of the wire used in the secondary winding. It is both practical from a winding standpoint and from the coil current output standpoint to have the wiring very fine. Many

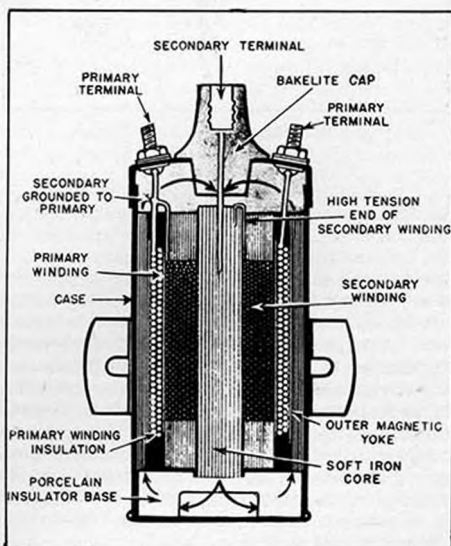


Fig. 104 - Induction coil with secondary winding next to core. (Dark arrows in coil ends indicate magnetic circuit.)

turns of wire can be used in order that a high voltage may be obtained.

3. The strength of the magnetic field established by the primary current. The stronger the magnetic field built up by the primary current flow, the stronger will be the induced current in the secondary. The magnetic field is determined by the ampere turns of the primary winding, and the period of time the primary current flows. The period of time the current flows is known as the "coil saturation period".

4. The rapidity of collapse of the magnetic field. The faster the collapse of the magnetic field, the higher will be the induced voltage. The entire primary ignition system is therefore designed to enable the circuit breaker points to open quickly and sharply so that the primary current will stop flowing decisively. It is the function of the condenser to aid the circuit breaker points in breaking the primary circuit quickly and sharply.

It is not within the scope of this discussion to cover completely the effect that unnecessary resistance in the secondary circuit has on the voltage induced. It is important, however, to realize that continued high resistance to the flow of secondary current, such as spark plug gaps that are too wide, resistance in the secondary wiring connections or contacts, and resistance in the wiring itself causes the coil to break down and become defective.

The most practical remedy for a defective coil is replacement.

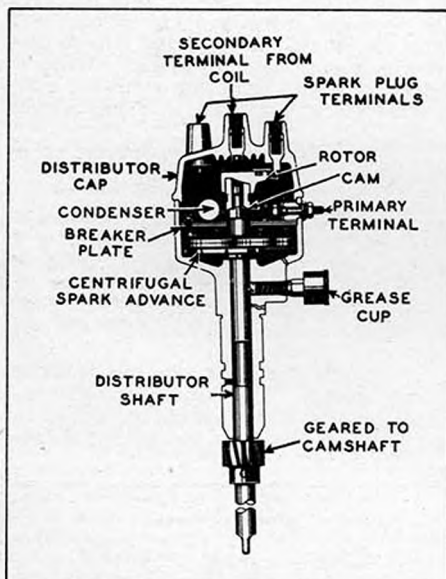


Fig. 105 - Distributor-circuit breaker assembly.

In aiding the circuit breaker points in breaking the primary circuit quickly and sharply, the condenser prevents arcing or "sparking" at the breaker points. When the primary circuit is broken, the magnetic field built up around the wires tends to keep the current flowing, acting very much like a flywheel which once set in motion tends to keep in motion. This tendency would cause the current to surge or "spark" at the points when the circuit was broken. The condenser, however, being connected in parallel with the points, absorbs this surge, and in effect, by doing so, opens the primary circuit almost instantaneously. Condensers, however, in order to function properly must be of the right type and have no defects. A breakdown in a condenser may take place gradually, and in doing so may seriously effect the efficient operation of the circuit breaker points and coil. The points may burn, or pit badly. The coil may have a very low secondary

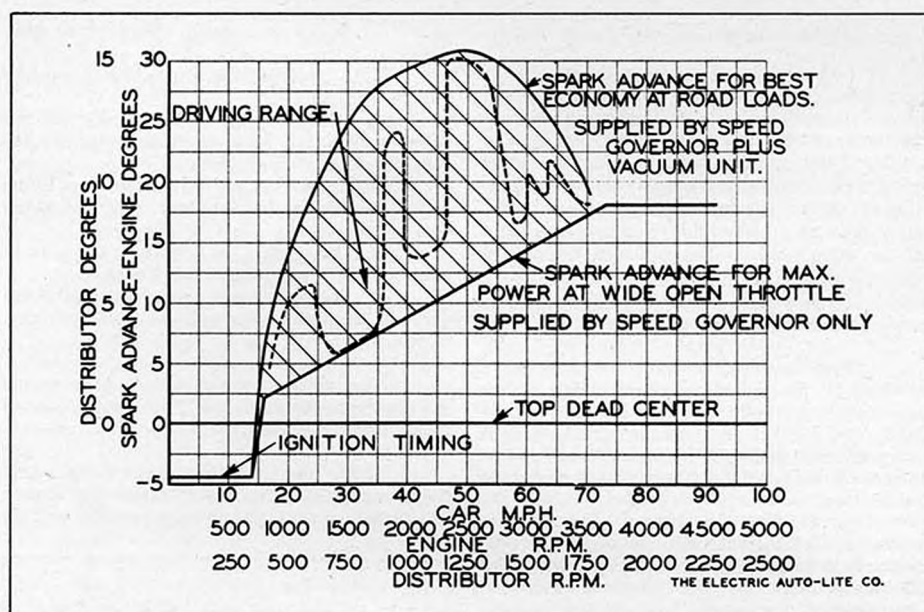


Fig. 106 - Spark advance chart.

output, causing high speed misses. A condenser should not be condemned hastily because the circuit breaker points are burned or oxidized. Oil vapor, grease from the distributor cam shaft, or high current in the primary circuit (due to breaker point setting too close, high voltage in the primary, etc.) may cause such a condition. When a condenser becomes defective, replacement is the most practical remedy.

Basically, the distributor-circuit breaker assembly is a high speed switch mechanically connected to the engine and designed to deliver current at high voltage to spark plug gaps at the correct instant in order to produce efficient combustion. Any variation in the timing of the circuit breaker points will cause rough engine operation, loss of power, and loss of economy of operation.

The principal parts of the distributor-circuit breaker assembly are the cap rotor, cam, points, and connecting leads. In order to obtain best condenser operation it is usually mounted within the housing or on the outside of the housing. See Figure 105

The secondary current coming from the coil enters the distributor cap through the secondary tower in the center of the cap, goes to the rotor, and from there is distributed to the spark plug terminals by the rotation of the rotor, mounted on the distributor shaft and turning with it. The rotation of the distributor shaft also opens and closes the primary circuit. As each cam lobe passes under the rubbing block of the movable circuit breaker arm, the circuit is broken. At the instant the primary circuit is broken the current begins to flow in the secondary. At this time the rotor is lined up with a spark plug terminal in the distributor cap. From there the current goes on to the spark plug connected to this terminal, and under the high voltage induced in the secondary the current is forced across the spark plug gap. The speed at which this is done is interesting. For example: a six-cylinder engine running at 3000 RPM requires 150 sparks per second. To produce each spark at this speed means that the circuit breaker points are closed only approximately .005 of a second for each spark. With the engine running at a speed of 550 RPM, an oscillographic study of condenser action has shown that the secondary spark is established before the points have opened .0015 of an inch.

Circuit Breaker points, after considerable

use, may not appear smooth and bright, but this is not necessarily an indication that they are not functioning properly and giving good ignition performance. They should be inspected periodically, and as long as proper operation is obtained the points should not be disturbed beyond the actual correction of point clearance.

Should the points become pitted or burned in operation, rub lightly with an ignition file. This can be done without removing them from the breaker assembly housing. In dressing contacts, it is not necessary to remove all trace of pits, as this only wastes the tungsten metal. Simply brighten the surface of the pitted point and remove the small raised portion from the surface of the opposite point.

It is important that the breaker point opening be set to the proper limits in order to obtain good performance and prolonged point life. Points that are set too close will tend to burn and pit rapidly, while points with too much separation will tend to cause ignition failure at high speeds.

In the magneto ignition systems, the magneto is its own source of current. The entire primary circuit and the distributor rotor and distributor are complete within the magneto. The cables leading to the separate spark plugs and the spark plugs are the only parts of the secondary circuit not contained within the magneto.

IGNITION TIMING

The correct time to ignite the air-fuel mixture in the cylinder is determined by the time combustion should be completed. This may vary in differently designed engines from 5 degrees to 20 degrees after top dead center. Igniting the mixture or "charge" at a certain point before top dead center is necessary in order to allow for burning time of the charge. For instance, in a cylinder 3" in diameter with a 5 to 1 compression ratio it requires approximately .003 of a second for the charge to burn. In order that the charge will have completed burning after top dead center, the charge must start burning before top dead center.

For an engine with constant load (constant throttle opening) running at a constant speed, timing of the spark would be simple, but when there is a wide variation of both load and speed timing is very complicated. Many factors in ignition timing must be considered. Proper engine design takes care of most factors.

There are, however, two fundamental conditions of engine operation. One is wide open throttle operation, such as top speed operation, acceleration, or hill climbing with the accelerator all the way down to the floor board. When operating in this manner, we are interested in power and pick-up only, regardless of economy. The other condition is sustained driving on a level road at a uniform rate of speed ranging from 30 or 40 to 50 miles per hour with the throttle only partly open. This is called "road load" operation, and requires best possible fuel economy in miles per gallon.

To obtain best power operation a centrifugal advance mechanism is contained within the distributor-breaker housing. This mechanism advances the spark according to engine speed at wide open throttle operation.

At road load the cylinders are not as fully charged as at wide open throttle operation. The charge burns slower, so an additional spark advance is required to start the charge burning sooner, so that it will have completed its combustion at the correct time.

At road load operation, which is partial throttle operation, the vacuum in the intake manifold is higher than at wide open throttle operation. This vacuum is utilized to give the additional advance required by action of this vacuum through a diaphragm. Under action of the manifold vacuum the diaphragm moves either the breaker point housing or the breaker point plate in a direction

opposite to the rotation of the breaker point cam. Another method used is for the vacuum to act on a vacuum brake that acts on a piston in such a manner as to allow the centrifugal weights of the centrifugal advance mechanism to advance the spark further. On either system, the instant the throttle is opened wide, the vacuum drops very quickly, which in turn retards the spark to wide open throttle operation, since there is no vacuum action either on the diaphragm or brake.

A spark advance curve for one engine is shown in Figure 106.

THE ACCESSORY CIRCUIT

In the modern automotive vehicle many units, many connections and switches, and much wiring are contained within the accessory circuit. On a wiring diagram, the usual accessory circuit is simple. On the vehicle many of the units are inaccessible, particularly some of the wiring and connections. It is fortunate, therefore, that of all the circuits the accessory circuit ordinarily has fewer malfunctions.

The units in the accessory circuit, as far as purpose are concerned, are by their names self explanatory. All parts of the accessory circuit are connected into the other circuits in various places. This in itself differs with vehicles. In most cases the circuits are connected in at the ammeter.

In order to become an accomplished trouble

shooter on the accessory circuit and any of its units, a thorough understanding of how each unit functions and how it should correctly function, the voltage and current requirement of each unit, and a wiring diagram of the vehicle concerned, is necessary.

As far as wiring and connections are concerned electrical faults can be divided into three types — loose connections (or opens), grounds, and short circuits.

A loose connection frequently offers enough resistance to limit the current to low value, or even stops its flow. Therefore, all the connections should be kept clean and tight. Loose or poor connections cause most of the trouble. When no current flows due to a loose connection or a broken wire, the circuit is said to be open.

An unintentional ground is generally due to an insulation breakdown of the wire. For instance, in the case of a wire going to a lamp with its insulation rubbed off at the place where it passes over the frame, the current will return to the battery by way of the frame, without passing through the lamp.

A short circuit is due to insulation failure between two conductors. For instance, if wire A is short circuited to wire B then the current would pass from A to B at the place of short circuit instead of going on from A through its normal circuit then back through B.

PART IV

THE POWER TRANSMISSION SYSTEM

A powerful engine is of no use in any vehicle until it is connected by some carefully engineered means to the final drive unit of the vehicle. In an airplane, it is a simple matter to attach a propeller, which is the final drive unit, to the crankshaft or propeller shaft of an engine, because the torque load variations imposed on the engine under operating conditions make this set-up practicable.

A ground vehicle, however, requires a much more elaborate system for transferring the engine power to its load. This system is the power transmission system. First, we have to fix the relative positions of these units, then we must provide some means of connecting the engine to the power transmission system. Then, paradoxically, we must provide a means of disconnecting or breaking the power train so that the vehicle may be stopped whenever the operator so desires without stopping the engine. Next, it is essential that we provide a unit for regulating the speed and torque of the final drive while the engine operates at a predetermined speed and power. Another point which we must consider in a ground vehicle is the relative distance covered by both sides in negotiating a turn. The outside wheel, or track, must cover more ground than the inner one, so we must introduce a compensating unit to provide for this feature.

CLUTCHES

The clutch in a motor vehicle provides a means of disconnecting the power of the engine from the driving wheels, and a means of engaging the power to the load gradually, thus allowing the engine to develop enough power to take up the load of driving the vehicle.

Clutches generally transmit power from the clutch driving member to the driven member by friction. This is accomplished by bringing one or more rotating driving members, secured to the crankshaft, into gradual contact with one or more driven members, secured to the unit being driven. These members are either stationary or rotating at different speeds. This contact is established

and maintained by strong spring pressure controlled by the driver through the clutch pedal and suitable linkage. As the spring pressure increases, the friction increases. Therefore, when the pressure is light, the comparatively little friction between the members permits a great deal of slippage. As the spring pressure increases; less slippage occurs. When the full spring pressure is applied, the speed of the driving and driven members is the same, all slipping stops, and there is in effect a direct connection between the driving and driven shafts.

Single plate clutches, Figure 107, are used in most automotive vehicles in the army, excepting tanks and very large trucks. The single plate clutch may be of one of many types of construction, and may use various types of springs to apply the pressure necessary for operation, but parts for these clutches may be divided into three main groups, according to function. They are (1) the driving members, (2) the driven members, (3) and operating members.

The driving members of a clutch usually consist of two steel plates or flat surfaces, machined and ground to a smooth finish. One of these surfaces is usually the rear face of the engine flywheel, and the other is a comparatively heavy circular ring of cast iron with one side machined and surfaced. This part is known as the "pressure plate". The pressure plate is fitted into a steel stamping called the "cover", which also contains some of the operating members, and is bolted to the flywheel.

The driven member shown in Figure 108, is made up of a hub with internal splines, to which is fastened flat steel segments or a single flat plate, usually about one sixteenth of an inch in thickness. To this steel plate the friction facing is fastened by means of copper rivets. The friction facing must be heat resistant, since friction produces heat, and most commonly used facings are made of cotton and asbestos fibres woven or molded together and impregnated with resins or

similar binding agents. Very often copper wires are woven or pressed into the material to give it additional strength. In order to make clutch engagement as smooth as possible and eliminate "chatter", several methods have been used to give a little flexibility to the driven plate. One type of plate is dished, so that the inner and outer edges of the friction facing make contact with the driving members first and the rest of the facings make contact gradually as the spring pressure increases and the plate is flattened out. In another type, the steel segments attached to the driven plate hub are slightly twisted, which also causes the facings to make gradual contact as the plate flattens out. Various other methods are employed to cause the facings to make gradual contact with the driven members.

The driven members in many plate clutches are provided with flexible centers as shown in Figure 109, to absorb the torsional vibration of the flywheel which would be transmitted to the power train unless it were eliminated. These flexible centers usually take the form of steel compression springs placed between the hub of the driven plate and the steel plate itself. The steel plate is fastened to the hub so that it can rotate slightly against the tension of the springs.

The operating members of a clutch are the springs used to apply pressure on the pressure plate for engagement, (three or more levers spaced equally around the clutch cover for the purpose of releasing the pressure of the springs on the driven plate when the clutch is disengaged); the clutch release or throwout bearing, which is brought to bear against the inner ends of the release fingers when the clutch is disengaged; and the mechanical linkages connecting this bearing to the clutch pedal. The springs may be either nine or more small compression springs, as in Figure 107, one large coil spring, Figure 110, or a saucer-shaped piece of spring steel punched to give it greater flexibility. They are placed between the pressure plate and the cover, and are held in compression by the release levers

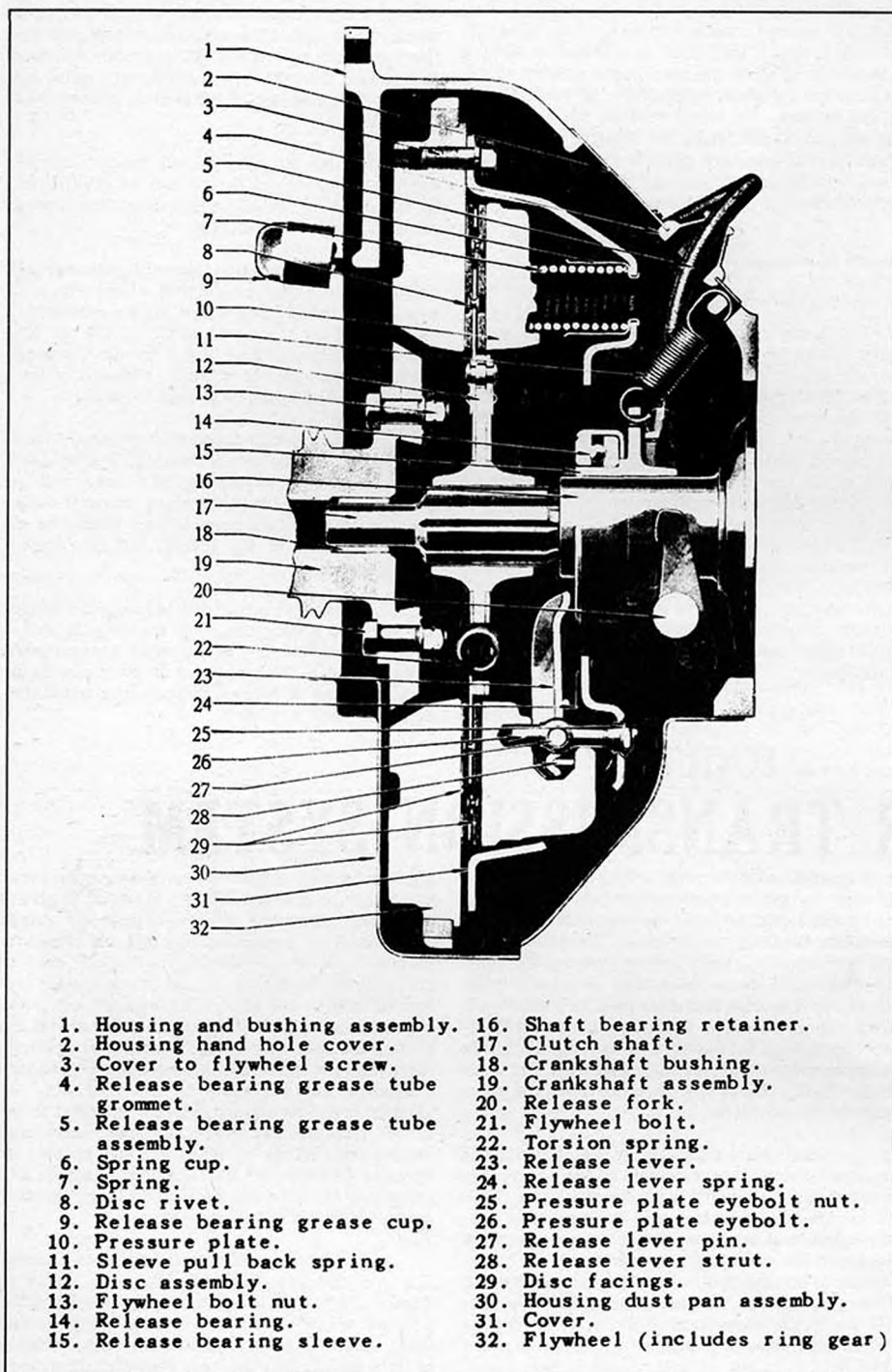


Fig. 107 - Clutch parts and flywheel.

which are fastened to the pressure plate at their outer ends and fastened a short distance from their outer ends by an eyebolt set in the cover. The release levers vary in number from three to as many as eighteen, and are provided for compressing the springs between the cover and the pressure plate to disengage the clutch. The clutch release, or throwout bearing, is a ball-thrust bearing contained in the clutch release bearing housing or collar, mounted on a sleeve attached to the front of the transmission case. The throwout bearing is connected through linkage to the clutch pedal, and is moved by the release yoke to engage the release levers and move the pressure plate to the rear, thus separating the clutch driving members from the driven member when the clutch pedal is depressed by the driver.

The operation of the clutch is as follows: When the clutch is fully engaged, the driven plate is firmly clamped between the flywheel and the driving plate by pressure of the clutch springs, forming a direct, non-slipping connection between the driving and driven members of the clutch. When the driver disengages the clutch by depressing the pedal, the release yoke lever is moved on its pivot by the clutch pedal and pressure is applied to the release collar containing the throwout bearing. The rotating race of the thrust bearing (throwout bearing) presses against the clutch release levers and moves them on their pivots. The outer ends of the release levers, being fastened to the pressure plate and pivoted on the eye-bolts holding them to the cover, move the pressure plate to the rear, compressing the clutch springs and relieving the pressure on the

driven plate, which is then left free between the flywheel and the pressure plate (the two driving members). When the clutch is in the disengaged position the driven plate and the clutch shaft can come to rest while the driving members continue to rotate. As long as the driver keeps the clutch pedal depressed, the engine will run without transmitting power to the transmission.

The power of the engine is carried to the transmission by a splined clutch shaft passing through the splined hub of the clutch driven plate, supported at the forward end by a pilot bearing in a hole drilled into the end of the crankshaft, and at the rear by a radial ball bearing set in the transmission. The latter bearing is held in place by the hollow sleeve supporting the throwout bearing collar. A gear on the end of the clutch shaft is meshed with the countershaft gear of the transmission, and when the driven plate is clamped between the flywheel and pressure plate the power of the engine is carried to the transmission through this shaft.

The clutch housing is stationary at all times. The release yoke moves only on its pivot, which is fastened to the housing by means of a bracket or a transverse shaft. All other parts of the clutch, except the throwout bearing and collar, rotate with the flywheel when the clutch is engaged. When the clutch is disengaged, the throwout bearing rotates with the flywheel, except the driven plate with its friction facing, and the clutch shaft.

ADJUSTMENT FOR CLUTCH WEAR

It will be seen from a study of the operation of the clutch that as the friction facing on the driven plate wears, the clutch release fingers move to the rear. Since the throwout bearing normally is positioned one-sixteenth of an inch away from the rotating release fingers, a small amount of wear on the friction facing will allow the fingers to move to the rear and contact the throwout bearing during engagement of the clutch. This does two things. First, it causes the movable race of the throwout bearing to rotate at all times when the engine is running, thus producing rapid wear on a bearing which was made to rotate only a few seconds at a time. Second, the fingers bearing against the throwout bearing will have the same effect as a partially engaged clutch, and cause slipping of the driven plate between the two driving members. This, of course, results in very rapid wear of the driven plate friction facing and loss of efficiency in power transmission of the clutch.

In order to keep the throwout bearing always the proper distance away from the release levers, it is necessary to keep adjusting the linkage connecting the bearing to the clutch pedal and move the bearing away. A turnbuckle is usually placed in the linkage connecting the throwout bearing yoke to the clutch pedal. A few turns on the buckle will shorten or lengthen the linkage sufficiently to move the throwout bearing the desired distance away from the release levers. The question is, how it is possible to tell when the driven plate is worn enough for the throwout bearing to require adjustment? This can be easily determined by finding the specified "free pedal play" for that particular clutch in the repair manual for the vehicle. This "free play" varies, ordinarily, from 1 inch to 1-3/4 inches, and is measured by placing a ruler against the bulkhead between the engine and drivers compartment, on a level with the top of the clutch pedal, and moving the pedal forward gently with the fingers until the resistance indicates that the throwout bearing has contacted the release levers.

TANK CLUTCH

The clutch in a light or medium tank is of the dry disc type, and its construction is similar to those used in most passenger automobiles and trucks. Since the torque requirements of the

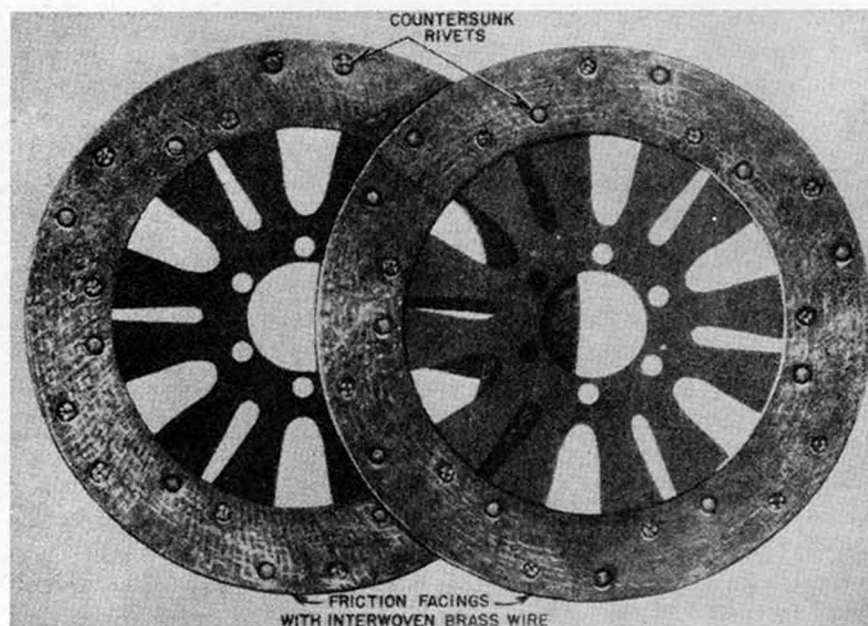


Fig. 108 - Clutch facings of asbestos fiber interwoven with brass wire riveted to clutch-driven members.

tank clutch are much higher than those of a clutch for trucks and lighter vehicles, we must enlarge the effective friction area of the tank unit. This is accomplished by using a multiple disc clutch. The multiple disc clutch has three driven plain steel plates with six effective plate areas as

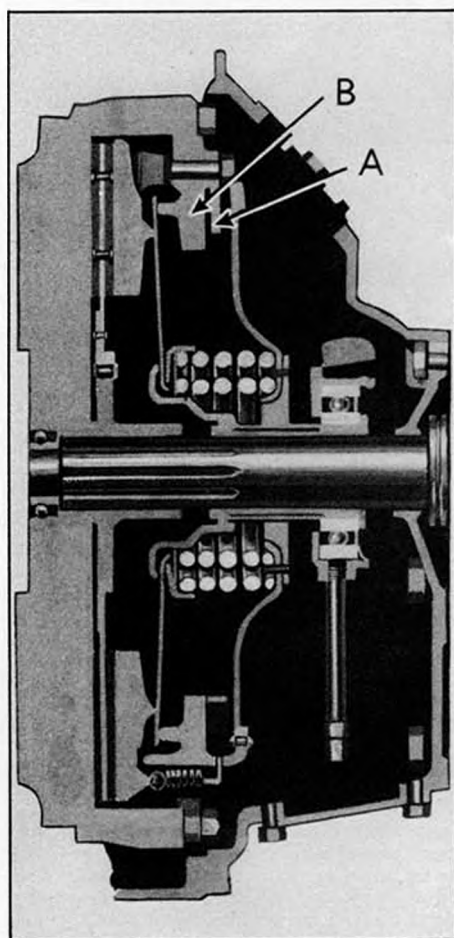


Fig. 110 - Half track clutch showing large coil spring in center.

compared with the two areas of the single plate automobile clutch. To drive these plates there are two metal driving plates splined inside the engine flywheel, so that they may move axially and still transmit torque or turning effort. Onto the face of these plates is fastened a soft copper alloy facing which is impregnated with compounds to improve the friction characteristics. This material is also attached to the faces of the flywheel and pressure plate which contact the two end driven plates. This clutch differs from the conventional clutch in that the friction material is fastened to the driving plates instead of the driven; but this in no way affects the amount of torque that may be transmitted, and is done only because engineering designers think it more practical in regard to fabrication and replacement.

The pressure plate, when engaged, is acted upon by nine or more heavy helical springs which provide the necessary pressure for clutch operation. As the plates are pressed together, the torque is transmitted from the driving plates to the driven, which are splined to the clutch spindle (corresponding to a clutch shaft in conventional vehicles) and thence to the transmission.

The axial movement of the pressure plate is accomplished by means of three levers or fingers which are equally spaced around the clutch cover and actuated by a sleeve moved by the throwout bearings attached through linkage to the clutch pedal.

Up to this point the spindle, or driving unit, was able to remain stationary while the flywheel and driving plates revolved about it on ball bearings, but as the force of the spring loading is released from the fingers and allowed to act wholly upon the pressure plate, the driving and driven plates become a solid unit, thus transmitting torque from the engine to the propeller shaft.

The light tank propeller shaft connects the motor to the transmission through the clutch. The shaft itself is made of steel tubing, having a splined plug welded to the front end and a yoke for a universal joint welded to the rear end. The front spline slides into the yoke of another universal joint, and this sliding spline takes care of the slight axial movement of the complete unit. Needle bearings in the universal joints reduce friction to a minimum.

TRANSMISSIONS AND TRANSFER CASES

An internal combustion engine can not develop appreciable torque at slow speeds, and it develops maximum torque only when it is operating at one speed. The crankshaft of an engine must always rotate in the same direction. A means

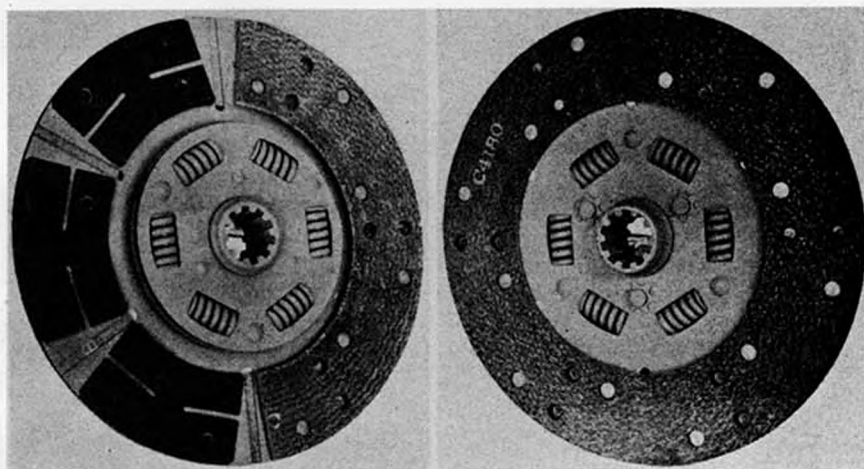


Fig. 109 - Clutch driven plate with flexible center.

should be provided whereby the vehicle could travel in reverse direction. For these reasons motor vehicles have a transmission; a system of reduction gears and idler gears placed between the clutch and the propeller shaft. The transmission provides the engine with mechanical advantage to permit it to start the vehicle and to handle it under adverse load conditions. The transmission also permits the driver a selection of speeds within the effective torque range of the engine, and allows a reversal of the flow of power from the engine to the wheels.

TRANSMISSIONS

Transmissions are classified according to the number of forward speeds they provide, the manner in which the gears are selected, the manner of engagement of the gears, and the type of gears. Most transmissions provide a neutral position, from three to five forward speeds, and a reverse speed. Light truck transmissions usually have four, but may have five, forward speeds; low, second, third, high (direct), and sometimes overdrive. Heavy truck transmissions may have as many as twelve forward speeds, usually accomplished by means of a transfer case, described later.

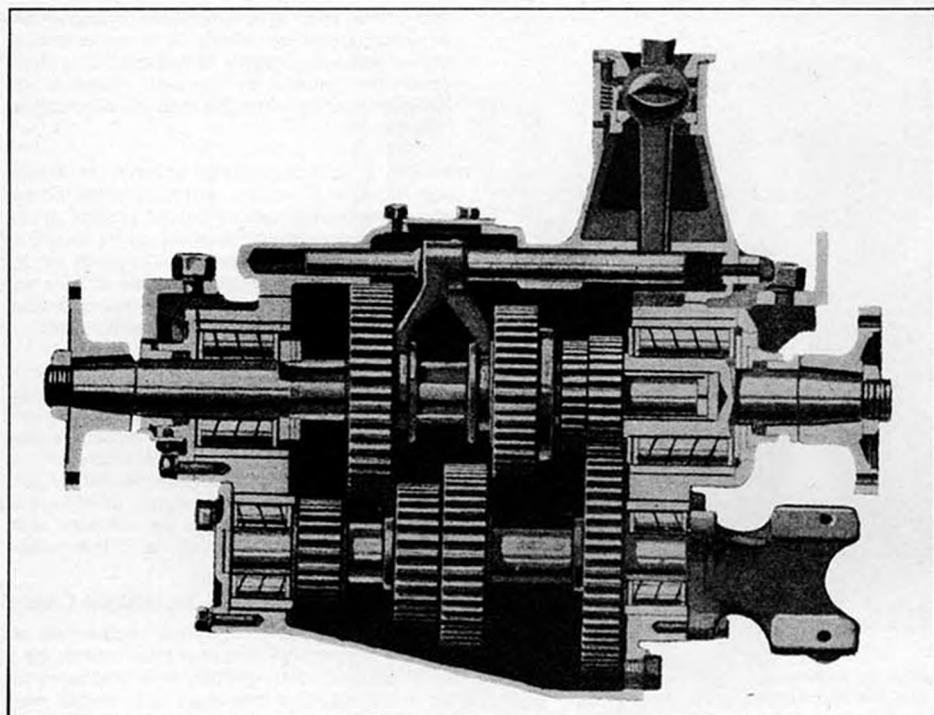


Fig. 111 - Four-speed truck transmission.

A selective transmission is one which provides a means of selecting any gear by a simple movement of the gearshift lever.

In a progressive transmission the gears must be used in order; for example, third gear can be reached only by going through first and then second gear. This latter type is used on most motorcycles.

A sliding gear transmission is one where engagement is secured by sliding the gears being used into mesh with each other.

Where the gears are always meshed with each other and are locked to the shaft by a sliding dog or jaw clutch, they are referred to as a constant mesh transmission.

Syncro-mesh refers to a refinement by which the driving and driven members are brought to the same speed of rotation just prior to meshing the gears or the clutches.

The type of gears used identifies a transmission as a spur, helical, or herringbone type. Spur gears have their teeth cut straight across the face of the gear, while helical gears have teeth cut diagonally across the face. Helical gears run more silently than spur gears, have more teeth in contact while in mesh, consequently are stronger, and are more widely used for this reason. Herringbone gears are sometimes used, and are really double helical gears with the teeth cut slanting in both directions to the center of the gear face. The object of this design is to equalize the side thrust which occurs in plain helical gears. In military combat vehicles helical gears are predominantly used.

Figure 111 shows a typical selective, sliding-spur-gear, four speed transmission. The main parts are the case, the rotating parts with their bearings, and the shifting mechanism.

The case is cast-iron or semi-steel casting. In large trucks or combat vehicles it may be mounted separately in the frame, but normally it is bolted directly to the rear of the clutch housing. It has a cover, which carries the shift-

ing mechanism and seals the transmission against dirt or water. The case is fitted with filler and drain plugs for the lubricant, some form of breather to take care of air expansion caused by heating (usually air spaces between the gear shift lever and the transmission case cover), and sealed seats for the bearings which carry the shafts.

LOW GEAR. - To obtain power for putting the vehicle in motion or to negotiate steep grades or difficult roads, the engine must be permitted to run at a high torque speed while the wheels move slowly but with great turning force. This is accomplished by driving from small to large gears. When the low main shaft gear is moved back into mesh with the countershaft low speed gear, Figure 113 (2), it meshes at the same time with the smaller reverse idler gear, which is mounted on a separate reverse idler shaft to the left of the countershaft. This reverse idler then turns on its shaft but drives no gear.

SECOND GEAR. - As the speed of the vehicle increases, less force is required to keep it moving, or the same force can be used to obtain higher road speed. To shift from low to second, the clutch is disengaged and the low-and-second main shaft gear is moved forward through its neutral position to mesh with the countershaft second gear, Figure 113 (3).

THIRD GEAR. - With further increase of speed, less mechanical advantage is required

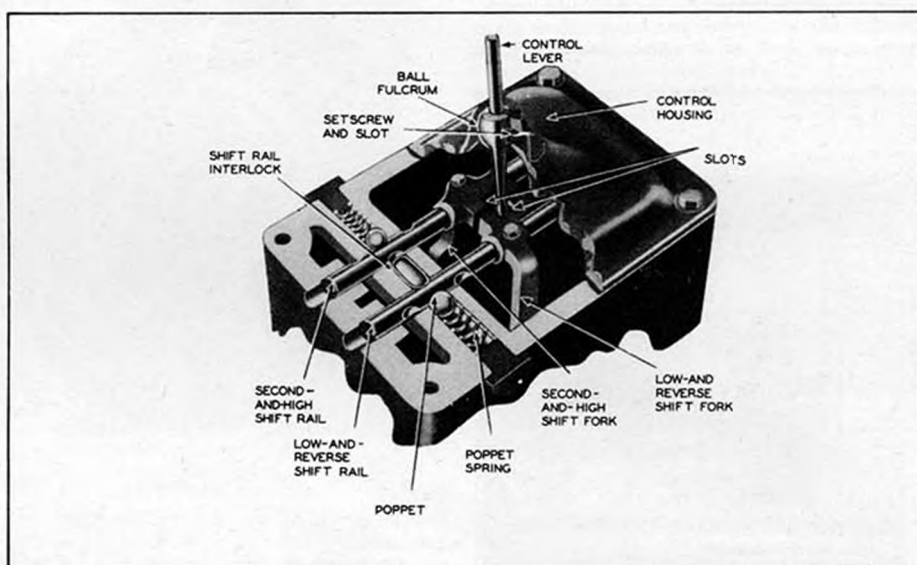


Fig. 112 - Transmission shifting mechanism.

ing mechanism and seals the transmission against dirt or water. The case is fitted with filler and drain plugs for the lubricant, some form of breather to take care of air expansion caused by heating (usually air spaces between the gear shift lever and the transmission case cover), and sealed seats for the bearings which carry the shafts.

The rotating parts are the shafts, gears, and bearings. All of these parts are made of finely finished hardened steel. The upper parts run in an oil spray created by the lower members running in an oil bath. The relation of these parts during operation is discussed in the following paragraphs:

Operation of the gear: NEUTRAL. - When power is not to be transmitted to the propeller shaft, as in starting or idling, the gearshift (control) lever is placed in the neutral position, Figure 112. With the lever in this position none of the sliding gears, including the reverse idler, is

by the engine over the wheels; therefore the transmission may be shifted into a higher gear, Figure 113 (4).

HIGH GEAR. - The high gear is used for further reduction in engine speed, or for increased vehicle speed. The high-and-third mainshaft gear is disengaged from the countershaft third-speed gear and is moved forward until the internal gear on its forward face overrides the small portion of the main drive gear (clutch shaft gear), making the clutch shaft and the main shaft turn as a unit, Fig. 113 (5). All the other gears rotate, but without load. This is the habitual gear used in driving, since it gives a direct connection from the clutch to the propeller shaft. In a transmission without an overdrive, a direct connection gives the greatest vehicle speed for a given engine speed. It also produces the least noise and wear. In this speed in the transmission, the crankshaft speed is the same as the propeller shaft speed, but the gear reduction in the final drive, which is about 4 to

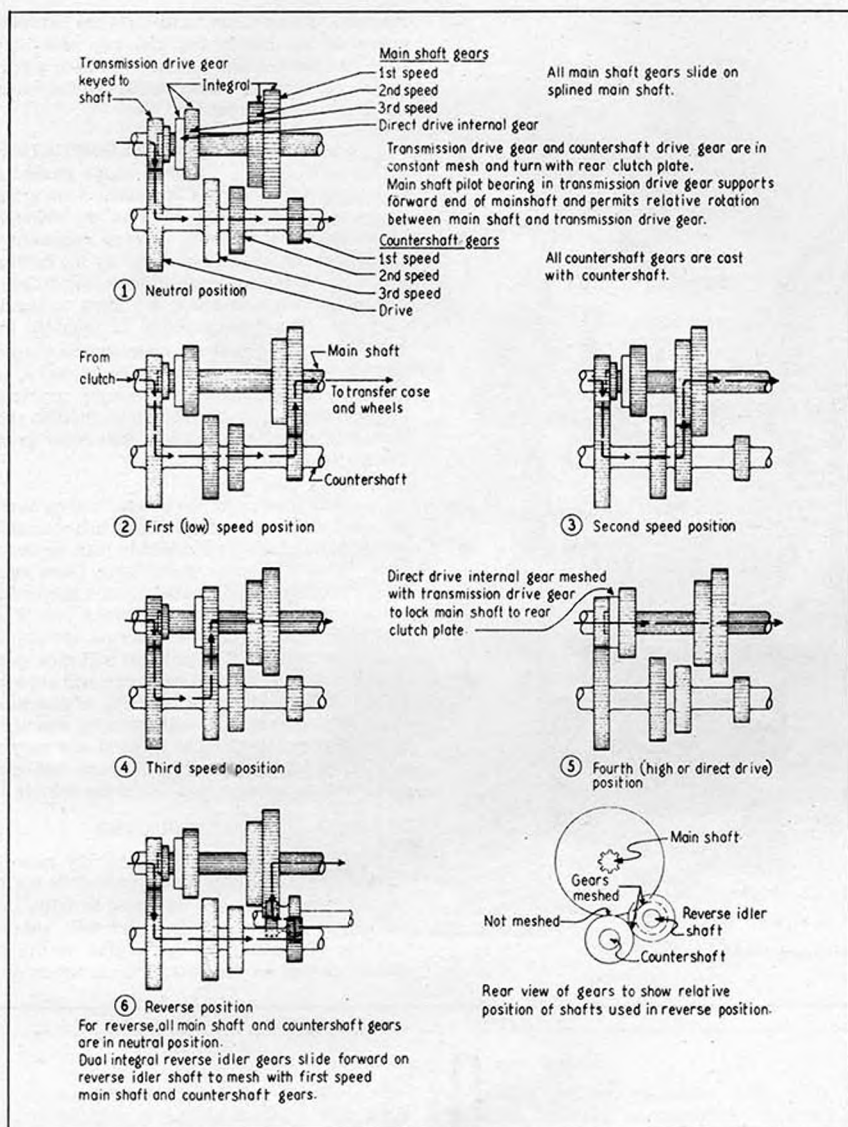


Fig. 113 - Operation of a four-speed transmission.

1, makes the crankshaft turn about four revolutions to one of the driving wheels.

REVERSE. - To reverse the direction of rotation of the main shaft an additional gear must be introduced. All other gears are put into the neutral position, the gearshift lever is moved over to engage the reverse gearshift fork. The fork is moved forward and carries with it the reverse idler gear, which slides on the reverse idler shaft, Figure 113 (6). The smaller gear on the idler engages with the low sliding gear (mainshaft), while the larger gear meshes with the low countershaft gear. The flow of power is now from the low countershaft gear, through the reverse idler gear, to the low mainshaft gear and the splines on the main shaft. In most transmissions a slightly greater gear reduction is secured through reverse than is secured through low gear.

ADDITIONAL GEARS. - If additional gear ratios are desired in a transmission, they may be obtained by the addition of gears on the main shaft, corresponding gears on the countershaft, and the necessary shifting mechanism.

The gearshifting mechanism provides a means of sliding the gears described in the preceding paragraphs. In the transmission shown in Figure 111, each sliding gear is moved forward or backward on its shaft by means of a separate shift fork. These forks are locked to the shift

rails by pins or lock screws. The gearshift lever can move but one fork and rail at a time, due to the action of the interlocking plungers. The rails are held in their forward, neutral, or rear positions by means of the shift rail poppets. Accidental shifting to reverse is prevented by the gearshift lever reverse plunger spring; the gears are moved into reverse only against the action of this spring, and necessitates more effort on the part of the driver than any of the other shifts.

OVERDRIVES. - Selective sliding overdrives to give speed ratios less than one to one between the engine and propeller shaft are used in some military vehicles. They consist merely of gears on both the main shaft and countershaft and the necessary shifting mechanism.

CONSTANT MESH TRANSMISSIONS. - Constant mesh gears, usually of helical design, are used in many transmissions. In transmissions of this type the higher ratio main shaft gears, instead of sliding, are constantly in mesh with their corresponding countershaft gears, Figure 114. The main shaft gears are not splined to the shaft but are free to rotate on it through bearings. Sliding hubs or gears, splined to the main shaft, slide into mesh with the constant mesh gears on the main shaft and connect them to the shaft. This is similar to the method employed in securing direct drive. These gears give quieter operation than do spur gears. The Half-Track, M2, transmission, constant-mesh throughout, is shown in Figure 115, with the transfer case bolted directly to the transmission.

SYNCHRO-MESH TRANSMISSIONS. - Synchronized meshes between intermediate and high gears are used on practically every passenger car and, although not used on trucks and current types of scout cars, have found frequent use in tank transmissions. The mechanism brings the gears or clutches to be engaged to the same rotating speed just before engagement; it thus permits the parts to be meshed without noise or damage, even at high speeds. Since all synchromesh transmissions operate on the same general principle, a description of only one is given.

Clutch ring and synchronizer. - In the transmission shown in Figure 116 a sliding gear, containing a synchronizer ball and spring, and encased in the direct-and-second-speed clutch ring, is mounted on the splined main shaft. The shifter fork moves the clutch ring with its in-

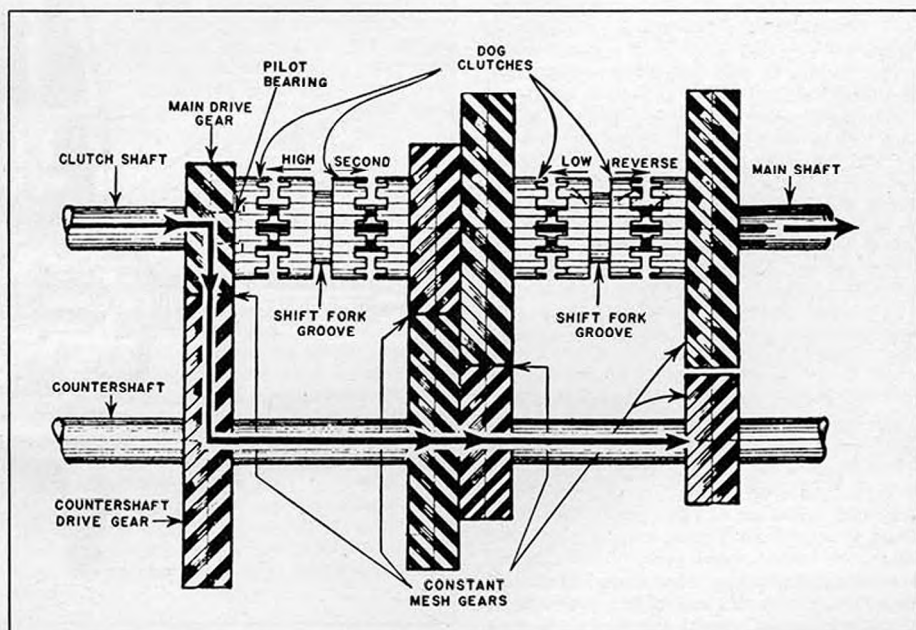


Fig. 114 - Principles of constant-mesh transmissions.

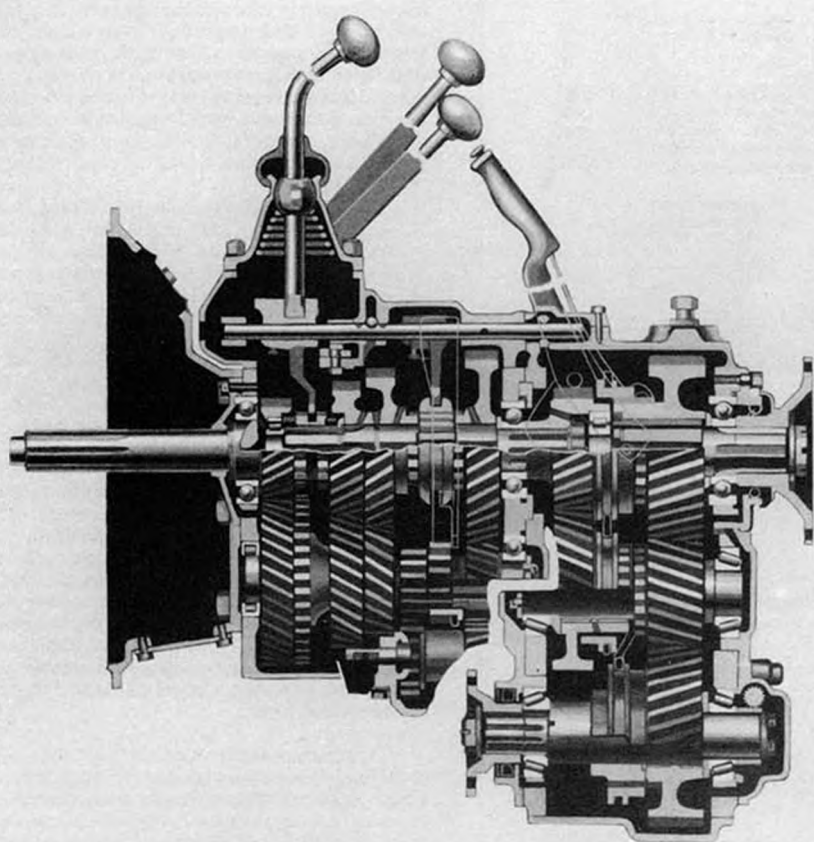


Fig. 115 - Section through transmission and transfer case.

closed parts toward the gear to be engaged. The interior of the clutch ring has longitudinal teeth, which can slide on the external teeth of the sliding gear when sufficient force is exerted to overcome the action of the synchronizer spring and ball. The sliding gear thus can be locked either to the clutch shaft or to the second speed gear. Also it has an internal cone on each side. The clutch shaft gear has an external cone on its right side, and the second-speed gear has an external cone on its left side.

OPERATION. - The operation of the mechanism in a typical shift is as follows. With the car running in high gear, the clutch shaft, clutch ring, sliding gear, and drive shaft are all rotating together, since the interior of the clutch ring is meshed with both the clutch-shaft gear and the sliding gear. The second speed gear, driven by the countershaft gear cluster, is rotating at a slower rate. When the shift from high to second is made, the clutch ring moves to the rear (right), and the synchronizer ball locks the ring and the sliding gear together. Further movement carries the assembly to the rear until the rear cone surface of the sliding gear bears against a similar surface on the forward exterior of the second-speed gear.

This contact reduces the speed of the sliding unit to that of the second speed gear. Additional movement of the gearshift lever overcomes the resistance of the ball and spring, and pushes the clutch ring over the teeth on the exterior of the second speed gear. The power then flows through the clutch shaft gear, counter shaft gear cluster, the second speed gear, clutch ring and the sliding gear, to the drive shaft. A similar cone action, clutch ring and sliding gear action, and synchronizer ball functioning take place when moving the sliding gear and clutch ring forward to put the transmission into high gear. In transmissions using synchro-mesh throughout, a clutch

ring and synchronizer unit is placed between two gears on the mainshaft; i.e. one unit between first and second and another between third and fourth, etc. Synchronizing units are not normally used for reverse speed.

MAINTENANCE AND LUBRICATION OF TRANSMISSIONS. - Transmissions generally do not require the constant and meticulous attention that some of the other units in the vehicle do, but certain maintenance is very necessary. A daily inspection should be made by the driver for leaks, and at least once a week the filler plug should be unscrewed and the level of lubricant checked. The transmission is included in the 1,000 mile or one month maintenance inspection for loose mounting bolts, noise of gears, leaks etc., and in the 6,000 or six months maintenance inspection the lubricant should be drained and the case flushed and refilled with the proper grade of lubricating oil.

Lubrication of the gears, shafts, bearings and various operating members is accomplished by the lubricating oil contained in the transmission case. This oil varies in viscosity from number 70 engine oil (used in the Half-Track transmission and transfer case) to number 90 and 140. The oil should be changed with the seasons, and it is well to bear in mind that an oil that will give perfect lubrication in 80-degree weather might not work at all in freezing or below freezing temperatures. Maintenance manuals will usually specify the type and viscosity of oil to be used, and very often this information is stated on the name and caution plate on the instrument panel of the vehicle.

TRANSFER CASES

Because practically all army motor vehicles, and especially those needed in the Ordnance Department, are designed to drive on all wheels, it is necessary to have a unit which will transfer the power of the engine to the front wheels as well as the rear. This is accomplished

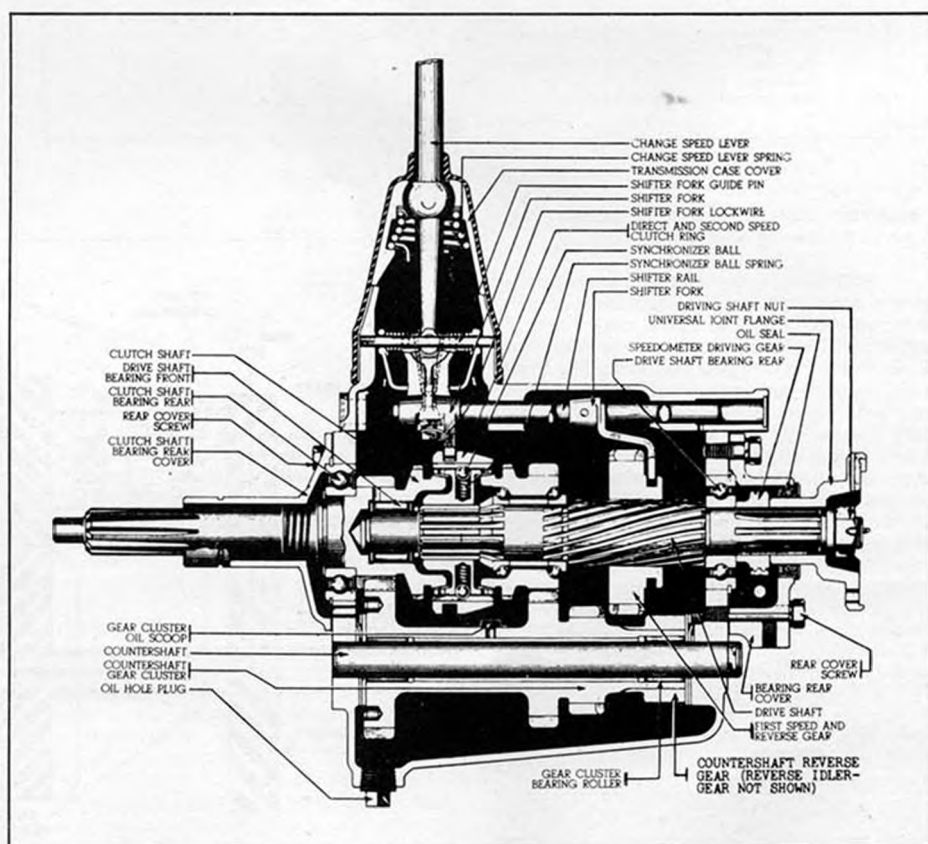


Fig. 116 - Three-speed selective all-helical-gear transmission with synchronized shift for second and direct drive.

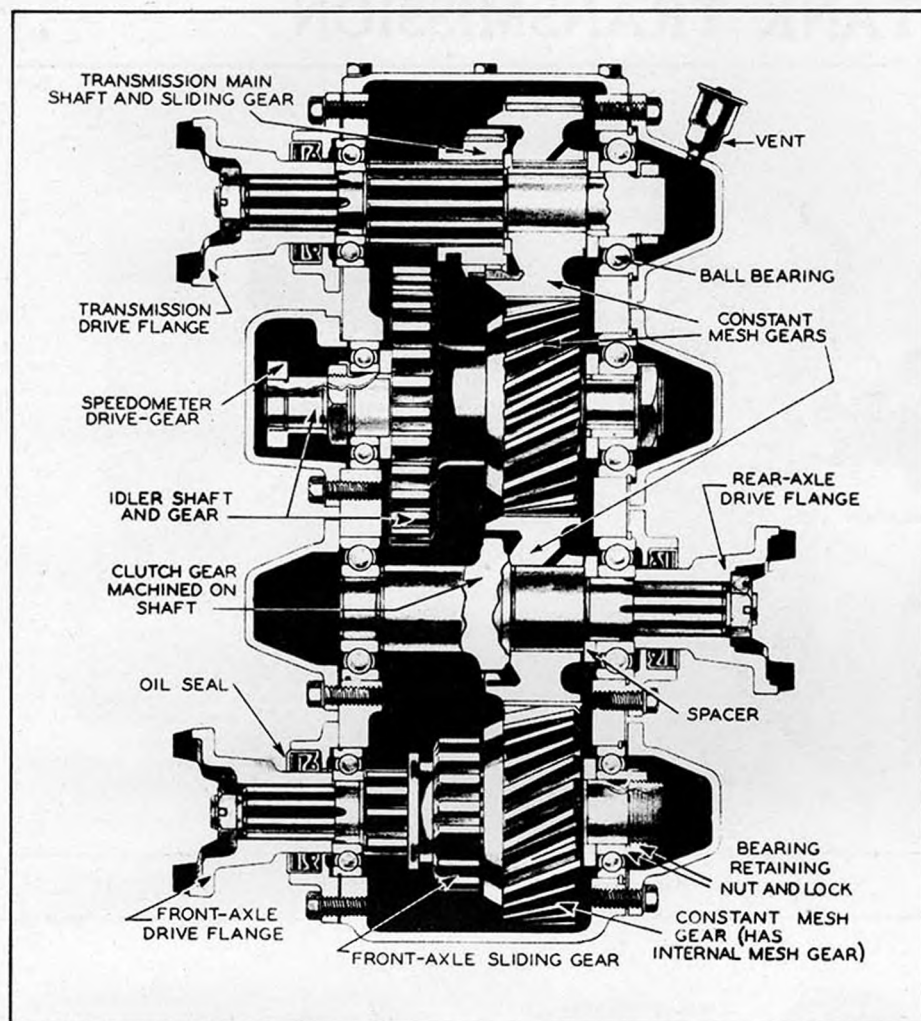


Fig. 117 - Transfer assembly, cross section.

by using a gear box called the transfer case, which, in addition to making it possible to drive with the front wheels, serves two other purposes. It provides an additional gear ratio to those in the transmission, and an additional shaft which can be used for power take-off, as in the case of the shop trucks where power is needed to turn a generator.

The transfer case shown in Figure 117 is an auxiliary gear train, a two speed transmission unit similar to the auxiliary transmission used in some vehicles. Power is transmitted from the transmission to the transfer case, usually by means of a propeller shaft, but may be connected to the transmission case, and the power taken from the transmission main shaft by a drive-in gear, similar to the clutch shaft gear in the front of the transmission. In most cases a shifter mechanism is incorporated in the transfer assembly for engaging and disengaging the drive to the front axle, and for shifting into high and low speeds. Each of these controls is operated by a lever in the driver's compartment. A notable example of a transfer case without a lever for disengaging the drive to the front wheels is the M3A1 Scout Car.

OPERATION. - In high ratio, (1:1) when driving both the front and rear axles, the external teeth of the sliding gear (splined to the transmission main shaft) are in mesh with the internal teeth of the constant mesh gear mounted on this shaft. Likewise, the external teeth of the front axle sliding gear are in mesh with internal teeth on the constant mesh gear.

The flow of power from the transmission

is through the two universal joints and short propeller shaft to the transmission main shaft in the transfer assembly, thence through the sliding gear to the constant mesh gear, and to the constant mesh gear on the idler shaft. From this gear the flow is to the constant mesh gear on the rear axle main shaft (this constant mesh gear is connected to the shaft through the external tooth clutch gear which is an integral part of the shaft). The drive for the rear axle is taken from this shaft. The constant mesh gear on the rear axle shaft in turn meshes with the constant mesh gear on the front axle shaft which provides the drive for the front axle.

Disengagement of the drive to the front wheels is accomplished by shifting the sliding gear on the front axle main shaft out of mesh with the constant mesh gear, permitting the latter to roll free on the shaft.

When using the low ratio in the transfer assembly, the sliding gear on the transmission main shaft is disengaged from the constant mesh gear and engaged with the idler gear on the idler shaft. This reduces the speed by having the sliding gear mesh with the larger idler gear. The shifting linkage on some vehicles is arranged so that shifting into the low gear is possible only when the drive to the front axle is engaged. This is the case in the Half-Track, M2 transmission. This prevents the driver from applying maximum torque to the rear drive only, which might cause damage.

MAINTENANCE LUBRICATION. - The same general rules for maintenance apply to the

transfer case as to the transmission. One point regarding bearings used in transfer cases is deemed worthy of note, however. The bearings in most transfer assemblies that support the shafts are of the type known as tapered roller, Figure 118. These bearings lend themselves to adjustment very readily, and in most cases adjustment is provided for by shims under the bearing caps on either side of the case. The shoulder on the bearing cap bears on the outer bearing race, so that when shims are removed, the outer race is forced down further on the cone shaped rollers.

The bearings should be adjusted to what is called a "snug fit"; that is, that no end play will be in the shaft, yet the bearings will not be "pre-loaded", i.e. the outer race forced down on the rollers so hard that the shaft will not turn freely. This adjustment should be checked during the 6,000 mile maintenance inspection, and always properly completed when a transfer case is disassembled for overhaul.

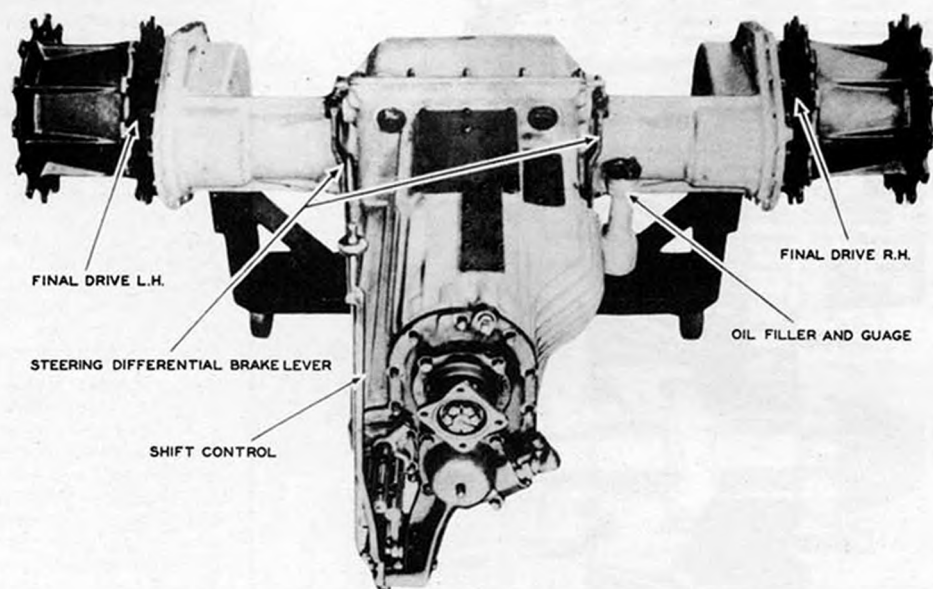
LIGHT TANK TRANSMISSION (Synchromesh)

The light tank transmission is a synchromesh unit with five forward speeds and one reverse speed. Power is applied to the front universal joint of the propeller shaft, bolted to the transmission input or driving shaft. The shaft is actually a cluster of four helical gears which become progressively smaller from rear to front. This shaft and all other shafts in the transmission are housed in a large aluminum case. This case is an example of the fine engineering design in our light tanks. Weight is saved on this large, internal shielded casting so that heavier armor plate can be used externally. It is divided into three sections, namely; the rear transmission compartment, the front transmission compartment, and the controlled differential compartment. The input shaft is supported at both ends on ball bearings mounted in the rear compartment bulkhead.

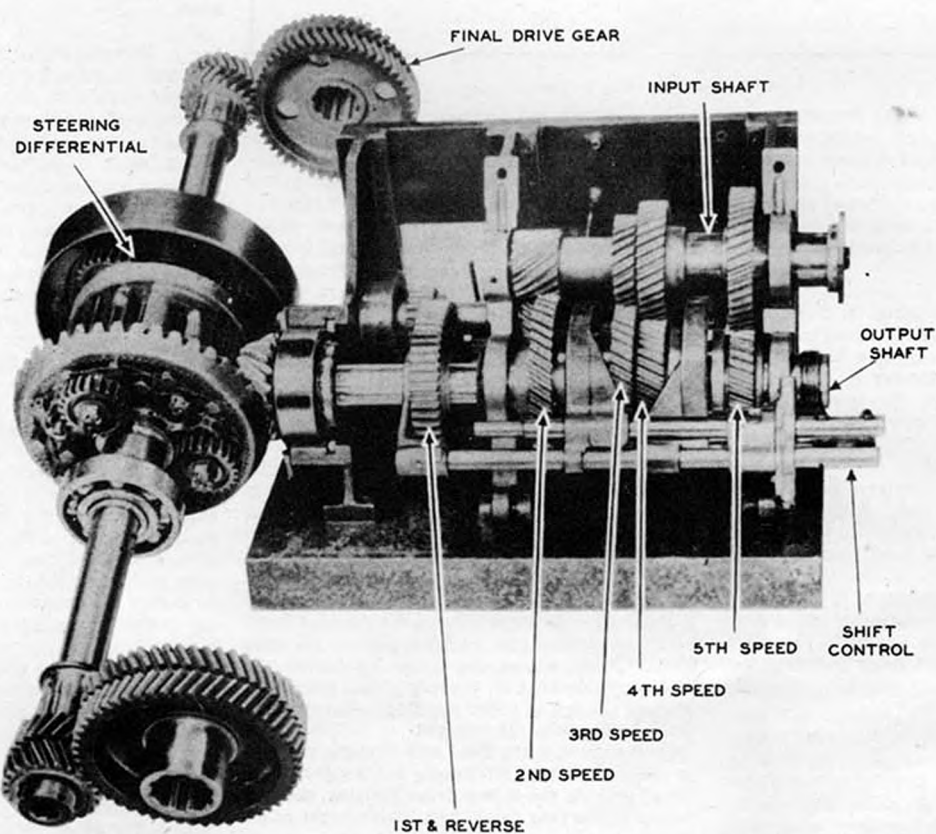
Directly below the input shaft is the output shaft. It extends from the transmission housing rear cover plate into the controlled differential compartment. At this end a bevel pinion gear is splined to the shaft and fastened by a nut. The output shaft is supported by three radial ball bearings, mounted in the transmission case. Each gear of the input shaft is meshed with a gear on the output shaft, and these four gears are permitted to rotate about the output shaft on needle bearings, since they are in mesh with the gears on the input shaft at all times. Starting with the rear gears on the output shaft, let us number the gears fifth, fourth, third, and second. Between the fourth and fifth gears, and the second and third gears on the output shaft a gear synchronizer is splined. This unit is the means of locking the rotating gear on the output shaft to the shaft, so that torque may be transmitted through the shaft to the bevel pinion mentioned above, and which is meshed with the ring gear. As the gear shift lever is moved to engage a gear it slides an internal cone on the synchronizer into contact with an external cone on the floating gear. This cone clutch causes the two gears being meshed to arrive at a common speed at or just prior to the moment of engagement. The actual engagement is accomplished as we continue to move the gear shift lever, by moving an internally splined sleeve (part of the synchronizing unit) into mesh with the external splines of the gear being fixed to the shaft. These splines are pointed to facilitate easy meshing.

The synchronizing unit is not provided for first or reverse gears. These are spur gears located in the front transmission compartment, and are driven by the second speed gear on the input shaft. A sliding gear splined to the output shaft is the means of engagement.

LIGHT TANK TRANSMISSION



Transmission—Rear View



Complete Transmission Gearing

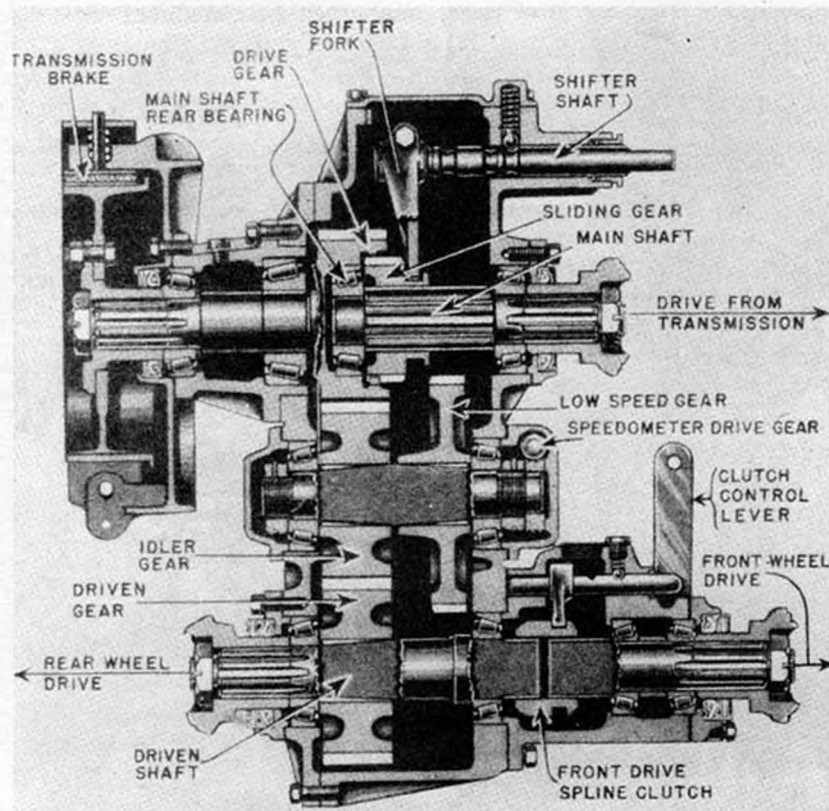


Fig. 118 - Cross section of two-speed transfer case.

PROPELLOR SHAFTS AND UNIVERSAL JOINTS

Power must be transmitted from the transmission to the live axle through a variable angle, because the driving axle of a motor vehicle is attached to the springs while the transmission is mounted on the frame, resulting in variable motion of the two. The distance between the two is also changing slightly due to the flexing of the spring. Some type of flexible drive is required, and the propeller shafts are used along with universal joints.

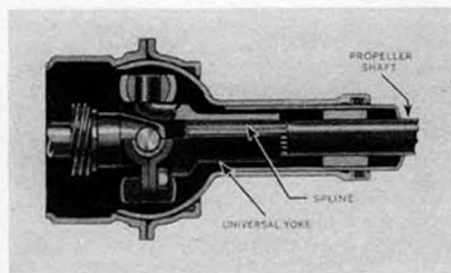


Fig. 119 - Trunnion-type universal joint.

PROPELLOR SHAFTS

Two types of propeller shafts are used, the solid and the tubular. Since the torsional stress is zero at the axis of the shaft, hollow shafts are used wherever practical. A hollow shaft is somewhat stronger than a solid shaft of the same weight. To compensate for the changing length of the propeller shaft, and at the same time transmit torque, it is usual practice to incorporate a slip joint between the propeller shaft and the universal joint. Slip joints usually consist of a splined stud shaft welded to one end of the propeller shaft, fitting into a splined sleeve integral

with the universal joint yoke, Figure 119. In vehicles provided with a true torque tube drive, which permits the rear axle to pivot about the universal on the front end of the propeller shaft,

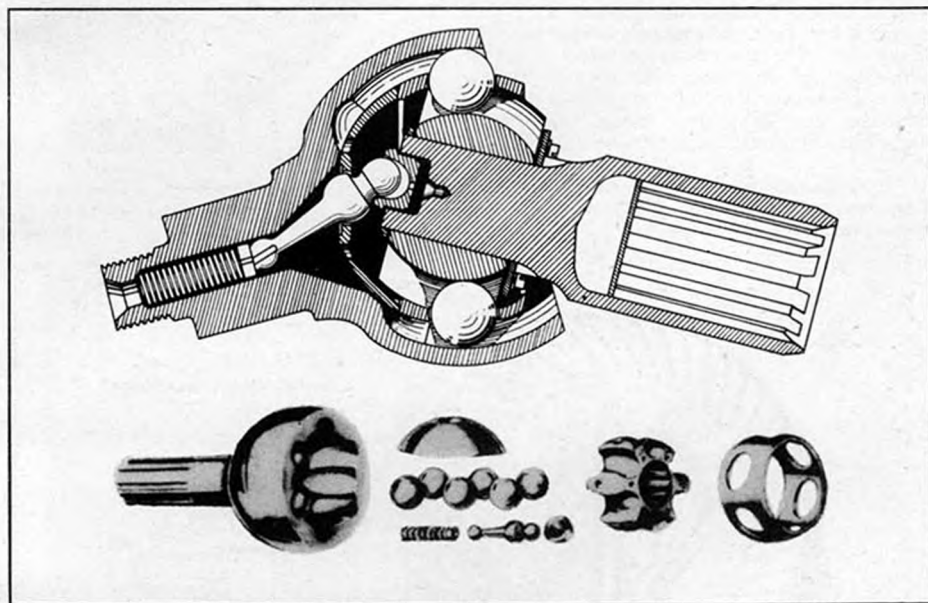


Fig. 121 - Rzeppa joint.

a slip joint is not required. It is necessary to keep the slip joint well lubricated, so that it will slide freely and prevent rapid wear and failure due to the excessive end thrust on the bearings that support the propeller shaft and universal joints.

See Figure 120.

In the constant velocity type of universal joint, the plane in which the balls rotate bisects the angle formed by the shafts. This type of universal is used where a uniform rate of rotation

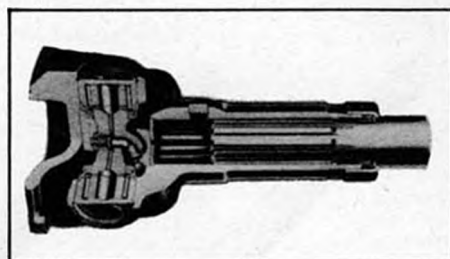


Fig. 120 - Companion flange universal joint.

UNIVERSAL JOINTS

The universal joint is a connection between two shafts that permits a driving shaft to drive a driven shaft at an angle. Most universal joints embody the principle of a cross with two yokes pivoted to its ends. Universal joints, excepting the constant velocity type, do not transfer uniform motion when the shafts are operating at an angle. If the driving shaft runs at a uniform speed, the driven shaft will increase to a maximum speed twice in each revolution. The reason is that the pivot pins do not revolve in the same plane. When two universals are used they must be so arranged that they neutralize rather than increase the fluctuations.

There are several types of universal joints: the cross and two yokes type, cross pin type, ring and trunnion type, split ring type, split ring and pin type, and the sliding ball and trunnion type.

A widely used universal joint is the cross and two yoke type. The cross is drilled to receive lubricant for the needle bearings which pivot the ends of the cross, or trunnions, to the two yokes. A relief valve is used in the center of the cross to prevent damage to the needle bearing retainer parts and oil seal when excessive oil pressure is applied. One yoke is integral with the splined sleeve of the slip joint and the other yoke is integral with a companion flange which mates with a companion flange on the transmission shaft.

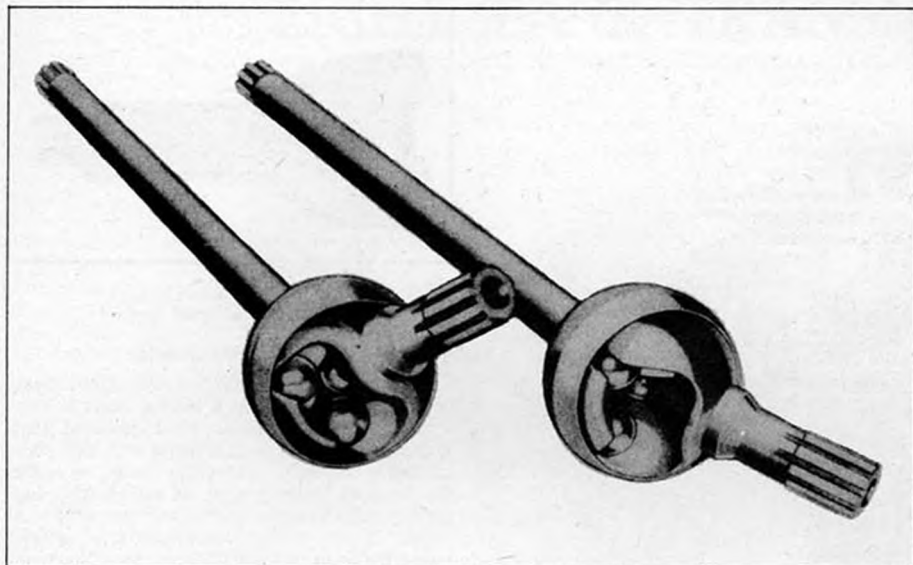


Fig. 122 - Bendix-Weiss constant velocity universal joint.

is required, as in the front driving axles and rear axle bogies. Two types of constant velocity universal joints are popularly used in front-wheel drive vehicles for connecting the axle shafts to the wheels; the Rzeppa and the Bendix-Weiss type. Each of the universals connects the driving and driven members by rolling contact between accurately fitted balls and grooves. Both are practical for drive angles up to 30 degrees. A plane passed through the points of contacts of the balls with their races would at all times bisect the angle between the driving and driven shafts.

The Rzeppa type of universal, Figure 121, consists of a driving member, driven member, and a close fitting ball cage separating the driving and driven members. Six balls engage a groove in the driven member; they form the driving contact. A pilot assembly controls the position of the balls and cage. A pilot pin, with ball ends, is held in its seat in the driving shaft by the pilot spring and plunger, and passes through a hole in the pilot. The pilot pin always forms an angle with the driven shaft that is half the drive angle and is so connected to the pilot and cage that it maintains the plane of ball contact at half the angle between the driving and driven shafts.

In the Bendix-Weiss universal, Figure 122, four steel balls are placed in nonconcentric, intersecting races cut in the yokes. The races

cause the balls to roll angularly one-half the distance traversed by the yoke. A smaller steel ball held in place by a pin, acts as a lock in holding the other four balls in position and as a thrust block between the two blocks. The balls may roll a small amount endwise, thus eliminating the use of slip joints.

The slipjoint of a propeller shaft entirely inclosed in a housing is provided with a lubricant fitting. A propeller shaft slipjoint inclosed within a torque tube is usually lubricated automatically from an adjacent unit or assembly and requires no attention. Exposed slip joints must be lubricated with a heavy-bodied lubricant to prevent the joints from sticking and rusting. Lubricant used on a universal joint should be fibrous and fairly viscous so that it will not throw off as the joint rotates at high speed. Oil is recommended for lubricating some makes of universal joints, in which case "Use Oil" is usually imprinted on the joint.

FINAL DRIVES

A final drive is that part of a power transmission system between the propeller shaft and the differential. It includes a reduction in speed between the propeller shaft and the differential, and turns the direction of the power through 90

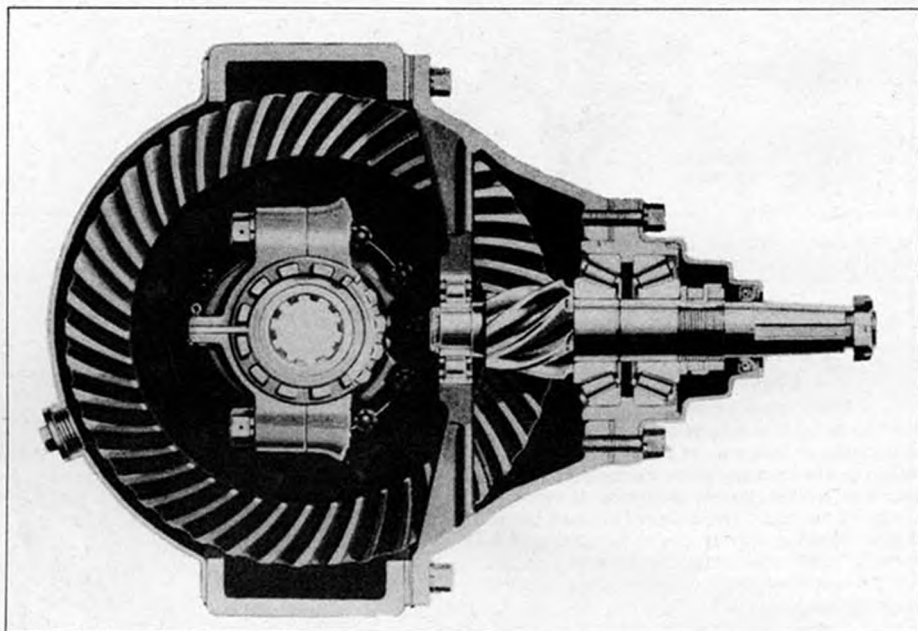


Fig. 123 - Bevel gear final drive with straddle mounted pinion.

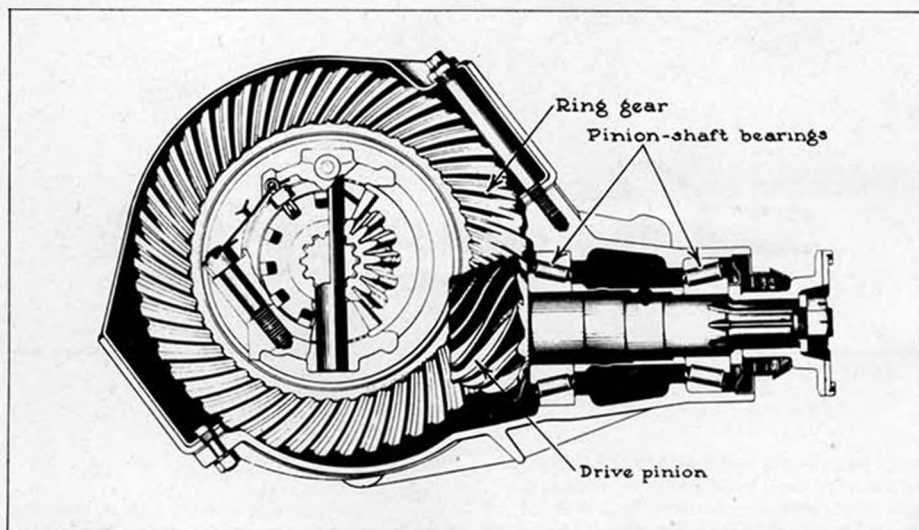


Fig. 124 - Packard hypoid-gear final-drive assembly.

degrees. The usual speed reduction in vehicles is between 3 to 1 and 5 to 1. There are several types of final drives in use: spiral, bevel gear, worm gear, chain, Hypoid, and double reduction. Double reduction final drives make it possible to secure high reductions with the use of small, accurately made gears.

The differential is usually housed with the final drive, but the two serve purposes having no relation to each other.

All the final drives in general use are the geared type. The most common type consists of a pair of bevel gears in which the drive pinion is connected to the propeller shaft and the bevel drive gear is attached to the differential case on the driving axle. These bevel gears may be spur, spiral, or hypoid. Spiral bevel gears are most used, Figure 123. Hypoid gears are used in several vehicles, where they permit the bevel drive pinion to be placed below the center of the bevel drive gear, lowering the propeller shaft and giving more body clearance, Figure 124. Worm gears are used because they give a large speed reduction; they consist of helical worms and

meshing toothed gears. Double chain drives are still used to a limited extent for heavy duty work; they are efficient and rugged, but become very noisy and are open to dirt and mud.

The bevel gear final drive consists of a main-drive pinion integral with its shaft, supported in the rear axle housing by a double row ball bearing at the front and by radial bearings at the rear, to take the high end-thrust of the gear teeth, which are specially cut. The outer end of the main drive pinion meshes with the ring gear, which may be bolted or riveted to the differential case, and through the medium of the differential mechanism the driving axles are rotated. The pinion usually has an odd number

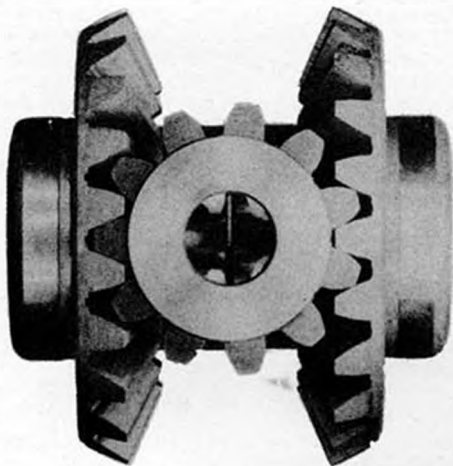


Fig. 125 - Differential side gears and pinions.

of teeth, and the ring gear an even number, so that the pinion teeth make contact with all the ring-gear teeth to reduce wear. The entire assembly is surrounded by the rear axle housing, and is filled with oil to the proper level for lubrication. Felt or leather washers are provided to prevent leakage. Adjusting rings or shims are provided to move the ring sideways, and the pinion forward and backward, to insure proper tooth mesh.

DIFFERENTIALS

A differential is a device to permit the driving wheels to turn at different speeds and, at the same time, permit the final drive to transmit equal torque to both wheels. The differential is used (a) in turning corners where the outside wheel travels a greater distance, and hence at a greater speed, than the inside wheel, and (b) when one wheel strikes a rise or depression, making it necessary for the wheel to cover a greater distance than the wheel on the other side.

The type of differential in general use consists of two or more differential pinions, pivoted radially in the case and meshed with two differential side gears. These are splined to the two axle shafts which drive the wheels. The axle shafts pass through each side of the differential case but rotate independently of it, Figure 125. In an actual differential, the differential pinions are pivoted on the trunnions of a spider. These trunnions extend outward beyond the pinions and their outer ends are held in recesses between the two parts of the case which hold the side gears in mesh with the pinions. The bevel pinion rotates the bevel gear and the differential case and the spider which are attached to it. The power is transmitted to the axle shafts through the differential pinions and the side gears. When there is equal resistance in each rear wheel, the differential pinion rotates the differential gears and axle shafts at the same speed, which is the speed

of the bevel gear. The pinions are not turning on the spider trunnions, and their teeth are not moving over the teeth of the side gear. When the vehicle turns a corner, one wheel must turn faster than the other. There is a movement of the differential pinions around the spider trunnions and over the teeth of the side gears. This makes one side gear and axle shaft, revolve faster than the other. Any movement of the differential pinions over the side gears accelerates one axle shaft and retards the other, Figure 126.

The final drive and differential are surrounded by a housing which is partially filled with oil for lubrication. An oil level plug is provided for filling, and a drain plug is located at the lowest point in the housing. The oil used is generally a heavy gear oil, and the type used depends upon the kind of final drive and the climatic conditions.

FINAL DRIVE UNIT (Tank)

The final drive unit is nothing more than a further reduction gearing, with a unit attached to each side of the controlled differential housing. The driving axle is splined into the compensating gear of the differential and has a herringbone gear of 22 teeth on the outside end. Forward of this gear, and meshing with it, is a 53-tooth driven gear, onto which the driving sprocket of the tank is attached. Each gear shaft is supported by a combination of ball and plain roller bearings.

The sprocket itself is worthy of mention, because it is the final connection between the power train and the tank track. Its 14 steel teeth fit in between each connecting link of the track, and in this manner the tank is moved along.

CONTROLLED DIFFERENTIAL USED IN TANKS

The differential in the tank is for the purpose of steering the vehicle. It is called a controlled differential because the relative speed of the two sides may be controlled by varying the speed of certain gears in the units. Large brake drums are attached to the sun gears of the planetary gear system on both sides of the housing, and by applying pressure on either brake, we obtain a variation in speeds of the final drive units. The most important point in this type of differential is that it does not completely stop the track on the side the brake is applied, but allows it to turn at a reduced speed.

The basic parts of the light tank differential include the ring gear, the differential housing, two sun gears, six external pinions, six internal pinions and two compensating gears. Power is brought into the ring gear (which is attached to the differential housing) by the bevel gear pinion attached to the output shaft of the transmission. When the speed of both tracks of the vehicle is the same the differential housing and all its gears revolve as one unit. In other words, none of the gears have relative motion to the housing, but

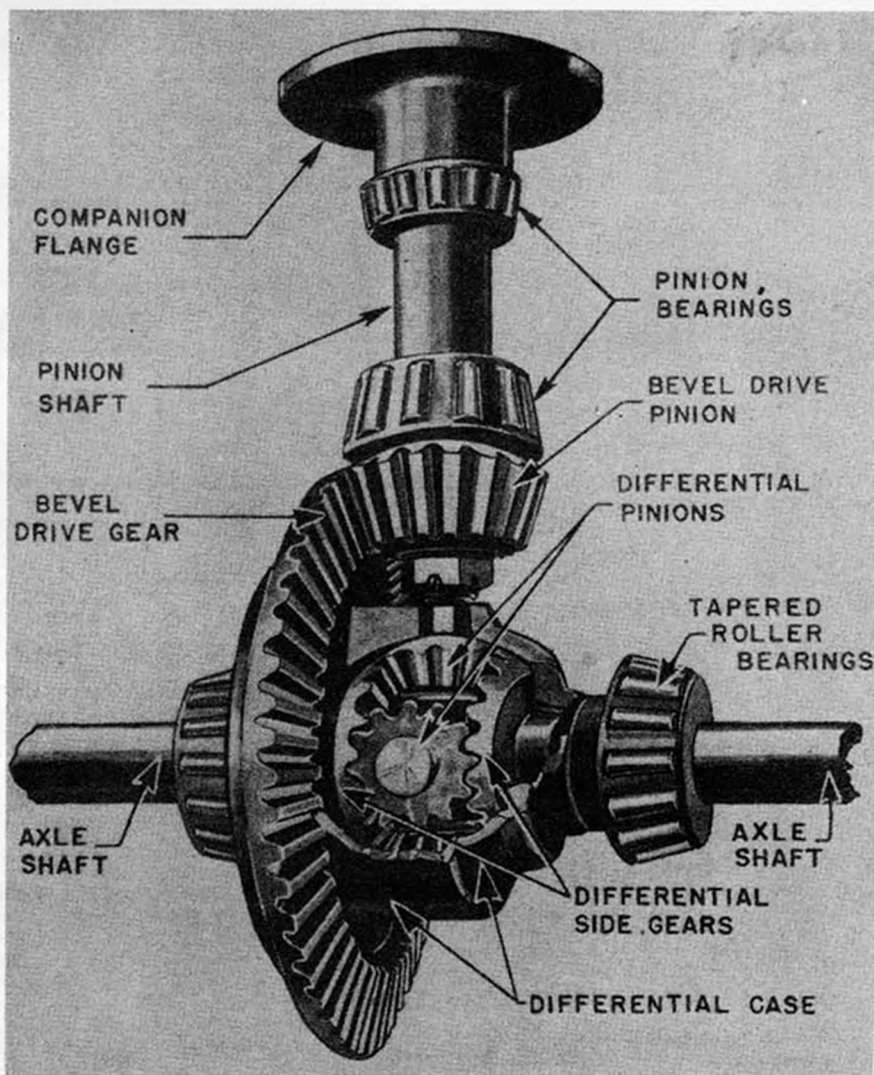
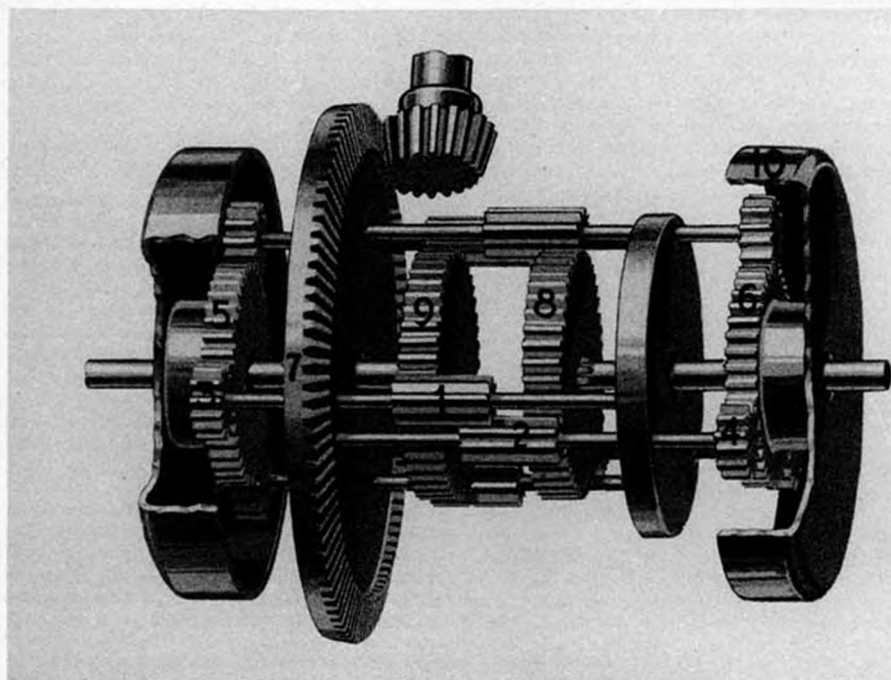


Fig. 126 - Differential with part of case cut away.



- 1, 2. Differential pinions.
3, 4. External pinions.
5, 6. Steering drum gears.

7. Ring gear.
8, 9. Main drive-shaft gears.
10. Steering drum.

Fig. 127 - Controlled differential steering.

revolve with it as if all were locked. It must be remembered that the housing revolves at all times if the tracks are turning, and the motion of the other gears in the system must be considered as relative to this motion whenever they are put into action. (For operation of the controlled differential as explained below, refer to Figure 127.)

Let us pretend to make a full right turn. We pull the right brake lever, which stops the right brake and holds the right sun gear stationary. For one revolution of the housing, the right internal pinion gears revolve around the right sun gear, but since the number of teeth on the sun gear is 27 compared to 21 teeth on the external pinion, the pinion gear revolves about its own axis $27/21$ revolutions. Since the external pinion is connected directly to the internal pinion we may now calculate how fast the right compensating gear turns during this one revolution of the housing. The internal pinion gear has 9 teeth and the compensating gear has 39 teeth. With one revolution of the pinion we would roll on the compensating gear $9/39$ of a revolution, but we have shown that it revolves $27/21$ revolutions, so it is easily seen that for a complete revolution of the housing the pinion rolls $27/21 \times 9/39$ or $27/91$ of one revolution about the compensating gear. Therefore, the effective turning speed of this right compensating gear is only $64/91$ revolutions. This reduced speed is then transmitted to the final drive shaft, which is splined into the compensating gear.

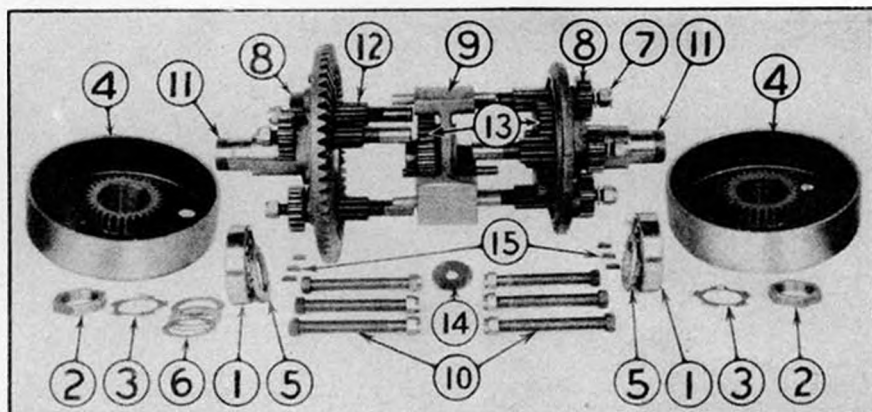
Now let us see what has happened to the left side of the differential. The right and left internal pinions are in mesh, and, as the right turns, it revolves the left pinion at the same speed, but in the opposite direction. Also, with one revolution of the housing, the right pinion rolled with the compensating gear for $27/91$ revolutions. The left pinions are turning at the same speed now, but they are turning against the left compensating gear. Therefore, in one revolution of the housing the left compensating gear will gain $27/91$ revolutions relative to the housing, for the housing will be turning one plus

is operating on a side slope or when it skids against an obstruction; and the resistance of the springs, radius rods, torque tubes, and the like, as the wheels advance or retard the frame with its load. Twisting forces are produced by: the drive from the differential to the wheels, or, when the load is driving the engine, from the wheels to the differential. A twisting stress is imposed on the axle by brake action.

Driving axles are classed as semi-, three-quarter-, and full-floating axles. In all these floating axles, the differential, rather than the inner end of the axle shaft, is mounted on bearings inside the housing. The axle is semi-floating if the outer end of the axle shaft is mounted in a bearing, and also has the hub mounted only on the shaft. The shaft, then, carries the load, resists bending, and delivers torque, Figure 129. The axle is three-quarter floating if the wheel is mounted on a radial bearing on the exterior of the axle housing, and is also splined to the shaft. Load is transferred to the housing and then to the hub, but the shaft carries the bending and torsional forces; the bending forces are reduced however, since forces due to brake reaction (horizontal) and weight are carried by the housing, Figure 130. An axle is full-floating when the hub is mounted entirely on tapered bearings on the exterior of the axle housing, and the axle shaft merely drives the wheels. The axle shafts may be removed and replaced without removing the wheel or disturbing the differential, Figure 131, in both the three-quarter and full-floating axle, simply by removing the driving flange.

STEERING MECHANISMS

The purpose of the steering mechanism,



- | | | |
|-------------------------|------------------------|------------------------------|
| 1. Differential Bearing | 6. Shims - as Required | 11. Compensating Case Covers |
| 2. Lock Nut | 7. External Pinion Nut | 12. Internal Pinion |
| 3. Lock | 8. External Pinion | 13. Compensating Gear |
| 4. Steering Drum | 9. Compensating Case | 14. Compensating Gear Washer |
| 5. Spacer | 10. Case Bolt | 15. External Pinion Key |

Fig. 128 - Parts of the controlled differential.

$27/91$ revolutions. The left track will then be traveling approximately 1.85 times as fast as the right track. A knock-down view of this mechanism is shown in Figure 128.

DRIVING AXLES

When a vehicle is in motion, the driving axles may be subjected to: (a) shear and bending, due to the weight of the vehicle; (b) bending due to the axial forces acting at the point of contact of the wheel with the ground; (c) torque, due to the power of the engine; (d) end-thrust, due to gear reaction and blows on the axle ends. Shearing stresses are caused by the transfer of weight from the springs to the wheels, and the transfer of road shocks from the wheels to the springs. Bending stresses are imposed upon the axle by the weight upon the springs, and road shocks; road resistance, which tends to make the wheels toe out; the leverage of the wheels when the vehicle

Figure 132, is to enable the driver to maintain control of direction, and a good mechanism will absorb enough of the road shocks so that the driver will not become unduly fatigued by the effort of steering.

Most steering gears employ some type of worm gear, since this gear is most adaptable to obtaining large reductions. Current steering gears in use in army vehicles are (1) Worm and Sector (2) Cam and Lever (3) Recirculating Ball. These will be described in the order named.

WORM AND SECTOR. - In the worm and sector steering gear, Figure 133, the steering wheel (not shown), hollow steering tube, and hourglass worm rotate as a unit. This rotation moves the sector gear. Integral with the sector gear is the sector (steering gear) shaft, on which the Pitman (steering gear) arm is mounted.

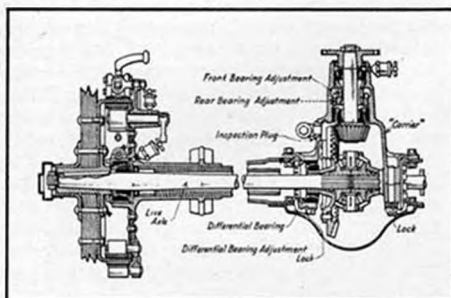


Fig. 129 - Semi-floating rear axle.

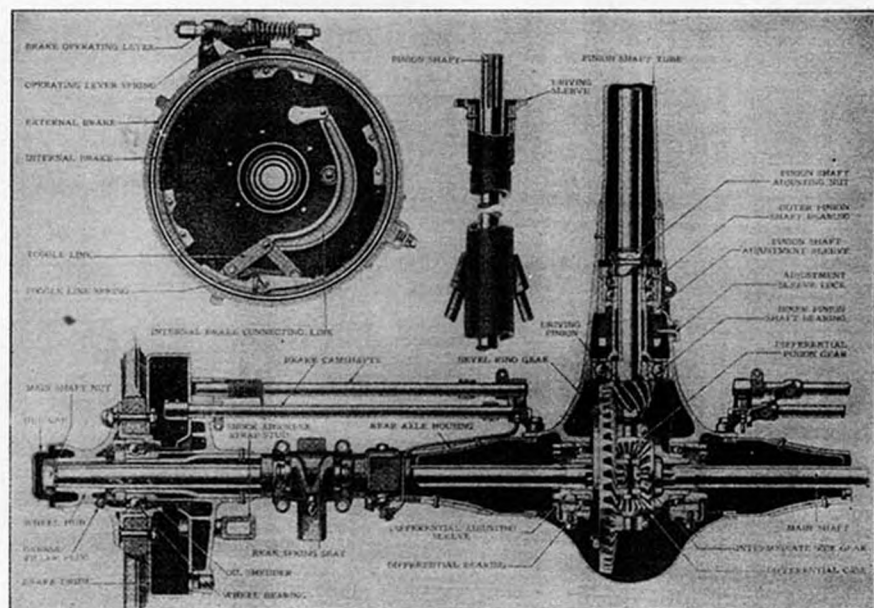


Fig. 130 - Three-quarter floating rear axle.

Hence the rotation of the sector is transmitted to the other parts of the steering mechanism through the steering gear shaft as shown in Figure 132. The sector shaft oscillates in bushings which are in the housing cover. The eccentric adjusting sleeve, Figure 133, provides for adjustment of the mesh of the sector with the worm. Because of a slight flattening of the hourglass worm at the center, this engagement is closest when the vehicle wheels are in the straight-ahead position. It is in this position that most of the wear occurs; therefore, later adjustment to take up this wear will not cause binding on that part of the worm which is engaged by the sector when the vehicle makes a sharp turn. Also, because the vehicle normally operates in the straight-ahead position, any play would permit injurious pounding. This is a general principle of steering gear construction. Axial thrust of the sector shaft is taken up by the thrust collar on the inner bushing and by a set screw A (with lock nut B), which bears against the head of the sector shaft.

The worm and roller steering gear, Figure 134, is a variation of the worm and sector type. In it a roller, mounted on ball or needle bearings, acts as the sector. The roller shaft may be straddle mounted.

CAM AND LEVER. - In the cam and lever steering gear, a cam replaces the worm discussed above. The cam is cylindrical in shape, its actuating part being a groove of variable pitch, made narrower at the center than at the ends. This permits adjustment for wear by removing shims to secure deeper setting of the lever stud. The lever is mounted on a sector shaft which turns in plain bushings. The lever stud is so placed that it engages the cam from the side, as contrasted with the underneath position of the

sector or roller in the worm types. The lever stud may be attached solidly to its shaft, Figure 134, or it may be mounted so as to rotate on bearings, Figure 135. A later model of this steering gear is the twin lever arrangement shown in Figure 136, which provides two follower pins or studs mounted on separate levers. The twin levers afford greater angular travel than the single lever, a shorter steering arm, and more advantageous use of the effective leverage in the range of lever travel. The cam turns with the steering wheel, while the double tip of the steering gear lever (actually two levers) shaft engages with the thread of the cam. It is important to note that the groove is purposely cut shallower

play in the worm shaft. Between the roller bearings, the worm is threaded with a precision finished helical groove corresponding to that in the worm. Within the length of the nut, the helical grooves are filled with steel balls conforming to specifications drawn up for this gear. There are two ball circuits in the nut. To keep the balls from running out of the ends the nut is fitted with two tubular ball guides, each of which deflects the balls from their helical path and guides them diagonally across the back of the nut, returning them to the helical path in the nut. The two guides, together with the helical grooves in the worm and in the nut, thus confine the balls within two distinct closed circuits, one in each end of the nut.

The balls within the helical path constitute a thread between the worm and nut, so that when the worm is turned, the nut moves along the worm, as with an ordinary screw thread. At the same time the balls roll freely between the worm and nut, circulating within their closed circuits, so that screw motion is obtained with rolling instead of sliding contact between the parts. Rack teeth are cut in that portion of the nut which faces the pitman shaft sector. The pitman shaft is mounted in anti-friction bronze bushing. A grease seal is provided near the outer end of the pitman shaft gear. The sector portion of the pitman shaft is provided with teeth which mesh with the rack teeth of the nut. The gear teeth are purposely cut in such a way that when the gear is adjusted to take out all backlash at the center of travel, there will be a slight backlash at each end of travel. This is so that snugness of the gear in the straight-ahead position can be obtained without sacrifice of perfect freedom at extreme positions of the front wheels.

STEERING LINKAGE. - Steering linkage provides a means of transmitting the steering gear control from the steering gear arm to the steering-knuckle arms. It consists of the drag link (steering gear connecting rod), the tie rod (connecting the two steering knuckles) and the fittings at the end of the rod.

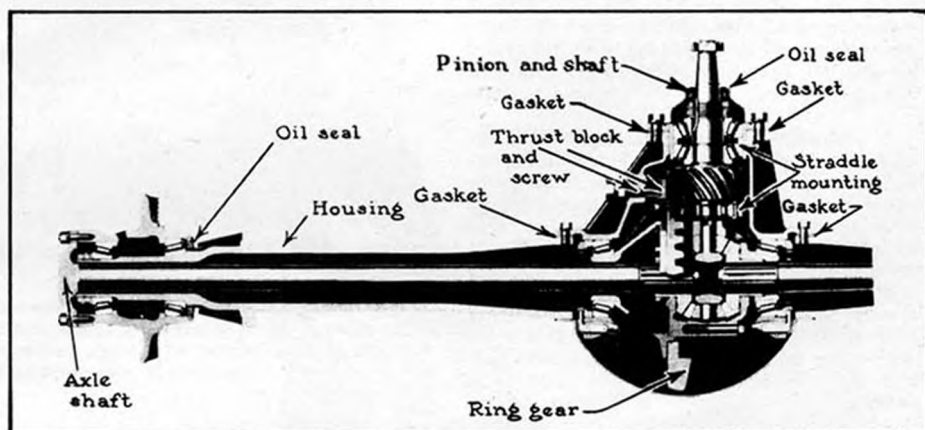


Fig. 131 - Rear axle assembly (full floating axle).

in the straight ahead driving position of each stud, Figure 137. This produces a high range in the groove, equal at each stud, which causes a closer mesh of the studs in the groove through the mid-position of travel of each stud. This feature permits a close adjustment for normal straight driving and take-up of backlash at this point, after normal wear of the groove, without causing a bind elsewhere.

RECIRCULATING BALL TYPE. - The principal working parts of the gear are the steering worm, the ball nut and the pitman shaft and sector. The worm is integrally welded to the steering main shaft and is mounted between two barrel roller bearings, the lower one of which is adjustable toward the upper for taking out end

There are four general types of linkage. The fore and aft linkage Figure 132, is conventional, and employed on most vehicles used in the army. Other types of linkage used mainly on vehicles having independent front wheel suspension are Cross-steering type, Center-steering, and dual drag link types.

MAINTENANCE. - Steering gears are mounted in gear boxes and are usually attached to some part of the frame of the car. The most important item of maintenance is the periodic lubrication and check at 1,000 and 6,000 mile intervals. Lubrication is either by special lubricant intended to withstand extreme gear pressures, or the same type of lubrication as used in transmissions and final drives. At the 1,000

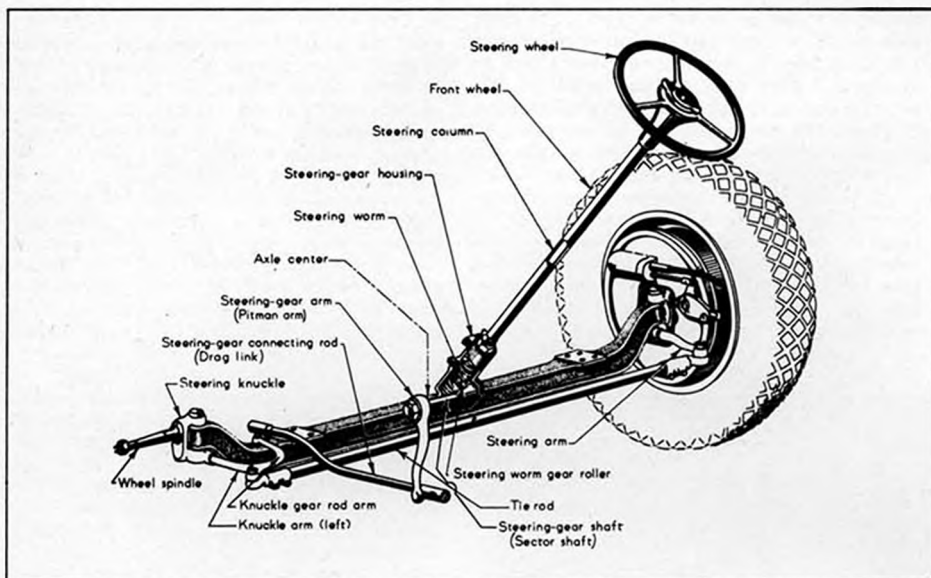


Fig. 132 - Diagram and nomenclature of complete steering mechanism. (Fore and aft linkage).

mile maintenance inspections the bolts holding the gear box to the frame should be checked for tightness, the level of lubricant should be checked and the gears examined for (1) mesh of sector or stud and worm or cam, (2) end play of cross shaft, and (3) end play of worm or cam shaft to which steering wheel is attached. This can be done by following directions in the maintenance manual for the vehicle being serviced.

BRAKES

BRAKING ACTION. - Braking action is the use of any force to reduce the speed of a moving vehicle or to prevent it from moving. When the braking force is applied it develops friction, which does the braking. Friction is the resistance to relative motion between two surfaces in contact. Thus, by forcing a stationary surface into contact with a surface on a revolving wheel of a moving vehicle, the resistance to relative motion or the rubbing action between the two surfaces will slow down the wheel and retard the vehicle. Automotive vehicles are braked in this manner.

BRAKING REQUIREMENTS. - A. Vehicle operators usually realize that to increase a vehicle's speed requires an increase in the power output of the engine. It is equally true, although not so apparent, that an increase in speed requires an increase in the braking action necessary to bring a vehicle to a stop. If the speed of a vehicle is doubled, the power required to move it is increased fourfold; likewise, four times as much braking action is required to stop it. This is the reason why well designed, powerful brakes have to be used to control the modern high speed motor vehicle.

B. Brakes are expected to decelerate a vehicle at a faster rate than the engine can accelerate it. Because of this, brakes must be able to control a greater power than that developed by the engine. A comparison between the horsepower developed by the engine and the horsepower absorbed by the brakes when stopping a passenger car is illustrated by the chart in Figure 138.

C. It is possible to accelerate an average passenger car with an 80-horsepower engine from a standing start to 80 miles an hour in 36 seconds. By applying the full force of the brakes, such a vehicle can be decelerated from 80 miles an hour to a full stop in 4.5 seconds. The time required to decelerate to a stop is one-eighth the time required to accelerate from a standing start, hence the brakes handle eight times the power developed

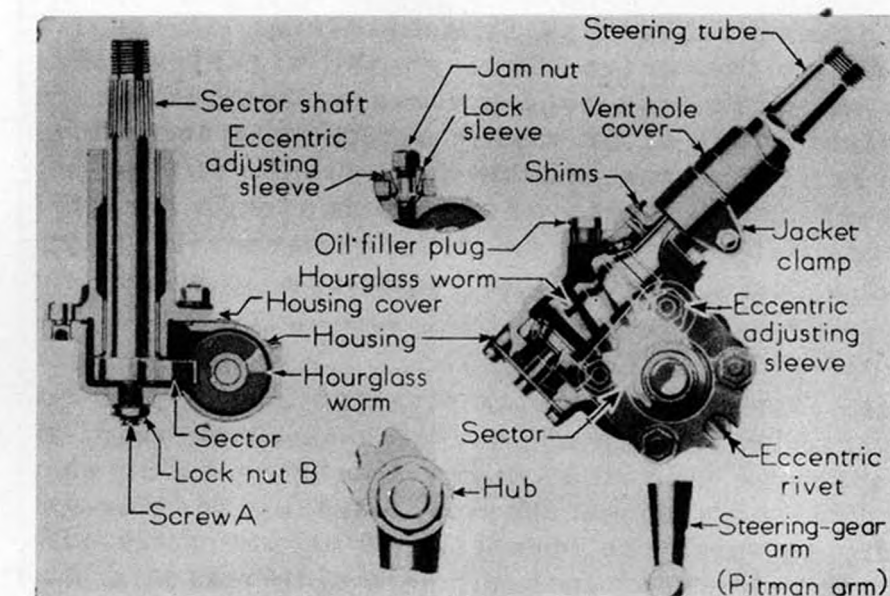


Fig. 133 - Gemmer worm-and-sector steering gear.

by the engine or (8 x 80), about 640 horsepower. All this power has to be expended by the friction surfaces of the brakes of an average passenger car to bring it to a stop from 80 miles an hour in 4.5 seconds.

STOPPING DISTANCE. - Brakes must not only be capable of stopping a vehicle but they must stop it in as short a distance as possible. The minimum distance in which a vehicle can stop at various speeds is limited, because no vehicle can be decelerated quicker than 32 feet per second even under ideal conditions. During the time that the driver is thinking of applying the brakes, and moving his foot to do so, the vehicle moves a certain distance, depending on its speed. This elapsed time before the brakes are actually applied is the driver's reaction time. The table in Figure 139 gives the minimum stopping distance required at various vehicle speeds when the brakes are in good condition.

MAXIMUM RETARDATION. - Maximum braking effect, or conditions insuring the quickest stop,

occur when the brakes are applied with such force that the wheels are not quite locked, but continue to turn without slippage on the road. More energy can be dissipated when the wheels are turning, because static friction is greater than sliding friction. Also there will be a slight loss of energy due to rolling friction between the tires and the ground, and because the rolling motion of the wheels must continuously supply energy to deflect the tire side walls and tread. Therefore, as each successive portion of the tire rests on the ground, without slipping, more force can be absorbed. This causes the brake drums and lining to heat, and also results in friction losses in the power transmission system, which must operate whenever the wheels are turning. This explains why it is best to use the deceleration of the engine, with or without the brakes, when stopping. This is especially true when stopping on slippery pavement.

MATERIALS USED IN BRAKES

BRAKE DRUMS. - Drums are made from cast iron or steel or a combination of pressed steel with a cast iron liner. See Figure 140.

BRAKE LINING. - Brake linings are classified as Woven, Woven Molded, and Full Molded. The main constituents of practically all

brake linings are; asbestos fibers, cotton fibers, copper or bronze wire, and some type of bonding compound, as tar or gum. Of these three types of lining, the woven lining usually has the highest friction, about .5. The woven molded type, Figure 141, has a lower friction, and the full molded, Figure 142, supplies our lowest friction lining, about .35. This is not always true, because today some high friction full molded linings are being manufactured.

BRAKE SHOES. - Brake shoes are made from cast iron, pressed steel sections welded together, or cast aluminum.

BRAKE CLASSIFICATIONS

The automotive vehicle brake may be divided into two parts: one, the fundamental brake consisting of the lining, shoes, drums, and their arrangement with each other; two, the type of brake, meaning the actuating mechanism of the brake.

TYPES OF FUNDAMENTAL BRAKES

A. Transmission brakes (hand brakes).

1. Band brakes or external contracting

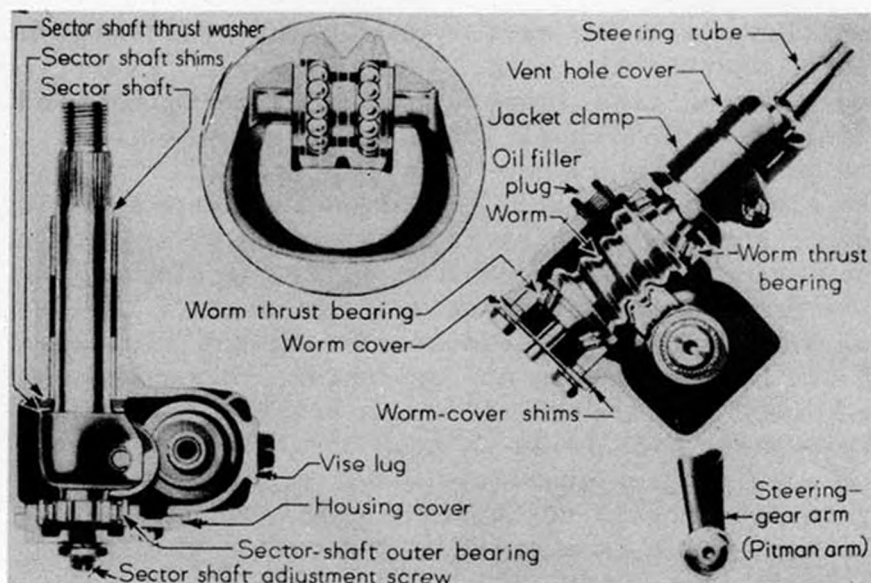


Fig. 134a - Gemmer worm-and-roller steering gear.

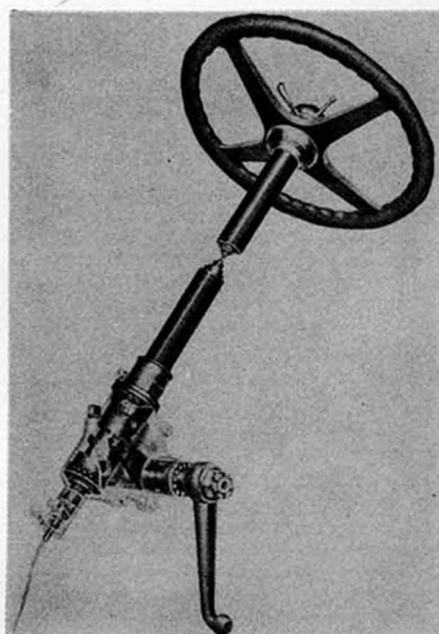


Fig. 135 - Ross cam-and-roller steering gear.

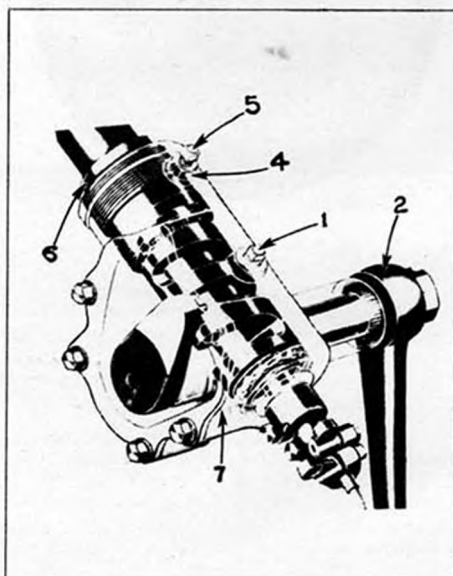


Fig. 134b - Cam-and-lever with internal stud.

brakes. These brakes are most commonly used as parking brakes, and are located just behind the transmission or transfer case. See Figure 143.

They are to be used only when parking or in the event of failure of the foot brakes.

The principle of operation of this brake is: the drum is fixed to some part of the drive shaft and revolves with it. Surrounding the drum is a brake band which is rigidly mounted. When the hand brake is applied, it contracts the brake band onto the drum, and by friction the drum is stopped from revolving. The stopping force is transmitted from the brake to the rear wheels through the differential.

2. The disk type transmission brake, commonly called the True Stop brake, is located either behind the transmission or transfer case, and should be used in the same manner as the band brake. See Figure 144. The True Stop brake is

better than the band brake, because it operates through a greater lever arm and it stays a little cooler than the drum type transmission brake.

When the brakes are applied the brake shoes are squeezed against both sides of the revolving disk, and the stopping effect is transmitted to the rear wheels through the differential.

Transmission brakes have the advantage of their retarding force being multiplied by the final drive ratio, and their action is equalized through the differential. Transmission brakes have the disadvantage of not being positive in action, they are hard to cool, and they exert a

severe strain on the power transmission system.

B. Wheel brakes (service brakes or foot brakes).

Wheel brakes are the brake assemblies that are mounted at the wheels, and consist of: the brake shoes, the brake shoe return springs, and the actuating mechanism. The brake assemblies are mounted on the backing plates.

There are several different types of funda-

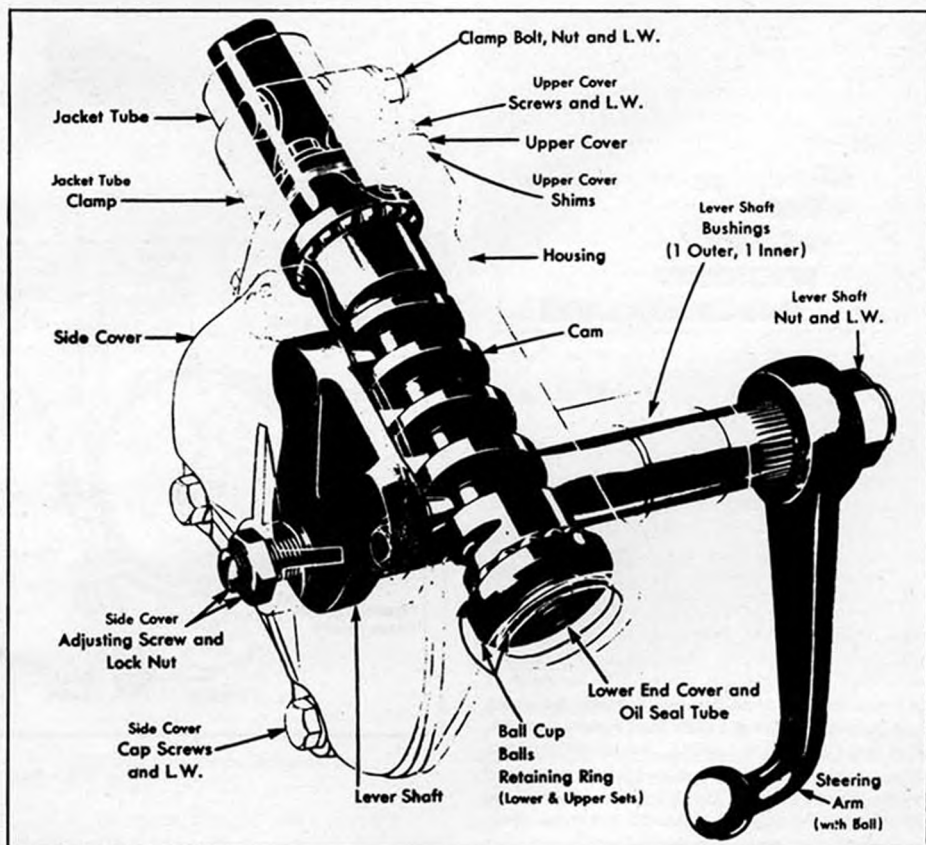


Fig. 136 - Phantom view of lower end of steering gear.

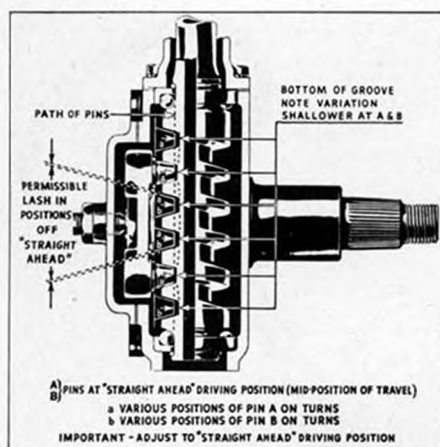


Fig. 137 - Adjustment for backlash of lever shaft pins in cam groove.

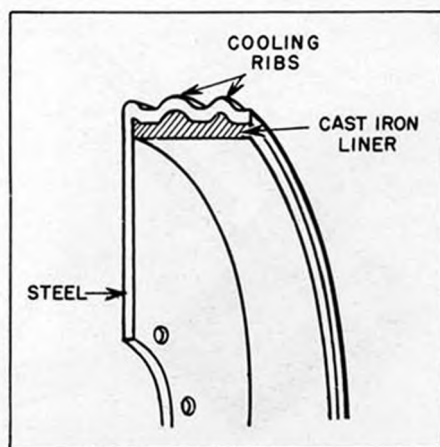


Fig. 140 - Centrifuge brake drum.

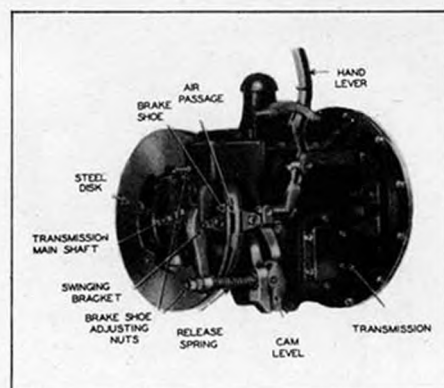


Fig. 144 - Disk transmission brake.

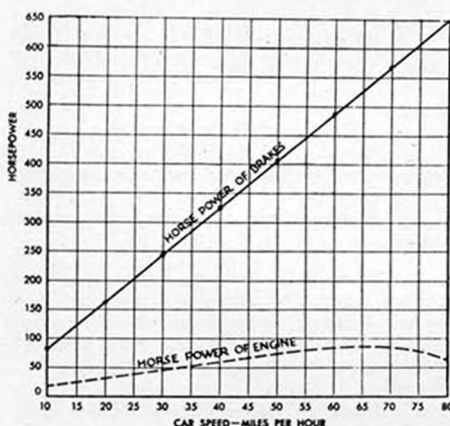


Fig. 138 - Comparison of horsepower developed by engine and horsepower absorbed by brakes on a passenger car.



Fig. 141 - Woven molded lining.

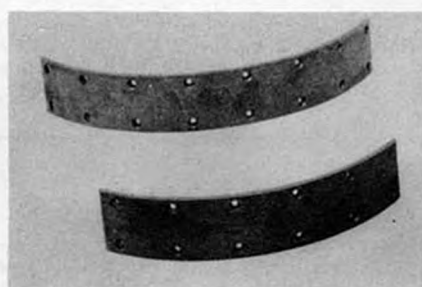


Fig. 142 - Full molded lining.

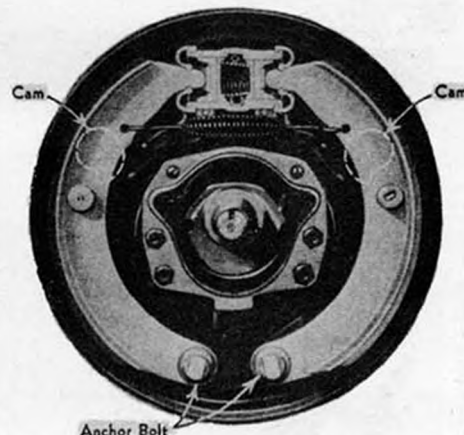


Fig. 145 - Lockheed hydraulic brake.

2. Lockheed Hi-Tork Brake.

This brake has been designed to overcome the unequal wearing conditions of the Lockheed Hydraulic brake, and to provide a more powerful stop with longer lining life.

Instead of having one serving (self-energizing) shoe when coming to a forward stop, the Hi-Tork has two serving shoes; and when making a reverse stop one of these shoes acts as a serv-

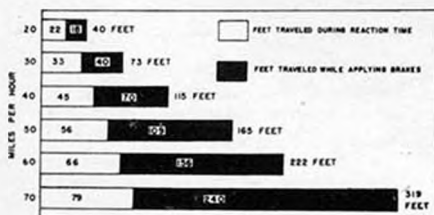


Fig. 139 - Distance required to stop a vehicle with brakes in good condition.

mental wheel brake assemblies. The most important are: Lockheed Hydraulic, Lockheed Hi-Tork, Bendix Mechanical and Hydraulic, Huck Hydraulic, Electric, and Heavy Duty Mechanical.

1. Lockheed Hydraulic. (See Figure 145.)

This is one of the oldest and most popular types of brake. The operation is very simple. Both shoes are mounted on eccentric anchors at the bottom of the backing plate. The toe ends of the brake shoes are held in contact with the wheel cylinder pistons by the brake shoe return springs. When the brakes are applied, the wheel cylinder pistons are pushed outward and force the brake shoes into the drum. The forward shoe will be tightly pressed into the drum by the rotation of the drum. The rear shoe will tend to be pushed away from the drum by the rotation of the drum. This is why the forward, or serving, shoe is made

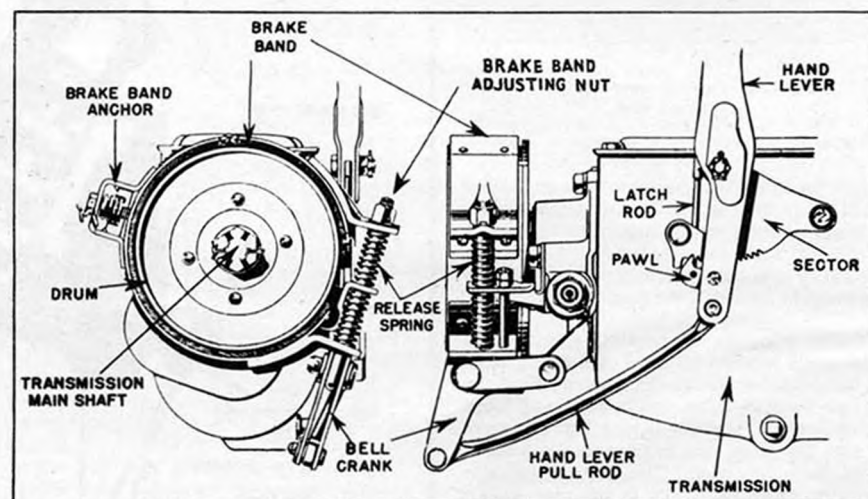


Fig. 143 - Hand braking system.

longer than the reverse shoe, and it also explains why the forward shoe wears faster than the reverse shoe.

ing shoe. See Figure 146.

When the vehicle is moving forward, and

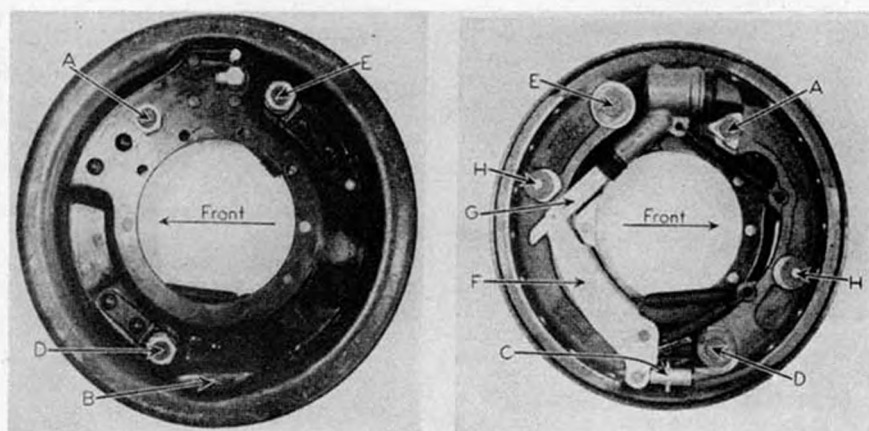


Fig. 146 - Left: Rear view of rear brake. Right: Rear brake.

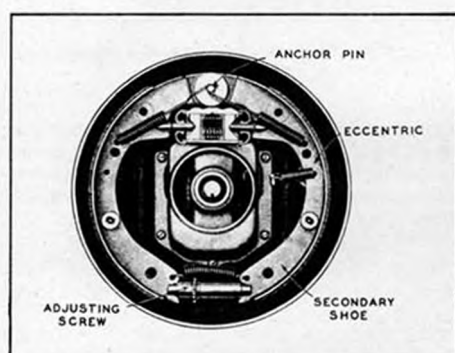


Fig. 147 - Bendix hydraulic brake.

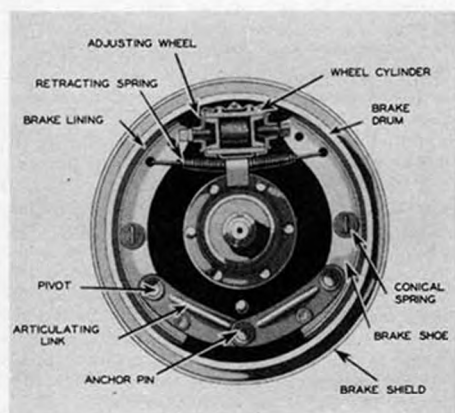


Fig. 148 - Articulating link wheel brake.

the brakes are applied, the forward shoe is pushed into the drum. When this shoe makes contact with the drum, it is carried around in the direction of rotation, and transmits a force to the secondary shoe through the floating star adjustment "C". This action, plus the force exerted from the wheel cylinder through levers "G" and "F", forces the secondary shoe into the drum, and the entire turning movement imparted to both the primary and the secondary shoe is supported on the eccentric anchor "E". This gives a full serving brake when making a forward stop. When making a reverse stop the forward shoe is pushed into the drum by the wheel cylinder action through levers "G" and "F". As the bottom end of the forward shoe contacts the drum, it is served around with the drum and is stopped by the reverse anchor "A". The rear shoe is also pushed into the drum through levers "G" and "F", but the rotation of the drum is such as to de-energize it; so we only have one serving shoe when making a reverse stop.

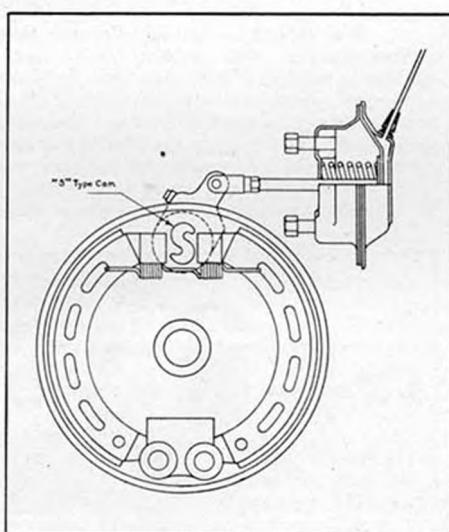


Fig. 149 - Westinghouse air brake.

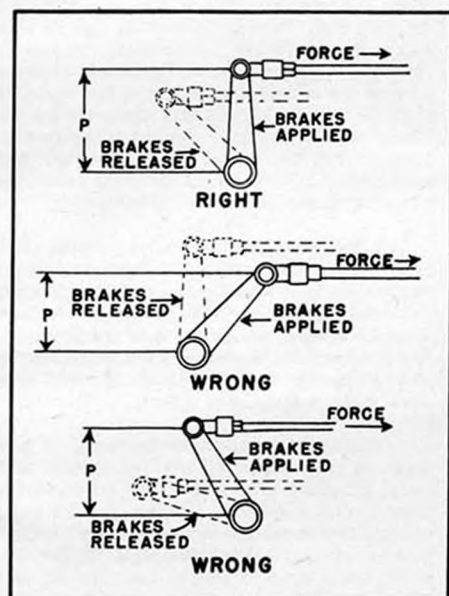


Fig. 150 - Proper lever adjustment.

3. Bendix Mechanical and Hydraulic.

This brake is known as the Bendix two shoe duo-servo single anchor brake. By duo-

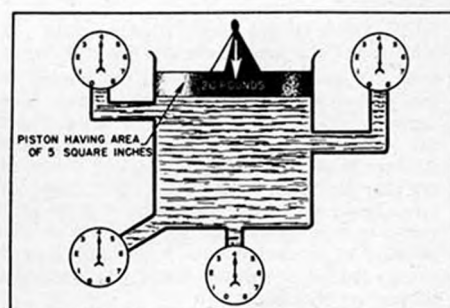


Fig. 151 - Force upon a confined liquid is equally distributed.

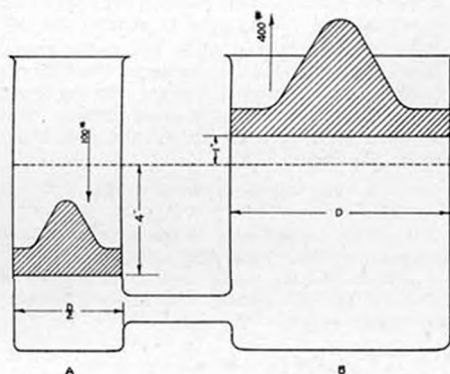


Fig. 152 - Mechanical advantage of the hydraulic brake system.

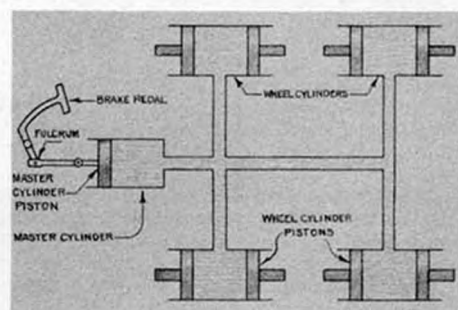


Fig. 153 - Diagram of a hydraulic brake system.

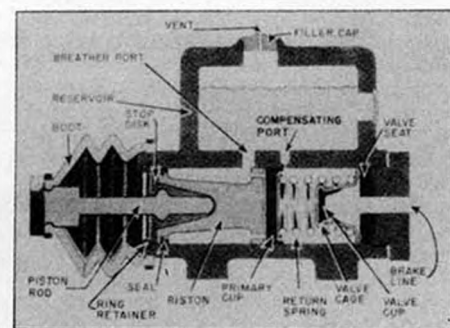


Fig. 154 - Sectional view of a master hydraulic brake cylinder.

servo is meant that regardless of the direction of movement when the brakes are applied, both shoes are served into the brake drums. This brake can be operated by mechanical means or by a hydraulic system. The hand brake is usually connected to the same brake shoes by a mechanical hook-up, and provides an excellent emergency

brake.

The principle of operation is simple. The initial braking action delivered to this brake comes from the wheel cylinder. When the brakes are applied the pistons in the wheel cylinder move outward, forcing the shoes into the drum, Figure 147. Since the shoe assemblies are coupled together at the bottom by an adjusting screw, and are only anchored in one place, both shoes will turn around with the drum until one of the shoes comes to rest against the anchor and is stopped. Because of its design, this brake will give an equally good stop, whether the vehicle is traveling forward or backward.

4. Huck Hydraulic.

This brake is similar in action to the Bendix Hydraulic. It is a single anchor duo-servo brake. When the brakes are applied, one shoe serves the other into the drum. In the Huck brake an articulating link is used to connect the two shoes together instead of an adjustable screw. This articulating link is so designed that it firmly holds the brake lining in contact with the drum, thus giving a good lining to drum contact. This provides good stopping ability and good lining wear. See Figure 148.

5. The Warner Electric Brake.

This fundamental brake assembly is a one piece internal expanding brake band. It has no adjustments for lining wear. Its method of actuation will be covered under types of brakes, Electric.

6. Heavy Duty Mechanical Brake.

This is usually found on the heavy pieces of equipment, and is almost always used with the Westinghouse Air Brake. See Figure 149. The principle of this brake is very similar to the Lockheed hydraulic brake, but is operated by a cam instead of a wheel cylinder.

TYPES OF BRAKES

The common meaning for "Type of Brake" is its method of actuation, such as: Mechanical, Hydraulic, Vacuum, Air, and Electric.

Throughout this discussion, keep in mind that all brakes are released by the action of brake shoe return springs located at the wheel assemblies, as well as throughout the various units of the actuating system.

1. MECHANICAL BRAKES. - By this term we mean that the brakes are operated by certain combinations of levers, push-pull rods, links, bell-cranks, and cables. Today the hand brake is the most common user of the mechanical method.

The one really important factor to keep in mind when adjusting mechanical brakes is: in order to deliver maximum braking power it is necessary to have the linkage adjusted so that all the linkage will form right angles when the brakes are in the applied position. See Figure 150.

2. HYDRAULIC BRAKES. - This term means that fluid is used to transmit the force applied at the brake pedal in the cab to the brake shoes located at the wheels. Since fluid movement in a closed chamber is involved, this system becomes known as the hydraulic system.

One fundamental of hydraulics is: Fluid cannot be compressed. Another is: A force, when exerted at any point upon a confined liquid, will be delivered equally throughout the liquid in all directions. See Figure 151.

In Figure 152 we see a mechanical advantage in a hydraulic system. By applying 100 pounds of pressure at surface "A" we are able to overcome 400 pounds of resistance at "B". This

is true because surface "B" is four times larger than surface "A", and pressure is transmitted equally in all directions. It is also notable that, while we have a four to one mechanical advantage, it is necessary to move piston "A" four inches in order to move piston "B" one inch. What we gain in power we lose in motion.

Figure 153 symbolizes the hydraulic system on an average four-wheel vehicle. From the drawing it is easy to see that a small amount of wear on the brake lining will cause a considerable loss of pedal.

All hydraulic brake systems work in the same way. The pressure applied on the brake lever, which pivots about the fulcrum, is transmitted with a mechanical advantage to the master cylinder. The master cylinder is a pump, and forces the fluid through seamless tubing to the wheel cylinders. Fluid under pressure in the wheel cylinders causes the wheel cylinder pistons to move outward, expanding the brake shoes and forcing them into the drums.

The heart of the hydraulic system is the master cylinder. One common type of master cylinder is shown in Figure 154. When the brakes are applied, the piston is moved forward by the brake pedal action, closing off the compensating port and forcing the brake fluid out to the wheel cylinders. When one movement of the brake pedal is not sufficient, and the brakes have to be pumped, the following takes place. The brakes are released,

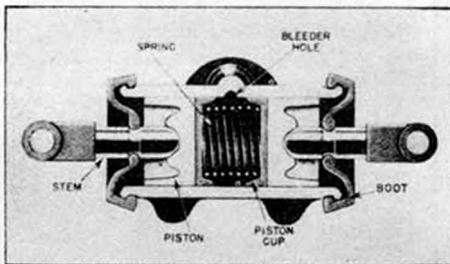


Fig. 155 - Sectional view of a wheel cylinder.

and the master cylinder return spring drives the piston and primary cup back, causing a suction on the right side. This sucks fluid through the holes in the piston and over the primary cup into the pressure chamber. When the piston is driven forward the second time, it forces this additional fluid through the system and stops the vehicle. When the pedal has to be pumped it is a good indication that the brakes need adjusting. It is possible that the free play of the brake pedal needs adjusting; it should be about 1/2 inch.

This free movement is important. If no free movement is provided, the primary cup will not be allowed to return far enough to uncover the compensating port when the brakes are released. This will prevent the excess fluid from returning to the reservoir chamber and will cause the fluid to be trapped in the brake lines and wheel cylinders, causing the brakes to drag.

If the brake pedal continually goes to the floor, and the brakes fail to hold, or if the brake pedal gradually goes to the floor when constant pressure is applied to it; then the trouble is either a leak in the system or the master cylinder is by-passing. If the difficulty is caused by a leak, it will be noticeable by fluid running out of the place where it is leaking. If no fluid leakage is noticeable, it will be necessary to remove the master cylinder and overhaul it, or replace it with a good one. Overhauling the master cylinder should not be attempted unless the proper gauges and honing equipment are available.

The other important parts of the hydraulic

system are the wheel cylinders. The wheel cylinders are of two main types: straight and stepped. See Figures 155 and 156.

The principle of the operation of the wheel cylinder is very simple. Fluid enters the cylinder at the center, and as the pressure increases, it moves the cups and pistons outward. As the piston moves outward, the shoes are expanded into the drum, and the vehicle is braked. The cups are so shaped that the pressure seals them

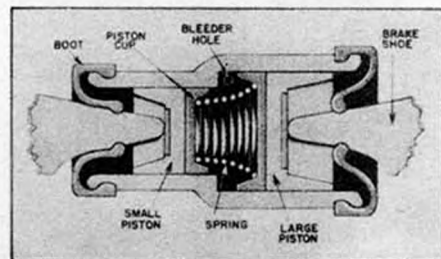


Fig. 156 - Sectional view of a stepped wheel cylinder.

against the sides of the cylinder, and thus prevents them from leaking. The wheel cylinder spring holds the cups and pistons snugly to the brake shoes whenever the brakes are in a released position. See Figures 155 and 156.

Some hints on the hydraulic system are as follows. Never use anything except genuine brake fluid in the system. The use of mineral oil in the system will result in much unnecessary trouble. When hand brakes are connected to the same fundamental brake assembly as the foot brake, never apply the hand brake without first expanding the brake shoes with the foot brake. Unless this is done, air will get into the system. Air in the system will cause a spongy brake pedal. This can be corrected by bleeding the brakes. If bleeding the brakes fails to correct the trouble, then the spongy pedal may be caused by improper brake adjustment or weak drums. If brake fluid gets on the brake lining it will cause the affected wheel or wheels to grab. The only remedy for this is a reline. Don't put one type of lining on one side of the axle and another type of lining on the other side; this will cause unequal braking. When in doubt, reline both sides. Some other troubles which may cause the vehicle to pull when the brakes are applied are: grease on lining; loose wheel bearings; improper brake adjustment; clogged flexible hose; pinched or clogged seamless tubing; and bad wheel alignment. Don't forget to fill the reservoir in the master cylinder before starting to bleed the brakes. Be sure to keep it full during the bleeding process.

3. VACUUM BRAKES. - When we say that a truck is equipped with vacuum brakes we mean that in addition to the complete braking system on that vehicle we have added a vacuum unit and the necessary valves and linkage to operate it. The addition of this equipment will make the brake application easier for the driver, and will give a better stop, because the vacuum unit makes it possible to deliver more power to the fundamental braking assembly than the driver could deliver without the vacuum booster.

In Figure 157 we can see that even if the booster were removed we would still have brakes. Vacuum brakes are always connected so that a failure of the unit will not leave the vehicle without brakes.

The principle of operation is this: a vacuum is created in the intake manifold of the engine. This vacuum, like all other vacuums, means that the air pressure has been reduced below atmospheric pressure, which is approximately 15 pounds per square inch. If atmospheric

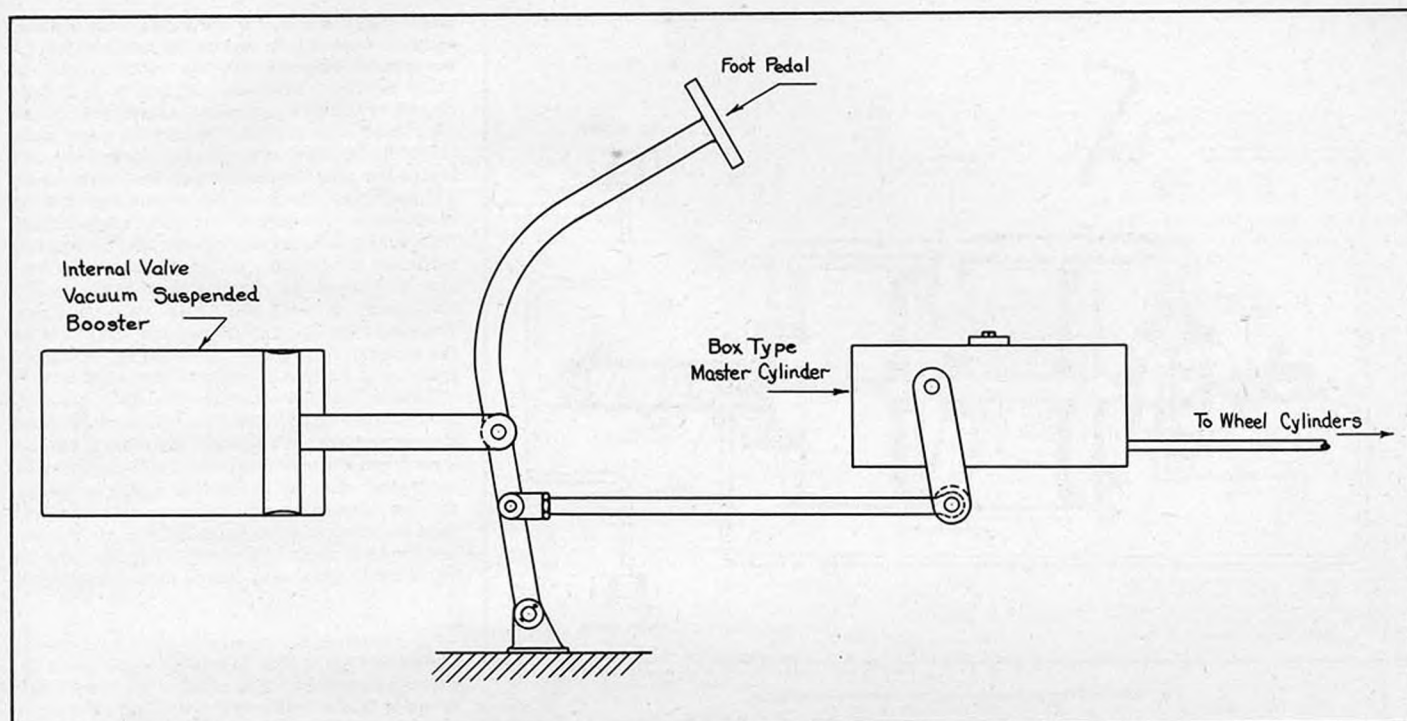


Fig. 157

air, at 15 pounds per square inch, is present on one side of a piston, as in "B" of Figure 158, and low pressure air, or a vacuum, is present on the other side of the piston, as at "A", then there will be an unbalanced force, and the piston "P" will try to move toward the left. If valves are designed to control these various pressures, to the different sides of a cylinder, and if the valves and cylinders are installed in the braking system in such a way that when we push on the brake pedal we open the valve, which in turn moves the piston in the cylinder and causes the brakes to be applied, then we have a vacuum brake system.

have a vacuum in chambers "A" and "B" when the brakes are not applied. When the brakes are applied we must create an unbalanced condition by having atmospheric pressure on one side and a vacuum on the other. In the case of the air suspended system, we must suck the air out of one side, and in the case of the vacuum suspended system, we must open one side to atmospheric pressure. It is easy enough to see that the vacuum suspended system will be much quicker than the air suspended system. This is true because it is

anywhere. This is a decided advantage, because it makes it possible to mount the assembly in an accessible place.

4. ELECTRIC BRAKE. - This brake is quite simple in action. See Figure 161. The brake band is a one-piece affair, and is mounted on the backing plate. Coupled to the brake band is an electric magnet. That is, it becomes a magnet when electric current is flowing through its windings. As the brake pedal is depressed it operates a rheostat, which regulates the amount of current permitted to flow, and in turn this regulates the strength of the electro-magnet. Fastened to the drum by means of flat springs, and revolving with it is the armature. The armature is made of steel and is progressively attracted to the magnet, depending upon the strength of the magnet.

When the armature is attracted to the electro-magnet, it tries to turn the magnet around with it. The turning motion, imparted to the magnet, is transmitted to the brake band and causes it to expand into the drum. From here a combination of pressure and self-energizing force causes the brakes to be applied.

The only adjustment that can be made on this brake is the adjusting of the armature with respect to the magnet. This is accomplished with shims.

5. AIR BRAKE. - Do not confuse the air brake, Figure 162, with the vacuum brake. The vacuum brake operates with pressure which is less than that of the atmosphere; the air brake operates with pressure which is considerably greater than that of the atmosphere.

The principle of operation of this brake is somewhat comparable to the hydraulic brake, but instead of using fluid it uses compressed air. The heart of the air brake system is the compressor, Figure 163. This is usually mounted on the side of the engine, and is either driven through a gear train or by a belt drive. The air is compressed in the compressor, passes out through the discharge valves, and is lead through copper tubing to a storage tank. From the storage tank, known as a reservoir, it is piped to the governor, the brake valve, and the relay valve. The governor, Figure 164, is usually set

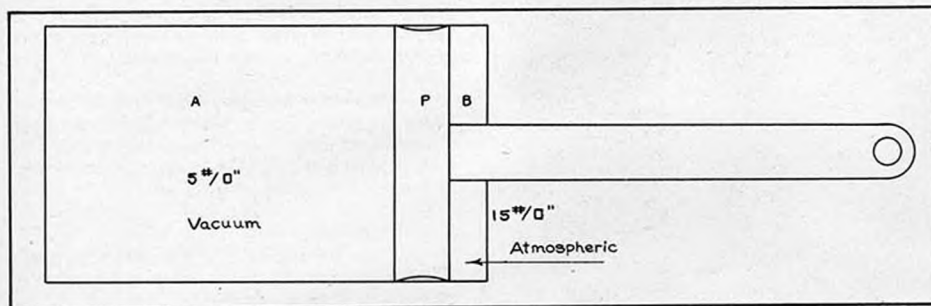


Fig. 158

Vacuum brake systems are of two main types: air suspended and vacuum suspended. The air suspended or atmospheric suspended system exists when we have atmospheric pressure in chambers "A" and "B" when the brakes are not applied. Vacuum suspension exists when we

much easier to destroy a vacuum than to create one.

The type of system in most common use on army vehicles is the vacuum suspended system, with the valve built into the power unit. See Figure 159.

Provisions are made for adjusting the time of opening of the valve at the point where the power unit is connected to the pedal linkage.

These units may be disassembled and overhauled if the proper replacement parts are available.

The latest design of B. K. Booster is the Hydrovac, Figure 160. This unit has been specially designed to operate with a hydraulic brake system. In reality it consists of a hydraulically operated valve, a power unit, and an additional master cylinder. The three units are combined into one assembly, and since the valve is operated by hydraulic fluid the assembly may be installed

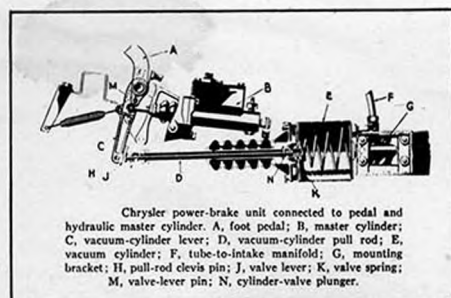


Fig. 159 - Sectional view of internal brake valve incorporated within the power cylinder.

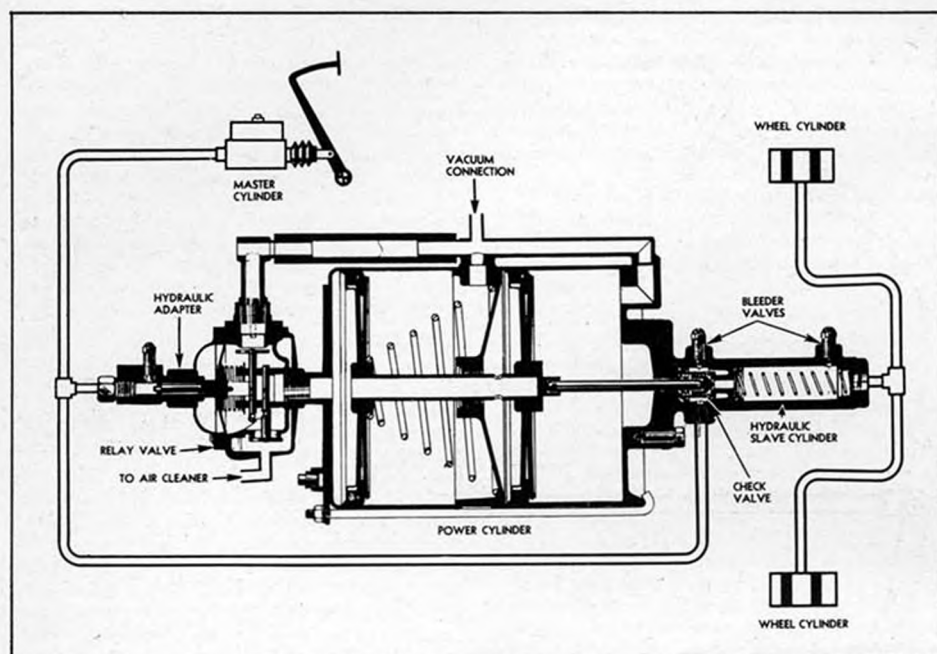


Fig. 160 - Diagrammatic view of Hydrovac assembly.

intake valve stems. The spring on the exhaust valve is weaker than that on the intake valve; so, the exhaust valve moves down and closes the exhaust passage. When the exhaust valve is fully closed, a further downward movement causes the rocker to pivot on the exhaust valve and compress the stronger spring on the intake valve, allowing the air to enter through the intake valve and pass out to the front brake chambers and the relay valve. The air will continue to flow through the valve until the pressure below the diaphragm is sufficient to overcome the graduating spring tension and cause the diaphragm to move upward sufficiently to cause the intake valve to close. The diaphragm does not move sufficiently to allow the exhaust valve to open. This is the lapped position. A further depression of the brake valve will cause the intake valve to open again, and very soon another lapped condition will occur at some higher pressure. When the brake pedal in the cab is released, the pressure below the diaphragm will be greater than the graduating spring pressure, and the diaphragm will move up sufficiently to open the exhaust valve and permit the air that was previously trapped in the brake chambers and the top of the relay valve to escape to the atmosphere.

Mention has already been made of the relay valve, Figure 166. The relay valve is not absolutely necessary. It is added to the system only to speed up the brake application and release.

By having a direct supply line from the reservoir to the relay valve, much tubing is eliminated in reaching the rear brakes. This means fewer curves, fewer joints, and less friction: result, quick acting brakes.

The relay valve is merely a balanced valve. When air pressure from the brake valve enters above the diaphragm, it pushes the diaphragm down. The downward movement of the diaphragm opens the supply valve and permits air to pass through the valve to the brake chambers. This speeds up the application. When the brakes are released, the high pressure air which is in the brake chambers is also below the diaphragm in the relay valve. This lifts the diaphragm up and provides a short passage for exhaust.

The brake chamber, Figure 167, is that part of the air brake system which delivers the push. It must be adjusted frequently, see Figure 168, and a new diaphragm should be installed at least once each year.

The Westinghouse Automotive Air Brake is the most powerful brake in use today, and will be found on the heavier units.

It is an excellent brake, and if the tanks are drained daily, and the other suggestions mentioned with the various illustrations are carried out, good results with this brake will be obtained.

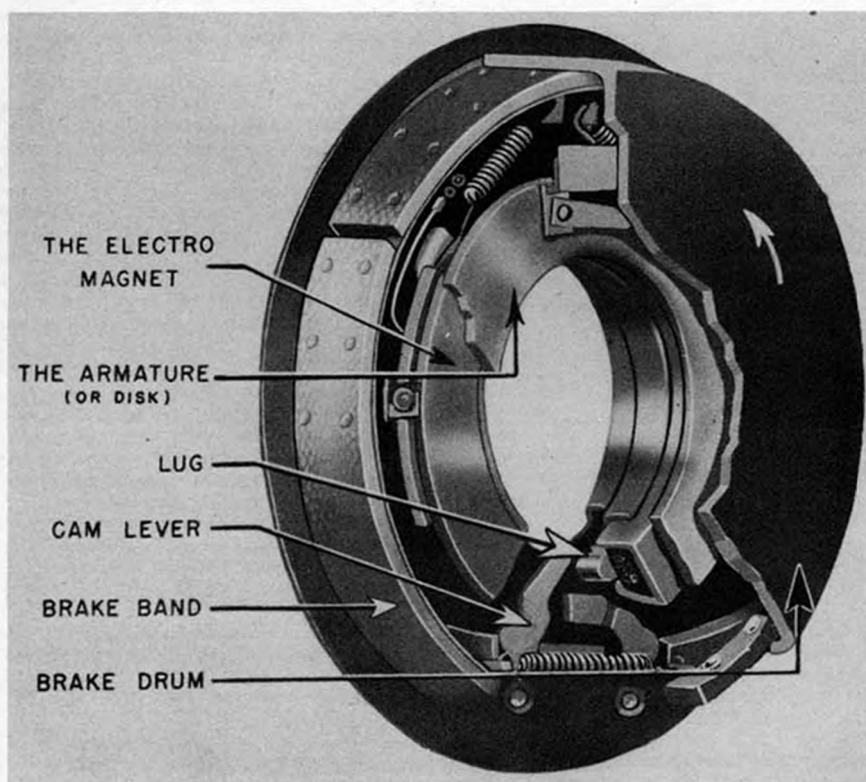


Fig. 161 - Sectional view of electric brake.

so that it remains closed until the air pressure reaches 105 pounds. When the pressure reaches this point, the governor opens and allows the air to pass through it to the compressor head, where it enters under an unloader diaphragm, which lifts up and opens the unloader valves. When these unloader valves are open the compressor will no longer pump air, but will merely push it back and forth from one cylinder to the other. This action continues until the pressure at the governor drops to approximately 85 pounds, at which time the governor closes and the pump begins to build the pressure in the reservoir back up to 105 pounds. This cycle is repeated over and over again.

Also, from the reservoir the air is led through copper tubing to the brake valve, Figure 165. The brake valve is mechanically connected to the brake pedal and is operated by means of levers and a coil spring. In the top half of the brake valve we find the graduating spring, and in the lower half the rocker, the intake valve, and the exhaust valve. The two halves are separated by an air-tight diaphragm. Mechanical pressure from the cab is used to compress the graduating spring. As the graduating spring is compressed, it causes the diaphragm to move downward, exerting a pressure on the center of the rocker arm, thus forcing it down. As the rocker arm moves down it contacts the top of the exhaust and

The following texts and manuals were used in the preparation of this material:
Elementary Automotive Instruction.
Field Artillery Book 120.
TM 10-585, War Department.

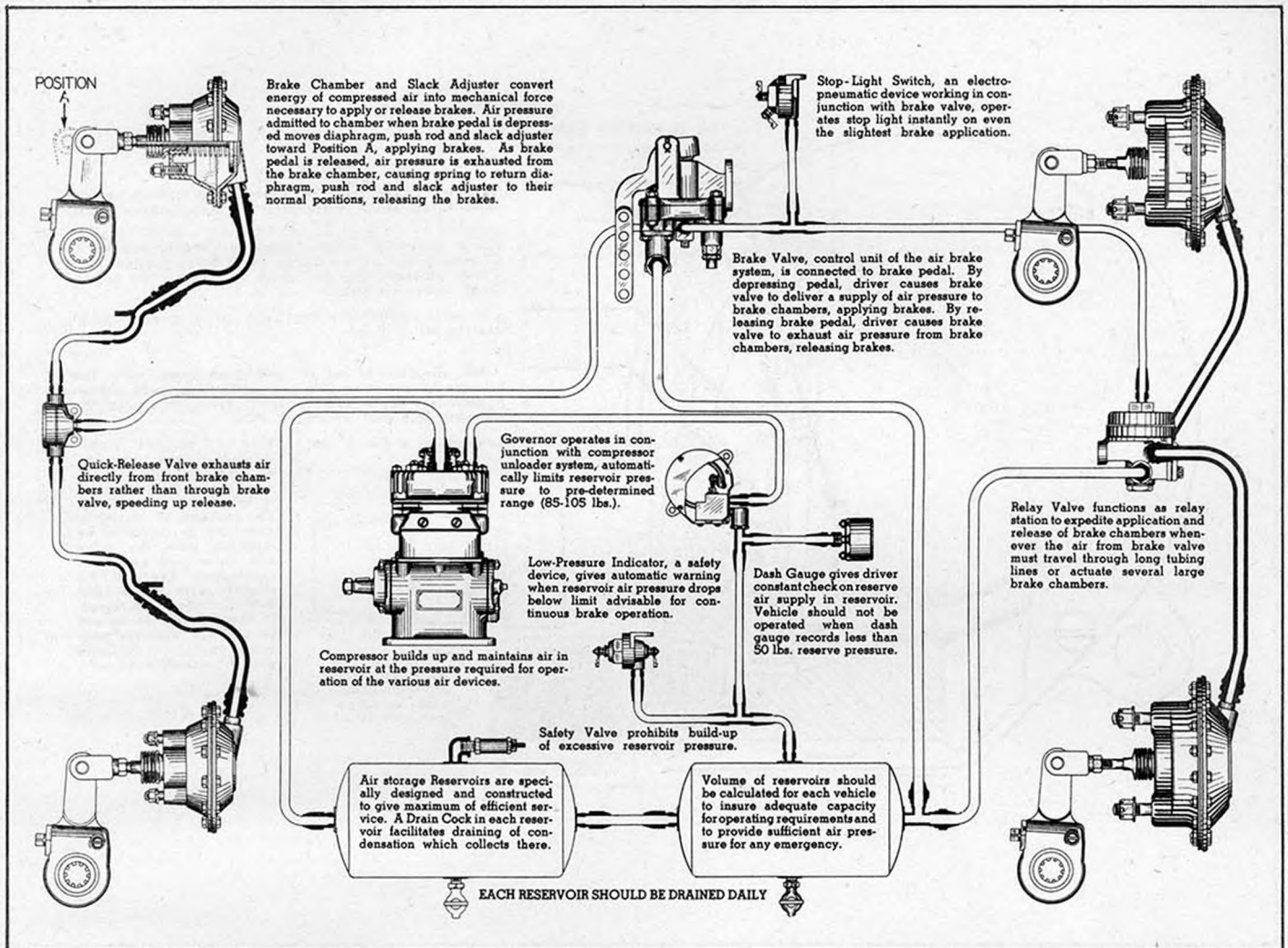


Fig. 162 - Piping diagram showing approximate location and method of connecting Bendix-Westinghouse automotive air brake units for truck or bus operation.

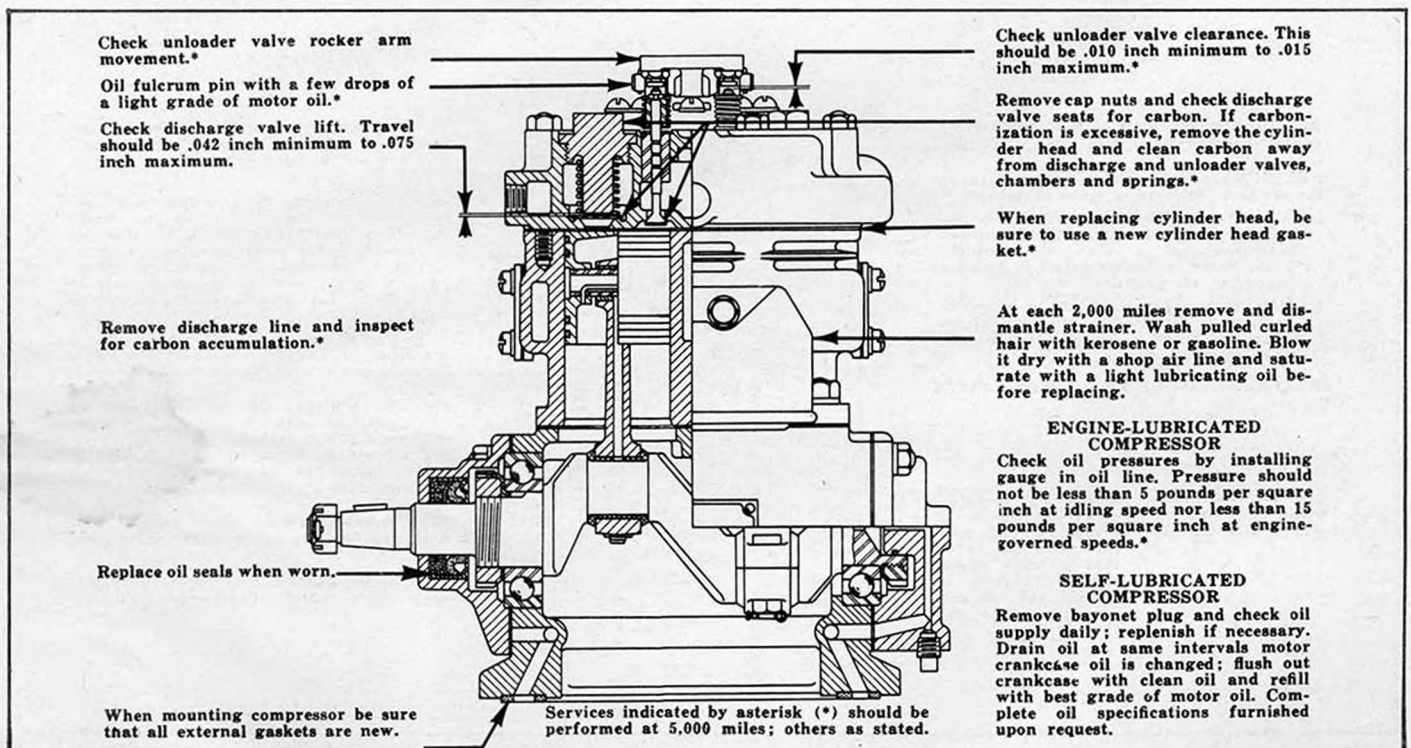


Fig. 163 - Compressor.

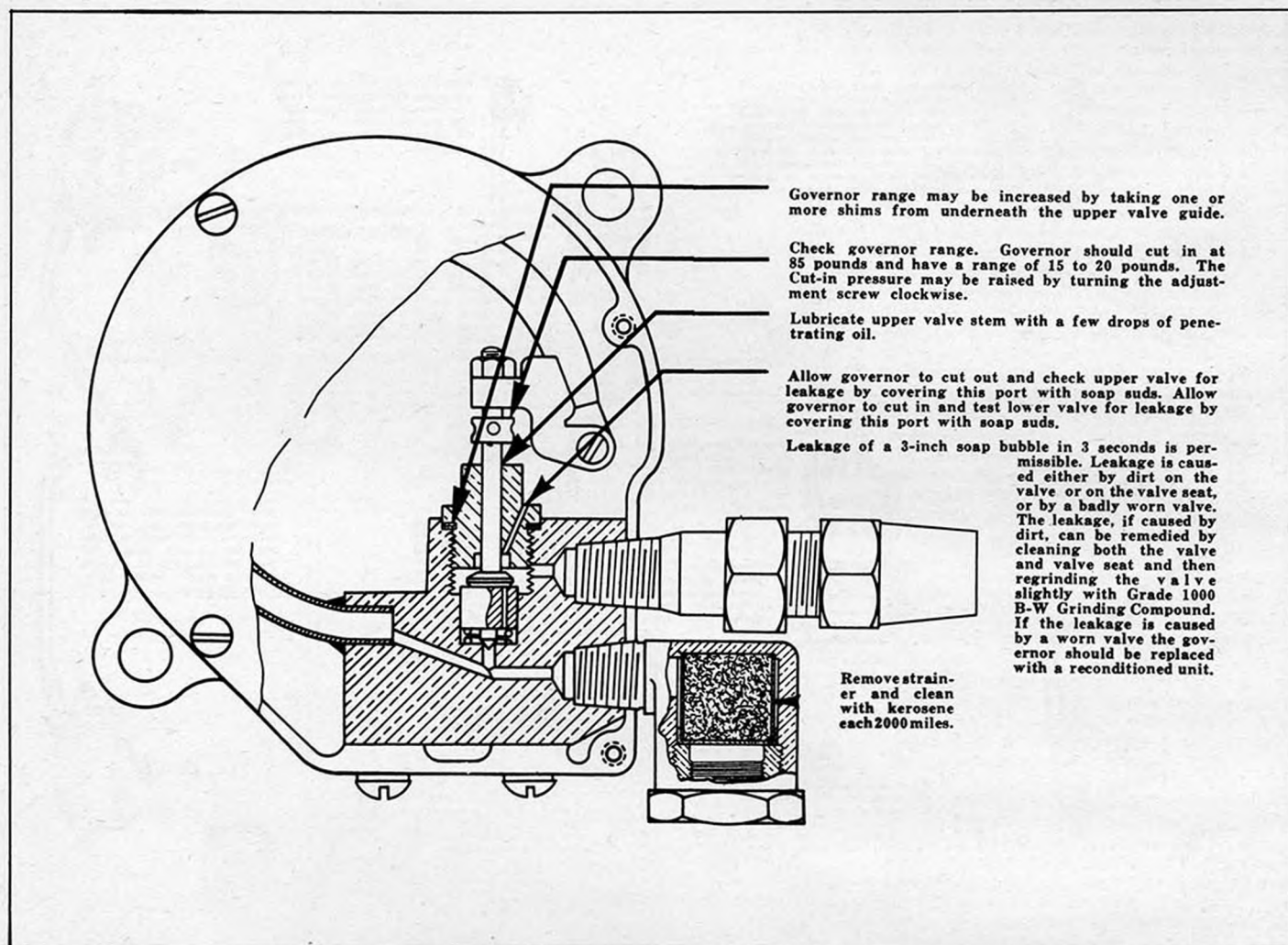


Fig. 164 - The governor.

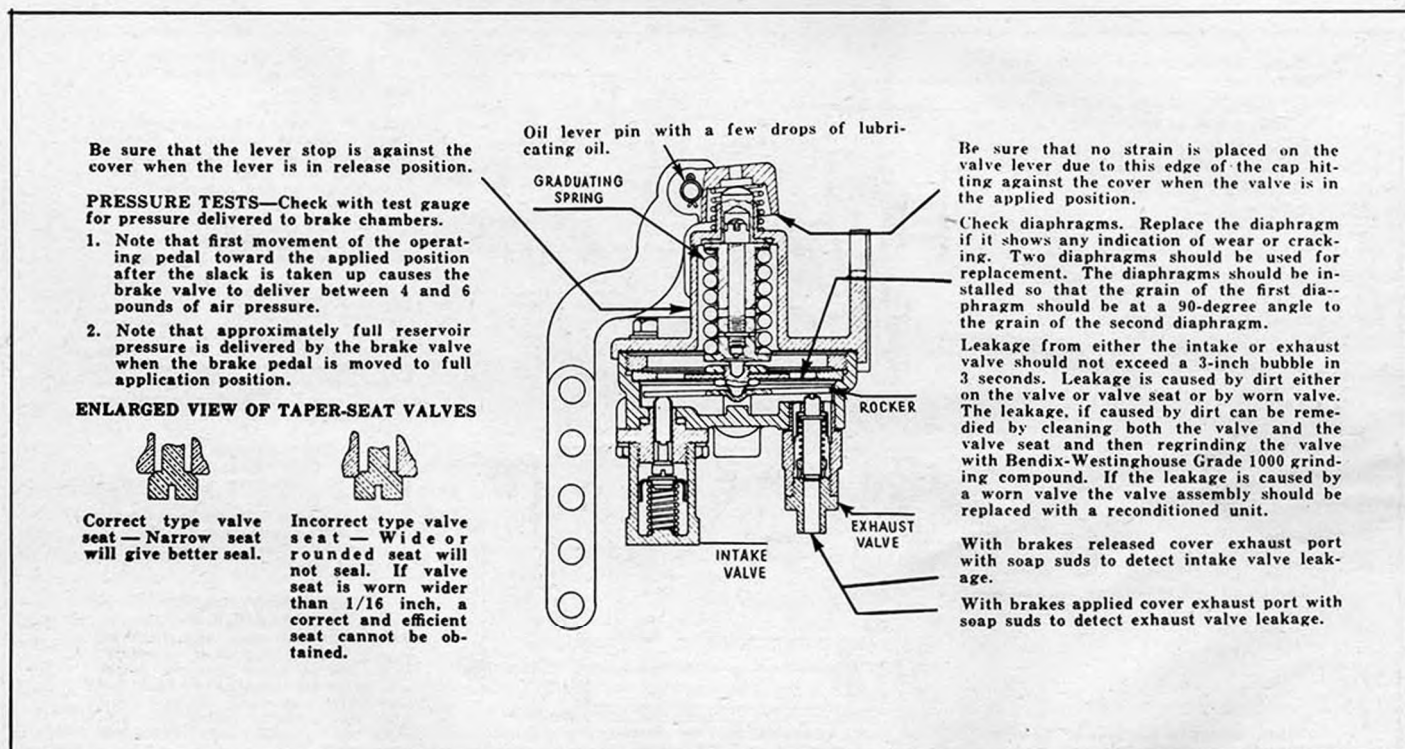


Fig. 165 - B 4 A Brake Valve.

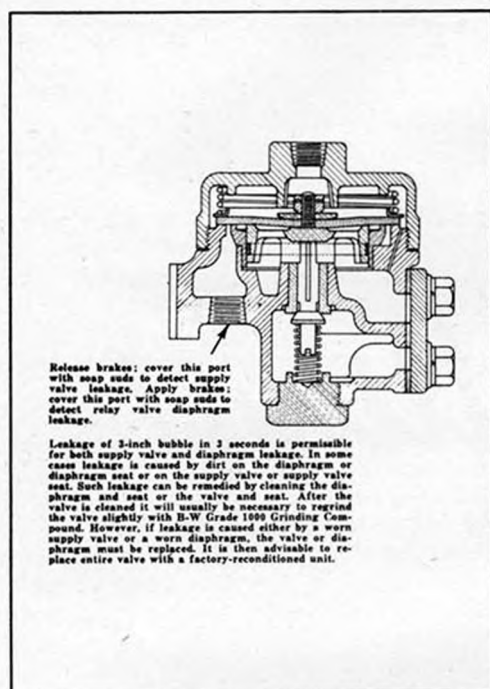


Fig. 166 - Relay.

BRAKE CHAMBER DATA (Dimensions given in inches)				
Type	Diam.	Maximum Stroke	Proper Maximum stroke when brakes are adjusted	Maximum stroke at which brakes should be adjusted
A, AA*	6 $\frac{3}{8}$	1 $\frac{3}{4}$	$\frac{3}{8}$	1 $\frac{3}{8}$
B	9 $\frac{3}{8}$	2 $\frac{1}{4}$	$\frac{3}{4}$	1 $\frac{3}{4}$
C, CC*	8 $\frac{1}{8}$	2 $\frac{1}{4}$	$\frac{3}{4}$	1 $\frac{3}{4}$
D, DD*	5 $\frac{1}{4}$	1 $\frac{3}{4}$	$\frac{1}{2}$	1 $\frac{1}{4}$
E, EE*	6	1 $\frac{3}{4}$	$\frac{3}{8}$	1 $\frac{3}{8}$
F	11	3	$\frac{3}{4}$	2 $\frac{1}{4}$
G	10	2 $\frac{1}{2}$	$\frac{3}{4}$	1 $\frac{3}{4}$

* The data for the double-acting AA, CC, DD and EE Brake Chambers are for one side only.

Fig. 168

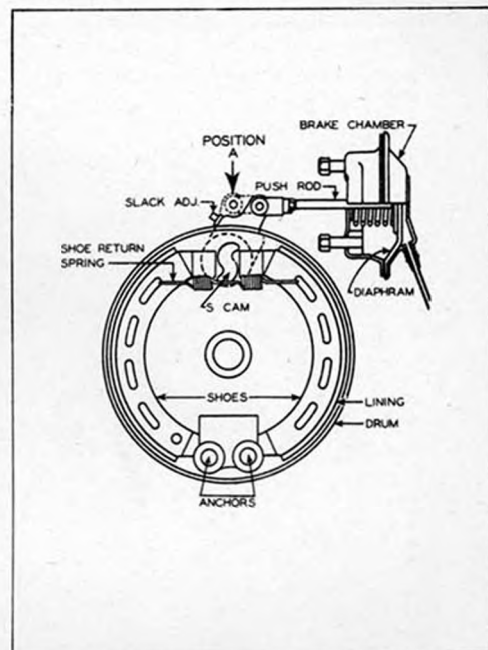


Fig. 167 - Brake chamber of the air brake system.



Keep 'em Rolling!



MACHINE SHOP (Continued from page 474)

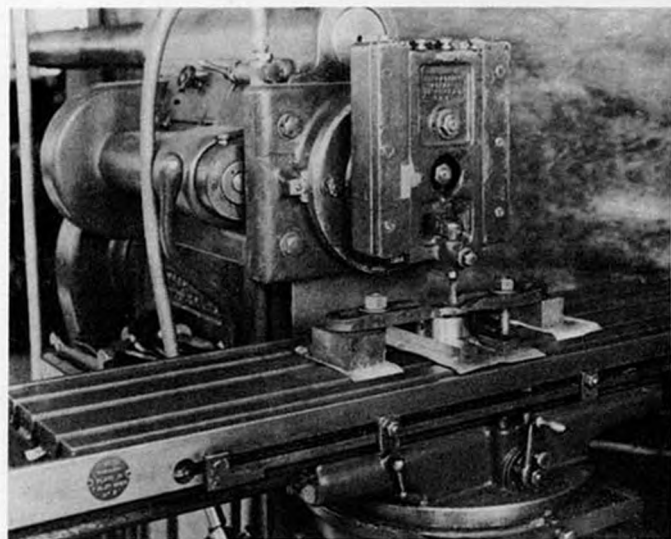
1. Purpose.

A machine for producing flat, angular, spiral fluted, circular or grooved shapes in metals.

2. Description.

The milling machine is to all intents and purposes a combination lathe and shaper, with a few additional features thrown in. Almost any job that can be done in these machines may be done in the miller, though many of them, for reasons of speed and economy, are best suited to the lathe or shaper.

The frame, column and base are usually cast in one piece. The column carries the knee on which is mounted the table. The knee may be fed vertically in either direction, and the table may be fed at any angle within the limits of the machine in a horizontal plane. On the table may be mounted a vise or a dividing or index head. The index head may be used by hand to turn the work a certain desired portion of a circle, or it may be connected by gears to the lead screw of the table, so as to revolve the work at a desired rate, as in a lathe. At the top of the frame over-



hanging the table is the overarm carrying the yoke and outer bearing, the purpose of which is to support the outer end of the arbor. The arbor carries the cutter and fits into a tapered hole in the spindle. The proper spindle speed may be selected by shifting the gears in the gear box on the side of the frame. Cutters may be obtained in any size and shape desired, and special cutters for unusual shapes are easily made by a skilled machinist.

3. Operations.

Possible operations on a universal milling machine are so numerous as to prohibit the mentioning of all but the most basic. However, it might be said that production of any practical shape in metals is limited only by the skill of the operator and the available shapes of cutters.

a. Plain Milling. - The cutting of the work so as to produce plane surfaces. This may be done by feeding either horizontally or vertically against the cutter.

b. Grooving, Keyway Cutting and Form Milling. - The cutting of the work by feeding it against a cutter having the reverse of the desired shape.

c. Indexing. - The cutting of several faces on the work by revolving it a desired amount after each cut. An example of this is the cutting of a square or hexagon head on a bolt.

d. Spiral Milling. - The cutting of the work so as to produce a spiral surface such as in a twist drill. This is done by gearing the index head to the lead screw of the

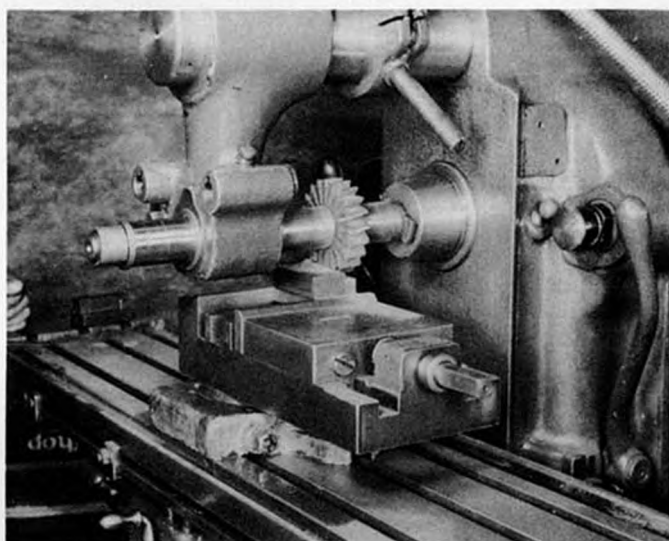


table so that the work will revolve under the cutter as it is fed along.

e. Slotting. - By use of an end mill, (a special type of cutter), slots, grooves and keyways may be cut. This method is sometimes more desirable than with a keyway cutter.

4. Cutting.

Cutting is accomplished by feeding the work at the desired rate under a revolving cutter. For certain jobs the work is also revolved.

The drawings on the following page show some of the problems our students are required to complete on the milling machine.

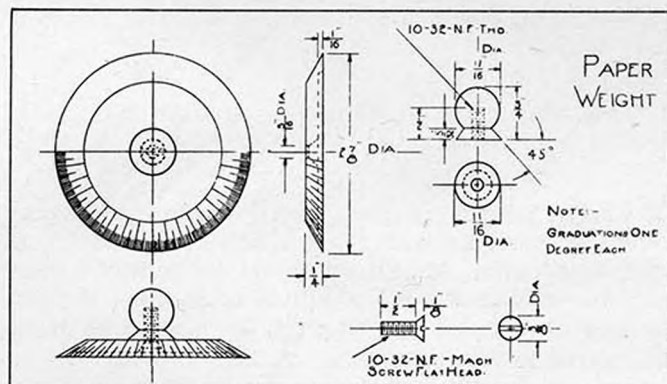
These particular problems, we consider, are necessary, and cover all the major operations which our students would encounter as potential Ordnance Machinists.

1. Paper weight.
 - a. Use of the Index Head
2. "V" Block.
 - a. Plain milling
 - b. Angular milling
 - c. Form milling
3. Cast Iron step block
 - a. Plain milling
 - b. Side milling
4. "T" Bolts
 - a. Side milling
 - b. Indexing to square head of "T" Bolt.
5. Bench Anvil
 - a. Plain milling
 - b. Gang milling
 - c. Angular milling
 - d. End milling
 - e. Elaborate set up

6. Twist drill
 - a. Spiral milling
 - b. End milling
 - c. Indexing
7. Hand tap
 - a. Indexing
 - b. Form milling

This covers the Milling Machine sufficiently, and although our students do not have an excess of practical experience, they do have the theory and a good basis with which they can continue their work.

(Continued next month)





Conducted by: W. G. Sylvester, Capt., Ord. Dept.

⊗ HARD SURFACING METALS ⊗

"Hard surfacing" or "hard facing" refers to the process of applying extremely hard alloys to the surface of a softer metal in order to increase its resistance to wear, abrasion, or cavitation, corrosion or impact. In most cases, the hard facing alloys can be applied to the point, surface or edge of any part by means of either the electric arc or oxyacetylene welding processes. The wearing surface of tools, drills, bits, cutters or other parts, when treated with these special alloys, will outwear the common steels 2 to 25 times, depending on the type of hard facing alloy used and the service to which the part is subjected.

No single hard facing material is satisfactory for all applications. To meet the various requirements for hardness, toughness, shock and wear resistance and other special qualities, many types of hard facing alloys have been developed.

CLASSIFICATION OF HARD SURFACING ALLOYS

These alloys may be generally classified into five groups.

GROUP 1. The alloys in this group consist principally of an iron base and have less than 20 per cent of alloying elements. The alloying elements used are mainly chromium, tungsten, manganese, silicon and carbon. Alloys in this class have a greater wear resistance than any machine steel. Although not as hard, they have greater toughness and shock resistance than other hard facing alloys. They are used to build up badly worn sections before applying a final harder surface with a better grade of hard facing alloy.

GROUP 2. This group consists of iron base alloys having 50 to 80 per cent of iron and 20 per cent or more of alloying elements. These alloying elements are mainly chromium, tungsten, manganese, silicon and carbon; also small percentages of cobalt and nickel are sometimes added. Some of the alloys in this class have the property of "red hardness", this is they remain hard even though operating at a red heat. These alloys are harder than those in Group 1 and are used for the final hard wear-resisting surface after the part is built up with a high strength rod. Broken edges of high carbon or high tensile low alloy steels in the heat treated condition may be repaired by using the transition bead method. This method consists of welding another metal or metals to the base metal before applying the hard-facing material and is

performed in the following steps: 1. Grind, chip or machine the broken or worn surface to clean the break. 2. Deposit a thin layer of stainless steel such as the 25% chromium 20% nickel rod or the 18% chromium 8% nickel rod containing columbium. 3. Build up the section to approximately the original dimensions using a 12-15% manganese steel or high strength rod. 4. Hard surface with one of the Group 2 alloys.

Alloys in this group are not as shock resistant or as tough as the Group 1 alloys; however, they are harder, more abrasive resistant and give longer service where sliding wear is to be overcome.

GROUP 3. This group consists of non-ferrous alloys of cobalt, chromium and tungsten as well as other non-ferrous hard facing metals. Some of these alloys also have the property of "red hardness". They are available in several different grades, all highly resistant to wear, but have a spread in strength and toughness which gives them a wide variety of applications.

GROUP 4. Alloys in this group consist of the so-called carbide materials or diamond substitutes and are the hardest and most wear resistant of all hard facing materials. Some of these alloys contain 90 to 95 per cent tungsten carbide, the remainder being cobalt, nickel, iron or similar metals. These are added to give strength, toughness, heat resistance, and impact strength to the tungsten carbide. Some of these alloys are almost pure tungsten carbide and contain no alloying elements. The materials or alloys in this group are furnished in the form of small castings which are welded onto the wearing surface by means of other metals. The heat of the oxyacetylene flame or electric arc does not melt the carbide materials, however they are readily "wetted" and are thus easily anchored or bonded to other metals or hard facing alloys. The application of these tungsten carbide pieces to wearing surfaces is known as "hard setting". A very highly abrasion and wear-resistant surface having good "red hardness" properties is obtained by setting the tungsten carbide pieces or castings with a hard-facing alloy.

GROUP 5. This group consists of crushed tungsten carbides of various screen sizes. These may be fused to strips of mild or low alloy steel, embedded in a hard facing material or high strength rod, or packed in mild steel tubes of various diameters. All of these types are available in short lengths which may be applied to the wearing surface as a welding rod. Crushed tungsten car-

bides are also available in loose form as granular pieces or powder which are sprinkled onto the wearing surface and melted into it. The materials in this group, although more expensive than the best of hard facing alloys, are used for many applications because of their long life.

APPLICATION OF HARD SURFACING MATERIALS

In general the hard facing alloys or materials can be applied by either the oxyacetylene or the electric arc welding process. Alloys in Group 1 and 2 are fusion welded to the base metal or surface. Care should be taken to avoid puddling or mixing the base metal with the hard facing material as dilution of the hard facing alloy with the base metal will lower the wear resisting properties of the surface coating. Those in Group 3 are usually "sweated" to the surface as in brazing without melting the base metal. None of the base metal penetrates into the hard surface layer to reduce its resistance to abrasion or wear. The materials or alloys in Groups 4 and 5 are not melted but are bonded by or embedded in mild or low alloy steels or hard facing materials, which in turn are welded to the base metal.

Hard facing alloys are applied with an oxyacetylene flame, using rods of suitable design when it is desired to spread the metal over the surface in a thin layer. The electric arc process is used where the surface wear is severe, and the somewhat irregular surface of the metal as deposited is satisfactory.

METALS AND ALLOYS THAT CAN BE HARD-FACED

Hard facing materials and rods can be applied satisfactorily to the following metals and alloys:

1. Low and Medium Carbon Steels. - All the plain carbon steels up to 0.50 per cent carbon can be hard faced by either the oxyacetylene or electric arc process.

2. High Carbon Steels. - The high carbon steels containing above 0.50 per cent carbon can also be hard-faced by either the oxyacetylene or electric arc process. In some cases, however, care should be taken to heat treat the base metal before and after hard facing to remove hardness and brittleness and thus prevent cracking, or the "transition bead" method previously described may be used.

3. Low Alloy Steels. - Hard facing alloys can be applied to these steels in the same manner as described for plain carbon steels. In some cases, depending upon the composition of the base metal, heat treatment is required after hard-facing.

4. High Speed Steels. - The hard-facing of these steels is not generally recommended. This is due to the fact that brittleness and shrinkage cracks develop in the base metal after hard-facing regardless of heat treatment, thus making the hard-faced piece valueless.

5. Manganese Steels (11-14% Mn). - The metallic arc welding process only is recommended for applying hard-faced materials to manganese steels. Care should be taken to avoid overheating.

6. Stainless Steels. - Stainless steels, including the high chromium and chromium-nickel steels can be readily hard-faced by means of either the oxyacetylene or electric arc processes. The physical properties of the

particular type stainless steel should be known in order to avoid brittleness or decreased corrosion resistance after hard-facing. Care should also be taken to avoid warping or cracking due to the higher coefficient of expansion of the stainless steels by uniform heating and slow cooling.

7. Cast Iron. - Gray and alloy cast irons can be hard-faced by means of either the oxyacetylene or electric arc process. Since the melting point of cast iron is lower than that of steel, special precautions should be taken when working on thin edges.

8. Malleable Iron. - Hard facing alloys can be applied to malleable iron; however, the iron underneath the hard-facing layer will be hardened by the heat used in the process. Some of this hardness can be removed by reheating the malleable iron to above 1500°F.

9. Monel Metal. - Monel metal can be easily hard-faced.

10. Brass and Bronze. - Since the melting points of brass, bronze and other alloys are very low, hard-facing cannot be satisfactorily applied to these metals. In some cases, heavy sections preheated to a red heat can be hard-faced by the electric arc process using the Group 3 alloys.

11. Copper and Copper Alloys. - These metals have high heat conductivities and relatively low melting points. They can be hard-faced only under the same conditions which apply to brasses and bronzes.

12. Aluminum and Aluminum Alloys. - These metals cannot be hard-faced.

HARD-FACING TECHNIQUE

Preparedness of base metal for hard-facing.

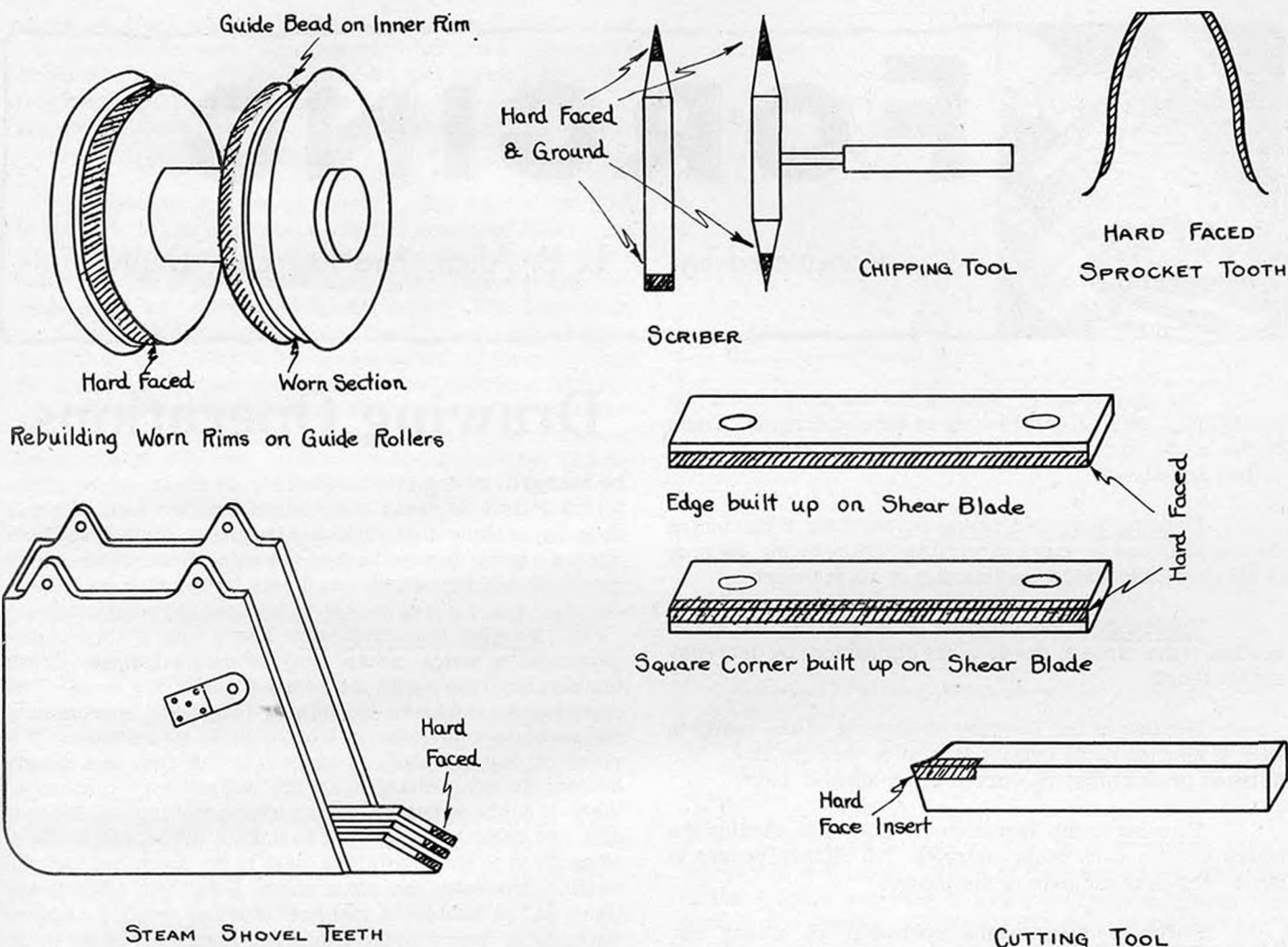
The surface of the metal to be hard-faced must be cleaned of all scale, rust, dirt or other foreign substances by grinding, machining or chipping. If these facilities are not available, the surface may be prepared by filing, wire brushing or sand blasting. This latter method of surface preparation is not very satisfactory as small particles of foreign matter which remain on the surface must be floated out to the surface during the hard surfacing operation. All edges of grooves, corners, or recesses must be well rounded to prevent overheating of the base metal.

Preheating

The same precautions for preheating should be taken in hard-facing as are required for welding the particular base metals. Steels in the heat treated condition should be annealed if possible before the hard-facing layer is applied. After hard-facing, the steels should be heated to their critical temperatures and quenched in oil to restore the original base metal properties. Quenching in water will crack the hard-facing layer. Where it is impossible or undesirable to anneal these heat treated steels before hard-facing, the transition bead method is used as previously described under the Group 2 alloys.

Use of Fluxes

No fluxes are required for applying hard-facing



TYPICAL APPLICATIONS FOR HARD FACING MATERIALS

materials using the oxyacetylene process. However, when depositing the hard-facing material in more than one layer a flux helps to remove any scale and oxides formed on the base metal. This applies particularly to hard-facing cast iron, in which case a cast iron welding flux is satisfactory. The film of flux formed on the molten metal reduces the rate of cooling of the deposited metal, thus permitting gas, oxides, and slag inclusions, which would otherwise be entrapped in the deposited metal, to come to the surface. This results in a hard and solid surface layer.

In the electric arc process, the hard-facing electrodes are provided with a flux coating which serves the same purpose as the flux used in the oxyacetylene process. No additional flux is necessary.

Thickness of Hard-Facing Deposit

In most cases, worn sections are rebuilt with hard-facing deposits ranging from 1/16 in. to 1/4 in. in thickness, depending upon the specific application. Where it is necessary to deposit hard-facing material in thicknesses more than a 1/4 inch, the parts are rebuilt with the Group 1 type of alloys to within 1/16 to 1/4 inch of the finished size. The final hard-facing deposit, consisting of the Group 2 or 3 alloys, is added, allowing some excess to permit grinding to the desired finish dimensions.

When the harder and more brittle Group 4 and 5

type of hard-facing materials are applied, either as a final hard-facing deposit or in a single layer, the shape of the deposit should be carefully controlled. This is important in order that impact or shock loads will be transmitted through the hard facing metal into the tougher base metal. Corners, sharp edges, or built up sections, when not backed up by tough base metal, will chip or break off in service.

Selection of Hard Facing Materials:

Before applying a hard facing material, the welder should determine the conditions under which the particular piece is to operate and the type of wear expected. There may be present any one or more of the following conditions to increase wear; namely, shock and impact, heat, corrosion, sliding, rolling friction, or abrasion.

In rock crushing equipment and similar applications, where resistance to shock and impact are most important and hardness is only secondary, the hard facing alloys of group 1 and 2 are used.

Valves designed for handling gas, oil, acids, high temperature and high pressure steam must resist heat, corrosion, and erosion. The group 3 alloys are used extensively for these applications, as well as for valve seats in internal combustion engines, because of their properties of red-hardness and corrosion resistance.

(Continued on page 558)



FORGING

Conducted by: B. L. B. Allen, 2nd Lt., Ord. Dept.

The operation of shaping or forming metal by hammering, rolling, or pressing is termed forging. Some of the more important forging operations may be described as follows:

Drawing down or drawing out consists of stretching the metal in one or more directions and reducing the size of its cross section by hammering or by pressure.

Upsetting is the process of increasing the cross section of the piece in one or more dimensions by decreasing its length.

Bending is the forming or turning of the metal in such a manner as to deflect it from a straight line. The finished product may be curved or an angular piece.

Twisting is the operation of twisting or winding the fibers around each other spirally. No change occurs in the direction of the axis of the piece.

Forge welding is the operation of uniting two pieces of metal into one solid piece by heating them to a welding heat in the forge fire and hammering or pressing them together.

The purpose of this article is to discuss the first of these forging operations; drawing.

Procedure for heating: The results obtained in forging and forge welding depend largely on the condition of the fire in which the work is heated. The fire must be kept clean and free from cinders or other foreign matter. The air blast should come up through the center and should pass through a solid bed of coke. Excessive blast pressure is to be avoided.

The work should be placed below the top of the fire, so that the oxygen of the surrounding air cannot come in contact with it. On the other hand, it must not be placed too low in the fire, or the oxygen from the air blast will come in contact with it. When highly heated iron comes in contact with air, it is oxidized rapidly by the oxygen, forming iron oxide or scale. Cinders and clinkers allowed to accumulate in the fire will let the air pass up through the fire without using the oxygen, thus allowing it to attack the metal.

To insure even heating, the work should be placed horizontally in the fire, with the hottest part of the fire surrounding the point that is to be heated. In the case of beginners, the work should be placed in such a position that the progress of the heating can easily be observed. If the work varies in cross section, the larger part should

Drawing Operations

be heated first, and then the smaller, as the larger requires a longer time to reach the desired temperature. This is done by shifting the work in the fire so as to bring both sections to the desired heat at the same time. Also, heavy pieces should be turned over in the fire occasionally.

Forging temperatures: There are definite temperatures at which metals may be safely forged. These temperatures vary with the composition of the metal. The experienced workman is able to judge the approximate temperature of a piece of iron or steel by its color. If a piece of iron or steel is placed in the fire and slowly heated, its color changes as the temperature increases. When it has been heated to such a temperature that it has a dull red color when viewed in a dark place, but is black when seen in the light, it is said to be black hot. As the heating proceeds, the piece shows a dull red color in the light, and is said to be red hot. Further heating changes the color to cherry red or bright red when seen in the light. As still more heat is applied the metal changes to an orange color, and then to a lemon color, and finally begins to spark. Just before it reaches the sparking heat it is white hot, and has a dazzling white glow. If heating is continued metal will be burned. Temperature colors are shown in Table I. Table II shows the melting points of some of the more common metals used in forging. For plain carbon steels, the melting point decreases as the carbon content of the steel is increased.

Tongs. - A very important point is the selection of the proper tongs to hold the work. Not only is good work impossible with tongs which do not hold it firmly, but their use is dangerous, because the hot piece of material is apt to fly out, and may strike the helper or the smith. If tongs must remain in the fire while the work is being heated, they should be cooled off before any hammering is done on the work. Always select tongs that grip the work firmly, and keep them cool.

Procedure for forging. - The smith should stand in an even and a naturally balanced position about 12 inches from the anvil. His feet should be approximately at right angles, with the heels about six inches apart, and with the left foot at about the center of the anvil. This position will place the body almost opposite the heel of the anvil with the face turned slightly toward the horn, working with the horn to the left. Tongs are held firmly in the left hand, straight out from the center of the anvil and at such a height that the work will be flat on the face of the anvil. If the hand is held too high or too low, the work will become bent by the hammer blows. The hammer is held in

the right hand, so that the handle will project about one inch beyond the hand. The hammer is gripped between the first two fingers and the thumb, so that the ring and little fingers close in on the handle lightly. If the handle is gripped so tightly as to jar the hand when striking a blow, a sore or blistered hand will be the result.

Striking is done as follows: The arm is held out to the side of the body just enough to give good clearance. The hammer is raised until the hand is above the shoulder and the wrist is then tipped backward. This wrist movement gives the hammer additional swing. The blow being produced with a full arm swing, the forearm unfolds from the elbow, and the hand moves downward at the wrist just as the arm reaches its full downward position. The beginner may find that at first he strikes wildly, but with short practice, coordination of the upper arm, forearm and wrist movements will enable him to deliver true and effective blows.

When light blows for finishing a piece are needed, the hammer handle is gripped about the middle between the thumb and forefinger, the thumb resting along the top of the handle, the blow being struck with a forearm movement.

Table I

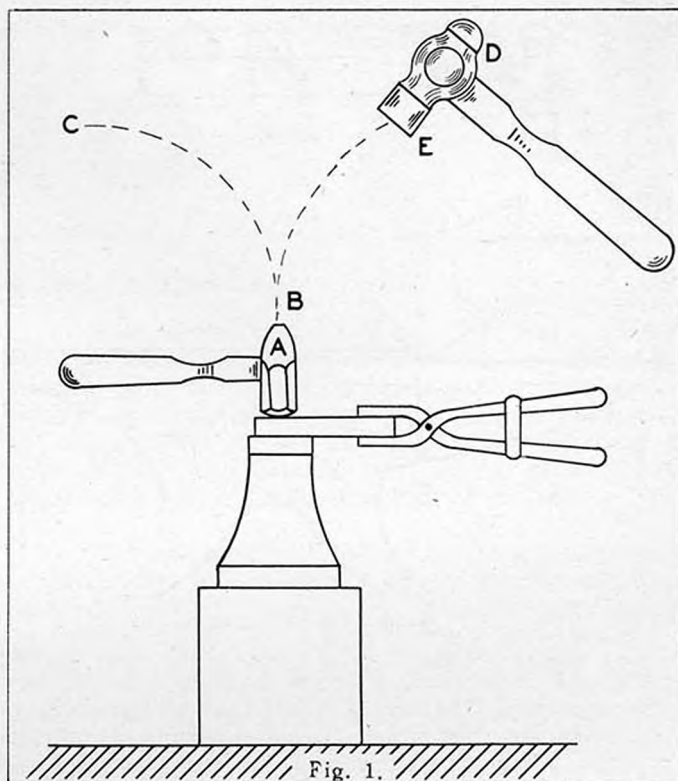
COLOR	:	°F
Faint red, visible in dark	:	750
Faint red	:	900
Blood red	:	1050
Dark cherry red	:	1175
Medium cherry red	:	1250
Cherry or full red	:	1375
Bright red	:	1550
Salmon	:	1650
Orange	:	1725
Lemon	:	1825
Light yellow	:	1975
White heat	:	2200

Table II

MATERIAL	:	MELTING POINT
Pure iron	:	2800
Wrought iron	:	2700-2750
Carbon steel	:	2500-2750

If a helper is used for handling a sledge, such as in drawing a piece of stock on the anvil, he should watch the manner in which the smith uses his hand hammer, and should try to strike similarly. For example, when the smith strikes flat on the work, the helper should strike flat with the sledge. When the smith strikes at an angle, the helper should strike at an angle, when he strikes heavily or lightly, the helper should strike in the same way. The paths of the sledge and hammer are shown in Figure 1. The sledge, "a" is raised along the dotted line "bc", and descends along practically the same line. Its blows are delivered alternating with those of the hammer, "d", which follows the line "be".

Drawing out consists of lengthening the stock by reducing the area of the cross section, either throughout its length or a portion of its length. The shape of the



cross section may be kept the same, or it may be changed, as from round to square or from square to round or octagonal.

If a bar of square section is to be drawn down to one having a smaller section of the same shape, the sides of the original bar help to guide the hand properly when turning the stock on the anvil. However, if a round bar is to be drawn down to one square in section, the amount of turn must be governed by the hand and eye. In drawing down a square bar to a square of smaller size, the piece is heated, brought to the anvil, and one of the sides held down flat on the face of the anvil. Blows are then struck squarely on the top side, drawing the stock down along its entire length. It is then revolved one-quarter of a turn, and the top side is hammered until the piece is about square. The piece is then given a half turn and this side hammered and, finally, the last side is brought under the hammer. The numbers in Figure 2 show the order in which the sides are brought under the hammer. This method of turning the work lessens the liability of getting the work twisted, or diamond-shaped, as shown in Figure 3. If the piece becomes diamond shaped, it should be held and struck in the manner shown, before it is brought too near its finished size.

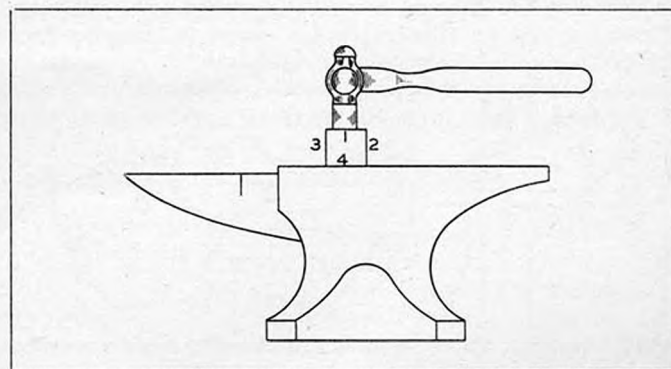


Fig 2.

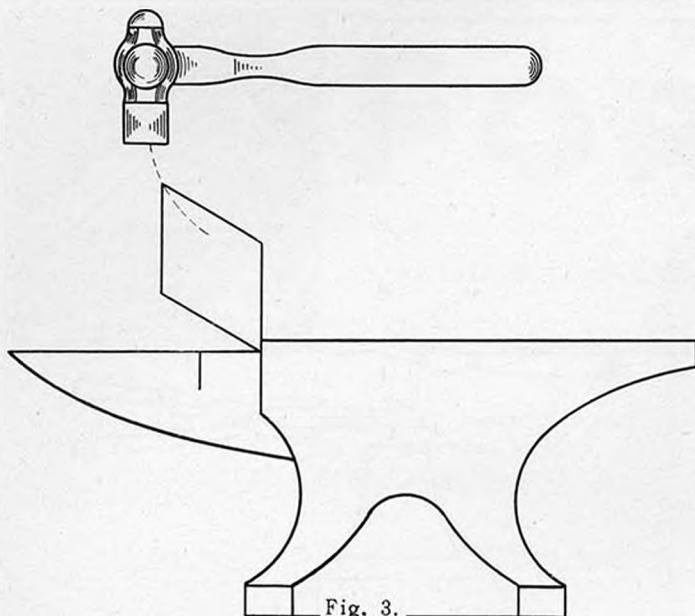


Fig. 3.

Another method of drawing, often used by experienced blacksmiths, is to turn the piece a quarter turn after each blow. The piece is turned a quarter turn counter-clockwise, and then turned clockwise back to its original position. After some hammering, the work is given a half turn and the same operation carried out on the other two sides. The work is thus kept more nearly square throughout the process than by the first method, and the fibers of iron are less likely to be separated.

Rectangular stock is handled in the same manner as square stock, after the sides of the rectangle have been made to bear the proper proportion to each other. Thus, if the dimensions of the stock to be drawn down are, say 2 to 1, as in (a) Figure 4, and the desired cross section is to be 3 to 1, as in (b) Figure 4, then face (c) should be struck to lengthen it and shorten face (d) until (c') is three times (d'); after that the sides should be kept in this proportion by using one of the two procedures described for drawing square stock.



Fig. 4.

Round stock which is to be drawn to a smaller diameter when finished should always be drawn down square to the required size, and then rounded by first hammering it to an octagon shape from square and then rounded by hammering the eight corners down with light blows. Figure 5 illustrates the steps in drawing from round to round: (a) shows the original stock; (b) shows the stock squared; (c) shows the stock in octagonal shape; then it is rounded up as in (d). In the first operation of squaring

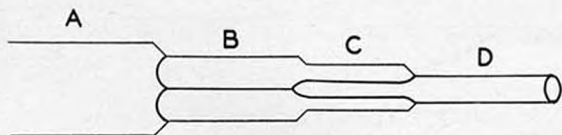


Fig. 5.

the stock from round, the square may be made somewhat smaller than the diameter of the finished round, because the sides of the square will bulge out somewhat when the

corners are flattened.

When drawing down a round point either on round or square stock, one must follow the same course. The end is drawn to a square pyramid of proper size and length, and then the procedure followed as in drawing round from square.

If it is attempted to keep the stock round throughout the process of drawing, the bar may become cupped at the ends, and split through the center, as shown in Figure 6. The cupping is due to the outer surface drawing faster



Fig. 6.

than the interior of the stock. The cracks are due to a movement of fibers, illustrated by Figure 7. A downward blow at (A) will tend to distort the circle to an ellipse, as shown by the dotted lines. When turned slightly for the next blow, the sides will tend to roll by each other, as shown in (B). Since the center of the stock is also the axis for this rolling action, cracking finally develops along the center line of the stock where the fibers have fractured.



Fig. 7.

For forging, stock should be heated to a lemon color, and worked until it reaches a full red. If the piece is not completed at this time, it should be reheated. The piece should never be forged below a dull red color.

For finishing a piece, light blows may be delivered between a dull red and a black heat. The latter may be used for finishing stock with flat surfaces, and the top and bottom round swedge for finishing round stock, blows being delivered to the finishing tool by a helper using a sledge as shown in Figure 8.

When a heavy piece is to be drawn down to a great extent, the process may be speeded by working it over the horn of the anvil, as shown in Figure 9. The horn acts as

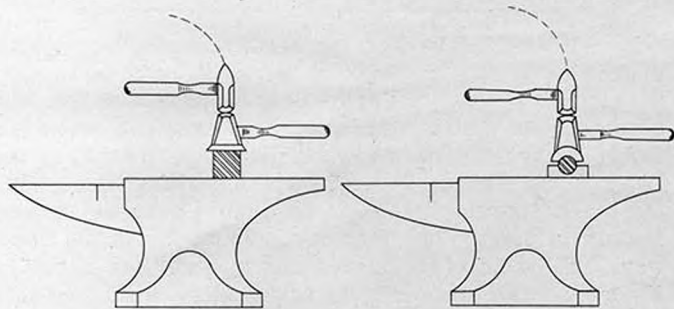


Fig. 8.

a dull wedge forcing the metal lengthwise without increasing the width very much. Forging a piece in this manner leaves the stock very rough, and the surfaces should be

(Continued on page 559)



Conducted by: L. I. Dance, 2nd Lt., Ord. Dept.

Antitank Mines

(SERVICE AND PRACTICE)

By: James T. Barnes, 1st Lt., Ord. Dept.

The Antitank Mine is an explosive device designed to be laid on the ground or planted flush with the surface for defense against track or wheeled vehicles. It is not designed to destroy the vehicle, but to stop it by breaking the tracks or wheels.

At present, there is a service and a practice antitank mine; the "antitank mine H.E., M1" and the "antitank mine practice, M1", respectively.

Antitank Mine H. E. M1: The complete round consists of two components, the loaded mine body and the fuze. A separate part of the body is the spider assembly which fits over the fuze, thereby increasing the effective size of its head.

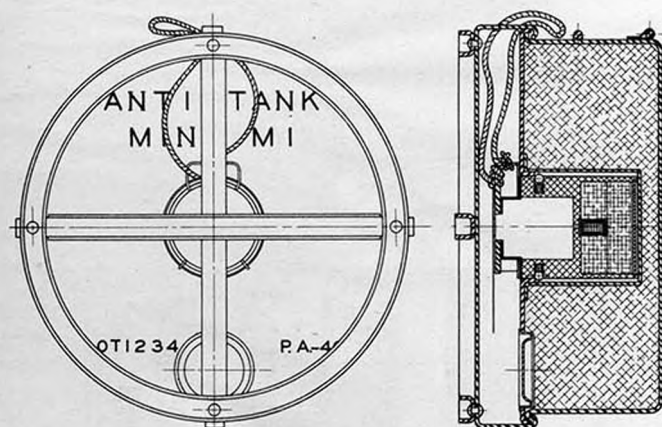
The steel body is cylindrical, approximately 2-3/4 inches high and 7-1/2 inches in diameter. A flanged top is notched in two places for assembling the spider. Centered in the top of the body and extending 2-5/16 inches into the body, is the fuze cavity with a diameter of two inches. Another hole of 1-1/2 inch diameter is between the fuze cavity and the edge of the top. This is the loading hole in which the high explosive charge is poured. To facilitate handling, a carrying ring is attached to the side of the mine. The complete round weighs about 10.4 pounds with approximately 6 pounds of TNT filler. The steel spider assembly is a ring with two hooked cross-arms riveted to it at right angles. The four hooks engage in the flanged top with the cross arms centered over the fuze.

Fuze, Antitank Mine H.E. M1: This fuze is for the service antitank mine only and contains the booster as an integral part. It consists essentially of a striker assembly and a body which contains the primer, detonator, and booster. The striker assembly, on the outer end of which is a two inch diameter head (painted yellow), protrudes about 3/8 inch beyond the body of the fuze.

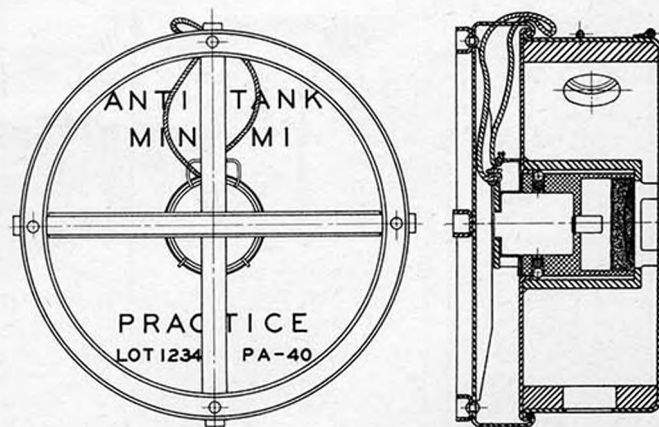
Four safety features prevent the firing mechanism, within the striker assembly from functioning until the required conditions are met: A safety fork (attached to the striker head by a cord) slips over a collar between the striker head and the fuze body. When the safety fork is removed, the fuze is in the armed position. A heavy foil collar is between the striker head and the fuze body. Two shear pins lock the firing pin retainer sleeve to the striker assembly. Lastly, two retaining balls are forced (by the firing pin) through holes in the sleeve into recesses in the striker assembly, thus allowing the firing pin, by its spring, to actuate the explosive train. These safety features necessitate a force of approximately 500 pounds on the striker head to function the fuze when it is armed (safety fork withdrawn). The added leverage gained by assembling the spider to the mine, reduces the pressure needed to 250 pounds if this pressure is applied to the rim of the spider.

As received, the spider is on the bottom of the mine and the fuze is in a separate compartment in the packing box. To assemble the complete round, remove the spider from the bottom of the mine. Insert the fuze in its cavity until two ball bearings on the side of the fuze body latch is in position. Leave the safety fork in place about the collar (unarmed position). Next, assemble the spider to the mine body by engaging two adjacent hooks to the top flange and placing the remaining two hooks in the notches. A one-eighth turn of the spider will then engage it in position.

The only time the safety fork should be removed is after the mine has been placed in position. It is left



HE



Practice

beside mine attached by the cord.

To disassemble and disarm the mine, the above procedure is reversed. The safety fork is replaced and the spider and fuze are then removed.

Antitank Mine, Practice, M1: The complete round and its components are similar in appearance to the service mine with some exceptions. The mine body has five holes equally spaced around its side. A cast iron ring is fitted inside the otherwise empty body to approximate the weight. There is no loading hole. Marking differences will be discussed in a later portion of this article.

The antitank mine practice fuze M1 is also similar in appearance to the service fuze with some exceptions. A spotting charge is substituted for the booster and a 32 blank cartridge is used in place of a detonator.

The practice mine is assembled and disassembled in the same manner as the service mine.

Marking: Both the practice and service mines are painted as a rust preventative and also for identification purposes. The service mine is painted yellow with the following information stenciled in black on the top of the body:

1. Type and model of mine.
2. Lot number.
3. Manufacturer's initials or symbol.
4. Date loaded.

The service fuze is unpainted except for its striker head which is yellow. The following information is marked in black on the side of the fuze:

1. Designation of fuze.
2. Fuze lot number.
3. Loaders initials.
4. Date loaded.

The practice mine is painted blue with white stenciling while its fuze has a striker head painted red.

Packing: Antitank mines are shipped as unassembled complete rounds packed five (5) per wooden box with two data cards enclosed. As shipped, the box has six compartments with the five fuzes in a fuze container in the end compartment. Five removable plywood separators or partitions have extra seating grooves so that in the field, the partitions may be moved. This allows the assembled complete rounds to be carried in the same box.

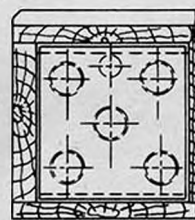
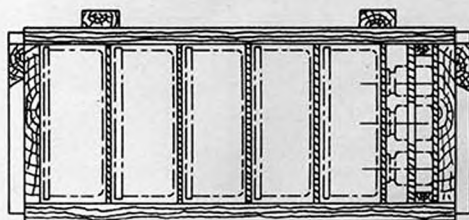
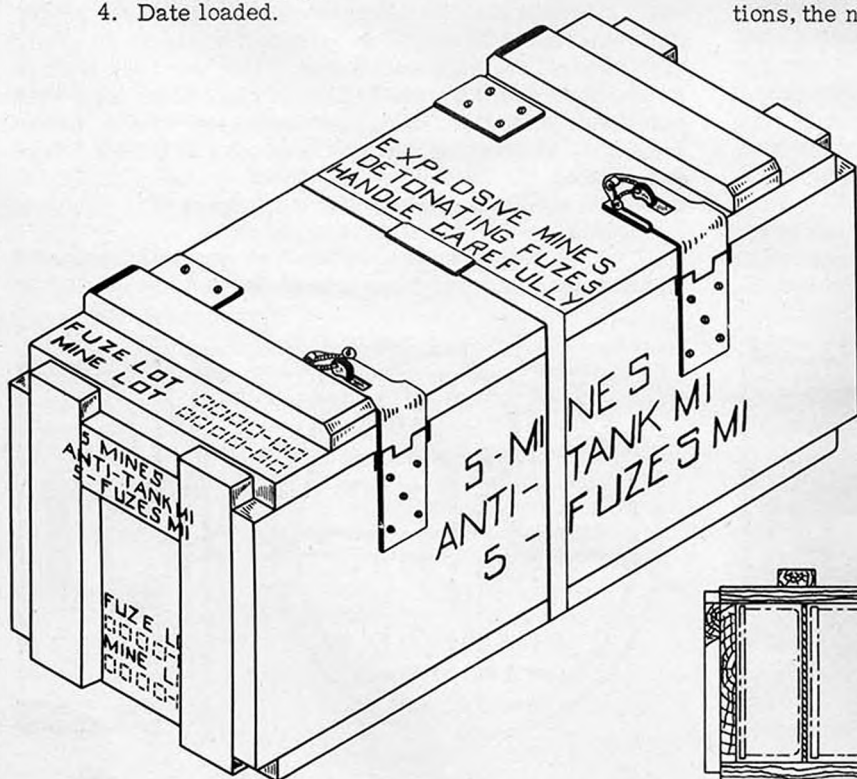
A box of five service mines weighs about 67 pounds while a box of practice mines weighs approximately 62 pounds. Boxes of service mines are unpainted but the practice mine box has blue end cleats and a three inch blue band around the middle of the box.

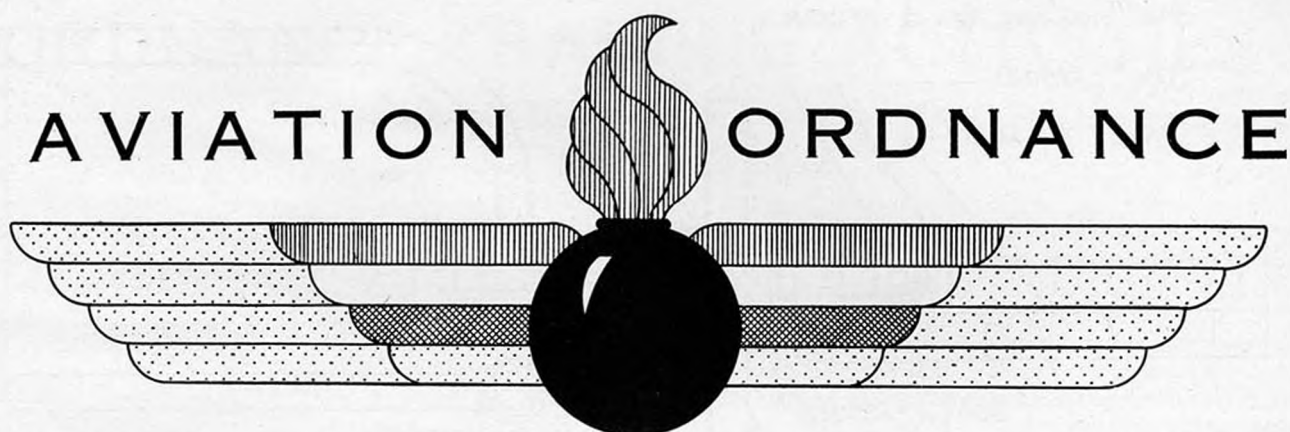
The procurement, storage, and issue of these antitank mines are the responsibility of the Ordnance Department.

The installation of antitank mines will normally be done or supervised by the engineer troops.

A word or two will be said about planting mines but for full information on their tactical employment, the following references are listed: FM 100-5, FM 5-30, and Training Circulars Numbers 8 and 41, War Department, 1941.

Mines may be laid singly or in multiple to give a more powerful blast. Again, the mines may be planted on or flush with the surface of the ground. Concealment may be effected by covering the mines with dirt or grass. Natural terrain lines should be followed where possible. Mine fields should not be geometric in pattern. A sketch of the mine field should be made, if possible. This sketch should show by pacing and azimuth the location of the individual mines or if it merely shows the mines by sections, the number of mines in the section should be shown.





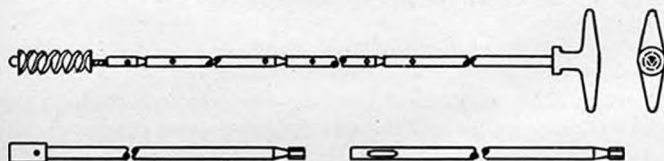
Conducted by: Glenn H. Staley, 2nd Lieut., Ord. Dept.

AUTHORIZED TOOLS FOR THE 20-MM AIRCRAFT GUN, M1 & M2

By: J. W. Simpson, 2nd Lt., Ord. Dept.

This is the second of two articles on the authorized tools for the assembly and disassembly of the 20mm Aircraft Gun, M1 & M2. The previous article gave a description accompanied by drawings of five (5) of the tools. This article will concern itself with the remaining authorized tools.

6. Staff, Cleaning, C70631. - The Staff, cleaning, consists of six (6) sections which are used in cleaning and preserving the bore of the tube. Three sections of the staff are assembled by screwing them together forming a long rod. The rear section has a T-shaped handle on one end and is threaded internally on the other. The other two sections are threaded externally on one end and internally threaded on the other. The remaining three sections are



Rod, Cleaning - C70631

Fig. 6.

known as "service sections". One is a cleaning brush connected to a short rod which is threaded externally at the rear end. Another is a plug connected to a rod which is externally threaded at the rear end. This section is to be used with patches. The last section is a rod flattened and slotted at one end for use with cloth strips. The rods are all made of brass to prevent injury to the bore of the tube. See Figure 6.

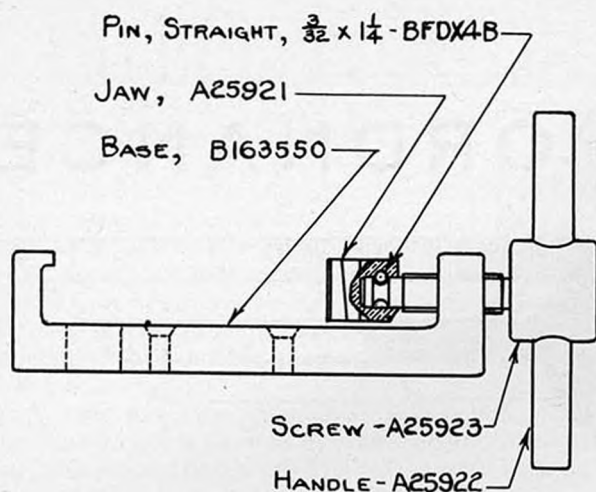
7. Rod, Magazine Charging, A25855. - This tool is a round straight steel rod, as shown in Figure 7, and is 3/8 inch in diameter. The rod affords a means of loading the 60 rd. drum type magazine. A shaft runs through the center of the magazine and a tubular extension protrudes about one inch on the front side. Four equi-spaced holes are drilled through this extension. The charging rod is inserted through the holes in the shaft and turned clockwise, winding the magazine spring. As the spring is wound, the magazine follower is pulled into the feed chute of the magazine. The charging rod is turned until two or three rounds can be fed into the magazine. The rod is turned



Fig. 7.

again and the operation is repeated. This is repeated until the magazine is fully loaded.

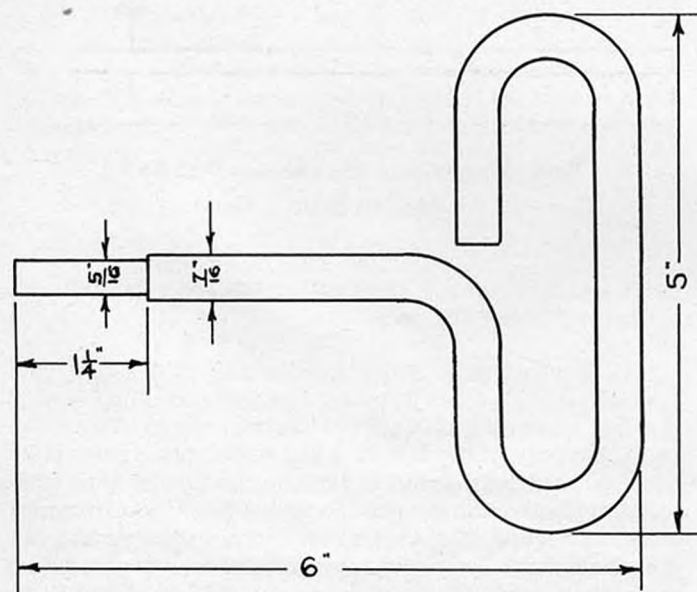
8. Tool, Sear Block Assembling, B163500. - This specially designed tool is used to assemble and disassemble the sear block assembly after it has been removed from the gun. The body of the tool is a flat, rectangular steel plate with each end bent upward to form projections or legs. One leg is drilled and tapped and the other has a lip on its upper end. A threaded shaft is screwed through the hole and has a T-shaped handle on the rear end and a notched plug on the forward end. The sear block assembly is taken from the gun with the sear buffer retaining tool in place and placed in the sear block assembling tool with the sear buffer spring plungers engaging the plug of the tool. The T-shaped handle of the tool is turned to the right until the plug pushes the sear buffer spring plungers into the sear block, against the sear buffer springs, far enough for the sear buffer spring retaining tool to be removed. The handle is then turned to the left until the sear block assembly can be removed from the tool. The sear block assembly may be reassembled by placing the sear buffer springs and plungers into the two holes in the front of the sear block and placing them in the sear block assembling tool and turning the handle to the right until the grooves in the plunger coincide with the hole in the front of the sear block. Insert the sear buffer spring retaining tool and remove the sear block assembly from the sear block assembling tool. See Figure 8.



TOOL, ASSEMBLING SEAR BLOCK, B163500

Fig. 8.

9. Tool, Sear Buffer Spring Retaining, A25917. - This tool is a round steel rod bent at the upper end to form an oval handle at the upper end and machined to a $\frac{5}{16}$ inch diameter as shown in Figure 9. A shoulder is machined near the middle of the tool to prevent its being inserted too far into the hole in the front end of the sear block. The tool is inserted in the hole in the sear block, engages the groove in the sear buffer spring plungers and

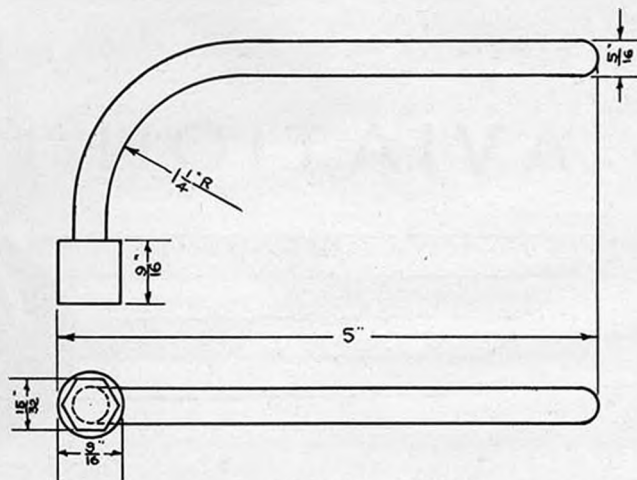


TOOL, SEAR BUFFER SPRING RETAINING
A25917

Fig. 9.

holds them to the rear so the sear block assembly may be removed from the gun. When the assembly is being assembled outside the gun, the sear buffer spring retaining tool again holds the sear buffer springs to the rear so the sear block assembly may be inserted into the gun.

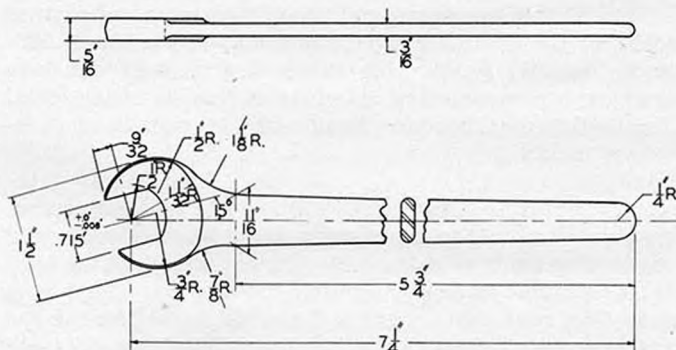
10. Wrench, A206913. - This tool is a small L-shaped thin walled socket wrench as shown in Figure 10. The wrench fits the $\frac{7}{16}$ inch sear cover plate screws. The hex socket is made thin walled in order to remove the two rear screws on the cover plate which are restricted by the design of the cover plate. The wrench is easily bought commercially and can be made thin walled with very little difficulty.



WRENCH A206913

Fig. 10.

11. Wrench, Engineers Single-head, A206718. - This tool, (shown in Figure 11), is a single-head open end



MATL - DROP FORGING-CHROME ALLOY, COM
WRENCH - FOR GAS VENT PLUG AND GAS
CYLINDER GUIDE

Fig. 11.

wrench. The wrench is used to remove and replace the gas cylinder guide and the gas cylinder vent plug.

Ordnance organizations experience change of stations more frequently now than in the past. In a few instances these changes have been reported to THE ORDNANCE SERGEANT in advance. It is known that in several cases the delivery of magazines has been delayed considerably because a change of address had not been reported. A few times magazines have been returned because of incorrect addresses. And in far too many instances, due to the fact that back issues are almost never available, organizations have asked for back issues to complete their files - because they had failed to report a change of address and had missed some issues.

If your organization moves, report the change as soon as possible. If it goes to foreign service, tell us your APO number. Report all changes to THE ORDNANCE SERGEANT, Ordnance School, Ordnance Training Center, Aberdeen Proving Ground, Maryland.

ORDNANCE TRAINING ACTIVITIES

Conducted by: G. D. Meixel, 1st Lieut., Ord. Dept.

Secretary, The Ordnance School

ORDNANCE TRAINING METHODS

By: P. J. Phillips, Major, Ord. Dept.

Director of Training Methods, The Ordnance School

Part III

QUESTIONS ARE IMPORTANT

No definite rules can be given to govern absolutely the way in which an instructor will use questioning in the class. Questions must be planned with care. The instructor should prepare in advance questions of real importance, selected for their definite bearing on the attainment of the objective of the lesson. These key questions should follow in a sequential order as prescribed by the nature of the job. Other minor questions may be added in support of the more important questions, as required to develop the subject under discussion.

The questions used in tests fall under two general classifications, namely: the free answer or essay type, and the objectively scored type.

The free answer or essay type of question is familiar to all, as the following example will reveal: "Discuss the functions of the primary coil in the ignition circuit." This type of question has its advantages in tests in certain subjects where a limited number of questions must be used to cover a great deal of subject matter and where other types of questions would be difficult to use. It has certain disadvantages; however. The student who has no definite knowledge of a subject may, by clever use of words, convince the instructor that he has some knowledge of the subject and thereby be credited with partial value of the question. Due to the length of time required to answer this type of question, it does not permit a proper sampling of the subject matter if the test is to be administered in a reasonable time. A third disadvantage is that uniform grading of this type of question is impossible.

The objectively scored type of question has been designed to overcome the disadvantages of the free answer or essay type of question. It permits uniform grading by anyone who possesses the key; a minimum of time is required by the student in answering it, and a more adequate sampling of the subject matter is thus possible; no partial credit on any one question is involved, the student either getting full credit or none; it lends itself to repeated use, and students seem to prefer this type of question because it eliminates writing and is not controversial.

The objectively scored type of question, like all others, has certain disadvantages. Good questions of this type are difficult to prepare, the student is greatly limited in the means of expressing himself, because such questions are not thought provoking; they depend more on memory and frequently tend to deal with trivialities, and they lend themselves to and encourage guessing.

Although the objectively scored type of question is found in numerous forms, only those in most common use are described here.

The "True-False" question is probably more frequently used than any other form of the objectively scored question. There should be approximately an equal number of true and false questions. The questions should be arranged according to relative difficulty; that is, the easiest questions first, the difficulty gradually increasing toward the last. "Determiners" such as "always", "never", etc., should not be consistently used, as such questions are nearly always false. However, they should be used occasionally. The true questions should not be placed in one group and false questions in another, nor should they fall in regular alternate order. They should be mixed. Unless a statement is true, wholly and without exception, it must be marked false; for example, one statement shown in Figure 4 is false, because such a parallelogram might be a rectangle and not a square.

EXAMPLE: A parallelogram whose angles are right angles is a square. 0

EXAMPLE. - Directions to the student: Below are a number of sentences. Read each carefully, and, if what it says is true (correct), place a plus (+) sign on the short line in the right margin. If what it says is not true (incorrect), place a zero (0) sign on the short line in the right margin.

1. The secondary coil has current of high voltage induced in it. +

Fig. 4 - Examples of true-false questions.

NOTE: In marking such questions, a true statement is indicated by means of a plus sign (+) and a false statement by a zero (0).

In using the multiple-choice form, there should be only one correct answer to each question to choose from, but all answers suggested should be plausible. Questions should be arranged in relative order of difficulty. See Figure 5.

Of the four forms described here, the completion question is probably the most difficult to prepare. Great care must be exercised in determining what words should be omitted. Do not omit too many words or unimportant words, or the test will degenerate into a puzzle. Sentences should be short, with only key words omitted. They should be arranged in relative order of difficulty. See the example shown in Figure 6.

This is the third of a series of articles published for the benefit of individuals who may be assigned to duty as instructors within their own organizations.

EXAMPLE. - Directions to the student: Below are a number of questions and unfinished sentences. Following each are several words, numbers, or statements. Select the one which correctly answers the question or completes the sentence. Write the number of the correct word or phrase on the line near the margin to the right of each question. Only one of the answers given in each case is correct.

1. Which of the following officers may not inspect Ordnance property at Fort Blank for condemnation:

- (1) The Corps Area Inspector General.
- (2) The Corps Area Ordnance Officer.
- (3) The Ordnance Officer, Fort Blank, Md.
- (4) An Artillery Officer stationed at Fort Blank who has considerable experience in Ordnance materiel.

(3)

Fig. 5 - Example of the multi-choice question.

In using the single answer form, it is necessary to be careful to call for answers which can be stated as far as possible by a single word, phrase, number, or symbol. Questions should be arranged in relative order of difficulty. See Figure 7.

All, or any combination, of these forms of objectively scored questions may be employed in any one test if proper directions are given to the student in each case, and the whole arranged in relative order of difficulty.

The matter of asking questions in class must not be taken lightly. The instructor who gives this matter his careful attention will likely develop a technique which will render his questioning very beneficial to his students.

Address questions to the class before asking a student to respond. This procedure has the advantage of securing the attention of the entire class; of affording each member of the class an opportunity to form a tentative answer to the question; and of bringing the attention of the whole class to the answer given, and attracting the interest of the entire class to the discussion.

EXAMPLE. - Directions to the student: Below are several sentences from which certain words have been omitted. Each word which has been omitted has been indicated by a short line enclosed in parentheses, thus: (). Fill in each blank with a word correct.

1. Acceptable explosives for freight shipment are divided into (three) classes.

Fig. 6 - Example of completion question.

Scatter questions as far as possible to the members of the class. Call upon all students in an irregular order, so that the distribution of questions will be fair and so as to prevent mental loafing on the part of class members.

Allow sufficient time for the formulation of student answers - without wasting time. It is foolish to try to extract answers from students about material that is new to them.

Occasionally ask questions of the inattentive. This brings back into the class discussion the student whose mind has wandered off into other interests.

Encourage the students to ask questions. The instructor should answer questions graciously.

Eliminate student questions that tend to lead the discussion into irrelevant fields.

Ask questions in a natural conversational tone - not explosively, loudly, or acidulously.

Questions should follow in a natural sequence, so as to provide unity and continuity to the lesson.

The question can be used for many different purposes by the instructor. Among these may be noted the following:

For the purpose of creating interest in the subject under discussion. - The instructor is teaching the law of

EXAMPLE. - Directions to the student: The questions listed below may each be answered in one word, phrase, number, or symbol. Write the answer on the short line on the right margin opposite each question.

1. The Range Finder has what kind of field of view?

split

Fig. 7 - Example of the single-answer question.

falling bodies and asks the question, "Which is the easier to catch, a high fly or a pop fly?" The answer being a pop fly, the teacher continues, "The purpose of this lesson is to find out why that is true."

For the purpose of recalling a fact needed at the time in teaching. - In a class in automotive electrical work, for example, the instructor wants to emphasize the fact that batteries can be damaged by charging at an excessive rate. He asks, "What is the effect on a storage battery if it is charged at a rate too high for its condition?"

For the purpose of reviewing the pertinent points in the last lesson as preparation for the first step of the new lesson. - The instructor may say, "What were the important things we learned in our last lesson?" and set the important answers down on the blackboard. In the last lesson he taught that gravity accelerates the falling body and retards the rising body. Today he asks, "What is the path of a ball thrown from A to B through the air?" When he is told that this path is a curve because the ball first rises, and then descends due to gravity, he says, "The purpose of this lesson is to find out why the ball does not follow a straight path?"

For the purpose of learning whether the student understands instructions that have been given him. - After giving instructions, the instructor pauses and then says, "What is that you are to do?"

For the purpose of finding out whether the students understand how to do a given job or perform a given process. - After showing the way in which one fraction is divided into another, the instructor says, "How do you proceed in dividing one fraction by another?"

For the purpose of finding out whether the student understands the cause of something. - The instructor says, "We have demonstrated that the front wheels of an auto are both turned in. Why is this done?"

For the purpose of making the student reason from cause to effect. - A student of carpentry is taking a slow stroke with the saw. The instructor asks him, "What would be the effect if you doubled the speed of the stroke?"

For the purpose of correcting a learner's misunderstanding of something. - In mixing electrolyte for storage batteries, the student says that water should be added to the acid. Thereupon, the instructor asks, "Is there any danger in mixing it that way?"

For the purpose of causing a student to analyze the steps in the performance of a given job. - He is asked by the instructor to describe the steps involved in the removing of the right front tire of a Ford 1/2-ton pickup truck.

For the purpose of causing a learner to plan his handling of a given job properly. - The instructor asks him, "What is to be done?" "What parts are needed?" "What approximate time is required?"

For the purpose of causing a learner to answer his own question. - This is sometimes called the "old Scotch game" of answering a question by asking another. A learner in baking produces a loaf of bread which is off color. Unable to account for the trouble, he asks the instructor, "What is wrong?" Instead of answering directly, the instructor says, "What are the possible causes of the trouble?" The learner answers by giving a few causes and saying that he has checked them. The instructor says, "There are other causes; what are they?" The learner does not know, thereupon, the instructor refers him to sources of information in references and asks him to make a list of other possible causes and to check them against the trouble.

For the purpose of testing at the close of a lesson whether the instructor has put over what he has tried to teach. - He has tried to teach a group of auto mechanics how to read the micrometer. He draws the "mike" and its markings on the board. He indicates certain marks and asks a member of the class to read it by saying, "What is the reading?" By changing the markings and repeating the question, he soon learns whether the class can read the micrometer. He checks by having them set a real micrometer for him.

For the purpose of stimulating the class to get important facts for themselves. - The instructor asks a question which no one can answer. He says, "You had better look it up, as it is important." The instructor must be sure that the means or references are available before making this statement.

For the purpose of developing a lesson from the knowledge possessed by the learners and not from what the instructor knows. - By skillful questioning the class is led to teach itself. In the experimental kitchen, the class in bread making has gone through the experiment of baking three loaves of bread - a standard loaf with a proper amount of salt, a second loaf without salt, and a third loaf containing too much salt. On the basis of this experience, the instructor asks such questions as these: "What effect

does too much salt have on the volume of the loaf? Too little salt? What effect does too much salt have on the color? Too little salt? What effect does too much salt have on the texture? Too little salt? By writing the correct answers on the blackboard, the after-results of varied amounts of salt are made plain to the students.

For the purpose of summarizing, by way of review, the main points brought out in a lesson. - In an automotive class the subject of lubrication has been discussed, and the differences in the kinds of lubricating oils have been pointed out. The instructor asks, "What were the different oils used?" and he lists them on the blackboard as they are named to him by the learners. He may, in a second column, list the reasons each oil is used.

For the purpose of providing additional work for the more capable or industrious members of the class. - For instance, students are induced to volunteer for additional assignments. In the auto shop, the construction and operation of a 1936 Chevrolet ignition system has been gone over thoroughly. The instructor asks this question: "How is the 1941 model ignition system constructed, and how does it work? Compare it with the 1936 model we have been discussing. Who will volunteer to bring a diagram and an explanation of the 1941 model?"

For the purpose of carrying class discussion over the "dead point" so as to get it moving again. - The instructor should be a director and manager of discussion by the class, occasionally furnishing statements or suggestive questions to clarify particular points or to keep the discussion from dying out. In a class in forestry there has been a discussion of how to put out a forest fire, and two students have differed on a point. The progress of the lesson has been stopped. The instructor asks what would be the results from following each method, listing in one column the results if A's method is followed, and in another column the results if B's method is chosen; the class then helps decide which is the more effective.

For the purpose of getting the attention of an inattentive student. - Suddenly asking a question and calling on him to answer is sometimes good strategy.

For the purpose of correcting errors - not merely for detecting them. - In questioning students in a class, question for the purpose of correcting errors and not for the purpose of detecting them. The discovery of errors has some value, but it is the correction of them that produces results.

From this discussion it should be apparent that the question is an important part of instruction. It should also be apparent that while an ordinary question may suffice for conversational purposes, the question used in instruction should be a GOOD question.

Questions should be asked very plainly and distinctly, in order that every student may hear them and know their meaning. After the question has been put, it should not be repeated for the sake of those who did not get it the first time. A good instructor makes it a point to hold the attention of every student. However, if he fails in this respect, he may then be expected to repeat questions for the sake of those who are not paying strict attention.

Repeating questions for the benefit of inattentive

students helps develop an attitude of indifference on the part of the students, and the efficiency of the class is lowered. No instructor should fail, however, to repeat a question or restate it for the sake of making it clear to members of the class.

Questions should be understood by the learner. To this end the student should be expected and encouraged, when he does not understand, to say so and to ask for a further explanation.

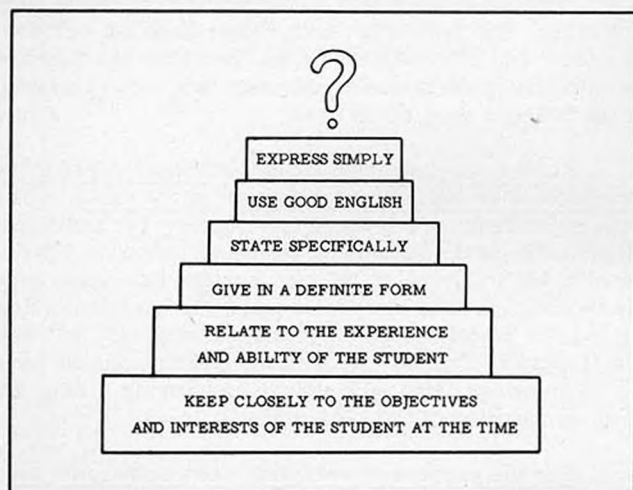


Fig. 8 - Steps to a good question.

Questions should be so stated that they can be interpreted in but one way.

Questions should be thought-provoking, and not such as can be answered by yes or no.

A GOOD question will fulfill all the requirements shown in Figure 8.

Part IV of this series, "Suggestions on Lecture Technique", will appear in the next issue of THE ORDNANCE SERGEANT, followed by "Demonstrations."



REMINGTON SHOTGUN

(Continued from page 461)

magazine lever acts to keep the magazine in line and locked to the barrel.

The barrel lug is kept in position on the barrel by means of the barrel lug screw, which fits into a blind hole on the barrel, and is assembled through the hole b.

INSPECTION AND REPAIR. - Inspect the barrel for dents. These can be removed in the same manner as described for the Winchester shotgun. If the magazine tube is dented, insert a mandrel or an iron bar into it and raise the dent by tapping gently with a hammer until the follower will pass through the tube freely.

If the seat for the magazine lever is torn out, a new plug must be inserted.

Check the magazine lever detent, and if found broken, replace with a new one.

Inspect the action bar. If bent, it can be straightened by hand. Check the action bar cam for a rounded or broken notch. If broken replace.

Inspect the foreend for cracks and, if necessary, replace with a new one.

Examine the ejector spring and if found to be weak or broken replace.

Inspect for weak or broken sear spring, replace if found defective.

Inspect the firing pin to see that the point protrudes at least 1/16 of an inch when released.

A defective sear should be replaced and under no circumstances must the slope of the sear be changed, in order to decrease or increase the trigger pull.

A bent trigger need not be replaced, as it can be straightened.

Test the trigger pull, which should not be less than five pounds.

Replace a damaged safety with a new one.

The interior of the receiver should be carefully examined for burrs which should be removed by filing or stoning.

Reassemble the weapon and test for ease of operation. Check the functioning of the safety features and using at least four dummy cartridges check the magazine feed.

This completes this article on the Remington shotgun.

Since the foregoing article was started, four other types of shotguns have been adopted. All four of the newly adopted types are Standard Commercial type shotguns, and are procured in two barrel lengths, 26" and 30" long. The 26" barrel guns are intended for guard duty and the 30" barrel guns for target practice, principally in the Air Corps.

The following is a brief description of each of the new models.

SHOTGUN, WINCHESTER, 12 GAUGE, M12. - It is a sporting type, hammerless, take-down repeating shotgun. Tubular magazine, capacity 5 rds. Side ejection, crossbolt safety and 7-1/4 pounds in weight.

SHOTGUN, REMINGTON, 12 GAUGE, M31. - This is a hammerless, take-down repeating shotgun. Tubular magazine, capacity 5 rds. Side ejection, crossbolt safety and solid breech. Weight 7-1/2 pounds.

SHOTGUN, ITHACA, 12 GAUGE, M37. - A hammerless, take-down repeating shotgun, shells fed in straight line into the chamber. Action release for removing shells. Bottom ejection, crossbolt safety. Tubular magazine, capacity 5 rds. Weight 6-1/2 pounds.

SHOTGUN, STEVENS, 12 GAUGE, M620. - A hammerless, take-down repeating shotgun. Tubular magazine, capacity 5 rds. Side ejection, independent safety and safety firing pin. Weight 7-3/4 pounds.



105MM HOWITZER

(Continued from
page 467)

The ideal pressure necessary to overcome the friction of the floating piston is 110 pounds per square inch but may vary between the limits of 90 and 250 pounds per square inch.

To again continue with the inspection, it is necessary to determine the pressure, in terms of pounds per square inch, necessary to overcome the combined frictions of the recoil piston and stuffing box packings (SBF). To accomplish this, after making the last gage reading above (AP - F), continue turning the piston rod jack in a counter-clockwise direction until the jack leaves the head of the piston. The jack screw should be turned at a uniform rate not to exceed 4 turns per minute. It will be noted that the pressure indicated by the gage will decrease at a fairly uniform rate until the jack leaves the piston head, at which time the gage hand will stop. Read the gage and record as SBF. The ideal pressure in this instance is 130 pounds per square inch but may vary between the allowable limits of from 100 to 280 pounds per square inch.

All the operations performed above in obtaining the various gage readings should be repeated until at least three (3) consecutive sets of practically uniform readings have been obtained. The mean of these three may then be considered as being the actual existing condition.

If in determining the pressure necessary to overcome the combined friction of the recoil piston and stuffing box packings it is found that the above test results in a value greater than the allowable limit, proceed as follows:

- a. Remove the gage connection plug.
- b. Turn the piston rod jack in a clockwise direction, displacing oil, until the piston has moved forward of the "in-battery" position about one inch.
- c. Replace the gage connection plug.
- d. Continue turning the jack until the gage shows a pressure of 1100 to 1250 pounds per square inch.
- e. Reverse jack and proceed with the test in the same manner as described above. If again the value obtained is above the allowable limits, displace enough oil to allow the piston to move forward two inches and repeat the test as before.

In cases where recoil mechanisms are being inspected and the Gun Record Book shows that there has been infrequent firings or that a considerable period of time has elapsed since the last firing, it is not unusual to find that the frictions are greater than the allowable limits. This is due to inactivity of the rubber packings and the tendency for them to stick to the walls of the cylinders and to the piston rod. This is not considered a serious condition, however, since exercising the mechanism, either by firing (performed of course by the using service in routine service practice or actual combat) or by several retractions (pulling howitzer well out of battery and allowing to return

rapidly), will almost invariably reduce the frictions to within allowable limits.

NOTE: In firing a weapon, when it is known that high frictions exist in the recoil mechanism, care should be exercised to insure that the weapon is not fired before it has returned to battery.

It sometimes will be found that leakage occurs at the filling and drain valve. This condition is usually caused by a damaged or worn leather valve gasket. In order to replace this gasket, remove the recoil cylinder filling plug retainer by use of a socket wrench, which will have to be improvised. Replace the old gasket, making sure that the hair side (smooth side) of the leather faces toward the valve.

In case it becomes impossible to secure pressure tight connections when using the oil screw filler or with the oil release when testing the mechanism, replace the recoil cylinder filling plug assembly.

If an excessive quantity of air is found to be present in the recoil mechanism it should be purged. To accomplish this proceed as follows:

- a. Connect the piston rod to the front of the cradle (howitzer having been dismounted).
- b. Elevate to maximum elevation and allow to stand for several hours.
- c. Slowly depress to about 5° elevation, disconnect piston rod from front of cradle and carefully slide to rear until the recoil cylinder rear head is slightly in rear of the rear end of the cradle.
- d. Install the piston rod jack.
- e. Remove the purge plug located on the top side of the recoil cylinder extension which is a part of the front yoke.
- f. Turn the piston rod jack slowly, displacing oil through the hole until the oil flow is free of air bubbles, and replace the plug.
- g. In a like manner, remove the purge plug from the recuperator cylinder extension of the front yoke and again turn the jack until the oil flow is free of air bubbles. Replace the plug.
- h. Remove the piston rod jack and refill the mechanism with oil to establish the proper reserve.

In case the air has not been completely expelled in the above operation when the limit of the jack screw has been reached, replace the purge plug; unscrew the jack screw; force oil into the mechanism until the recoil piston rod is again in the "in-battery" position and repeat the above operations.

Information as to pressures, frictions and tolerances used in this article were received from the following sources:

Teletype from C. G., R.I.A., May 7, 1942.
Inclosures to: Q. O. 473.82-588,
A. P. G. 473.82-302,
R.I.A. 473.824-4735.

NOTE: Two lectures illustrated by film strips have been prepared at The Ordnance School on this subject, FS 9-26, Part I, Basic Disassembly and Assembly, and FS 9-27, Part II, Nomenclature, Disassembly and Assembly of Units, Inspection.

COMPANY
PUNISHMENT(Continued from
page 472)

The accused will be given "reasonable time" to make up his mind whether he will take company punishment or demand a trial. If no demand is made, the commanding officer is authorized to impose punishment and to notify the recipient immediately of this action. At the same time the commanding officer also will notify the accused of his right to appeal such punishment to "the next superior authority."

(Provided the notification and communication to the accused was in writing, notification of the punishment imposed — including any reprimand or admonition which may be included — will be by indorsement on the original notification. The accused will be directed to reply by return indorsement in which he may include any appeal he may wish to make.)

APPEALS

Although the person punished under A. W. 104 considers the punishment unjust and appeals to the next superior authority, he will be required to undergo the punishment pending a decision. Such appeals must be made within a reasonable period. An appeal will be in writing — through proper channels — and will include a brief, signed statement of the reasons such punishment is considered unjust. The officer who imposed the punishment will include a record of the case. It is well to note that the commanding officer who utilizes company punishment jurisdiction, his successors in command, and superior authority are empowered to lessen or remit any remaining portion of the punishment.

The next superior authority will not hear witnesses in considering an appeal. If he determines the punishment unjust he will modify the measures imposed or set them aside. He is not, under any condition, authorized to increase the punishment or impose a different kind. After consideration he will return the papers through channels to the appellant, with a statement of the disposition and directions to the appellant's immediate commanding officer for file.

While a record of courts martial is kept in the soldier's Service Record, there is no record made of company punishment. Such records of company punishment are maintained in the company orderly room for the information of the commanding officer only. The company punishment record of an individual is not forwarded to the Adjutant General with the Service Record in the event of discharge or retirement.

As mentioned before, the record usually is in the form of a ledger, or "black book", or a file.

The company record will include:

1. Date of commission of the offense.
2. The punishment.

3. The authority that imposed it. In the case of a written notice, the date the accused received such notice and the imposition of the punishment and the decision of higher authority will be included.

4. Any remarks or additional data desired.

COMPANY "A", 99th INFANTRY,
FORT BLANK, ILLINOIS

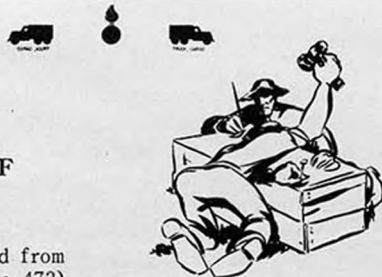
NAME	RANK	DATE	CAUSE	ACTION	APPEAL*
DOE, John E.	Pvt	April 2/42	Absent from reveille	Seven days' restriction	No
ROE, Melville	Pvt	April 2/42	Absent from reveille	Seven days' restriction	No

Reviewed and approved by

* Yes or no as the case may be.
Should the accused appeal, record of the final disposition will be attached to this sheet.

JOHN R. PLATERANGE,
Capt., Inf.
Comdg.

As a final consideration it must be kept in mind that the authority imposing punishment under A. W. 104 may not multiply the restrictions that may be imposed. Neither should there be unreasonable multiplication of the charges for which an individual is punished. For example, a soldier may not be given extra fatigue for one week and confinement for one week for drunkenness in barracks which also involved insubordination. The soldier should be punished for the offense of drunkenness alone and given a single punishment, extra fatigue for one week, for the offense charged.

SHIPMENT OF
PROPERTY(Continued from
page 473)

or the large part of the barrel. In marking irregular shaped packages or crates, the method of marking should follow along the same principals as nearly as possible.

The use of tags for marking property for shipment is permissible, but they should be of good quality. When tags are used on packages where it is not possible to fasten them with large headed tacks, the tags should have reinforced eyelets, and a good grade of cord or stout wire used. When labels are used they should be fastened to the package with waterproof glue. The markings of cloth, leather, and waterproof tags should be made with waterproof ink, metal tags can be marked with punches or dies.

If the prescribed paint is not available for the marking of packages the marking can be accomplished with the use of a good grade of paint, and the markings given a

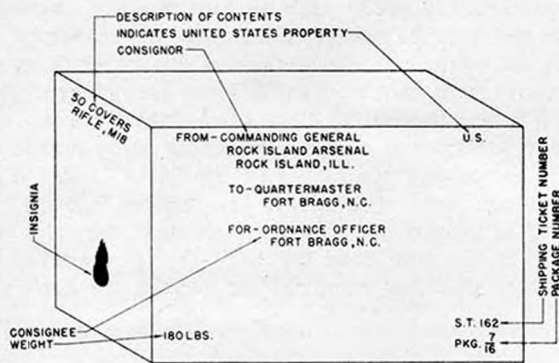


Fig. 1 - Plate showing standard markings for domestic shipments.

coat of varnish. A coat of varnish over labels will also help.

The following markings on packages of domestic shipments will normally be sufficient:

- a Name and address of consignee.
- b Name and address of consignor.
- c Number of shipping ticket.
- d Number of the package.
- e The letters "U. S." to denote United States Property.
- f Description of contents.
- g Insignia or symbol of the Ordnance Department.
- h Gross weight in pounds.

Special markings of the following type are required in some cases:

- a Fragile handle with care.
- b This side up.
- c Use no hooks.
- d Glass handle with care.
- e Do not store in a damp place.

There are many more of these markings, only those most commonly used are mentioned here.

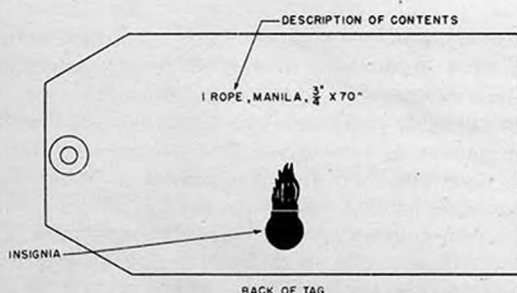
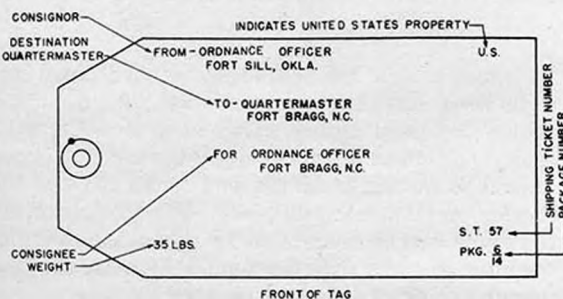


Fig. 2 - Plate showing standard markings for domestic shipments.

In the shipment of some types of property it is also necessary to include technical data, such as the mark, or model number, and special markings when required by the Ordnance Department.

If the property is for overseas shipment the following additional markings should be included on the packages:

- a For export.
- b Displacement of shipping volume in cubic feet.
- c The port quartermaster to whom the shipment is to be sent for transshipment, to the overseas destination.

When necessary to further identify the address of the consignee it is sometimes advisable to include the county in the address. This is especially true should there be two or more towns by the same name in the state. When

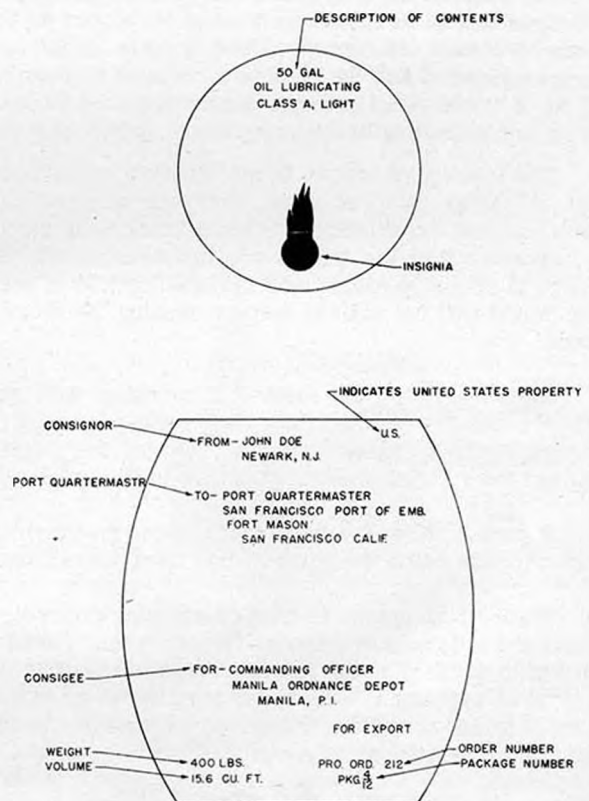


Fig. 3 - Plate showing standard markings for overseas.

the freight, express, or mail service is such that the package cannot be delivered to the consignee, the name of the place where the consignee will accept the property should also be included.

In making carload shipments of a given kind of article in uniform containers, when the shipment is to one consignee, the markings as outlined herein can be omitted except those that are required by the carrier. In shipments of less than a carload when the shipment consists of one kind of an article in packages of uniform size and weight the numbers may be omitted from the packages.

The loading of railroad cars and automotive trucks for shipment is also an important subject. When ordering railroad cars care should be exercised in ordering the right type and size of car. Railroad cars come in different sizes, with each size having its own minimum weight to

be shipped as a carload. In the event a larger car is ordered than is required for a particular shipment, and this car is not loaded to capacity, a charge is still made for the minimum weight of that car, resulting in an excess cost of transportation. Before cars are loaded they should be checked for nails in the walls and floors, the floor of a box car should be swept. In loading the car, care should be taken to distribute the weight of the shipment evenly throughout the car. In no case should the shipment be loaded in one end of the car, as this is liable to cause accidents.

The packages should be arranged in the car so that they will not shift while in transit. The shipment should be properly blocked in place so that there will not be any danger of the packages breaking loose and becoming damaged. Lumber is permitted to be used for blocking shipments, and can be nailed to the floor and wall of the car. If the shipment is to be loaded the entire length of the car, boards should be placed in front of the doors so that they can be opened and closed without trouble. If the cars are properly loaded and the shipment remains in position, it will be of untold value to the personnel required to do the checking and unloading of the shipment.

The loading of trucks is not quite as complicated as that of loading railroad cars, everyone at some time or other has had experience in loading trucks. However, it is important that the trucks are not overloaded, and the cargo is properly loaded and fastened or tied in some way so that it will not shift in transit causing the truck to overturn.

Figure 1 shows the method of marking packages. It will be noted that on the lower right hand corner of the package appears the number of the package, the shipping ticket, and the total number of packages in the shipment.

Figure 2 shows the method of placing the markings on tags, which is much the same as that used for packages.

Figure 3 shows the method of marking a barrel. In this case the shipment is intended for overseas. It will be noted that in addition to the information mentioned in this article there appears also an order number, which is used when the supplies are procured from a civilian manufacturer and are being shipped by him.



HARD SURFACING METALS

(Continued from page 543)

The group 4 and 5 alloys, being very rough and extremely hard, are used where the wearing parts come in contact with earth, sand, and gravel. These alloys are used on blades of road scraping and grading equipment, rotary drilling bits, airplane tail skids, steam shovel teeth, and similar applications where high resistance to abrasion is desired.

The hard-facing materials classified under group numbers are available under various trade names and in forms suitable for application with either the electric arc or oxyacetylene process.

Hard Facing Steel by the Oxyacetylene Process:

The oxyacetylene flame allows close control over

the operation and produces a smooth deposit. Particles of scale and foreign matter are easily eliminated by this method, and edges and corners are easily formed. This is particularly important where it is later necessary to grind the hard facing deposit to close dimensional limits. The degree of penetration of the hard-facing alloy in the base metal is accurately controlled by the flame. This is important, since some of the alloys are puddled into the base metal while others are merely "sweated" onto the base metal. The tip size used for hard-facing should be two sizes larger than that required for welding the same size rod.

In applying hard-facing alloy rods of Group 1 to steel, the flame should be adjusted to contain a slight excess of acetylene, since a neutral flame will cause boiling and produce unsatisfactory results. If a higher hardness is desired in the deposit, the amount of excess acetylene used in the flame should be increased. The hard-facing rod should be puddled into the base metal sufficiently to obtain good fusion without diluting the hard facing metal with the base metal and thereby softening it. The deposited metal should be slowly cooled to give high hardness. If quenched in oil from a high temperature, the hard facing layer will be tougher than, but not as hard, as the slower cooled metal.

The hard facing alloys in Group 2 are applied to steel by welding them to the surface of the base metal in a manner similar to that used for the Group 1 alloys. Sweating is not advisable. The flame should be adjusted to give an excess streamer of acetylene approximately twice the length of the inner cone. The penetration of these hard-facing metals into the base metal does not affect the hardness of the deposit, as their carbon content is high.

The hard facing alloys in Group 3 are non-ferrous and should be applied to steel by sweating them onto the surface without stirring or puddling the rod or melting the surface of the base metal. The flame should be adjusted to give an excess streamer of acetylene extending to double the length of the inner cone. This excess of acetylene acts to prepare the base metal, to allow free spreading of the hard-facing metal, and to prevent oxidation ahead of the fusion zone.

A small area of the surface to be hard faced should be brought to a sweating temperature. At the proper temperature the hard facing material will melt, wet the base metal, and spread evenly over the surface. Additional metal should be melted from the end of the rod and added to the molten metal already in place. The thickness of the deposited layer can be controlled by spreading the molten metal over the surface with the flame. Some of the alloys in this group can be shaped to a desired contour by wiping with a flattened tool or with the side of the welding rod.

The Group 4 materials require that the surface of the steel base metal be grooved by means of either the oxyacetylene cutting torch, by machining, grinding, or by the use of a forging hammer. The flame should be adjusted to give an excess of acetylene. Since these tungsten carbide materials are available as inserts in various sizes and shapes, they should be spaced evenly over the surface to obtain uniform wearing qualities. One insert should be fastened to the end of a steel welding rod by welding and the steel in one groove in the base metal should be heated until molten. At this point the insert should be pushed into place and sufficient of the welding rod should be

melted to completely cover the insert and weld it to the base metal. This procedure is repeated until the surface to be hard-faced is covered with the desired number of inserts. Where severe wear resistance is required these inserts are covered with one of the Group 5 alloys.

The alloys in Group 5 are crushed tungsten carbides embedded in steel strip, rod, or tube. The flame should be adjusted to give a slight excess of acetylene. The surface of the base metal should be melted and the rod puddled or stirred to obtain an even distribution of the crushed carbides in the deposited metal. Care should be taken not to overheat the molten metal, as these rods do not flow as freely as steel welding rods.

In applying any of the above hard facing alloys or materials to steel, the exact amount of excess acetylene in the welding flame should be found by trial deposits on waste material. That flame adjustment which gives a quiet puddle and good flowing qualities for the particular hard facing metal should be used.

In some cases, where a thin edge is to be hard faced or a desired shape is to be built up with the hard facing materials, a mold or back up strip of copper or a carbon block should be used.

Hard Facing Cast Iron by the Oxyacetylene Process

Except for minor variations in the adjustment of the carburizing flame, the Groups 1, 2, or 3 alloys may be applied satisfactorily to cast iron in the same manner as outlined for steel. The Groups 4 and 5 alloys are rarely applied to cast iron.

In some cases a cast iron welding flux helps to break up and float oxides and other foreign materials to the surface. Hard facing materials do not flow over the surface of cast iron as readily as they do on steel.

This often requires working of the molten metal with the end of the rod to distribute the metal and to obtain good fusion to the base metal.

Hard Facing by the Electric Arc Process:

The base metal should be prepared in a manner similar to that outlined for hard-facing with the oxyacetylene process. Every hard facing metal, in either coated or base electrode types, is applied using reverse polarity except for some of the Group 5 alloys. The flux coating on the electrodes reduces spatter loss, assures good penetration, prevents oxidation of the deposited metal and helps to stabilize the arc. The bare hard-facing electrodes are used only when it is necessary to apply a heavy bead or when depositing the metal against a copper form. The metal should be deposited using as long an arc as possible for best results. The voltage should be set as high as possible and the current should be adjusted for the thickness of base metal and the particular size and type of hard facing rod used.

The following table may be used as a guide for current settings for hard-facing electrodes.

<u>Diameter of Electrode — Inches</u>	<u>Current in Amperes</u>
1/8	100-150
3/16	150-200

1/4

200-250

Hard-facing by the Carbon Arc Process.

The carbon arc process can also be used to apply hard facing materials to the surface of metals which can be hard faced by the metallic arc process or the oxyacetylene process. The welding machine should be set for straight polarity and the heat of the arc can be used to melt the hard facing metals and weld them to the surface being hard faced. This process is used principally for the application of the Group 5 alloys, in granular or powdered form, to the surface of the steel. In this case fine particles of tungsten carbide are sprinkled on the surface and welded to the base metal by means of the heat of the carbon arc. In general, the same procedure should be followed in preparing plate surfaces for hard facing by the carbon arc process as is used for the metallic arc and oxyacetylene processes of hard facing.



DRAWING OPERATIONS

(Continued from
page 546)

finished on the face of the anvil using the flatter or hand hammer.

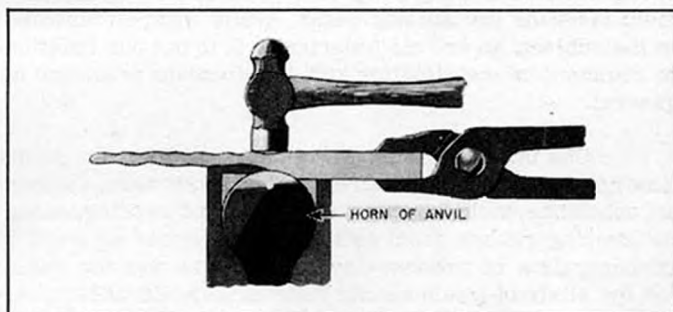


Fig. 9.

A piece of flat stock which is to be spread and tapered on the end, as in Figure 10, may be drawn rapidly by using the cross peen hammer as shown in Figure 10, the peen of the hammer acting as a wedge and forcing the metal to flow in the desired direction. This operation also

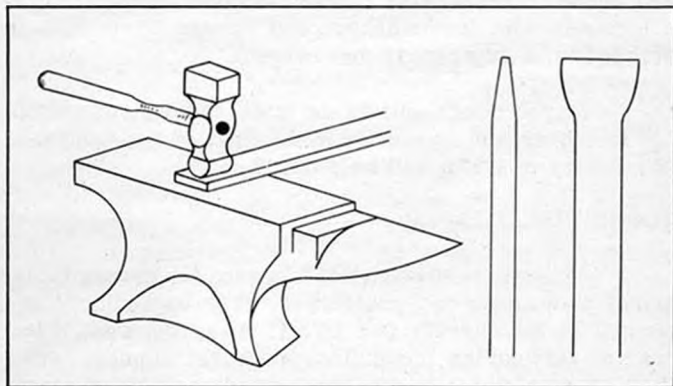
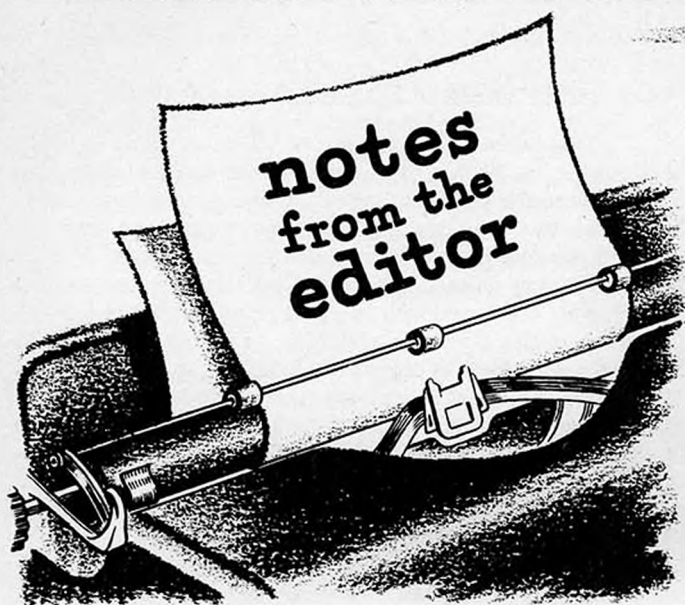


Fig. 10.

requires finishing with the face of the hammer or flatter.

Other forging operations will be considered in the next issue of THE ORDNANCE SERGEANT.



RUBBER 'ELIXIR'

Although this issue of THE ORDNANCE SERGEANT gives special attention to the Automotive vehicle, space has not permitted the discussion to progress as far as the tires, items which are causing a great deal of nation-wide comment since the present war began. While we are interested in the subject, as are all Americans, it is not our function to comment on the situation and its attendant problems in general.

One thought, though, is of interest and at the same time not surrounded by controversy. Rubber ages, as does all substance, including our own bodies, and seeking means for keeping rubber from getting old is almost as much a preoccupation of present-day chemists as was the quest for the elixir of youth among their alchemical ancestors. The newest effort along this line is represented in a process recently patented in which a coal-tar derivative, indene, plays the principal part.

Aging in rubber takes place primarily in its combining with oxygen in the air. This makes it stiff, deprives it of elasticity, and finally produces breakdown. To ward off this fatal oxidation, compounds known as anti-oxidants are added in processing rubber. Indene, in the form of compounds with formaldehyde and related chemicals, is claimed to be superior in this respect.

Maybe indene will do the trick, and dry rot and old age in rubber, and especially in the tires of our thousands of military vehicles, will be reduced.

TOUGH TUNGSTEN

Tungsten is so tough that it is used for cutting tools, armor plate, guns and projectiles. It is exceedingly important in the current war effort. Away out west, if you roamed through the mountains, you might stumble onto a little town which to all appearances could be a 'ghost town', but only because all the male inhabitants, and the ladies are in a noticeable minority, are down in the earth getting out tungsten.

It takes tough men to tunnel in tungsten, and getting the metal to a useful place is just as tough a job. This

Buy Bonds to Avoid Bondage

little town expects to produce one fourth of our requirements of tungsten, even though every ounce of it must be hauled by truck over an 80-mile mountain road. Last winter two men froze to death in the area, and as a rule the snow was four feet deep on the level, if you could find a level spot.

The workings, in addition to tungsten, produce antimony and cinnebar. And gold and silver are there, also, but these ordinarily precious metals aren't so important in war time. The toughies who tear at the tungsten say that there is enough ore blocked out to keep the trucks hauling ore until Landmark Summit is worn down to a button. And that's more than a mile high.

SMOKE vs. TANKS

We've heard quite a lot about anti-tank operations already, and we plan to hear more about this subject later. The Chemical Warfare Service, in a recent issue of its quarterly BULLETIN, tells of the effective use of smoke in combating tanks in the field.

During the Second Army Maneuvers in Arkansas and Louisiana last fall eight riflemen using smoke under the direction of chemical warfare officers delayed an entire motorized regiment for an hour and a half.

"Anti-tank units", the BULLETIN said, "have been quick to adopt smoke as a means of slowing up, to cause loss of direction, and to paralyze tank movement temporarily. Wherever desired, smoke can be lifted to provide a better target of approaching tanks, since they would be silhouetted against the smoke background."

Primarily, of course, this presents a problem for the men who man the tanks, but it may indicate an Ordnance problem as well.

INDIVIDUALISTS

The latest issue of the ADJUTANT GENERAL'S SCHOOL BULLETIN extracts the following inspiring remarks regarding the American soldier from TM 12-250, Administration — Company and Regiment.

"Personnel management includes the establishment and maintenance of discipline. The United States soldier is an individualist. He may be easily led, he is very hard to drive. He is usually young, healthy, accustomed to a great deal of personal liberty in thought and action, proud of his ability to take care of himself in any situation, and entirely willing to demonstrate that ability with his fists upon anybody, anywhere, at any time. He is convinced that, individually and collectively, he can 'lick any other soldier on earth.' He is constitutionally opposed to regimentation, but has an instinct for participation in those affairs which concern him. He is quick to resent inefficiency — yet will follow his leaders to the limit when convinced of their judgment and skill. He is by turns taciturn and gregarious. He is, in a word, a hundred and seventy-five pounds of mercurial and contradictory personality."

There's food for thought in them there words.