LUBRICATION
FUNDAMENTALS AND PRACTICES

Sessions I, II and III

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FOREWORD

This manual is one of a series of training manuals produced by the Armstrong Cork Company of Lancaster, Pennsylvania. The company has been kind enough to make this material available to the International Cooperation Administration for reproduction and use overseas in the industrial technical cooperation program.

Although this series of manuals was prepared for the specific use of the Armstrong Cork Company, the material contained therein can be readily adaptable to other industries.

APRIL 1957
INTRODUCTION

As the course in "Lubrication Fundamentals and Practice" consists of seven sessions, it is presented in two technical bulletins by the Training Materials Service of the Technical Aids Branch, Office of Industrial Resources, ICA/W. Technical Bulletin No. 43 contains material for Sessions I, II and III, and Technical Bulletin No. 44 contains material for Sessions IV, V, VI and VII.

Certain charts to which reference is made in the text have not been prepared and included in the text. It is suggested that these charts be prepared, or the leader, if he prefers, may write the information contained in the charts on the blackboard. Reference is made to the following charts:

SESSION I

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SESSION II

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GENERAL INSTRUCTIONS TO THE LEADER

This course, Lubrication Fundamentals and Practice, was developed by the Engineering Department and the Training Section of the General Personnel Department to help you, the man responsible for plant lubrication, train your employees.

The course consists of seven sessions, each session requiring 2 to 2-1/2 hours to present. The material starts with the basic principles of lubrication, covers the characteristics of various general types of lubricants and methods of applying them, and then covers in detail the lubrication of various kinds of equipment in the plant.

In order to make the most effective presentation of this material, the following suggestions are offered:

PREPARE FOR YOUR MEETING

Assemble all materials needed for each session....Have enough Review Questions for everyone....Familiarize yourself with the Leader's Guide so you can tell the story in your own words....Follow the organization of the Leader's Guide closely.

The motion picture film used in Session I can be borrowed from the Training Section, General Personnel Department, Lancaster....Only one copy is available, so make your arrangements as far in advance as possible and return the film promptly....When using the film, set up the projector and screen ahead of time....Check the focus and the volume and have everything ready to run before the meeting starts.

GIVE YOUR TALK

Tell the story in your own words....Follow the organization of the Leader's Guide closely....Turn to chart drawings as directed in the Guide....Allow ample time for questions and discussion as you go along to be sure your presentation is understood.

Introduce the motion picture by telling the group what they will see....Show the film....Discuss the film....A script of the film is included on yellow paper for the Leader's reference.

USE REVIEW QUESTIONS

Distribute the Review Questions, one copy to each man....Tell the members they can keep the questions in the cover provided for reference.....Allow 10 minutes to answer.

Discuss one question at a time....Have the group tell you the answer....Discuss the question with the group, then give the correct
Have each member correct his own paper and mark down correct answers. Have each member mark down one point for each incorrect answer. Pass around a sheet of paper for each member to write down his number of incorrect answers. If total group score is high, some key points were not understood. Review any subject that is not clear.

CLOSE THE MEETING

Announce the subject and the time and place for the next meeting.
CONTENTS

Principles of Lubrication — — — — — — — — Session I

Introduction, Importance, Lubrication Defined,
Friction, Oil Film Formation, Viscosity vs. Speed
and Load, Movie "Oil Films in Action"

Characteristics of Lubricants — — — — — — — — Session II

Refining, Specification of Oils, Types of Oils,
Specifications of Greases, Types of Greases,
Oil vs. Grease

Methods of Applying Lubricants — — — — — — — — Session III

Bottle Oiler, Wick-Feed Oiler, Drop-Feed Oiler, Ring
Oiler, Bath Oiler, Splash Oiling, Centralized Oiling
Systems, Grease Cups, Grease Fittings, Centralized
Grease Systems

Gears and Their Lubrication — — — — — — — — Session IV

Types of Gears, Contact between Gear Teeth, Film
Formation on Gear Teeth, Lubricants for Gears,
Care of Gears

General Bearings, Electric Motors and
Their Lubrication — — — — — — — — — — — — Session V

Types of Bearings, Oil Grooves, Care of Bearings,
Cost of Bearings, Lubrication of Bearings,
Electric Motor Lubrication

Lubrication of Plant Equipment — — — — — — — — Session VI

Turbines, Steam Cylinders, Air Compressors, Refrigeration Compressors, Chain Drives, Hydraulic Systems,
Cutting Oils

Lubrication Department Operation — — — — — — — — Session VII

Handling and Storage of Lubricants, Care of Lubrication
Equipment, Reclaiming Oils, Lubrication Schedules and
Records
We extend our thanks to the following organizations for permission to use materials from their literature as shown.

Session I
Plates B, C, D, E, F, G, J . . . . . . . . . . . . Shell Oil Company

Session II
Basic Lubricant Guide Card . . . . . . . . . . . . Power Magazine

Session III
Plates A, B, C, F, I . . . . . . . . . . . . . . . . Shell Oil Company
Plates D, H . . . . . . . . . . . . . . . . . . . . . . . © Sun Oil Company
Plate E . . . . . . . . . . . . . . . . . . . . . . . . . Manzel
Plate J . . . . . . . . . . . . . . . . . . . . . . . . . Stewart Warner Corporation
Plate K . . . . . . . . . . . . . . . . . . . . . . . . . The Dingle-Clark Company

Session IV
Plates A, B, C, D, E, H, I . . . . . . . . . . . . Socony-Vacuum Oil Company

Session V
Plates A, B, D . . . . . . . . . . . . . . . . . . . . Shell Oil Company
Plate I . . . . . . . . . . . . . . . . . . . . . . . . . © Socony-Vacuum Oil Company
Plates J, K . . . . . . . . . . . . . . . . . . . . . . . . Mill and Factory

Session VI
Plate B . . . . . . . . . . . . . . . . . . . . . . . . . The Terry Steam Turbine Co.
Plate D . . . . . . . . . . . . . . . . . . . . . . . . . Shell Oil Company
Plates E, G . . . . . . . . . . . . . . . . . . . . . . . . © Sun Oil Company
Plate H . . . . . . . . . . . . . . . . . . . . . . . . . Diamond Chain Company, Inc.
Plate K . . . . . . . . . . . . . . . . . . . . . . . . . The Texas Company

Session VII
Plate D . . . . . . . . . . . . . . . . . . . . . . . . . © American Machinist
Session I

PRINCIPLES OF LUBRICATION

* Materials needed for running this session are:

1. Leader's Guide, Session I
2. Chart Drawings A-X, Session I
3. Motion Picture "Oil Films in Action"
4. Review Questions and Covers
   (One set for each trainee.)

* All items in boxes are instructions to the leader, and are not to be read to the group.
INTRODUCTION TO LUBRICATION FUNDAMENTALS AND PRACTICE

This meeting is the first of a series of meetings and open discussions we will hold on the "Fundamentals and Practice of Lubrication." When I say open discussions, that is exactly what I mean. Feel free to interrupt and ask questions at any time. It is your privilege to insist that each point be covered to your satisfaction. If we can cover, in a general way, the facts about lubrication that are important to you as lubrication service men, then we will have accomplished a big step in the right direction.

These meetings and open discussions were requested by some of the men in Armstrong plants in their desire for more information about the "mysteries" of lubrication. I believe that now we can clear up many of these so-called "mysteries" and give a practical explanation for most of the things you have been curious about.

No doubt, some of the material will seem a little elementary to some of you. We can't ignore the fact that you fellows already know quite a bit about lubrication. However, we will cover the elementary phases as briefly as possible. For some of you it will be a review of what you already know. For others it will be new. The discussion will become more interesting and involved as we progress deeper into lubrication, and as you ask questions that lead us into detailed discussions.

Lubrication is as important to industry as any other phase of engineering, though it has been slighted and neglected until recent years. With this program we are recognizing that you men, who are responsible for the lubrication of millions of dollars worth of equipment, are the only ones who can prove lubrication's rightful place in our plant. This will be accomplished by your increased skill and knowledge in your lubrication job. Just as important, if not more so, will be your ability through your alertness and understanding to report malfunctions of equipment long before the equipment actually fails.

To give you some idea of what we will cover in these meetings, I'll run briefly through the schedule of subjects. The entire series consists of seven sessions.

Session I  covers Principles of Lubrication
Session II  covers Characteristics of Lubricants
Session III covers Methods of Applying Lubricants
Session IV  covers Gears and Their Lubrication
Session V  covers General Bearings, Electric Motors and Their Lubrication
Session VI  covers Lubrication of Plant Equipment, such as Turbines and Compressors
Session VII covers Lubrication Department Operation
In our discussions on these subjects we'll use movies, samples of oils and greases, and large easel charts to illustrate the various kinds of equipment we lubricate.

At the end of each session you will be given a set of review questions to answer. But remember, I said these were discussion meetings and not classroom sessions. So after you have answered the review questions and we have discussed them, you may keep them.

Now, let's start with Session No. I, Principles of Lubrication.
PRINCIPLES OF LUBRICATION

IMPORTANCE OF LUBRICATION

Someone once said that lubrication can be considered as vital a part of a machine as any of the working parts. He was certainly right. Of course the various bearings, gears, and cams which make up any machine today must be carefully designed and precision made of the best materials to meet the demands of modern high-speed production. But without proper lubrication, these same working parts would soon develop rapid wear and eventual failure. Then the machine would be useless as a production tool.

The Armstrong Cork Company has long been aware of the importance of lubrication to the efficient operation of the millions of dollars worth of machinery and equipment in our plants. All of us in the plant have an important part to play in an effective lubrication program. The foreman and machine operator can be sure of "getting out the goods" only if the lubrication service man has properly lubricated the machine. In turn, the lubrication service man can lubricate his machines properly only if the engineer has properly designed the machine and specified the right lubricant for it. And in turn, the maintenance mechanic depends upon proper lubrication to keep the machines running and to keep his work load at a minimum. It's a program in which all of us have an important part to play.

EARLY USE OF PETROLEUM

Lubrication as we know it today had its beginning many years ago. Contrary to what most of us have believed, petroleum did not make its first appearance when Drake's historic oil well was developed in Pennsylvania in 1859. Early records indicate that petroleum products were used by the Egyptians as early as 5000 years before Christ.

Coal oil for use in lamps was distilled from coal in 1832. This product sold for $2.00 a gallon in New York City at that time. It was this high price that led Drake to search for oil bearing lands and the drilling of that historic oil well in Pennsylvania years ago.

Since then, petroleum has played an important part in revolutionizing our way of life by making possible the beginning of the industrial age. Without petroleum and modern refining methods we would not have electricity and all its conveniences: radio, television, refrigeration, and electric illumination; we wouldn't have modern transportation or modern clothing, or so many other necessities of life. In fact, if it wasn't for petroleum we would still be back in the days of the horse and buggy.
FUNDAMENTALS OF LUBRICATION

We have reviewed briefly the importance of oils or lubricants to industry, and a brief history of the development of petroleum. Now let's get down to the basic principle underlying lubrication. Here is a good point to remember. Fundamentally, lubrication is the reduction of friction to a minimum by replacing solid friction with fluid friction.

Friction - Logically our next question is, what is friction? Friction can be defined as the resistance to movement between any two surfaces in contact with each other.

Man has known friction since time began. When he rubbed two dry sticks together to produce fire, he used friction. This was desirable friction, the same kind of friction that keeps our feet from slipping around when we walk. When this same kind of friction occurs in our industrial machinery, it is not so desirable. It destroys the effectiveness of the equipment through wear, heat, and shortened life. This is the friction we seek to overcome in lubrication.

The ancients found that it required considerable effort to push or drag a heavy stone along the ground as you see in Figure 1. They found that it was much easier to roll the stone as shown in Figure 2.
Man later discovered that a log, almost impossible to slide as in Figure 3, was easily rolled as in Figure 4, and when it was placed in the river, as you see in Figure 5, moving it was child's play by comparison. With the log in the river, we see fluid friction in action for the first time. The fact that the log is floating in the water is not the key point. When the water comes between the log and the bottom of the river, the only force resisting the movement of the log is the resistance of one particle of water sliding over another. This is much less than the resistance encountered when the log was sliding in direct contact with the ground.

There are examples of man's early struggles with friction in one form or another. Out of the early struggles, through long years of scientific study, have come the present day concepts of friction and lubrication.
MODERN CONCEPTS OF FRICTION

Friction, as we know it today, can be classified into two types; solid friction which may be either sliding or rolling, and fluid friction.

Turn to Chart D
"Solid Friction"

These are the types of the solid friction which we have just been discussing, and which must be overcome with lubrication. They are examples of where we will find sliding and rolling friction. In both examples shown on the chart, remember that sliding and rolling friction occurs when there is no lubrication.

Sliding Friction, shown in Figure 6, occurs when two surfaces slide over each other without lubrication as in a plain bearing or between a piston and a cylinder.

Rolling Friction, shown in Figure 7, exists when a cylindrical or spherical body rolls over another surface without lubrication as in the modern ball and roller bearings. We need less force to overcome rolling friction than sliding friction. However, when no lubrication is present, we can expect the same wear, heat and eventual seizure of the contact surfaces in both instances, but to a lesser degree in the case of rolling friction.

It's interesting to see what the highly polished surfaces of these bearings look like under the microscope.

Turn to Chart E
"Magnified Bearing Surfaces"

In Solid Friction, two metal surfaces, even if highly polished, will be seen under the microscope to be made up of hills and valleys, as in Figure 8. If these two metal surfaces slide over each other in a dry state without lubrication, these hills and valleys tend to interlock and grab. This causes wear, development of high heat, "welding," and eventual seizure. The result is complete failure of the bearing or other machine parts. Remember that solid friction occurs when there is no lubrication.
Now, to compare Fluid Friction with solid friction, if we introduce a film of oil under pressure between the same two surfaces we have been talking about, the hills and valleys are filled up by the particles of oil. When a sufficient number of these particles of oil are placed between the two surfaces to produce a thick strong film, then the hills and valleys slide by each other without interlocking, as shown in Figure 9.

When such surfaces, either flat, curved or spherical, are kept apart by a fluid film, we have what we call fluid friction, and these surfaces are lubricated. In Figure 10 you see Figure 9 magnified still further. Figure 10 shows five "layers" of oil between the two bearing surfaces. By showing the oil in layers we can illustrate what happens when these bearing surfaces slide across each other.

The layer of oil shown as "1" clings to the top bearing surface and moves with it.

The layer of oil shown as "5" clings to the bottom bearing surface and moves with it.

The layers of oil shown as "2," "3," and "4" slide in between layers "1" and "5."

As an example, let's move the top bearing surface about 4 inches to the right and see how the layers of oil move. If the top bearing surface moves 4 inches to the right, then oil layer "1" will move approximately the same. Oil layer "2" will move about 3 inches; oil layer "3" will move only 2 inches; and oil layer "4" will move only 1 inch to the right. Oil layer "5" clinging to the lower bearing surface will not move at all.

When these "layers" of oil slide over one another, the only friction that occurs is between the oil particles themselves. The particles of oil have less resistance to sliding over one another than do solid surfaces. Therefore, in lubrication we actually reduce friction to a minimum by substituting fluid friction for solid friction.
THEORY OF OIL FILM FORMATION

We now have defined lubrication in terms of friction. Next, let's see what happens when we actually introduce a film of oil into a plain journal bearing.

In Figure 11 you can see a journal at rest. When the journal is at rest, the oil film between it and the bearing is squeezed out at the bottom and the load is carried on the metal surfaces at the point of contact "A."

As the journal starts to rotate, in Figure 12, it climbs up the bearing surface in a direction opposite to rotation. The layer of oil next to the slowly revolving journal clings to the journal and rotates with it. This layer of oil is dragged into the converging space between the journal and the bearing, and begins to form a tiny film of oil at point "B."

The journal rotates with a thin film of oil until sufficient oil has been dragged into the converging space between journal and bearing to separate the surfaces further, as shown in Figure 13.

Notice that here we have an action similar to the action of the layers of oil between the two flat bearing surfaces shown on the last chart. The oil next to the journal clings to the journal and rotates when the journal rotates. The oil next to the bearing clings to the bearing and remains stationary. The layers of oil in the center slide between these two outside layers; the oil closest to the journal moves the most while the oil closest to the bearing moves the least.

As speed increases, the wedging action of the lubricant moves in the direction of rotation and becomes stronger, lifting the journal into the position shown in Figure 14. Then, as we see in Figure 14, the journal is riding on a film of oil and lubrication is functioning perfectly.

Let's run through this again so we can have a good idea how the oil film is formed.
When the bearing is riding on a full film of oil, the hills and valleys on the two surfaces are completely separated and all of the solid friction is gone, replaced by fluid friction.

In describing this build-up of a film of oil in a plain journal bearing, we have illustrated the "oil-wedge" theory of lubrication. The term "oil-wedge" is used because of the shape of the oil film. The oil next to the revolving journal forms the point of the oil wedge and pulls the adjacent layers of oil into the wedge-shaped clearance between journal and bearing. This "oil-wedge" theory is widely accepted today as the basic principle of film formation in plain journal bearings.

You can see in Figure 14 that the journal is not running in the center, and the oil film that surrounds the journal is not uniform in thickness. The point where the film is thin is known as the "high-pressure area," and is shown as "C" on the chart. On top where the film is thickest we have the "low-pressure area." Oil that is introduced into this "low-pressure area" is carried around with the shaft, is forced into a thin-film at the "high-pressure area," and has a lifting effect to support the journal in the position you see in Figure 14. The oil should always be introduced into a bearing in the "low-pressure area," and not into the "high-pressure area."

Now we'll stop for a moment and see if someone can describe this oil wedge action in a journal bearing.

Have the group tell you how the oil wedge builds up the oil film. Be sure the group understands this part.

However, an ideal oil film is what we are after in every lubrication job. What is an ideal oil film, and how does it govern good or poor lubrication in a bearing?

An ideal oil film is a film of oil with sufficient body to keep the two metal surfaces separated under the speeds and loads imposed on the bearing. However, the oil must not be so heavy-bodied that the internal friction from the oil itself causes excessive heating and wasted power.

The most important single factor that determines the effectiveness of the oil film is the viscosity of the oil. Let's look at viscosity, and then see how viscosity, speed, and load affect the oil film.
Viscosity is a measure of the oil's resistance to flow. This chart illustrates the action of high and low viscosity oils. For instance, water which flows freely is considered as having a low viscosity, while molasses which flows sluggishly has a high viscosity. So thin oil which flows like water is a low viscosity oil.

An ideal oil film on a bearing depends upon selecting an oil with the right viscosity to allow the "oil-wedge" action to raise the journal sufficiently off the bearing to maintain separation of the two metal surfaces.

The Speed of the Journal and viscosity are closely allied in maintaining a good oil film in the bearing. The slower the journal speed, the higher viscosity or thicker oil we must use. As journal speeds are increased, a thinner or lower viscosity oil is needed.

For the sake of clarity, let's look at Figure 15. Low speed bearings usually have relatively wide clearances between the bearing and the journal. Therefore, a heavy or high-viscosity oil is used. High speed bearings usually have closer fitting parts. Therefore, a thin or low-viscosity oil is required.

Now, let's look at bearing loads and viscosity.
Bearing Loads must also be considered because the oil must have sufficient viscosity or body to maintain a good oil film to support the load. On Figure 16 we can see the effect of using the same oil under different loads. The 500-lb. load squeezes the oil but the viscosity of the oil is enough to keep the bearing surfaces apart. When a 1000-lb. load is applied to the same oil, the squeezing action on the oil is greater. Therefore, it is reasonable to assume the oil film will be thinner under the heavier load. If we want to maintain a proper oil film under the 1000-lb. load, we must use a heavier oil. The surfaces must be held far enough apart to keep those hills and valleys on the surface from interlocking. At the same time, the oil must not be so heavy that heat is produced from the internal friction of the oil itself.

A little later on we will discuss viscosity more thoroughly. In the meantime, this brief discussion will help you get more out of the motion picture which follows. Before we start the motion picture, we'll take time to discuss any questions you might have about what we've covered so far today.

NOTE: The motion picture, the title of which is "Oil Films in Action", mentioned in the paragraph above is an 18 minute, 16mm, color, sound film.

This film is available on a loan basis from the Film Loan Library on request to the Technical Aids Branch.

The film may also be purchased (cost - $105.00) from the General Motors Corporation Film Library, General Motors Building, 3044 West Grand Boulevard, Detroit 2, Michigan.
The motion picture you are about to see is called "Oil Films in Action." It demonstrates very clearly what we have been saying here about oil films. Make notes of any points covered in the picture that are not clear to you, and we will discuss them as soon as the picture is through.

This movie will show us these four main points:

1. The effect of bearing loads on the oil film.
2. The effect of speed on the oil film.
3. The effect of viscosity on the oil film.
4. How oil-film pressure is built up.

Watch for these four points when the film is run to see how many of the four you can remember.

Show the movie "Oil Films in Action"

Discuss the following questions.

Now, who can tell me how oil-film pressure is built up?

Who can tell me the effect bearing loads have on the oil film?

What effect does speed have on the oil film?

What is the effect of a change in viscosity on the oil film?

Now, we have reviewed what happens when oil is placed between two bearing surfaces to replace solid friction with fluid friction. This is what we call "lubrication." Let's see how we do on the review questions. Remember, after you answer the questions, we will discuss the answers, and then you may keep the questions for your own reference in the cover we have provided.

Give each man a set of Review Questions.
Allow 10 minutes to answer.

Then discussing one question at a time, have the group tell you the answer. Discuss the question, then give the correct answer.
Have each man correct his own paper as you go along. Have each man mark down one point for each incorrect answer. Pass around a sheet of blank paper for each man to record his own score. A high total score for the group means some key points were not clearly understood.

Before we go further into lubrication of bearings, we will take a look at oil itself, where it comes from, how it is refined, and what characteristics it might have. That's our subject for next time.
"This model was built to demonstrate some fundamental facts about journal bearing lubrication. This is the bearing—this is the journal—and this is an indicator for indicating the coefficient of friction.

The bearing is loaded by the means of a weight which is placed on the platform suspended from the bearing. We lubricate the bearing by means of a device called an oil bath. The oil used in this demonstration has been dyed red so as to make it more easily seen. An interesting fact about the oil bath is that the level of the oil in the bath is of no consequence so long as the journal touches the oil. When the rotating journal touches the oil, it picks up a film of oil and carries it up into the bearing.

When rotation starts, the coefficient of friction is quite high but as soon as the journal has made about half a turn so that it has dragged the complete film of oil into the bearing, the coefficient of friction immediately falls off to a very low value and the bearing oscillates freely about the journal. If we were to wait long enough for the oscillations to damp out, we would see that the running friction coefficient is very close to zero.

We have placed a small pin in a hole which is drilled through the bearing and which communicates with the oil film. This pin is essentially a piston which will move in response to any unbalanced pressure acting upon it.

Here is a close up of this operation. Notice that the pin is ejected from the hole and that oil then flows out over the top of the bearing. This demonstrates what is perhaps the most important single fact about journal bearing lubrication. The oil film in the bearing is under pressure. Sufficient pressure in this case to eject the pin and pump oil over the top of the bearing. It is this pressure that counterbalances the squeezing effect of the applied load that keeps the bearing and journal surfaces from touching.

Because the oil film separates the bearing and journal surfaces, contact and wear are prevented and, most important of all, fluid film friction is substituted for solid friction resulting in an important reduction in the running coefficient of friction of the bearing.

We could let the oil continue to flow out of the bearing until the level of the oil bath was lowered so much that the journal could no longer touch it, but there is little to be gained by this. So, we shall wipe off the top of the bearing and insert a small tapered pin which cannot be forced out so easily by the oil film pressure. When we start rotation of the journal, we see again that the starting friction is high but the running friction immediately drops to a low value indicating that the high pressure oil film has been established.
"This brings us to the important question—DOES THE PRESSURE VARY IN THE OIL FILM? In order that we may study the variation in oil film pressure, we have substituted a lucite bearing for the aluminum bearing used in the previous demonstration. The holes drilled through the bearing serve as pressure gages.

"Viewing the bearing from the circumferential plane, we see that the pressure builds up from zero on the incoming side at the left to a peak which is slightly to the right of the center line and then falls off sharply until on the outgoing side, as we shall see, it becomes negative.

"Here we see the oil film pressure in the axial direction. The pressure profile is approximately parabolic. It is a maximum in the center and falls off to zero or atmospheric at either edge where leakage takes place.

"We mentioned a moment ago that there is negative pressure on the outgoing side of the bearing. Here is evidence of this negative pressure which is caused by the divergence of the oil film. The oil film is unable to sustain a tensile stress and so it ruptures producing the cavitation which we see here.

EFFECT OF BEARING LOADS ON FILM PRESSURE

"Let us examine the effect of changes in load on the oil film pressure. When we remove the load, the pressure of the oil film diminishes. When we replace the load, we shall see that the pressure increases. In each case, the oil film pressure is directly proportional to the load on the bearing. Here is the bearing with the load on. The pressure is high. Remove the load and the pressure drops to a lower value. Replace the load and the pressure again increases. In every instance, the pressure adjusts to changes in loads. So whatever the load may be, there is sufficient pressure to support the load.

EFFECT OF SPEED ON FILM PRESSURE

"Here we examine the effect of changes in journal speed on the oil film pressure. We reduce the speed to about one-half its former value and observe that no changes are produced in the oil film pressure. The total pressure remains fixed while the shape of the pressure profile changes to such a small extent in this case, as to be imperceptible. Here the journal is turning slowly. Increasing the journal speed, we again see that there is no change in the oil film pressure.

EFFECT OF VISCOOSITY ON FILM PRESSURE

"To examine the effective changes in viscosity on the pressure of the oil film, we have prepared two oils of different viscosity. The falling ball demonstration shows that the blue oil is much less viscous than the red oil. How will these oils affect the oil film pressure?
"While the bearing is running on the red oil, notice the characteristic pressure profiles in the circumferential and axial planes. Now let us compare these pressure profiles with those which we shall get when we run the bearing under the same conditions of load and speed but using the blue oil, the less viscous oil. Running the bearing on the blue oil, we see that the pressure profiles in the circumferential and axial planes are essentially the same as they were when the bearing was run on the red oil. The total pressure is the same and the shape of the pressure profile has changed only slightly. We may conclude then that the oil film pressure is substantially independent of lubricant viscosity.

"Summarizing briefly, we have found that the bearing and journal surfaces are separated by a pressurized oil film. That the pressure of this oil film is proportional to the load on the bearing and that it is independent of journal speed and lubricant viscosity.

HOW THE PRESSURE IS BUILT UP

"We are now ready to turn our attention to a question of considerable importance. It is, HOW IS THE PRESSURE BUILT UP IN THE OIL FILM? In order that we may demonstrate the mechanism of pressure development in the oil film, we shall use a different kind of bearing—a tilting pad bearing. This is the bearing and it is loaded by means of these weights. The load is applied through the knife edge pivot. On the two ends of the bearing are dial indicators which are used to indicate the thickness of the oil film.

"When rotation of the turntable is started, notice that pressure is built up in the oil film. The pressure profile is very similar to that which we obtained in the case of the journal bearing. This is not surprising for a journal bearing is essentially a tilting pad bearing which is wrapped around a journal.

"Let us examine the effect of changes in load on the pressure produced in the tilting pad bearing. Remove one of the load weights and the pressure diminishes. Remove the other load weight and the pressure falls still lower, nearly to zero. Returning the first weight we see that the pressure build back up and returning the second weight the pressure returns to its original value. The oil film pressure is again proportional to the applied load.

OIL FILM THICKNESS

"Let us consider the oil film thickness. The thickness of the oil film at the leading and trailing edges is shown by the dial indicator. If rotation of the turntable is stopped, the load will squeeze out the oil film so that the film thickness becomes the same on both ends.

"Starting rotation of the turntable again we see that the film thickness increases much faster on the leading edge than on the trailing edge. We have, therefore, a fluid wedge under the bearing and it is this fluid wedge that supports the bearing.
"Repeating the demonstration in close-up, we stop rotation of the turntable and permit the load to squeeze out the oil film. Of course, the tubes still appear to indicate pressure because the oil in them has been trapped. Starting rotation of the turntable we again see that the thickness of the oil film at the leading edge is much greater than that of the trailing edge, resulting in a wedge shaped oil film.

EFFECT OF LOADS ON FILM THICKNESS

"Let us examine now the effect of changes in load on the oil film thickness. Remove the load, and the oil film thickness increases. However, the ratio of the film thickness at the leading and trailing edges being a function of pivot location, does not change. Replace the load and the film thickness decreases again. The film thickness does not decrease directly as the load increases, however, because the film tends to act somewhat stiffer as the load on the bearing increases. The thickness of the oil on the trailing edge is, that we have seen, very small but it is not zero. A continuous film of oil passes under the bearing as may be demonstrated by wiping it away as it emerges from under the trailing edge of the bearing.

OIL FILM WHIRL

"The phenomenon which you see here is known as oil film whirl, a kind of cyclic failure of the oil film which is of considerable theoretical and practical interest at the present time. Notice that there periodically appears in the bearing a light spot where there is little or no oil film. Because there is little or no oil film at this light spot, there is an increase in rubbing friction at this spot. Whenever the light spot appears, the friction between the bearing and the journal increases with the result that the bearing grabs the journal and is jerked forward until the restoring moment overcomes the friction moment.

"Here is the whirl viewed from the top of the bearing. This is the same bearing, the same oil, the same speed, and the same load as we had before, but notice that the position of the load has been changed. This is significant. There are, as a matter of fact, two interesting observations which may be made about this particular kind of whirl. The first is that the whirl always occurs on the unloaded side of the bearing. The second is that the whirl rotates at approximately one-half journal speed.

"Here the bearing is not whirling and the load is separately supported under the bearing. Let us examine the effect of unloading one side of the bearing. When we move the load out to the extreme edge of the platform, the load is concentrated on the right edge and there is practically no load on the left edge. Notice that the whirl now commences at the unloaded left edge. This is characteristic of oil film whirl, which is a form of film failure, for we usually associate oil film failure with very heavy loads rather than with very light loads.
"The second interesting fact about oil film whirl is that the whirl rotates not at journal speed but at one-half journal speed. A button has been placed on the front of the journal so that we can compare the journal speed with the whirl speed. Notice that the journal makes two revolutions for each revolution of the whirl. The explanation is simply that the whirl rotates at the average speed of the oil film. The speed of the oil film adjacent to the bearing is zero. While the speed of the oil film adjacent to the journal is journal speed. The average speed of the oil film and therefore of the whirl is then approximately one-half journal speed.

"Let us summarize what we have seen. Facts about hydro dynamic lubrication.

First, the bearing and journal are separated by a film of oil.

Second, the friction between bearing and journal is fluid film friction rather than solid friction.

Third, the pressure of the oil film is directly proportional to the load and it is this pressure that supports the load.

Fourth, the pressure of the oil film is independent of journal speed and lubricant viscosity.

Fifth, the pressure is built up by the flow of the oil film into the converging clearance space between journal and bearing.

Sixth, under certain conditions hydro dynamic lubrication may become unstable resulting in oil film whirl and other types of film breakdown."
Review Questions

Section I - Principles of Lubrication

(Directions: Check all of the correct answers to each. Of the following questions. Each question may have more than one correct answer.)

1. A minimum effort is required to move the log in the river because of
   a. ( ) solid friction
   b. ( ) fluid friction
   c. ( ) sliding friction
   d. ( ) lubrication

2. As the oil wedge is formed in a journal bearing, the rotating shaft
   a. ( ) centers itself in the bearing housing
   b. ( ) is lifted by the oil wedge
   c. ( ) seeks an equilibrium between load and wedge

3. Which arrow indicates the high pressure area of this rotating journal?
   a. ( )
   b. ( )
   c. ( )
   d. ( )

4. Is this statement true or false? A low viscosity oil will flow faster than a high viscosity oil at the same temperature.
   True ( )
   False ( )
5. Check your selection of high or low viscosity oil for each of the following speed and load conditions.

   High Load
   a. { } High Viscosity
   b. { } Low Viscosity

   High Speed
   a. { } High Viscosity
   b. { } Low Viscosity

   Low Speed
   a. { } High Viscosity
   b. { } Low Viscosity

6. Fundamentally, lubrication is the reduction of__________________ to a
   ____________________________ by replacing________________________ with ____________
   ____________________________.
Session II
CHARACTERISTICS OF LUBRICANTS

* ( ) 

Materials needed for running this session are:

1. Leader's Guide, Session II
2. Chart Drawings A-G, Session II
3. "Basic Lubricant Guide" cards
   (One card for each trainee.)
4. One set of oil and grease samples
5. A glass of water and wiping rag
6. Review Questions
   (One set for each trainee.)

* All items in boxes are instructions to the leader, and are not to be read to the group.
CHARACTERISTICS OF LUBRICANTS

The last time we met we talked about the "Principles of Lubrication" and how oil lubricates. Today, we will discuss where oil comes from, how it is refined, and how oils and greases are classified according to their individual characteristics. The logical place to start our discussion is at the oil well.

REFINING

We all know oil comes from the ground in the form of crude oil. There are many types of crude oil depending upon the location of the well. West Coast crude oils are different from Texas crudes. Texas crudes in turn are different from Pennsylvania crudes and from foreign oil fields. For our discussion, we will confine ourselves to general comments and not get too involved in chemical formulas which would be of no interest to any of us.

Refining crude oil is the process of separating the crude oil into different fractions or "cuts." We know these different fractions or "cuts" as naphthas, gasoline, kerosene, light and heavy oils, and residues. Each type of crude oil gives different amounts of each "cut." The type of refining can also be varied to give different amounts of each "cut."

We see here a diagram of a typical refinery which shows where the various "cuts" come off. The crude oil is introduced into the still from a pre-heater. As the still temperature rises, the lighter parts of the crude oil, that is the naphthas, boil and vaporize first and are taken off as shown. As the temperature rises still further, the other parts of the crude boil and vaporize and are taken off at different levels as indicated.

We are concerned only with the lubricating oils, so we will follow the cuts where most of the lubricants are taken off. The oil is sometimes run through a vacuum still to remove any light ends such as naphthas that may be left in it. Then it is sometimes run through an acid treatment to remove undesirable liquids from the oil and filtered or de-waxed—then to a compounding plant where it is finished by the producer's own patented methods by adding special compounds to improve some of its properties.

This is a very brief description of the refining process, but it should be enough for our purpose. It shows us how the lubricating oils are taken out of the crude oil, and some of them given further treatments for special uses.

Now let's take a look at the specifications of some of these lubricants and see how one differs from another.
Specifications, or physical properties of lubricants, are the characteristics by which lubricants are selected for various uses or applications. When we have summed up all the conditions under which a lubricant is to operate, then we can begin to select the lubricant that fits. However, there is no table of standards by which lubricants can be selected. The conditions overlap and make the selection of the proper lubricant a procedure which must be dealt with carefully.

We have listed a few of the major physical properties of lubricants on the chart. These are all important in our lubrication of plant equipment, some to a greater degree than others, depending upon the particular lubrication job to be done.

Lubricating Oils are selected according to physical properties. Some of these are:

- Viscosity @ 100°, 130°, 210°F.
- Flash Point
- Fire Point
- Pour Point
- Carbon Residue
- Gravity
- Color

And Other Qualities

Let's take a brief look at each specification to see exactly what it means.

**Viscosity** is the measurement of the rate of flow of an oil in seconds. Taking water and molasses as examples, a cubic inch of water flows through a pin hole much more rapidly than does a cubic inch of molasses. Now moving back to oil, let's take a cubic inch of low viscosity oil and let it run through the same hole. This low viscosity oil will run through the hole in a low number of seconds, say 50 seconds, whereas a high viscosity oil would require maybe 600 seconds to flow through the same hole. Then you see that the thin oil flowing through the hole in only 50 seconds is a low viscosity oil, and the heavy oil, requiring 600 seconds to flow through the hole is a high viscosity oil.
### LUBRICANT USES

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
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<tbody>
<tr>
<td>Steam-Boiler Circulating Systems</td>
<td>Steam Turbines</td>
<td>Electric Motors and Motor-Generator, G/F and G/F</td>
<td>High-Speed Chain, Belt Drive, G/F</td>
<td>Electric Motors and Motor-Generator, 200-1200</td>
<td>Gear and Pinion Type Pumps, 1200-12000</td>
<td>Direct-Connected Turbines, Governor Set (Governor System)</td>
<td>Wound-Field Alternators</td>
</tr>
<tr>
<td>I</td>
<td>J</td>
<td>K</td>
<td>L</td>
<td>M</td>
<td>N</td>
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<td>P</td>
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<tr>
<td>Gear and Pinion Type Pumps, 1200-12000</td>
<td>External Lubrication of Steam Engines and Steam Pumps</td>
<td>Flexible Couplings of the Fan, Blower, Chain and Jaw Type, 1200-12000</td>
<td>Flexible Couplings at the Fan, Blower, Chain and Jaw Type, 12000-12000</td>
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<td>Q</td>
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<td>X</td>
</tr>
<tr>
<td>Steam Turbines, Ring-Clined Bearings Without Cooling or Circulating System</td>
<td>Flexible Couplings of Gear, Flanges, Key and Flexible Flange Pumps, 0-700</td>
<td>Flexible Couplings, between 0-700 and 700</td>
<td>Flexible Couplings, between 700 and 7000</td>
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### BASIC LUBRICANT GUIDE

<table>
<thead>
<tr>
<th>SU Vacuum</th>
<th>Gear and Pinion Type Pumps, 1200-12000</th>
<th>Electric Motors and Motor-Generator, 200-1200</th>
<th>High-Speed Chain, Belt Drive, G/F</th>
</tr>
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<tbody>
<tr>
<td>10°F</td>
<td>20°F</td>
<td>30°F</td>
<td>40°F</td>
</tr>
<tr>
<td>A</td>
<td>B</td>
<td>C</td>
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<tr>
<td>E</td>
<td>F</td>
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*Letters A through H refer to machinery listed on reverse side.*

-24-
This procedure is not the exact test used to determine viscosity. The actual test requires the use of elaborate laboratory equipment. However, this procedure does illustrate how viscosity is measured.

The rate of flow of an oil through the test hole will vary with the temperature. Therefore, when the viscosity is said to be 50 seconds, the temperature must also be specified, say at 100°F. The three temperatures at which viscosities are measured are usually 100°, 130°, and 210°F. The viscosities are taken at different temperatures for each oil to give some idea of the oil's ability to withstand temperature changes. We call this ability to withstand temperature changes, viscosity index or V.I. A high V.I. means the oil withstands temperature changes very well and doesn't change viscosity as much as a low V.I. oil does. This viscosity index is no indication of the quality of the oil. It merely indicates what effect temperature changes have on the lubricant.

Now I'm going to pass out some pocket cards that show the relationship of viscosity to the SAE numbers and AGMA numbers.

Let's go over the card together. Turn to the side marked "Basic Lubricant Guide." The left hand column lists viscosities in seconds at 100°F, from 45 seconds to 1000 seconds. At the bottom of the same column we see viscosity listed at 210°F, from 175 seconds to 350 seconds.

Column two shows SAE engine grades from 10 to 70 grade. Let's take SAE 50 for example and see if we can determine its range of viscosity. If we draw a line across the top of the SAE 50 square, and another across the bottom of the SAE 50 square, the lines would cross the viscosity column at 650 seconds and 1100 seconds. Therefore, we see that oils with viscosities from 650 to 1100 seconds at 100°F, would fall approximately in the SAE 50 range.

Column three shows SAE transmission grades and column four shows AGMA numbers. These two columns can be compared with viscosity in the same way as column two.

Keep your cards available because we will be referring to the "Lubricant Uses" column and the back side of the card in a few minutes.

Do you have any questions about viscosity or anything else we've covered?
The **Flash Point** of an oil is that temperature at which the oil gives off enough vapors to be ignited in the presence of an open flame. At the flash point, the oil itself does not burn. Just the vapors flash, burn up, and then go out.

The **Fire Point** is the temperature at which the oil will continue to burn when subjected to the flash point test. This temperature is usually about 50°F higher than the flash point. Both the flash point and the fire point must be considered when a lubricant is selected for use under elevated temperatures. The lubricant must have a flash point higher than the anticipated temperature of operation.

The **Pour Point** of a lubricant is the lowest temperature at which the lubricant will actually flow. This characteristic is of prime importance when we are selecting a lubricant for below freezing temperature such as in a refrigeration compressor. Refrigeration compressor oils operate in a normal range of temperatures from 25°F to 35°F below zero F. However, there are lubricants available for systems operating 50°F to 75°F below zero F. These are usually special oils to which has been added what we call a "pour depressant" which imparts a low-pour-point quality to the oil.

The **Carbon Residue** is a measure of the amount of carbon or residue which remains after a given amount of the product has been burned. Oils with a low carbon residue are more desirable as lubricants than oils with high carbon residue.

**Gravity** is the relation of the product's weight to water. The gravity of an oil does not indicate in any way its quality as a lubricant. It is used primarily for the calculation of volumes of oil, and isn't of much use to us now, though it is a definite physical property.

The **Color** of the oil is no indication of quality. It is controlled by the refiner to maintain a stable color as a trademark for each type of oil.

Other qualities can be given to the oils, and the aforementioned characteristics can be improved, through the use of additives. We can define "additives" as being the materials not originally present in the crude oil, which are combined with straight mineral oils during refining to improve the performance of the oil. Additives, in addition to giving the oil certain desired properties,
may also give the oil undesired properties if used in a service not intended by the oil manufacturer. The types of additives include:

1. Fatty oils cause the oil to emulsify or mix well with water, thereby improving lubrication under wet conditions.

2. Oxidation inhibitors prevent sludge or varnish formation and bearing corrosion.

3. Detergents keep engine surfaces clean.

4. Extreme pressure agents give the oils a higher film strength which in turn supports higher loads and extreme pressures. E.P. agents prevent scuffing or high rate of wear through their ability to cool rapidly.

5. Rust preventives prevent rust by coating the metal surface with a tenacious film.

6. And other additives may give the oil anti-foam quality, or other properties.

Are these physical properties of oils all clear to you?

{ Answer any questions. }

Now let's see how lubricating oils fit these specifications.
TYPES OF LUBRICATING OILS

Each major oil company will have in its line of oils more than 300 different industrial and automotive types. For simplicity we have listed eleven classifications on the chart which include practically all of these 300 different types.

Turn to Chart C
"Types of Lubricating Oils"

The eleven classifications we have listed are:

- Spindle Oils
- Gear Oils
- General Bearing Oils
- Electric Motor Oils
- Steam Cylinder Oils
- Turbine Oils
- Air Compressor Oils
- Refrigeration Compressor Oils
- Hydraulic Oils
- Cutting Oils
- Automotive Oils

Each type of oil listed has certain characteristics about it that make it well adapted for the application where it will be used. We won't be able to discuss them all or we would be here for hours. So let's pick out a few and see how they fit the specifications.

Turn to Chart D
"Specifications of Typical Oils"

Select two samples from the rack.
1. Spindle Oil
2. Gear Oil

The Spindle Oil I have here is an example of a very low viscosity oil, having a viscosity of around 50 seconds at 100°F. This other sample has a very high viscosity and is approximately the highest viscosity oil represented here in our samples. It is heavy Gear Oil with a viscosity around 1500 seconds at 100°F. Within these limits of 50 to 1500 seconds at 100°F, these other oils will fall.

2-19-52 -28-
Turn to the back of your card and locate Spindle Oils and Gear Oils. I think you'll find Spindle Oils under "A", "B", or "C", and Gear Oils under "F" and "R". Now turn to the front of the card and locate "A", "B", and "C" in the right-hand column. We can draw horizontal lines from "A", "B", and "C" across to the viscosity column. This will tell us what a good viscosity for Spindle Oils would be. It looks to me as if "A", high speed spindles, needs a viscosity of around 45-60 seconds. Do you get the same reading?

Let's look at Spindle Oil and see what kind of lubricant we have.

Spindle Oil got its name from its use on spindles—those small rotating shafts on upright drills which have high-speed and low-load characteristics. This viscosity of around 50 seconds is lighter than your SAE 10 automobile oil. The viscosity is the most important specification for this type of oil. Temperatures are seldom high enough to make flash or fire points critical, nor low enough to make the pour point an important consideration.

Gear Oil differs in color from the spindle oil, as you can see from these samples. But remember, color is no indication of the quality of an oil. Gear oils are usually of a heavier grade because of the rubbing action of the gear teeth and high pressures on the teeth. The 1500-second viscosity I mentioned before applies only to this sample. Gear oil viscosity usually ranges from 60 seconds to over 150 seconds, at 210°F.

The gear oil should have anti-foam characteristics to prevent foaming that may be caused by the gears churning the oil, or if a spray system is used which tends to cause foaming. Remember this anti-foam characteristic is given to the oil by the refiner through the use of additives in the oil.

Flash, fire, and pour points must be considered in gear oils if temperatures will be encountered that make these points critical.

These two oils, Spindle Oil and Gear Oil, are at opposite ends of the viscosity range displayed here, one high viscosity and one low. In between these two fall the rest of the oils on the list. Let's look at four more; Turbine Oils, two types of Compressor Oils, and General Bearing Oils.

The Turbine Oil is one of the highest refined oils that we use. It is essential that these oils be controlled to very close tolerances in their physical properties because of the conditions under which they must be used.

The viscosity needed in a turbine oil depends to a large extent upon how the turbine is used. This viscosity may be as low as 150 seconds at 100°F., or as high as 500 seconds. See blocks "F", "J", and "M" on your card.

Turbine oils must be heat-resistant and rust-resistant. They must have water-resistant properties and be foam-resistant. The
flash and fire points are more important than the pour point, for operating temperatures are usually high. Color in a turbine oil is no indication of quality, as we mentioned before.

Air Compressor Oils must lubricate under very difficult conditions. Under these conditions the oil comes in contact with air under elevated temperatures and high pressures which tends to cause oxidation of the oil. Flash and fire points must be high enough to guard against possible fires. Safe flash and fire points would be around 400° and 160° respectively for systems handling up to 150 psi.

Viscosities of air compressor oils will range between 300 and 500 seconds at 100°F. These air compressor oils must have low carbon residue also. The elevated temperature under which they are used makes the formation of carbon easy, unless the oil has a low carbon-residue characteristic.

Refrigeration Compressor Oils are usually straight mineral oils that have much the same characteristics as air compressor oils. However, flash and fire points are not so critical, and pour point becomes very important because of the low temperatures of operation. Oftentimes a "pour depressant" is used by the refiner to lower the pour point of his refrigeration oils. Viscosities range from 200 to 300 seconds at 100°F.

General Bearing Oils are usually of secondary quality as most of the time they are used in "once through" systems, that is, they go through the bearing once, and are wasted. These general bearing oils are not usually recommended for use in circulating systems because they don't have the ability to stand up under extended circulation and use.

Viscosity is very important in general bearing oils. Speeds, loads, and temperatures must be considered when you are making a viscosity selection. Viscosity may be from 300 to 1000 seconds at 100°F. High loading and extreme temperatures are usually not encountered. Therefore, flash and fire points are usually not critical.

We have only covered 6 of these classifications of oils, but that should be enough to make us realize that the old saying, "Oil is oil," is not exactly true. There are many different kinds of oils. I don't mean different oil companies like Standard, Shell, and Texaco. I mean different types of oils—an oil to fit every different kind of service and condition.

In a later session we will discuss each type of oil in detail as it fits the major types of equipment to be lubricated. Now, let's look at specifications of greases.
LUBRICATING GREASES

Our previous discussion was confined to types of lubricating oils. There is another class of lubricants which hold just as important a place in industrial lubrication as do oils. These are the greases.

A lubricating grease is usually a mineral oil to which has been added a special soap compound to produce a plastic mixture, suitable for lubricating some types of machinery. The special soap compound acts to carry the lubricant into the bearing surface and hold it there where it will do the most good.

Turn to Chart E
"Specifications of Lubricating Greases"

Lubricating greases are selected according to their physical properties in much the same way as oils. Some of these properties are:

Penetration Number
Dropping Point
Soap Base

The Penetration Number is the measure of the consistency of the grease. The penetration number of a grease is obtained by dropping a pointed object into the grease to see how far it will penetrate. For example, compare a grease that is soft like mayonnaise with a grease that is hard like butter fresh from the refrigerator. The grease that is soft like mayonnaise has a high penetration number, whereas the grease that is hard like butter has a lower penetration number. It's easy to see that when a pointed object is dropped into a soft grease it will penetrate a lot farther than when dropped into a hard grease.

The important point to remember about penetration number is that it indicates the consistency of a grease. For lubricating a plain bearing that has small clearances, a grease with a soft consistency or a high penetration number is usually recommended. A high penetration number indicates the grease is a soft grease and will have good flow characteristics and will thoroughly coat the bearing surfaces in spite of the small clearances.

The Dropping Point of a grease, sometimes referred to as Melting Point, is the temperature at which the grease melts and actually drips from
a sample being tested. This dropping point must be compared with anticipated operating temperatures when we are selecting a grease for a specific application. For example, if the operating temperature of a bearing is 220°F, we must use a grease with a dropping point above 220°F. So the grease will not melt and run out of the bearing during operation. Some greases have a tendency to separate at these elevated temperatures.

Are there any questions about Penetration Number or Dropping Point?

{ Answer all questions. }

Now let’s see what the Soap Base used in a grease means to us.

The Soap Base used in the manufacture of a grease is of interest so that we can select the proper grease for high and low temperatures, wet and dry conditions, or combinations of these.
TYPES OF GREASES

Greases are usually classified by the soap compound used in their manufacture. The properties of the grease are influenced considerably by the type of soap compound used in making the grease.

Turn to Chart F
"Types of Lubricating Greases"

We have listed on the chart a breakdown of greases according to their base. These are:

- Calcium-Lime-Base Greases
- Soda-Base Greases
- Bentonite-Base Greases
- Barium-Base Greases
- Lithium-Base Greases
- Silicone Greases

A Calcium or Lime-Base used in the grease will give the grease a smooth buttery appearance. These calcium- or lime-base greases are highly resistant to water. If we were to take a sample of this grease in the palm of our hand and try to mix water in with it, we would find that the grease and water would not mix. For this reason calcium- and lime-base greases find many uses where water is present.

Calcium- and lime-base greases, however, will not stand high temperatures, say above 225°F. They tend to break down if heated beyond this point and will not return to their original state when cooled. The soap base remains separated from the oil. This separation is very harmful to bearing surfaces. The separated soap particles become hard and very abrasive. Many instances of scored bearings and journals can be traced to the abrasive action of these soap particles, resulting from the use of calcium- and lime-base greases where temperatures are too high.

Place a small sample of the lime-base grease in the palm of one hand. Add a small amount of water and try to mix the grease and water together. Show the group how the water runs off and does not mix.

I will pass this jar of calcium-lime base grease around so you can take a sample between your thumb and forefinger and feel its smooth buttery texture.
Soda-base greases, on the other hand, can be used where temperatures are higher. They are good at temperatures up to 375°F, without danger of separation of oil from the base.

These soda-base greases are usually fibrous in texture. If we were to place a small bit of the grease between the fingers and pull the fingers apart, the grease would appear to stretch into stringy fibers between the two fingers. Actually no fibers are used in the grease. This is merely the way the grease is compounded—as if it were mixed with threads or fibers. This fibrous nature of soda-base greases makes them capable of withstanding heavy bearing loads and they are ideal for use on mills and calenders, and similar heavy machinery, and on ball and roller bearings.

Soda-base greases have one disadvantage—they are more or less soluble in water and should not be used where water conditions exist. If we were to take a sample of a soda-base grease in the palm of one hand and try to mix water with it, we would see that it turns into a milky mixture and becomes unfit for use as a lubricant.

Special High-Temperature Greases have been developed for use where temperatures are even higher than 350°F. Examples of these are the Bentonite Greases, the Barium and Lithium Base Greases as well as the more recently developed Silicone Greases.
Bentonite-base greases have a base commonly made from bentonite, which is nothing more than plain Missouri clay. They have an unusually high melting point—the actual temperature limit is open to argument. However, bentonite greases are good lubricants for high-temperature use where soda-base greases are not satisfactory. These bentonite greases are more expensive than the conventional lower-temperature greases, but they last much longer. They are good for lubricating spots that are hard to reach. When using them, we do not need to lubricate so often.

Barium-base greases are good up to 450° and above. Lithium-base greases are good up to 380° and above. Their long life makes them well suited to lubrication in inaccessible locations. Lithium is also suitable for low-temperature lubrication.

Silicone greases are synthetic greases which are relatively new to lubrication. They are said to have longer life, good stability, and heat resistant properties different from the conventional types of greases. Their longer life is probably their most outstanding property. They are very expensive, the cost ranging in the neighborhood of five or six dollars per pound.

Extreme Pressure Greases — Greases have been developed which will maintain an adequate lubricating film under severe operating conditions. These greases are called "extreme pressure greases," or more commonly "E.P. greases." E.P. greases are the oil industry's answer to the increased speeds and heavy loads being exerted on bearings as a result of modern production demands. You will no doubt agree that our plants are no exceptions to this modern demand of "more and more speeds for greater output of goods."

In general terms, extreme pressure greases are greases to which have been added a lead-soap compound or other additive of the E.P. type to improve the load carrying capacity of grease.

E.P. greases are being used in many applications in our plants where high bearing loads demand high film strength. Typical examples are in our ____________________________

Now let's talk about greases. What would you like to discuss?
LUBRICATING OILS VERSUS GREASES

Now that we have discussed lubricating oils and lubricating greases, the logical question is, "When do we use an oil and when do we use a grease?" The answer is controversial. Each type has distinct advantages and disadvantages. Which one we will use will depend more or less on bearing design, operating conditions and type of machine to be lubricated.

We have listed here a few comparative advantages of oils and greases. This comparison cannot be considered to cover all lubricating conditions, but can be used as a general guide in selecting a suitable type of lubricant.

Here are a few advantages of grease.

1. Frequency of lubrication is usually less where grease is used rather than oil. Lubrication time is therefore reduced and less work is required. This makes grease ideal for hard-to-get-at lubrication points.

2. Grease can be better confined in a bearing housing than can oil, due to its plastic nature. Therefore, it is possible to use a simpler seal design.

3. Grease is less liable to leak from a bearing housing, especially where seals are worn or not used. This is a distinct advantage on machinery where contamination of product is a danger.

4. Usually, less grease is needed for good lubrication of a bearing than would be the case if oil were used. This is especially true in ball and roller bearings.

5. Grease acts as a natural sealing medium against outside contamination. This, again, is an advantage in the protection of the highly polished surfaces of some bearing parts.

Now here are a few advantages of oil. Compare these with the advantages of grease.

1. Oil is more adaptable to all parts of a machine, such as bearings, gears and ways.
2. Oil is easier to handle in draining and refilling bearings and enclosed gear cases. This is a distinct advantage when frequent re-lubrication is required, due to severe operating conditions.

3. It is easier to control the correct amount of lubricant in a bearing when oil is used.

4. Oil is more suitable for a wide range of temperature and operating speeds. This is especially true where temperatures are below 32°F, and above 200°F. If cooling of the lubricant is required due to high operating temperatures, we can use an oil circulating system or cooling coils in the bearing housing.

5. Oils offer a wider range of viscosities to choose from for a wider range in speeds and bearing loads, than do greases.

6. A wider choice of methods of application is possible with oil than with greases.

When you think over the advantages of each type of lubricant, you can see that the choice of which one to use will depend upon the conditions and requirements of each point to be lubricated.

Later, we will discuss in some detail the type of lubricant that is the best for each type of equipment.

Now what questions do you have about oil refining or about specifications and comparisons of oils and greases?

{Answer all questions.}

Now, let’s try our hand at these Review Questions. Answer the questions carefully, then we’ll discuss them and clear up any points that are not clear.

{Give each man a set of Review Questions. Allow 10 minutes to answer.}

Now let’s check our questions. You tell me what you think is the correct answer to each question, then we’ll discuss it. Correct your own papers by marking down one point for each incorrect answer. When we are through, I will pass around a blank sheet of paper for each of you to mark down your own score. Do not mark down your name. We want to check the material we have presented to see if everything was satisfactorily explained—we do not want to grade you.
Discuss the questions, one at a time. Have the group tell you the answer. Discuss the question, then give the correct answer to the group.

After the last question, pass around a sheet of blank paper for each man to mark down his own score. A high total score for the group means some key points were not clearly understood.

At the next session we will go into the lubrication of the different types of gears we use.
Review Questions

Section II - Specifications of Lubricants

(Directions: Check all of the correct answers to each)
(of the following questions. Each question may have)
(more than one correct answer.)

1. What physical properties are you most concerned with in selecting an oil as a lubricant?
   a. ( ) Gravity
   b. ( ) Flash Point
   c. ( ) Viscosity
   d. ( ) Fire Point
   e. ( ) Carbon Residue
   f. ( ) Pour Point
   g. ( ) Color
   h. ( ) Transparency

2. Lubricating greases are selected according to their
   a. ( ) Dropping Point
   b. ( ) Color
   c. ( ) Specific Gravity
   d. ( ) Penetration Number
   e. ( ) Base

3. Soda-Base Greases
   a. ( ) are fibrous in texture
   b. ( ) can be used when water is present
   c. ( ) can be used for temperatures up to 375°F.

4. Calcium-Lime Base Grease is
   a. ( ) buttery and smooth
   b. ( ) water repellent
   c. ( ) not suitable for high temperatures above 225°F. because it breaks down and does not return to its original state when cooled
5. Check the advantages of grease.
   a. ( ) Easier to remove and apply
   b. ( ) Frequency of application is usually less
   c. ( ) Less liable to leak
   d. ( ) Is more adaptable to all parts of a machine; bearings, gears, ways.

6. Check the advantages of oil.
   a. ( ) Correct amount of lubricant is more easily controlled
   b. ( ) Offers wider range of viscosities for a wider range of speeds and loads
   c. ( ) Acts as a natural seal against outside contamination
   d. ( ) Less liable to leak

7. Extreme Pressure Greases
   a. ( ) Are used on large low-speed and low-load gears
   b. ( ) Have high film strength
   c. ( ) Have low-pour-point characteristics

8. What lubricant would you use in
   "A grease lubricated journal bearing operating at slow speed and low load on the wet end of a machine."
   Answer

9. What oil characteristics or specifications would you be most interested in for lubrication where temperature ranges between 35° below and 200° above zero F?
   Answer

10. Determine from your pocket card the Viscosity, SAE Numbers, andAGMA Numbers for oils for these applications:

    | Chain Drive (High Speed) | Chain Drive (Slow Speed) | Steam Turbine (Ring-Oiled Bearing) |
    |-------------------------|--------------------------|-----------------------------------|
    | Viscosity                | Viscosity                | Viscosity                         |
    | SAE No's.                | SAE No's.                | SAE No's.                         |
    | AGMA No's.               | AGMA No's.               | AGMA No's.                        |

2-19-52 REVIEW QUESTIONS
Session III
APPLYING LUBRICANTS

* Materials needed for running this session are:
   1. Leader's Guide, Session III
   2. Chart Drawings A-K, Session III
   3. Review Questions
      (One set for each trainee.)

* All items in boxes are instructions to the leader, and are not to be read to the group.
APPLYING LUBRICANTS

Now that we have some idea of what a lubricant is, and how a lubricant lubricates, let's take a look at some different methods of applying lubricants and see how each functions. We will discuss methods of applying oil first, and then methods of applying grease.

APPLYING OIL

Oil can be supplied to bearings by many different methods. Most of these methods are, or have been, in use in Armstrong plants. Such devices may be extremely simple, such as the common oil can, or may be completely automatic and equipped with safety devices to warn of lubrication failure or excessive bearing temperatures.

The common oil can, one of the oldest methods of applying oil in use today, is one of the worst offenders. It is not reliable or efficient. The effectiveness of lubrication, when the oil can is used, depends upon how well the person using it understands what he is doing.

If you use it properly, you don't just stick the spout into the oil hole and squeeze the bottom of the can. Try to put in the amount recommended, and not to flood the oil hole. If the bearing requires a few drops, put in a few drops. A great deal of care is necessary to be sure the bearing is not over-lubricated or under-lubricated. It all depends upon the individual using the can.

Now let's look at a few of the more common types of oilers.
A typical Bottle Oiler is shown in Figure 1. As the name indicates, these oilers consist of an inverted bottle-shaped reservoir with a threaded neck for mounting on top of a bearing. A metal spindle or plunger feeds the oil from the reservoir to the journal on which it rides.

Starting and stopping of the oil feed is entirely automatic, controlled by the rotation of the journal. Slight irregularities on the surface of the journal, combined with the rotating motion, cause the plunger to be alternately raised and lowered. This vibrating action causes oil to flow down the plunger to the journal through the restricted opening around the plunger in the oil hole.

A precaution we should always observe with this type of oiler is, never fill the bottle completely full. You can see that a full bottle would not have an air space as shown in Figure 1. The lack of air space caused by filling the bottle completely full can retard the flow of oil from the bottle.

As we can see from the action of the bottle oiler, it can only be used on horizontal bearings. It is not suitable for bearings exposed to wide temperature ranges, or high speeds. It is well suited for bearings which require only a small continuous supply of oil. It is widely used on overhead line shafting, particularly where bearings are difficult to reach for re-lubrication.

In Figure 2 we see another type—the Wick-Feed Oiler. This oiler employs the principle of syphoning oil by the capillary action of a porous material such as the strands of yarn in a wick.

The oil-soaked wick, with one end immersed in the oil in the reservoir and the other end extending into the bearing housing, carries the oil to the proper place. The flow of oil is regulated by varying the number of strands of wicking used, and by varying the height between the oil level in the reservoir and the lower end of the wick.

Whenever the machine is shut down, the flow of oil should be stopped to prevent over-lubrication and waste of oil. To stop the flow of oil, the upper end of the wick must be removed from contact with the oil in the reservoir. Even then, the oil will continue to flow until the wick has drained.

It is important that the right type of wicking is used. Wool waste is better than cotton waste as cotton tends to pack down.
The cotton also tends to glaze when in contact with the journal and cuts down on the proper flow of oil.

In this wick-feed oiler, it is important to keep a constant check on the condition of wicking, as many bearing troubles can be traced to this source.

The Drop-Feed Oiler, another device for applying oil is shown in Figure 3. It is widely used on all types of machinery for lubricating bearings, gears, chain drives, etc.

In this drop-feed oiler, oil flow is controlled by an adjustable needle valve. A snap lever on top of the cup permits starting and stopping the feed of oil. This lever must be kept in the off position when the machine is not running, to avoid over-lubrication, and must always be turned on before the machine is started. The lever should also be in the off position when filling the oiler so that any bubbles which form will not be drawn into the needle valve area, thereby blocking the flow of oil. The transparent portion in the base of the oiler permits a visual check on the flow of the oil to the bearing. The flow should always be checked after servicing to be sure the proper rate is maintained.

The drop-feed oiler has a few disadvantages.

(1) The rate of oil feed is affected by changes in the oil level and the oil temperature in the reservoir.

(2) The regulating needle-valve may become clogged by particles of dirt which restrict the oil feed.

(3) The drop-feed oiler requires considerable attention in filling and regulating the flow of oil.
In Figure 4 we see a typical Ring Oilier. The principle of the ring oiler is simple. Lubrication is accomplished by means of rings around the journal having a larger I.D. than the O.D. of the journal. The bearing is provided with an opening or slot in which the ring freely rides, with a hinged cover over the upper half of the journal. As the shaft rotates, the ring is also rotated. The lower half of the ring is immersed in the oil in the reservoir below the journal.

As the ring rotates, it picks up oil from the reservoir. The oil is wiped off as it passes over the top of the journal and enters the bearing area from the top, or low pressure side.

The ring oiler is used extensively on horizontal bearings, such as line shafts, electric motors and generators, small steam turbines, steam engines, and outboard bearings on air compressors and refrigeration machines.

The particular advantage of the ring oiler is that it automatically supplies a large quantity of oil to the journal as long as there is oil in the bearing, and as long as the rings are free to rotate and distribute oil to the journal. There may be one or more of the rings depending upon the size of the bearing. This ring oiler cannot be used on high-speed bearings, for the ring would slip at the top where it contacts the journal and would not carry up enough oil to lubricate effectively.

Chain Oiling is another adaptation of ring oiling. In this case, a chain is used in place of the ring. The flexibility of the chain allows it to contact more surface of the journal than does the ring. As a result, the chain will supply greater quantities of oil at low speeds than would be supplied by the ring.

Periodic checks must be made of the oil level in the reservoir to insure that the ring or chain is properly immersed in the oil. The oil in the reservoir must be kept clean and free from contaminants by periodic oil changes and flushing. Otherwise sludge resulting from oil breakdown or contamination can retard free movement of the ring and prevent proper distribution of the oil to the journal.

Bath Oiling, as illustrated in Figure 5, is another means of applying the lubricant to the bearing area. In bath oiling, the bearing is run in contact with the journal in an oil bath. This type of lubrication is very economical and requires no attention other than regular inspection of correct oil level, and a periodic draining and refilling of the oil reservoir.
Oil level, when ball or roller bearings use bath lubrication shown in Figure 6, should be maintained so that between 1/3 and 1/2 of the lowest ball or roller is immersed in the oil. Too high a level results in excess churning of the oil by the rotating parts and results in heat generated by internal friction in the oil itself. This can raise bearing temperatures too high with resultant damage to the bearing parts. On the other hand, if the oil level is allowed to drop too low, insufficient lubrication will result.

In Figure 7 we see another lubricating system known as the Splash System. The rotating and reciprocating parts dip into the reservoir and splash the oil into bearings or into passages or pipes from which it flows in mist form by gravity to the various parts requiring lubrication.

Here again, proper oil level in the reservoir must be carefully maintained. Regular periodic oil changes must be scheduled to insure good lubrication with clean oil. Schedules of oil changes will depend on operating conditions and location of the equipment. In dirty or dusty locations, oil changes should be made more frequently than in clean locations.

The splash system is widely used for machinery having cranks, and other moving parts enclosed in oil-tight housings which serve as oil reservoirs. Such machinery includes air compressors, refrigeration compressors, and steam engines.
All of these methods of lubricating that we have just discussed are used for applying oil to single or several bearings, and they are all accomplished by hand or with semi-automatic devices. When we lubricate by some of these methods, it requires considerable time and attention. This is particularly true where large numbers of bearings are involved, and frequent relubrication is required.

CENTRALIZED OIL SYSTEMS

When centralized lubrication systems are used, we do away with some of these disadvantages. The centralized lubrication system supplies a controlled or measured quantity of the lubricant to the bearing area, and is available in either the "continuous flow" or "one shot" type. The system may be either hand-operated or power-driven and fully automatic. Many of these centralized systems are already being used in Armstrong plants. The trend is toward replacing the existing gravity-feed and hand systems with the new centralized systems wherever it is considered justifiable in the interests of higher production output and reduced maintenance costs. There are three types of centralized oiling systems in general use today: the one-shot system, the mechanical lubricator, and the circulating system.

The One-Shot System shown in Figure 8 is hand operated. It consists basically of an oil reservoir, a pump, oil metering valves, and distributing lines with metering valves at each lubrication point.

The system operates like this. When you depress the pump handle, oil is delivered to the distributing lines under pressure. When pressure in the lines reaches a predetermined point, the outlet check valve in each oil-metering device opens, and oil is delivered simultaneously to all lubricating points. After all the meters in the system have delivered the required amounts of oil, the line pressure is relieved and the system is ready for the next lubrication cycle.

On some installations a pressure gage shows us when the line pressure is relieved and the lubrication cycle is complete. On other installations we must judge from the pressure against the pump handle. The pressure against the pump handle will fall off immediately when the metering valves open thus indicating to us that the lubrication cycle is complete.

Each metering valve can be adjusted to feed the correct amount of oil for any particular bearing size or operating condition. This type of system requires a minimum of maintenance.
Mechanical Lubricators, illustrated in Figure 9, are perhaps the most widely used form of automatic oiling systems in use today. Units of the Manzel, McCord, and Madison-Kip type are standard equipment on most large air compressors found in our plants. These units are fully automatic.

The central part of a typical mechanical lubricator consists of a reservoir, located at some convenient point adjacent to the machine to be lubricated. Inside the reservoir are a series of individual plunger-type pumping units, one of which is shown here. Mechanical lubricators may be obtained with single pumping units, or up to a dozen or more pumping units enclosed in the same case.

All of individual units are operated by a common cam shaft. On the downward stroke of the primary plunger oil is drawn through the screen near the bottom of the reservoir into the space above the primary plunger. As the primary plunger moves upward, the oil is forced through the sight feed. The secondary plunger draws the oil from the sight feed cup and forces it through the double ball checks to the bearings.

The lubricator may be motor-driven or driven by some rotating shaft or reciprocating mechanism of the machine itself. There is very little waste of oil and complete and dependable lubrication is possible with mechanical lubricators of this type.

Since the lubricator, in most cases, does not work when the machine is not in operation, there is no waste of oil during these periods. Little attention is required other than to regulate the flow of oil, and to refill the reservoir as needed. The flow of oil can be regulated by the feed regulator at the top. Turning this regulator changes the length of stroke of the primary plunger, and thus changes the amount of oil drawn in on each stroke.

When mechanical lubricators are motor-driven, it is the general practice to interlock the lubricator motor with the driving motor of the machine to be lubricated. This is done in such a way that it is impossible to start the machine unless the lubricator is first running. In event of failure of the lubricator, the machine automatically shuts down. This is a very desirable feature where machines are operated on a 24-hour production schedule, and lubrication personnel on the two late shifts are limited.
Circulating oil systems are installed where large supplies of oil are required for the purpose of lubricating and cooling. They are also used where operating conditions make it necessary to provide a flushing action within the bearings to remove dirt, grit, metallic particles and other contaminants which may find their way into the system.

A Gravity-Circulating Oil System is shown in Figure 10. This system takes advantage of the natural laws of gravity to conduct oil from an elevated supply tank to the parts to be lubricated. The gravity feed from the supply tank supplies a steady flow of oil to the bearings. The surplus oil falls off the bearings into the reservoir in the bottom of the unit, and is pumped back up to the supply tank.

This is an extremely simple circulating system. Now let's take a look at a more complex system, used on turbo-generator installations.

Oil-circulating systems, such as this one shown in Figure 11, provide thick-film lubrication, which is required where operating temperatures and bearing loads are high, and where a continuous supply of oil is necessary. To maintain the oil in the system in good condition during long periods of service, some type of oil cooler and filter is usually provided to cool the oil and to remove as much as possible of the contaminating material that enters the oil. The oil cooler is shown as point 10 and the centrifuge or filter as point 15 on the chart. Later on in our discussions, we will discuss the effectiveness of these filters.

Safety devices are always recommended for use in these oil-circulating systems to warn against low oil pressure, and abnormally high bearing temperatures. Audible alarms or lights which warn of such dangerous conditions are sometimes used. A more positive device is to incorporate pressure cut-out switches on the high-pressure side of the oil delivery lines to shut down the machine entirely when oil pressure drops below a safe limit. A device to accomplish this is shown on the chart at point 8. This method does not require so much attention on the part of the lubrication service man, and is the most widely used safety device on large circulating systems in our plants today.
Oil is drawn from the reservoir, point 1, by the main oil pump, point 2, which is driven by the turbine.

The oil is passed through a twin strainer, point 3, to the primary and secondary governor relays, points 4 and 5, to the oil-operated throttle valve, point 6, and to the overspeed governor and low-oil-pressure trips, points 7 and 8.

A relief valve, point 9, maintains the oil pump discharge at 50 p.s.i., and discharges through an oil cooler, point 10, to all bearings and gears requiring lubrication, identified as points 12.

Bearing oil pressure is maintained at 15 p.s.i. by a relief valve, point 11, which discharges to the oil reservoir, point 1.

Oil from the bearings and relay is returned to the reservoir.

The auxiliary oil pump, point 13, used during starting and stopping, discharges through a check valve into the main-oil-pump discharge pipe.

An overflow line, point 14, from the reservoir discharges to a centrifuge or filter, point 15, and the clean oil is returned for re-use by a separate pump at point 16.

Do you have any questions about the operation of this system?
APPLYING GREASE

These methods of applying lubricants which we have just discussed have all been for applying oil. Now, we come to the methods generally used for applying grease.

Grease can be supplied to bearings by many different methods. These methods range from the hand-application method in its simplest form up to centralized and fully automatic greasing systems.

Hand Application, the simplest of greasing methods, is used to pack certain types of bearings with grease before final assembly, or at the time of relubrication.

These hand application methods are wasteful. There is also a chance for dirt and other foreign matter to enter the bearing with the grease. However, hand application is sometimes the only method that can be used.

The Compression Grease Cup shown in Figure 12 rather widely used on certain types of machinery, screws directly into the bearing. The cup is loaded by unscrewing the cap, filling it with grease, and then screwing the cap back onto the base far enough to engage the threads. As the cap is screwed further onto the base, the grease is forced through the opening in the bottom of the base and into the bearing area. The cup must be reloaded when the cap has been screwed all the way down on the base. The rate of feed is usually specified in a certain number of turns of the cap per hour, or per day, or other unit of time.

While this method is a great improvement over the hand packing method, it still does not provide a uniform or efficient delivery of grease to a bearing and requires frequent attention.

The Automatic Grease Cup shown in Figure 13 is a refinement of the ordinary compression cup. It consists of a reservoir filled with grease, and a spring-actuated leather-packed plunger which forces grease slowly into the bearing. The "T-shaped" fitting that is screwed onto the top of the screw shaft just outside the cap of the reservoir limits the quantity of grease fed to the bearing. In the position shown, the "T" is against the cap thereby preventing the
plunger from moving downward and forcing more grease into the bearing. If we were to screw the "T" upward on the shaft it would permit the spring to force the plunger downward, slowly forcing grease into the bearing until the limit of travel had been reached with the "T" resting against the cap again.

The screw valve in the base of the reservoir can be turned fully "off," fully "on," or to any point in between to regulate the flow of grease.

These cups are sometimes equipped with pressure fittings to allow them to be filled with a hand grease gun. Neither this automatic grease cup, nor the compression type, are recommended for use in locations subject to wide temperature variations, which may affect the grease.
The Pressure Application Method, for which we see the fittings on the chart, is by far the most widely used method of grease application today. Grease is applied through pressure fittings of the Almite or Zerk type. It may be applied by means of a hand-operated grease gun, either the electric or compressed-air type. This compressed-air type is one we see used in the modern gasoline service station or garage.

These pressure fittings can be screwed directly into the bearing housing. Figure 14 shows the ball check which opens when grease is applied under pressure at the top. The grease flows past the ball check into the bearing area. When pressure is removed the ball check closes and seals the bearing against dirt and prevents leakage that may be caused by back-pressure in the bearing.

These fittings are available in a number of different designs to fit particular needs in machinery applications. Figure 15 shows some typical grease pressure fittings used in Armstrong plants.

These pressure grease fittings are much to be preferred over grease cups. Here are a few of their advantages:

1) With pressure lubrication, it is possible to flush the bearing of old used grease and outside contaminants.

2) Pressure fittings give a better protection of bearings against the entry of foreign particles.

3) More efficient lubrication can be expected with pressure systems, as grease waste is usually less.

For these reasons, it is the general practice throughout Armstrong plants to replace grease cup fittings with the pressure-type fitting.
Centralized systems of lubrication are also available where grease is used. Centralized grease systems are many times more reliable and economical as far as time and grease consumption are concerned, than are the various hand greasing methods we just discussed. Centralized grease systems permit the lubrication of all bearings and moving parts of a machine while the machine is in operation. Even more important, centralized grease systems eliminate the hazard in applying grease to bearings that might otherwise be difficult or dangerous to reach.

These centralized systems are available in two general types, Manual and Fully Automatic. There are a number of such systems available, among them are units made by Alemite, Farval, Lincoln Engineering, and Trabon, all of which are used in Armstrong Plants.

The Manual Grease System is shown in Figure 16. This particular illustration shows the Alemite Lubrometer System. In this system, individual valves, connected in a single-line dead-end system, automatically provide each bearing on a machine with a predetermined amount of grease when the pump at the system inlet is operated. After all of the valves in the system have delivered the required amount of grease to each bearing, an indicator on each valve rises and falls to signal the operator that lubrication is complete.

In most cases, the valves can be screwed directly into the bearing housing, which makes possible positive delivery of the grease to the bearing.

This manually-operated grease system is adaptable to most any type of machine, and is generally used where bearings do not require relubrication more frequently than once or twice per operating shift.
Fully Automatic Grease Systems which we see in Figure 17 are generally employed where bearings have high operating temperatures and pressures and require frequent application of grease to insure their proper operation. This Farval Lubrication unit we see here is a typical example of the modern centralized fully-automatic grease system. This type of system is used extensively in Armstrong plants on such equipment as mixing mills, rubber mills and calendars, Banbury mixers, and similar heavy-duty machines that require the best lubrication methods obtainable to maintain maximum production with a minimum of downtime.

The system shown consists of a motor-driven central pumping unit, two main supply lines, and a metering valve for each bearing and moving part on the equipment. In a system of this type, generally known as a dual-line system, the two main supply lines pass through each metering valve forming a complete circuit, or loop, and return to a four-way hydraulically operated reversing and control valve. Lubricant pressure at the return end of either main supply line automatically operates the reversing valve to direct the flow of lubricant into the other main supply line.

Since the pressure control is located at the return end of the supply lines, the grease must first pass through the entire system and develop sufficient pressure to operate all metering valves, before the reversing valve will function to re-direct the flow into the other supply line.

This means that all bearings must be properly lubricated before the action of the reversing valve will indicate the completion of the lubrication cycle. This is a very desirable feature in any fully automatic greasing system from a standpoint of dependability and machine protection.

The frequency of operation of a system of this type is controlled manually or through an electric time clock, which can be set to operate the system at any desired interval. Suitable safety devices are usually provided to protect the machinery in event of failure of the lubrication pumping unit, or in case of a break in one of the main grease supply lines. Should either of these failures occur, an electrical interlock between the lubricator and the driving motor of the machine provides complete shutdown of the machine before serious bearing failure can result from lack of lubrication.
This brings us up-to-date on some of the methods we use for applying oil and grease to bearings, and how each one works. If you have any further questions about how any of these methods are used, I'll be glad to answer them now.

Now, let's try our hand at these Review Questions. Answer the questions carefully, then we'll discuss them and clear up any points that are not clear.

Next time we'll go into the lubrication of gears. If you have any questions on gear lubrication, bring them with you and we'll talk them over.
Review Questions
Session III
"Applying Lubricants"

Directions: Check all of the correct answers for each of the following questions. Each question may have more than one correct answer.

1. When servicing this type oiler, precautions should be taken to:
   a. ( ) Shut snap lever to prevent flow of oil when machine is not running.
   b. ( ) Raise wick, check for glazed strands, and replace.
   c. ( ) Check plunger to make sure it is riding on journal.
   d. ( ) Check feed rate after servicing.

2. This bearing
   a. ( ) is collar oiled.
   b. ( ) is not high speed.
   c. ( ) is ring oiled.
   d. ( ) could use a chain as a substitute.

3. The correct oil level for this bearing is
   a. ( ) 1/3 to 1/2 of the bearing covered.
   b. ( ) 1/3 to 1/2 of the lower race covered.
   c. ( ) 1/3 to 1/2 of the lowest ball covered.

4. This type of fitting
   a. ( ) does not give uniform delivery.
   b. ( ) will not over-lubricate.
   c. ( ) is usually replaced on Armstrong equipment.

5. Bearings in this system are lubricated by
   a. ( ) a pump to spray and splash the oil.
   b. ( ) a splash system.
   c. ( ) a pressure system.

6. This typical hand-operated oiling system is usually used for
   a. ( ) periodic lubrication of multiple points.
   b. ( ) delivery of different amounts of oil to different bearings.
   c. ( ) a circulating pressure system.
7. This type of mechanical lubricator
   a. ( ) can lubricate various points with different amounts of oil.
   b. ( ) is always motor driven.
   c. ( ) if motor driven, should be interlocked with starting motor for safety.

8. This typical manual grease system
   a. ( ) is recommended for machines requiring frequent lubrication.
   b. ( ) is generally used where lubrication is not required oftener than 2 or 3 times per shift.
   c. ( ) a predetermined amount is delivered on each stroke.

9. This fully automatic grease system
   a. ( ) is generally used where frequent application of lubricant is required.
   b. ( ) lubricant is delivered in measured quantities.
   c. ( ) must be checked often to prevent over-lubrication.

10. A circulating oil system for large quantities of oil usually contains which of the following:
    a. ( ) oil cooler
    b. ( ) centrifuge or filter
    c. ( ) return lines to the reservoir from all lubricated points
    d. ( ) low-oil-pressure cut-out switch

11. A piece of equipment has 15 grease cups that must be lubricated twice per day. What recommendation would you make to improve this method of applying grease?

   Answer
   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________
SESSION I
Kinds of Friction

Fig. 1 Sliding Friction

Fig. 2 Rolling Friction
Kinds of Friction

Fig. 3 Sliding Friction – Most Effort

Fig. 4 Rolling Friction – Less Effort

Fig. 5 Fluid Friction – Least Effort
Types of Solid Friction
(to be overcome with Lubrication)

Fig. 6 Sliding Friction

Fig. 7 Rolling Friction
Magnified Bearing Surfaces

Fig. 8
Magnified Bearing Surfaces with a Fluid Film

Fig. 9

Fig. 10
Oil Film and Wedge Formation

Fig. 11

Fig. 12

Fig. 13

Fig. 14
Viscosity

Low Viscosity Oil
(thin like water)

High Viscosity Oil
(thick like molasses)
Journal Speed and Viscosity

Fig. 15

No. 1 Low Speed Journal
Large Clearances

No. 2 Medium Speed Journal

No. 3 High Speed Journal
Small Clearances
Bearing Loads and Viscosity

*Fig. 16*
Refining

Oil Well

Pipe Still

Bubble or Fractionating Tower

Napthas

Gasoline

Kerosene

Oils

Residues

Acid Treatment

Filtered De-Waxed

Additive Compounding

Finished Lubricating Oils
## Important Specifications of Typical Oils

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<th>Pour Point</th>
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SESSION III
Common Oilers

Fig. 1
Bottle Oiler

Fig. 2
Wick-Feed Oiler

Fig. 3
Drop Feed Oiler
Common Oilers

Fig. 4
Ring Oiler

Fig. 5
Bath Oiled Friction Bearing

Fig. 6
Bath Oiled Ball Bearing
Splash Lubrication

Fig. 7
Centralized Systems
Typical One-Shot Oil System

Fig. 8
Centralized Systems
Typical Mechanical Lubricator

Oil to Bearing

Sight Feed

Feed Regulator

Fill Hole

Ball Checks

Secondary Plunger

Primary Plunger

Shaft

Cam

Reservoir

Oil Enters
Typical Gravity Circulating System

Fig. 10
Typical Oil-Circulating System for a Steam Turbine

Fig. 11

1. Reservoir
2. Main Oil Pump
3. Twin Strainer
4. Primary Governor Relay
5. Secondary Governor Relay
6. Throttle Valve
7. Overspeed Governor
8. Low-oil-pressure Trip
9. Relief Valve, 50psi
10. Oil Cooler
11. Relief Valve, 15psi
12. Bearings and Gears
13. Auxiliary Oil Pump
14. Overflow Line
15. Centrifuge or filter
16. Return Pump
Grease Application

Compression Grease Cup
Fig. 12

Spring Compression Grease Cup
Fig. 13
Typical Pressure Fittings

Fig. 14

Fig. 15
Centralized Systems
Typical Hand-Operated Grease System

Fig. 16
Centralized System
Typical Automatic
Dual-Line Grease System

Fig. 17