Program : **B.Tech**

Subject Name: **Maintenance Management**

Subject Code: **ME-8004**

Semester: **8th**

Mechanical Engineering Department
Maintenance Management (UNIT – 4: Notes)

PROCEDURE FOR RESTORATION

1. Symptom recognition
2. Symptom elaboration
3. Listing of probable faulty functions
4. Localizing the faulty function
5. Localizing the trouble to a faulty component
6. Failure analysis
7. Retest requirements

When necessary, each of these steps should be used in the proper order. Deciding when each is necessary is a very important part of troubleshooting. This is where a strategy is developed into a procedure. Many of the more modern designs of equipment in use today offer extensive diagnostics programs and tools as an integral part of the equipment. Some have internal troubleshooting programs that allow the equipment to "troubleshoot" itself to a large degree. These programs and tools usually check inputs and outputs against pre-programmed normal parameters. If a discrepancy is noted, that function is flagged as a potential problem. Some programs are more sophisticated and will actually check functions to a component level, but they usually are only found on very expensive and high-tech equipment. The strategy that the program uses is a simple logical input-output comparison. Systems or equipment that are designed for some form of self-troubleshooting obviously do not require implementation of every one of the seven steps. The equipment itself may perform any one or all of the steps, with the exception of failure analysis and retest requirements. All that is required of the troubleshooter is an understanding of what the equipment diagnostics is indicating and what the quickest and most effective way of clearing the fault is. When any troubleshooting effort is necessary, writing down or referring to the seven steps will ensure that a conscious decision is made as to what steps apply and what steps do not apply. Approaching the problem in this fashion will ensure that valuable time is not wasted back-tracking to an action or thought process that was skipped initially. Next, we will take a look at each of the seven steps individually to see what should be accomplished for each step.

Step 1: Symptom Recognition

This is the most fundamental step in troubleshooting. Each and every person that has ever fixed anything has accomplished it. This step asks the question "Does a failure exist" The first step in identifying a failure is recognizing that a failure exists. This sounds ridiculously simple, and usually it is, but it is also very important. For example, a common failure can be as simple as the power is not connected to a power supply. Electric motors and electrical circuits will not operate without electricity! This is very simple troubleshooting, but it can save a lot of time and potential embarrassment. The symptom recognition step is very straightforward. It requires an entry in the troubleshooting log that states what the indications of a problem are.

For example, the indication might be that pump does not start. Always check for additional symptoms of common problems. Unusual symptoms of common troubles occur more often than common symptoms of unusual troubles. The following list provides some guidelines for entries made during the symptom recognition step:

- Try to be as specific and defining as possible in stating the problem that is occurring.
- Always check to ensure equipment is lined up for normal operation, i.e., On/Off switch, test switch, mode selection switch, etc.
- Analyze the performance of the equipment to make sure it actually has a failure and is not simply reacting to an external condition.
- Try to determine if the failure is total or if the equipment is operating with degraded performance.
- Know the equipment; realize when it is showing the symptoms of impending failure.

Step 2: Symptom Elaboration

The symptom elaboration step is the beginning of "actual" troubleshooting. The objective of this step is to obtain as much information about the problem as possible. Symptom elaboration is where the question "What is the problem" is asked. As its name implies, this step elaborates on the symptom written in step one. For example, perhaps the cylinder extension stroke is too slow but the retraction stroke timing is satisfactory. This step provides all of the information necessary to narrow the problem down in a logical fashion. The following points would be considered in the symptom elaboration step. *Be aware that a large number of equipment faults can produce similar symptoms. During this step, try to differentiate as much as possible between the characteristics of the symptoms.

- Start the troubleshooting log with as much background information as possible and document each adjustment and its results.
- Note how readings are affected by all modes of operation and switch lineups.
- Be sure to observe all gages, meters, and other indicators as to how they are responding due to the problem.
- Always note if an adjustment has no effect on the symptom; this will help eliminate possible causes later on.
- Determine if the trouble has slowly developed (i.e., drift) or if it is a sudden failure.
- Perform control manipulation with care since detrimental effects can occur to associated equipment or components within the failed equipment.

-There may be a possibility of improper pressures, flows, or voltages exceeding maximum design specifications.

- Do not go for the answer in one step. Troubleshooting should be a series of small logical steps, each one chosen to show a result leading to discovery of the problem or problems. Remember, troubleshooting can last two hours or two weeks. Be sure to record all troubleshooting actions taken in the log accordingly. Do not leave anything to memory.

Step 3: Listing of Probable Faulty Functions

This step is intended to narrow down the possible faulty functions based on the information obtained in steps one and two. A functional block diagram of the equipment and the troubleshooting log (steps one and two) are needed for this step. The question asked by this step is "Would failure of this function cause the symptoms I am seeing" Again, the purpose of this step is to narrow the possibilities down to a list of probable faulty functions. Key points for this step include:

Always use the functional block diagram to ensure all the possible functions are checked.

- Write down all probable faulty functions, even if it is apparently obvious that some of them are working correctly. Then, write down why it is thought to be functioning correctly.
- Be sure to include functions such as detectors, switches, cables, meters, wiring, connectors, piping, filters, and regulators. Wiring is always a probable cause!
- Do not get locked in on what a technician "knows" the trouble has to be. Past troubleshooting experience and hunches certainly play a part in figuring out which is the faulty function. However, do not ignore hard evidence just because one assumes trouble is known prior to proper troubleshooting steps.
- Always ask: "Would a failure of this function cause these symptoms"

Step 4: Localizing the Faulty Function

This step requires careful evaluation of each of the probable faulty functions listed in the previous step. The goal is to determine exactly which area of the system is causing or generating the problem. This is the first step that requires taking a measurement. The measurement taken may be a system pressure, operating speed, sequence, time delay, temperature, or any variable parameter that is related to the equipment operation. The purpose of this step is not to find the faulty component; it is just to isolate the problem to a circuit or function. More than one of the previously listed probable faulty functions may be contributing to the overall problem. This step is not complete until each and every listed possibility is properly checked. The following key points should be noted:

- Check all pressures, flows, inputs, and outputs associated with the areas of probable faulty functions.
- If an abnormal reading is obtained, the equipment setup used to obtain the reading and the reading itself should be rechecked.
- Do not be discouraged if several hours of troubleshooting reveal that a function is good. Proving a function is operating properly is important to the troubleshooting effort because it

narrows down the possibilities of where the problem is located. The first function you choose to check out often will not be the faulty one.

- Check the troubleshooting log periodically to ensure that troubleshooting efforts are still working in the right direction and have not lost sight of the original troubleshooting goal.

Step 5: Localizing the Fault to a Component

This step continues isolating the fault once the faulty function or functions have been determined. A thorough knowledge of the equipment operation, as well as individual component characteristics, is required for successful completion of this step. Schematic diagrams should be used at this point to ensure that no details go unnoticed. When localizing the trouble to a faulty component, keep in mind the following points:

- Evaluate each component within the faulty function to determine which components are probable sources of the symptoms noted.
- Careful consideration must be given to how each component could affect overall function of the system under both normal and failed conditions.
- Removal of components from the system and use of a test stand may be helpful or even necessary to ascertaining the function of more complex components.

Step 6: Failure Analysis

This step requires the failed component(s) to be repaired or replaced and, most importantly, the cause of the failure corrected. The following key points should be noted.

- Knowledge of component failure modes and rates is very important. Always make a complete check of the associated components of the failed unit.
- A considerable amount of information can be rapidly gained through a careful visual inspection.
- Avoid replacing a component until the exact cause of the problem is found and repaired. Keep in mind though; the main purpose of troubleshooting is to get the equipment operational. Additional troubleshooting failure analysis can be done after the equipment is running.
- Documentation is imperative at this point, both to aid in troubleshooting the problem should it return and to point out recurring design deficiencies.

Step 7: Retest Requirements

Now that the equipment is operational, check all the functions that have been affected by the failure. Although the equipment has been repaired and is now functioning, all operations must be checked and verified. The information obtained in this step can also aid in troubleshooting next time by providing some baseline information. One key point to remember is:

- Fail Safe: do all checks that will ensure the equipment is operating correctly.

PURPOSE AND METHOD OF LUBRICATION

Lubrication is one of the most important factors determining bearing performance. The suitability of the lubricant and lubrication method have a dominant influence on bearing life.

Functions of lubrication:

- To lubricate each part of the bearing, and to reduce friction and wear
- To carry away heat generated inside bearing due to friction and other causes
- To cover rolling contact surface with the proper oil film in order to prolong bearing fatigue life
- To prevent corrosion and contamination by dirt

Bearing lubrication is classified broadly into two categories: grease lubrication and oil lubrication.

Comparison between grease and oil lubrication

Item	Grease	Oil
Sealing device	Easy	Slightly complicated and special care required for maintenance
Lubricating ability	Good	Excellent
Rotation speed	Low/medium speed	Applicable at high speed as well
Replacement of lubricant	Slightly troublesome	Easy
Life of lubricant	Relatively short	Long
Cooling effect	No cooling effect	Good (circulation is necessary)
Filtration of dirt	Difficult	Easy

GREASE LUBRICATION

Grease lubrication is widely applied since there is no need for replenishment over a long period once grease is filled, and a relatively simple structure can suffice for the lubricant sealing device. There are two methods of grease lubrication. One is the closed lubrication method, in which grease is filled in advance into shielded/sealed bearing; the other is the feeding method, in which the bearing and housing are filled with grease in proper quantities at first, and refilled at a regular interval via replenishment or replacement.

Devices with numerous grease inlets sometimes employ the centralized lubricating method, in which the inlets are connected via piping and supplied with grease collectively.

- **Amount of grease**

In general, grease should fill approximately one-third to one-half the inside space, though this varies according to structure and inside space of housing.
It must be borne in mind that excessive grease will generate heat when churned, and will consequently alter, deteriorate, or soften.
When the bearing is operated at low speed, however, the inside space is sometimes filled with grease to two-thirds to full, in order to

- **Replenishment/replacement of grease**

The method of replenishing/replacing grease depends largely on the lubrication method.
Whichever method may be utilized, care should be taken to use clean grease and to keep dirt or other foreign matter out of the housing.
In addition, it is desirable to refill with grease of the same brand as that filled at the start.
When grease is refilled, new grease must be injected inside bearing.

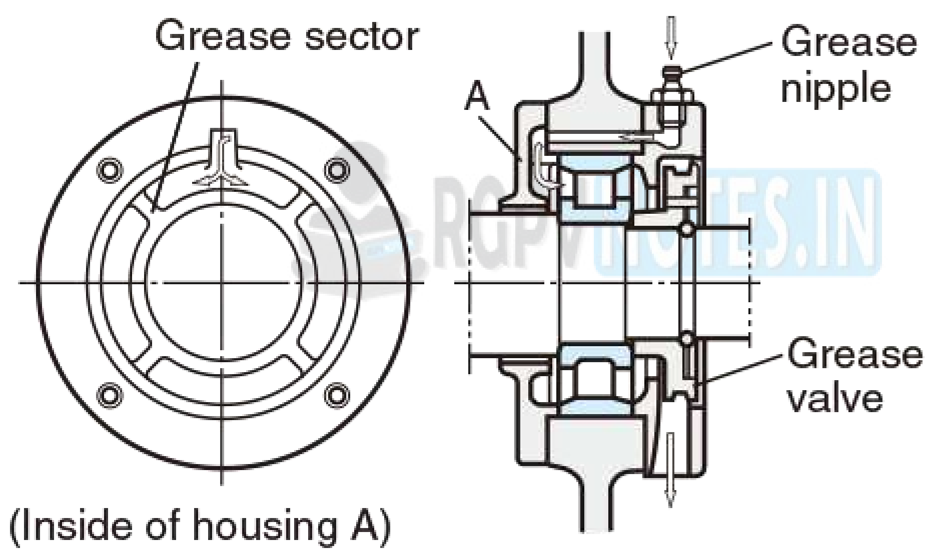
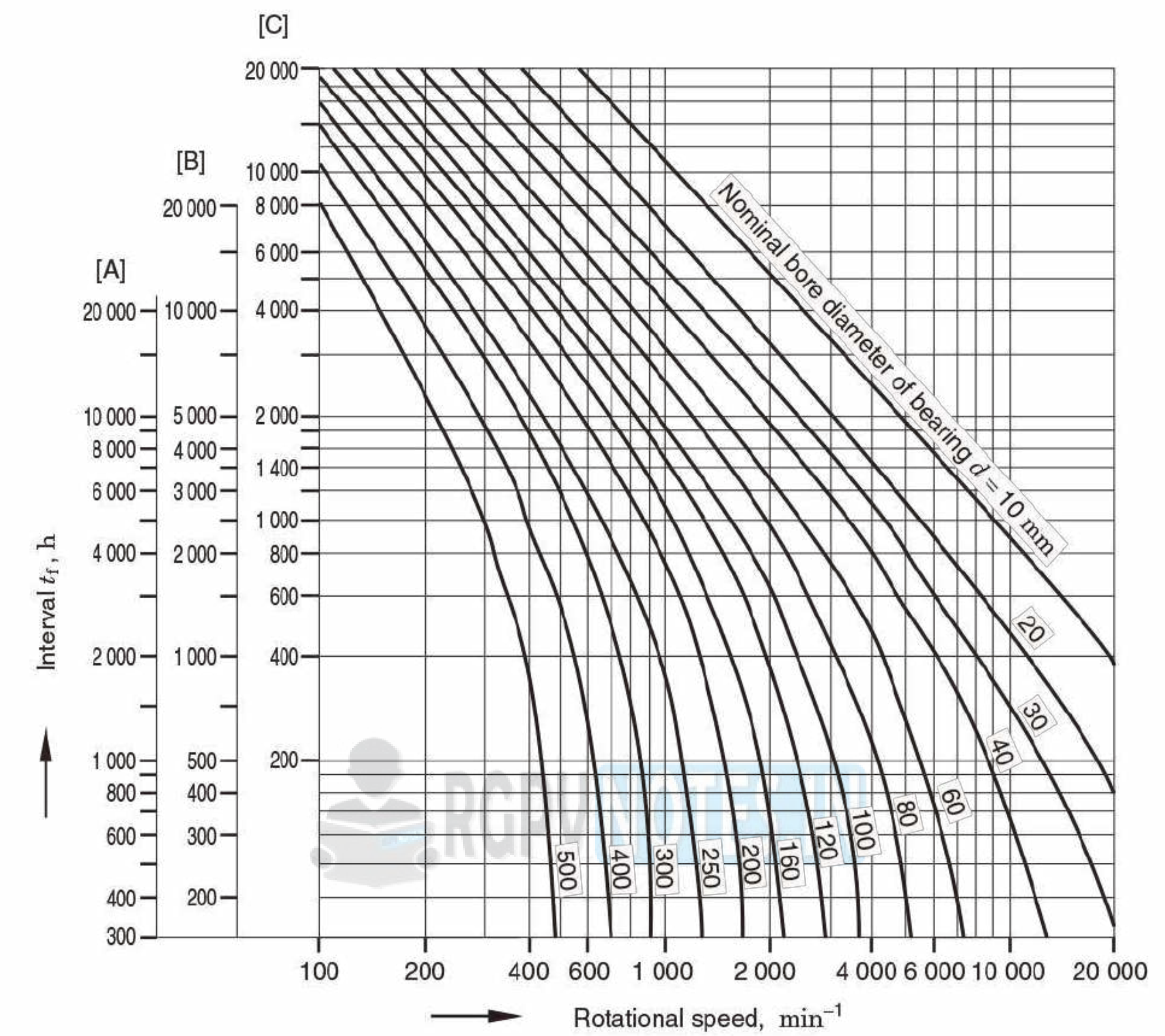


Figure: Grease feeding method

In the example, the inside of the housing is divided by grease sectors. Grease fills one sector, then flows into the bearing. On the other hand, grease flowing back from the inside is forced out of the bearing by the centrifugal force of the grease valve. When the grease valve is not used, it is necessary to enlarge the housing space on the discharge side to store old grease. The housing is uncovered and the stored old grease is removed at regular intervals.

Grease feeding interval

In normal operation, grease life should be regarded roughly as shown in Figure, and replenishment/replacement should be carried out accordingly.



[Notes] 1) [A] : radial ball bearing

[B] : cylindrical roller bearing, needle roller bearing

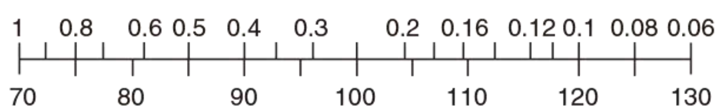
[C] : tapered roller bearing, spherical roller bearing, thrust ball bearing

2) Temperature correction

When the bearing operating temperature exceeds 70°C, t_f', obtained by multiplying t_f by correction coefficient a, found on the scale below, should be applied as the feeding interval.

$$t_f' = t_f \times a$$

Temperature correction coefficient a



Bearing operating temperature T °C

Figure: Grease feeding interval

Grease life in shielded/sealed ball bearing

Grease life can be estimated by the following equation when a single-row deep groove ball bearing is filled with grease and sealed with shields or seals.

$$\log L = 6.10 - 4.40 \times 10^{-6} d_m n - 3.125\left(\frac{P_r}{C_r} - 0.04\right) - (0.021 - 1.80 \times 10^{-8} d_m n)T \quad \cdots \quad (12\text{-}1)$$

where :

L	: grease life	h
d_m	$= \frac{D+d}{2}$ (D : outside diameter, d : bore diameter)	mm
n	: rotational speed	$\min^{-1}$
P_r	: dynamic equivalent radial load	N
C_r	: basic dynamic radial load rating	N
T	: operating temperature of bearing	°C

The conditions for applying in equation are as follows:

a) Operating temperature of bearing : T °C

Applicable when $T \leqq 120$

$\left(\begin{array}{l}\text{when } T < 50, \\ T = 50\end{array}\right)$

When $T > 120$, please contact with JTEKT.

b) Value of $d_m n$

Applicable when $d_m n \leqq 500 \times 10^3$

$\left(\begin{array}{l}\text{when } d_m n < 125 \times 10^3, \\ d_m n = 125 \times 10^3\end{array}\right)$

When $d_m n > 500 \times 10^3$, please contact with JTEKT.

c) Load condition : $\frac{P_r}{C_r}$

Applicable when $\frac{P_r}{C_r} \leqq 0.16$

$\left(\begin{array}{l}\text{when } \frac{P_r}{C_r} < 0.04, \\ \frac{P_r}{C_r} = 0.04\end{array}\right)$

When $\frac{P_r}{C_r} > 0.16$, please contact with JTEKT.

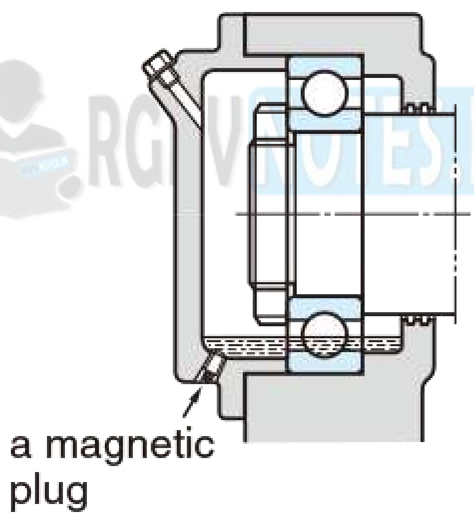
Oil lubrication

Oil lubrication is usable even at high speed rotation and somewhat high temperature, and is effective in reducing bearing vibration and noise. Thus oil lubrication is used in many cases where grease lubrication does not work.

1. **Oil bath**

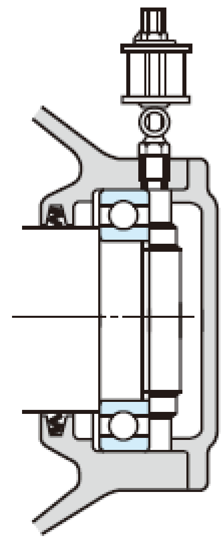
Simplest method of bearing immersion in oil for operation.

- Suitable for low/medium speed.
- Oil level gauge should be furnished to adjust the amount of oil.
  (In the case of horizontal shaft)
  About 50 % of the lowest rolling element should be immersed.
  (In the case of vertical shaft)
  About 70 to 80 % of the bearing should be immersed.
- It is better to use a magnetic plug to prevent wear iron particles from dispersing in oil.



2. **Oil drip**

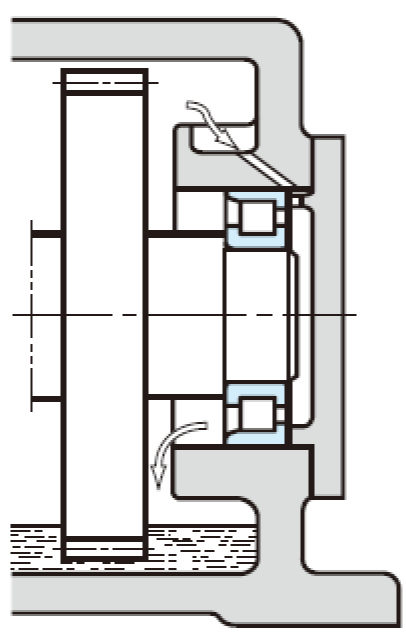
- Oil is dripped with an oiling device, and the inside of the housing is filled with oil mist by the action of rotating parts. This method has a cooling effect.
- Applicable at relatively high speed and up to medium load.
- In general, 5 to 6 drops of oil are utilized per minute.
  (It is difficult to adjust the dripping in 1mL/h or smaller amounts.)
- It is necessary to prevent too much oil from being accumulated at the bottom of housing.



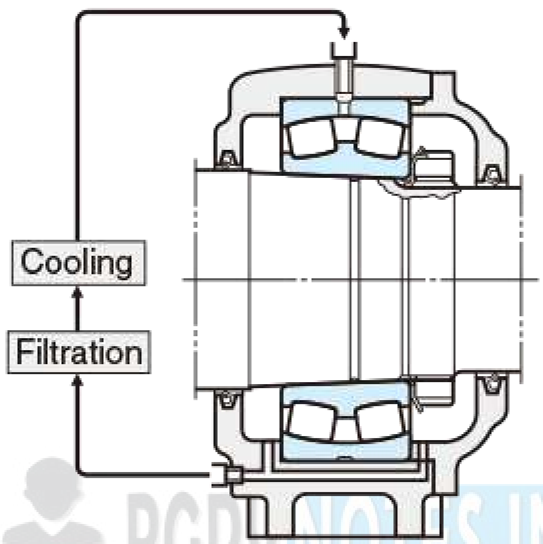
3. **Oil splash**

This type of lubrication method makes use of a gear or simple flinger attached to shaft in order to splash oil. This method can supply oil for bearings located away from the oil tank.

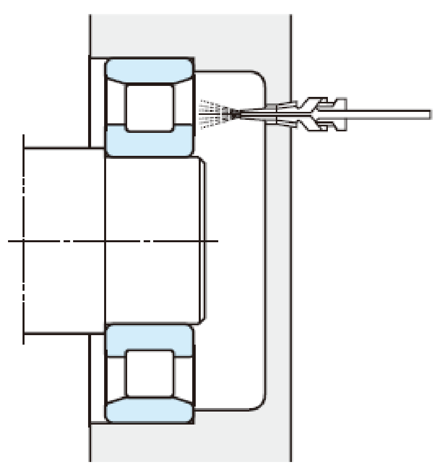
- Usable up to relatively high speed.
- It is necessary to keep oil level within a certain range.
- It is better to use a magnetic plug to prevent wear iron particles from dispersing in oil. It is also advisable to set up a shield or baffle board to prevent contaminants from entering the bearing.



4. **Forced oil circulation**
   - This method employs a circulation-type oil supply system.
     Supplied oil lubricates inside of the bearing, is cooled and sent back to the tank through an oil escape pipe. The oil, after filtering and cooling, is pumped back.
   - Widely used at high speeds and high temperature conditions.
   - It is better to use an oil escape pipe approximately twice as thick as the oil supply pipe in order to prevent too much lubricant from gathering in housing.



5. **Oil jet lubrication**
   - This method uses a nozzle to jet oil at a constant pressure (0.1 to 0.5MPa), and is highly effective in cooling.
   - Suitable for high speed and heavy load.
   - Generally, the nozzle (diameter 0.5 to 2 mm) is located 5 to 10 mm from the side of a bearing. When a large amount of heat is generated, 2 to 4 nozzles should be used.
   - Since a large amount of oil is supplied in the jet lubrication method, old should be discharged with an oil pump to prevent excessive residual oil.

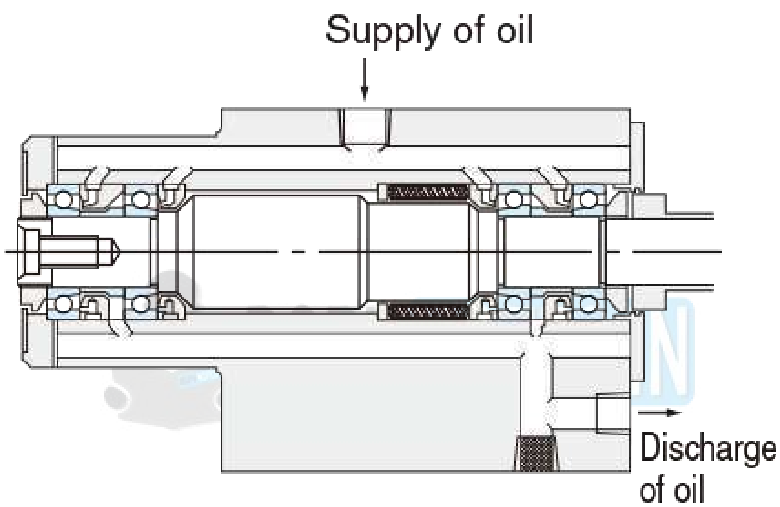


6. Oil mist lubrication (spray lubrication)

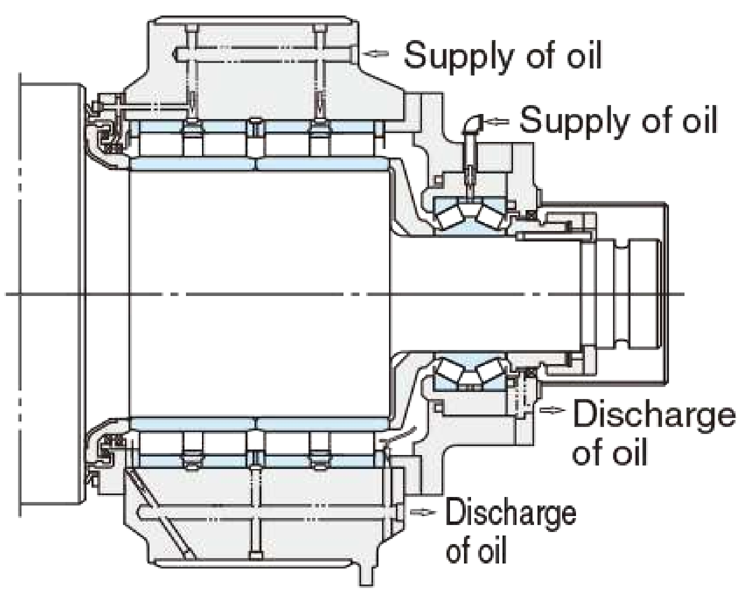
This method employs an oil mist generator to produce dry mist (air containing oil in the form of mist). The dry mist is continuously sent to the oil supplier, where the mist is turned into a wet mist (sticky oil drops) by a nozzle set up on the housing or bearing, and is then sprayed onto bearing.

This method provides and sustains the smallest amount of oil film necessary for lubrication, and has the advantages of preventing oil contamination, simplifying bearing maintenance, prolonging bearing fatigue life, reducing oil consumption etc.

(Example of grinding machine)

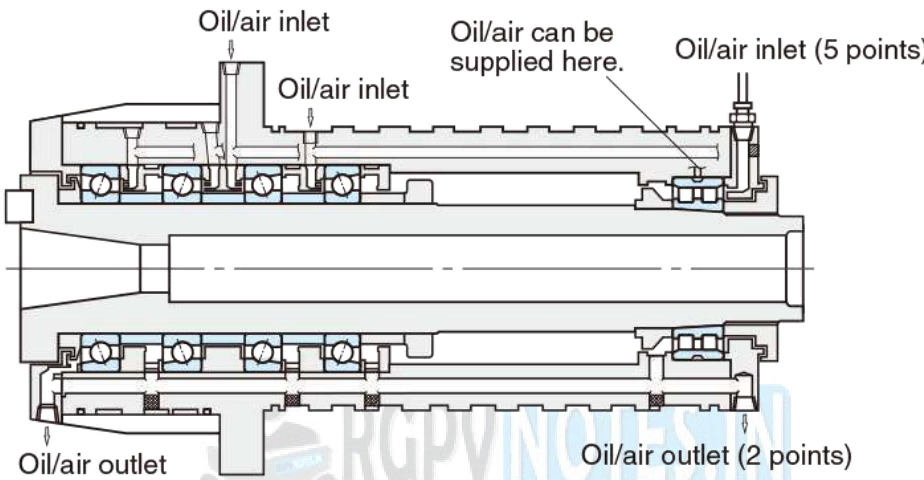


(Example of rolling mill)



Oil/air lubrication

- A proportioning pump sends forth a small quantity of oil, which is mixed with compressed air by a mixing valve. The admixture is supplied continuously and stably to the bearing.
- This method enables quantitative control of oil in extremely small amounts, always supplying new lubricating oil. It is thus suitable for machine tools and other applications requiring high speed.
- Compressed air and lubricating oil are supplied to the spindle, increasing the internal pressure and helping prevent dirt, cutting-liquid, etc. from entering. As well, this method allows the lubricating oil to flow through a feeding pipe, minimizing atmospheric pollution.



(Example of spindle unit incorporating oil/air lubrication system)

■ JTEKT produces an oil/air lubricator and, air cleaner, as well as a spindle unit incorporating the oil/air lubrication system. Please refer to brochure "oil/air lubricator & air clean unit".

$$G = \frac{1.88 \times 10^{-4} \mu \cdot d \cdot n \cdot P}{60 \; c \cdot r \cdot \Delta_T}$$

where :

G	:	required oil supply	L/min
μ	:	friction coefficient (see table at right)	
d	:	nominal bore diameter	mm
n	:	rotational speed	min^{-1}
P	:	dynamic equivalent load of bearing	N
c	:	specific heat of oil	1.88-2.09kJ/kg·K
r	:	density of oil	$\mathrm{g/cm}^3$
Δ_T	:	temperature rise of oil	K

