KITA

Autonomous maintenance (TPM) training

Centrifugal Pumps

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Centrifugal Pumps

Table of contents

1	Overview of Centrifugal Pumps
1-1	What are pumps?

Pumps are fluid machines that give mechanical energy to liquid to raise **the pressure of the liquid of a required quantity** to a required level and transfer it to a target location. In plants, a variety of pumps are used according to the purpose of usage.

Pumps are generally categorized into the following three types based on differences in the operating principle:

① Turbo pumps

A turbo pump rotates the impeller in the casing to give energy to liquid. Turbo pumps are divided into three types: centrifugal pumps, mixed flow pumps, and axial-flow pumps, from the relationship between the rotating shaft and the direction of flow of liquid when it passes through the impeller inside. There are single-stage, multi-stage, horizontal shaft, and vertical shaft types in each of those types. Turbo pumps have a wide range of applications of low head to high head and are used most often.

② Positive displacement pumps

A positive displacement pump changes the volume of liquid (displacement action) existing in a certain spatial volume by reciprocal or rotational motion to give the liquid energy.

③ Special pumps

Those pumps use a jetting force of water or steam or compressed air as the driving source.

< Pump categories >

- **Pumps**
  - **Turbo pumps**
    - **Centrifugal pumps**
      - **Volute pumps**
      - **Turbine pumps**
    - **Mixed-flow pumps**
    - **Axial-flow pumps**
  - **Positive displacement pumps**
    - **Reciprocal pumps**
      - **Piston pumps**
      - **Plunger pumps**
      - **Diaphragm pumps**
    - **Rotary pumps**
      - **Gear pumps**
      - **Screw pumps**
      - **Vane pumps**
  - **Special pumps**
    - **Regenerative, jet, and air lift pumps, hydraulic ram, etc.**

* In recent years, canned motor pumps or magnet pumps are used as pumps without leakage, or so-called seal-less pumps having no shaft seal, in a wide range of applications. These seal-less pumps have been developed as “volute pumps of zero leakage.”

1	Overview of Centrifugal Pumps
1-2	Types and features of pumps
1-2-1	Centrifugal pumps

1. Centrifugal pumps

Centrifugal pumps are of the type that gives velocity energy to liquid by the rotation of the impeller to obtain pressure or a flow rate. They have the following features and are most often used.

- The ranges of the height (head) for which liquid can be transferred and the amount (flow rate) of liquid are wide.
- Compact and lightweight
- High efficiency
- Easy to maintain and long life

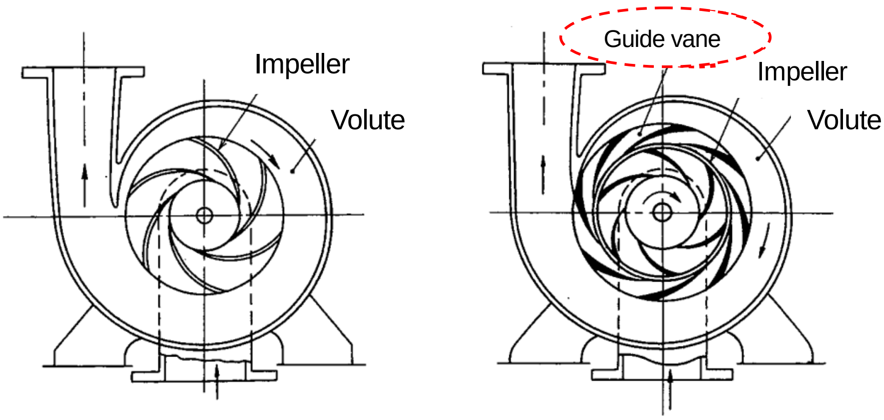
The direction of flow-out of pumped liquid is square to the pump shaft and centrifugal pumps are classified into volute pumps and turbine pumps depending on the provision/non-provision of a guide vane at the outlet of the impeller.

● Volute pumps (on the left in the figure below)

In a volute pump, liquid to which centrifugal force is given by the impeller is collected and pressurized in the volute before being discharged. Volute pumps are most widely used among centrifugal pumps.

● Turbine pumps (on the right in the figure below)

A turbine pump is equipped with a guide vane at the impeller outlet, which enables velocity energy to be converted into pressure energy efficiently. This enables the pump to attain a high efficiency. Turbine pumps are often employed in multistage pumps or high-lift pumps of a head of 20 m or more. Turbine pumps are also called diffuser pumps.



Volute　　　Turbine pump

<< Notes >>

- Running a turbine pump at a point of a small or large quantity of water that is out of the design point causes a disagreement between the angle of water discharged from the impeller and that of the guide vane, which may cause noise and vibration to occur.
- In recent years, the use of turbine pumps has been reduced with improvement in the performance of volute pumps.
  * Volute pumps, simple in construction and capable of being compact, have advantages over turbine pumps.
- In JIS, turbine pumps are called “diffuser pumps” and the expression of “turbine pump” is not used.
  * In recent years, there is a tendency of calling them diffuser pumps.

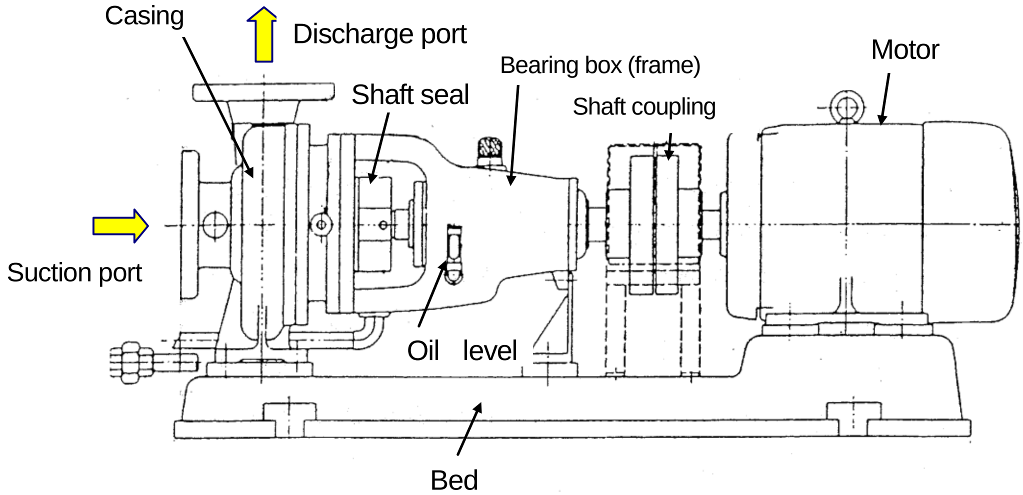
1	Overview of Centrifugal Pumps
1-3	Construction and functions of centrifugal pumps
1-3-1	Configuration of centrifugal pumps

The mechanical elements constituting a centrifugal pump include the casing, impeller, main shaft, bearings, shaft seal, shaft coupling and there are various types of centrifugal pumps according to combinations of those components. Therefore, a wide variety of centrifugal pumps have also been used in the industries according to application purposes. This document describes those constituting elements on the basis of single-suction single-stage volute pumps of the horizontal shaft type that are most often used in chemical plants and have high versatility.

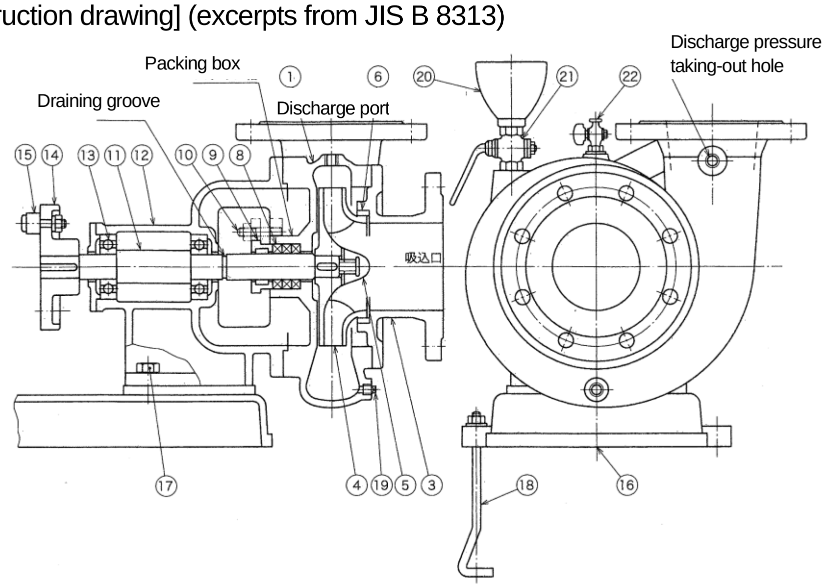
1. Configuration of single-suction single-stage volume pumps

   The following shows the appearance and construction example (cross sectional figure) of a single-suction single-stage volute pump.

[Outside drawing]



[Construction drawing] (excerpts from JIS B 8313)



No.	Name
1	Casing
3	Suction cover
4	Impeller
5	Impeller nut
6	Liner ring
8	Packing
9	Packing holder
10	Packing holder bolt
11	Main shaft
12	Bearing housing
13	Ball bearing
14	Shaft coupling
15	Coupling bolt
16	Common base
17	Mounting bolt
18	Foundation bolt
19	Draining plug
20	Priming funnel
21	Priming cock
22	Air vent cock

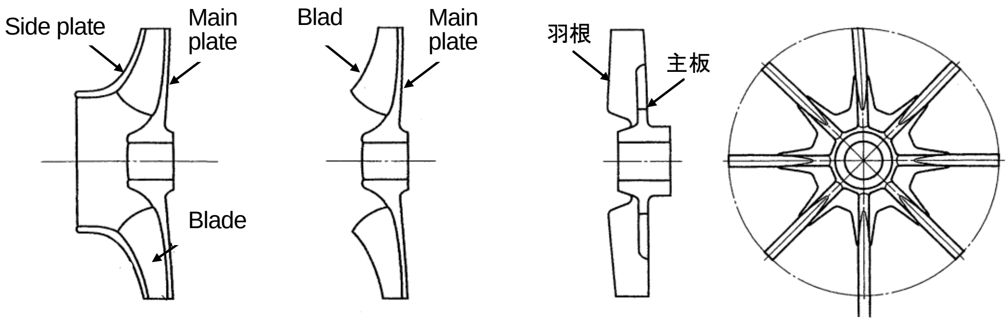
* This drawing shows gland packing for ⑧ packing (shaft seal); however, mechanical seals are generally often used in process pumps.

<u>Impeller</u>

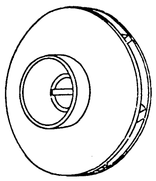
For centrifugal pump impellers, the closed type, most general, consisting of blades, main plate, and side plates and the open type without side plates that is used in handling slurry or when the impeller is covered with rubber, etc. are used. In general, impellers are manufactured by monobloc casting; however, there are cases where the main plate and blades are mono-bloc cast and then side plates are jointed to the monobloc body if the outlet width is narrow or if blades are to be finished precisely. The number of blades is generally selected in a range of six to eight blades.
In addition, balancing holes or pump outvane may be provided to keep the axial thrust in balance.

1) Closed and open types

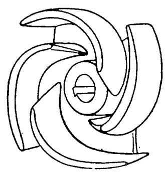
The open type is further divided into the semi-open type in which the main plate is extended up to the outer perimeter of blades and the (full) open type in which the main plate is shortened as much as possible.



Closed type　　Semi-open type　　(Full) open type



Closed type



Open type

① Closed impeller

This is the most general impeller. It has a good efficiency and is used for any kinds of fluids not containing solid content.

② Semi-open impeller

The semi-open impeller consists of only main plate and has no side plates. There are cases where it has a pump outvane on the back side of the main plate and where it has not.

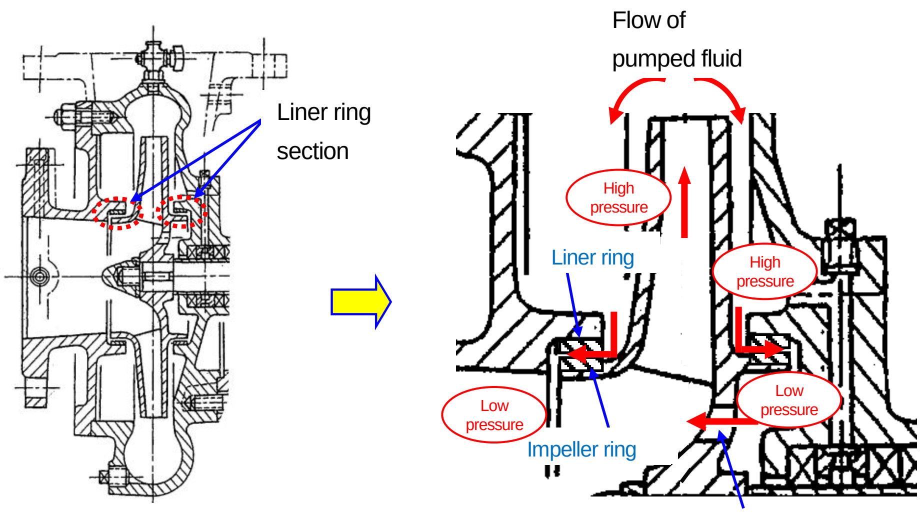
③ Open impeller

The open impeller does not have a so-called main plate and side plates and consists of only blades and the boss. For impellers with long blades, the main plate of a minimum required limit is provided from the viewpoint of strength. Instead of having no main plate and side plates, an open impeller has a liner on the opposite casing and rotates by maintaining a small clearance from the liner. The open impellers are used for slurry fluid or pumping fluid of substances apt to clog.

2) Impeller ring and liner ring

As understood from the construction of a volute pump, there are a high-pressure area (discharge side) and low-pressure area (suction side) in the casing interior. Therefore, there occur flows of pumped fluid as shown in the arrows in the figure below, resulting in leakage losses, which affects the pump efficiency. Thus, to control leakage, it is necessary to minimize the clearance between the impeller and the casing's sliding section. To make this clearance appropriate, a set of rings are generally installed. These rings form a kind of a throttle and a ring on the impeller side is called an impeller ring, while a ring on the casing side is known as a liner ring.

It is ideal to maintain the clearance between the rings uniform in the full circumference during operations. However, it is difficult to achieve this due to slight distortion caused by loads applied from piping to the casing, wear on the bearings, an alignment failure of the coupling, deflection caused by the own weight, etc. In many cases, it is inevitable that there is a slight contact between them. Therefore, it may be considered that those rings play a role of bearing. (As long as this contact is slight, there is no problem if foreign matter does not exist or in the case of fluid with lubricity.)



Balanced impeller

A large clearance between the rings due to wear on a ring results in a reduced pump efficiency caused by an increase in the leakage amount or increased vibration; they are designed to be replaceable when worn out.

<< Notes >>

・The impeller of a single-suction single-stage volute pump has the construction overhang from the bearing section, causing not some little deflection.

・JIS-based terms

Impeller ring: Ring installed to the impeller with respect to the sliding part of the liner ring
* Impeller ring is often called a wear ring.

Liner ring : Ring installed to the casing with respect to the impeller or the sliding part of the impeller ring

・Apart from the use of cast iron and bronze as materials, there is generally a difference in the hardness between both the rings. If the same material is used for them, the clearance between them is made slightly greater than usual.

1	Overview of Centrifugal Pumps
1-3	Construction and functions of centrifugal pumps
1-3-3	Bearings

Bearings

Bearings support the rotating shaft in a specified location. They are mechanical elements that keep safely the weights of the shaft and impeller and loads acting upon them during running, or so-called radial load (load in the shaft radial direction) and thrust load (load in the axial direction).

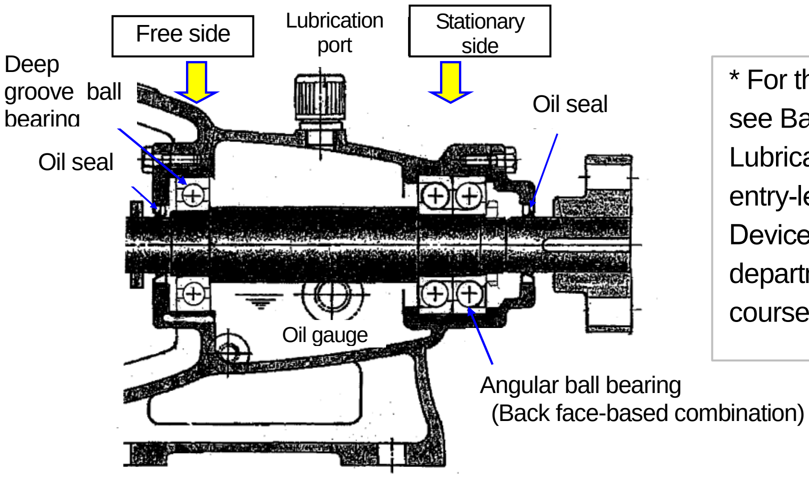
A damaged bearing results in trouble such as the occurrence of vibration, contact between the impeller and the casing, or leakage from the shaft seal. Bearings are very important parts in terms of safety operations of rotating equipment.

Bearings are broadly classified into slide bearings and roller bearings. Excepting those of heavy loads particularly, roller bearings, available at low cost and in many types and having compatibility, are used in many cases.

Both radial and thrust loads act on the main shaft of a centrifugal pump; bearings capable of supporting both of those loads or a combination of bearings that bear each type of load are used. In compact centrifugal pumps, deep groove ball bearings that can bear both radial and thrust loads are often used. If thrust load is greater than radial load, angular contact ball bearings, etc. are used. In addition, to smooth out thermal stress caused by temperature changes, one of two bearings is made a fixed side, while the other is made a free side (moving in the axial direction).

For long, stable operations, it is most important to control lubrication for bearings and it is necessary to pay attention to lubricant leakage and ingress of dust, rain water, etc. from the outside.

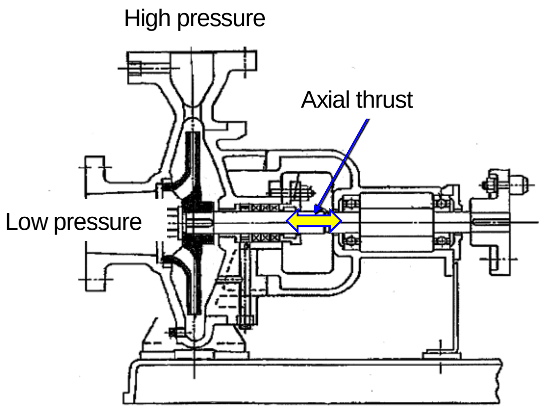
[Example of installation of a bearing]



* For the details of bearings, see Basics of Bearings and Lubricant and Shaft Seal in entry-level 1 "Equipment and Devices" of the production department personnel training course.

<< Notes >>

□ Axial thrust of cantilever hangover type



* In the case of most general hangover-type axial thrust, the direction of axial thrust is reversed between in liquid filling and during operation.

(There appears a differential pressure of the cross-sectional area of the shaft.)

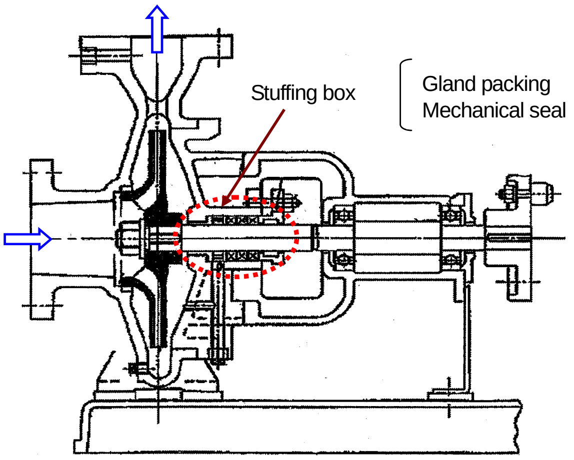
Direction of axial thrust

	Position of the impeller	
	Shaft end (Overhang)	Shaft through
In liquid filling	→	- (Not caused)
During operation	←	←

1	Overview of Centrifugal Pumps
1-3	Construction and functions of centrifugal pumps
1-3-4	Shaft seal (1/3)

Shaft seal

There is clearance in an area where the shaft passes through the casing and to prevent fluid from leaking from the clearance, shaft seal is provided. There are two types of shaft seals: gland packing type and mechanical seal type. It is necessary to properly understand the construction and features of these seal types because the mechanism of them is completely different. As noted in 1-1, canned motor pumps and magnet pumps have recently been employed in a wide range of applications as the "volute pumps of zero leakage," or so-called seal-less pump without shaft seal.



* Stuffing box
A chamber for installing gland packing or mechanical seal. It is also called a packing box.

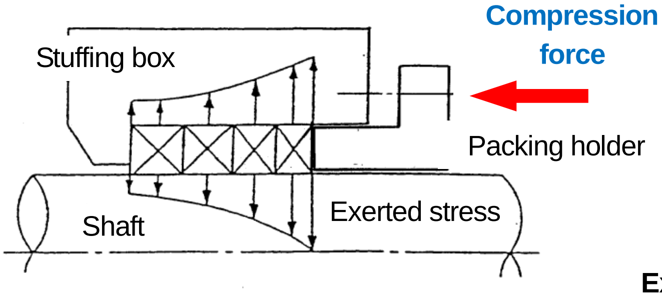
1) Gland packing

The sealing mechanism of gland packing is shown in the figure below.

When a compression force is given in the axial direction on gland packing using a packing holder, stress is exerted in the radial direction, increasing intimate contact between the packing and the shaft and stuffing box, which causes the fluid to be sealed. Generally, four to six pieces of gland packing are fitted. Gland packing is low priced and easy to install, but has the following drawbacks:

- Gland packing comes in contact with the shaft in a wider area; a rotational friction is large.
- There occurs friction heat; pump needs to be run by letting fluid leak to some extent, which also plays a role of lubrication and cooling. Therefore, there are limitations on fluids to be handled.
- Leakage becomes greater due to time-based deterioration; it is necessary to retighten packing appropriately.

Direct contact between the shaft and gland packing causes the shaft to wear out; shaft sleeves are generally fit to protect the shaft. If a shaft sleeve wears out severely, it is repaired or replaced.



Example of wear on shaft sleeve

2) Mechanical seal

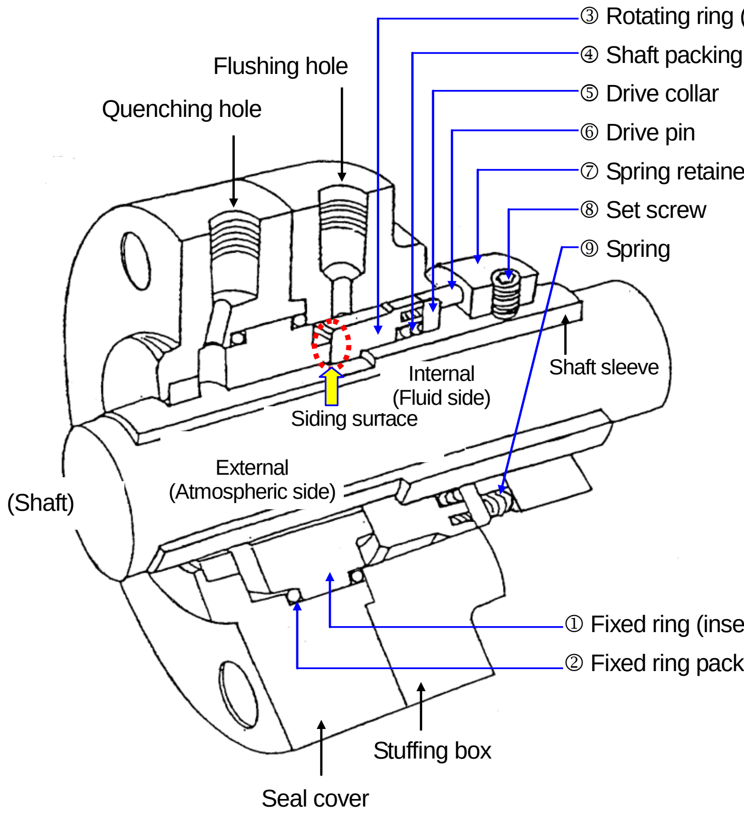
① Basic construction

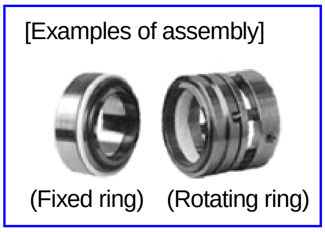
Unlike gland packing, mechanical seals can stop leakage almost completely; they can be used in a wide range of fluid. A variety of types of mechanical seals are used depending on the usage conditions. The following figure shows the most general construction.

Gland packing provides sealing by a cylindrical sliding surface between the shaft and packing, while a mechanical seal performs sealing by sliding of the end faces of the fixed ring ① fastened to the seal cover and the rotating ring ③ rotating with the shaft that is square to the shaft. Both two surfaces are precisely finished flat. The rotating ring can also move in the axial direction and is pushed against the mating face with spring ⑨ so that a stable surface pressure is held between the two faces against wear on the sliding surface, pressure variations, or vibration. The spring also has the function of pressurization to prevent the two faces from being apart after installing the mechanical seal over the shaft. Seal between the fixed ring and the seal cover and seal between the rotating ring and the shaft are called secondary seals and each is provided with packing ② and ④.

For the material of the sliding section of the fixed and rotating rings, hard materials such as carbon, stellite, carbide, and ceramic are used in combination.

There are many types of mechanical seals and the suitable types are employed according to uses.



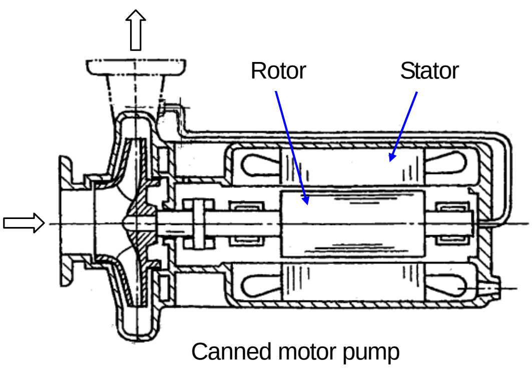


3) Comparison between mechanical seals and gland packing

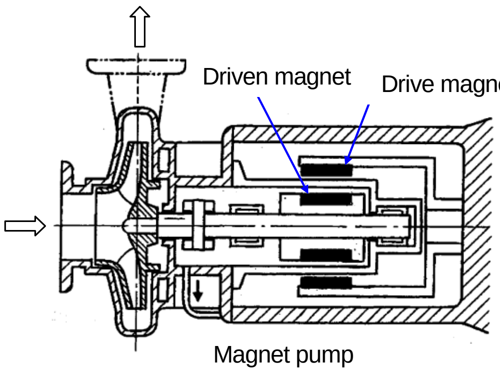
	Mechanical seal	Gland packing
Amount of leakage	Very small. Generally, it can reduce leakage to 3 ml/h or less in the case of seal for pumps.	Very large. It is inevitable that a leakage of approx. 1000 m/h occurs and loss caused by leakage of mother liquid is large.
Wear on shaft and sleeve	It does not slide against the shaft or sleeve; no wear occurs.	Wear is caused because it slides with the shaft and sleeve directly.
Construction	Precise and the number of parts is large; it is complex.	Accuracy is low and construction is simple.
Maintenance & adjustment	If a sliding surface is worn out, mechanical seal tracks it automatically by the action of spring, etc.; however, it needs to be replaced once leakage starts.	The amount of leakage can be adjusted by retightening; however, it needs to be replaced if the wearing of packing, shaft, or sleeve becomes severe.
Replacement	A pump needs to be disassembled.	No pump is required to be disassembled and replacement is ease.
Usage limit (Pressure, temp, peripheral velocity)	Appropriate materials and design allow it to be used in a wide range.	To reduce leakage, the usage conditions are limited.
Power consumption	Small	Friction between the shaft and packing is large, resulting in large power consumption.
Cost	Large (but running cost is small)	Low (but running cost is large)

4) Pumps without shaft seal

Mechanical seals enable the amount of leakage to be very small; however, it is impossible to achieve zero leakage. Thus, there arises a problem if it is used for fluid whose leakage poses a risk (toxicity, explosiveness), pollution, or environmental contamination. For these fluids, pumps of complete non-leakage that have no shaft seal, or so-called seal-less pumps, are used. The seal-less pumps include “canned motor pumps” and “magnet pumps” shown in the figure below.



Canned motor pump



Magnet pump

<< Notes >>

・Non-seal Pumps, well known, are the trade name of Nikkiso’s canned motor pumps.

2	Daily Inspection of Pumps
2-1	What is daily inspection?
2-1-1	Purpose of daily inspection

A daily inspection of equipment is inspection mainly conducted from the appearance to check for an abnormality in each section by a combined use of five senses and simple instruments or monitoring instruments provided for the equipment during operation. Its purpose is to “maintain the equipment in sound condition and find an abnormality at an early stage to prevent failure.” A daily inspection of pumps include inspection based on sound, heat, or vibration, lubricating condition check, and checking for leakage from sealed sections, etc.

Centrifugal pumps are superior in the principle, operating performance, and practicability, simple in the construction, and are most often used by comparison with other pumps in the equipment-intensive industry. Therefore, their degree of importance is also high in processes and it is necessary to perform daily inspection control by thoroughly understanding the pumps’ usage purpose, usage conditions, construction, features, etc. The intervals of daily inspection cannot be determined uniformly, but are established in consideration of the categories of the degree of the importance of equipment based on the standardized philosophy in combination with periodic inspection. In establishing or reviewing the intervals of a daily inspection, the following conditions should also be considered.

① Change in the operating conditions or operation abnormality
Changes in the operating conditions that must be particularly noted include the following:
  a. Change in the fluid property
  b. Change in components, pH, etc. and change of material properties, additives, etc.
  c. Change of fluid pressure, temperature, etc.
  d. Change in the operating conditions of related equipment
② Results of periodic inspection
③ History and characteristics of equipment
④ Examples of troubles of similar equipment
⑤ Content and intervals of daily inspection conducted by personnel in charge of equipment control

To conduct inspection efficiently, it is necessary to narrow down points and conduct an inspection appropriate to degradation phenomena by assuming the causes of degradation damage on equipment based on combinations of the service temperature, pressure, the properties of substance to be handled, equipment’s material and construction, etc. and their areas.

(Example of the outline drawing of a single-suction volute pump)

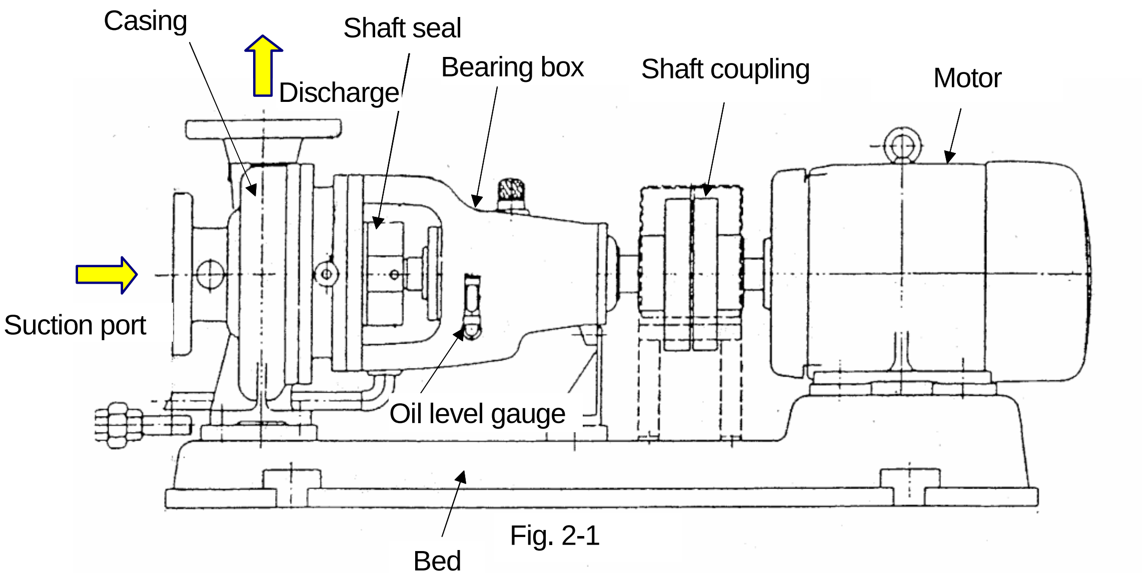


Fig. 2-1

2	Daily Inspection of Pumps
2-1	What is daily inspection?
2-1-2	Daily inspection and maintenance control

To understand the importance of daily inspection, it is necessary to recognize an overall view of maintenance control of equipment. There is no established theory on the category of maintenance activities and the actual condition is that they are performed based on the interpretation of each company. Figure 2-2 shows an example of the categories of maintenance (details of each item are omitted to be described in this document).

Generally, maintenance conducted by the maintenance department is called specialized maintenance and maintenance performed by the operation department is known as autonomous maintenance and an example of the categories of maintenance is shown in Table 2-1. So-called "autonomous maintenance" conducted by the operation department is daily inspection. In addition, daily inspection is included in preventive maintenance (PM) – time-based maintenance (TBM) in terms of the maintenance categories.

(Example of the maintenance categories)

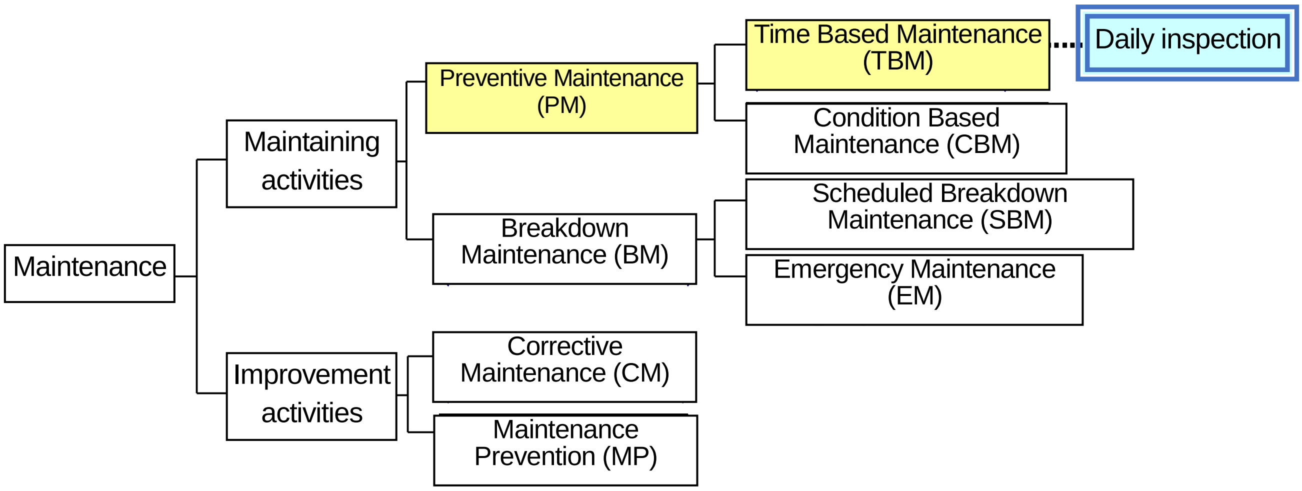


Figure 2-2

(Specialized maintenance and autonomous maintenance)

	Specialized maintenance (Maintenance dept.)	Autonomous maintenance (Operation dept.)
Daily maintenance [Period of less than a month]	Patrolling	Check list-based Inspection Lubrication Adjustment Cleaning
Periodic maintenance	・Inspection using simple measuring instruments ・Inspection using precision measuring instruments ・Periodic maintenance	・Five senses-based inspection ・Law-based autonomous inspection ・Simple disassembly & maintenance
Predictive maintenance	Predictive inspection and maintenance Rotating machinery condition surveillance, non-destructive inspection, etc.	—
Preventive maintenance Emergency maintenance	Repair	Minor repair Simple disassembly and repair, part replacement, etc.

Daily inspection

(Maintenance and safety of Chemical Equipment Handbook)

Table 2-1

2	Daily Inspection of Pumps
2-2	Equipment failure
2-2-1	Equipment's life characteristics

For equipment, the occurrence rate of failure changes depending on the time in the life period of installation to withdrawal from service. The relationship between the failure rate and time is represented as the "bath-tub curve" as shown in Figure 2-3 and change in the failure rate is largely classified into three periods: initial failure period, random failure period, and wear-out failure period. For the random failure period, it is unknown when failure occurs and is important to find an abnormality at an early stage by daily inspection. In contrast, the wear-out failure period is a period during which a failure rate increases and during this perio, it is required to reduce the failure rate. Thus it becomes important to improve the maintenance control technology including daily inspection. Note that if these three periods are compared to the lifetime of humans, it can be said that they correspond to the infancy, adolescence and late middle age, and senescent, respectively.

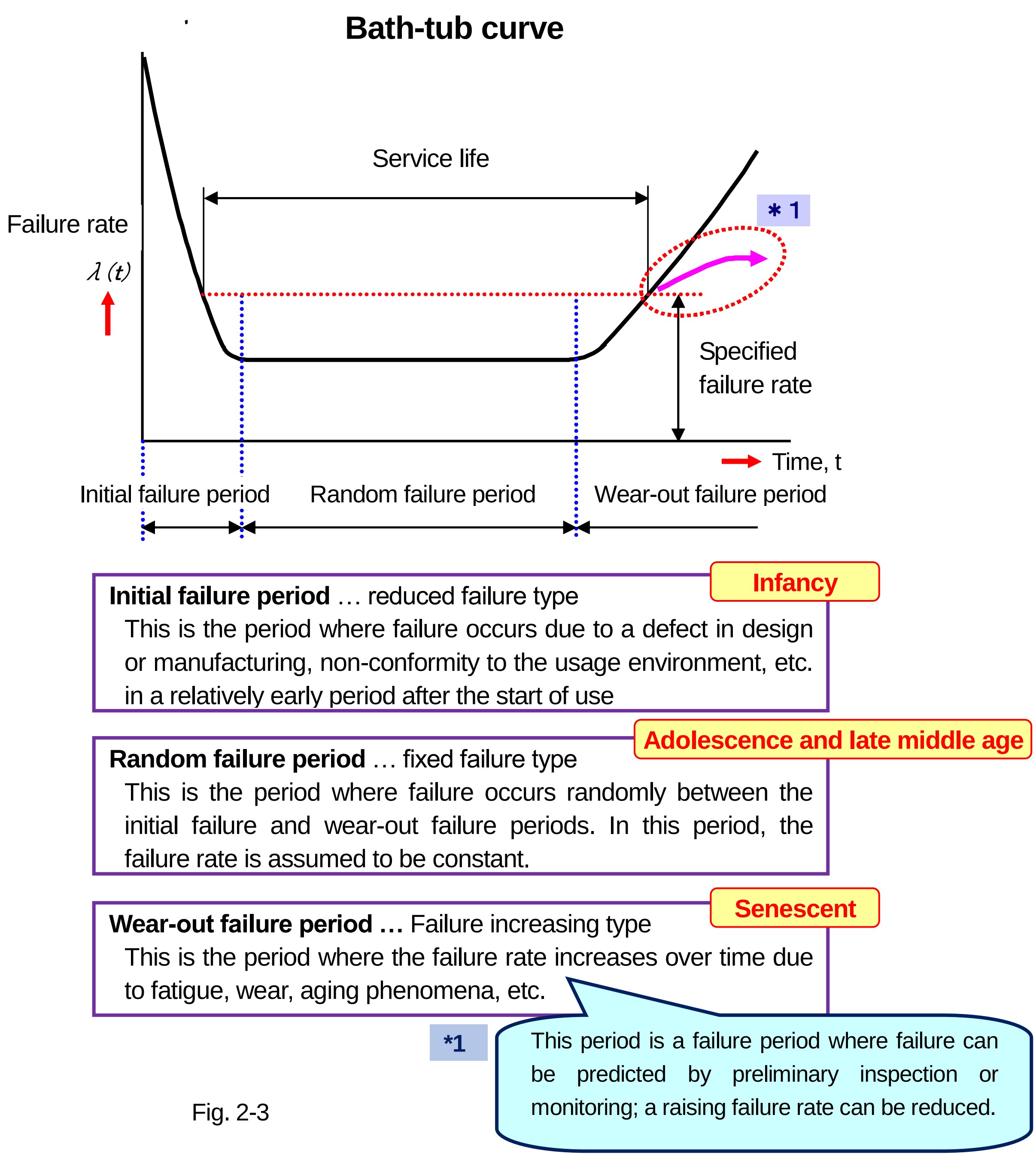


Fig. 2-3

2	Daily Inspection of Pumps
2-2	Equipment failure
2-2-2	Functions and failure of main parts

When pump failures are broadly classified, they can be divided into those in the rotating section and those in the non-rotating section. To improve the effectiveness of a daily inspection, it is necessary to thoroughly understand the functions of each part and a failure mechanism together with the construction. Table 2-2 shows the functions and failures of the main parts and Figure 2-5 (on the next page) shows the failure mechanism for each part.

(Functions and failure of the main parts)

Item / Area	Function	Failure
Frame	**Secures the shaft center.**	**Inadequate strength**
Casing	**Holds fluid and secures the stream.**	**External leakage** **Clogging**
Liner ring	**Maintain pressure energy.**	**Failure to attain specified pressure or flow rate**
Impeller	**Converts mechanical energy into pressure energy to achieve a specified flow rate.**	**Failure to provide specified pressure or flow rate**
Main shaft	**Transmits motor rotation to the impeller.**	**Bend, breakage, and/or wear**
Bearings	**Provides smooth rotation.**	**Seizure & stop, uneven rotation**
Coupling	**Transmits motor rotation to the shaft.**	**Breakage**
Shaft seal	**Seals fluid by the mating faces of the rotating and fixed sections.**	**Leakage**

(Maintenance Handbook)

Table 2-2

(Example of the construction of a single-suction volute pump)

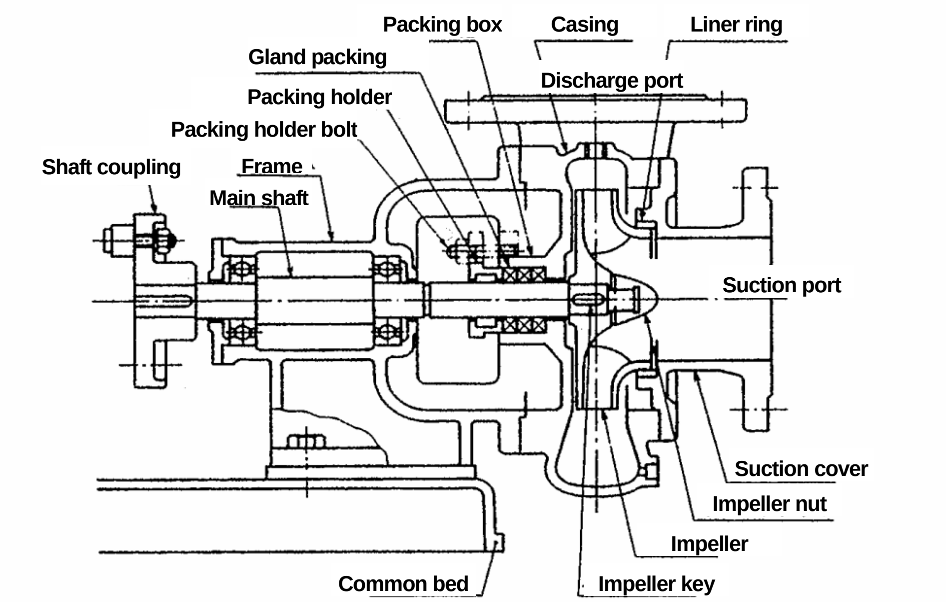


Fig. 2-4

2	Daily Inspection of Pumps
2-2	Equipment failure
2-2-3	Failure mechanism of parts

(Failure mechanism of parts)

			Area	Failure mechanism (Deterioration mode)	Failure mechanism (Failure mode)
Volute pumps	Non-rotatin	Non-wetted section	Foundation bolts and liners	Looseness, coming off, or corrosion	Strength reduction, vibration
			Common bed	Corrosion (wet)	Strength reduction, vibration
			Frame	Corrosion (wet)	Strength reduction, vibration
			Stuffing box	Corrosion (wet)	Strength reduction, vibration
		Liquid-wetted section	Casing	Overall wear	Reduced capacity, leakage
			Suction cover	Overall wear	Reduced capacity, leakage
			Liner ring	Wear	Reduced capacity
	Rotating section	Non-wetted section	Main shaft	Fatigue, cracking	Vibration
			Shaft coupling	Looseness, miss-alignment, unbalance	Vibration
			Bearings	Flaw, rattling, breakage	Vibration
		Liquid-wetted section	Shaft sleeve	Fretting corrosion	Vibration
			Impeller	Corrosion, partial wear, unbalance	Reduced capacity, vibration
			Shaft seal	Sticking, deterioration	Functional loss (leakage)
			Impeller nuts and key	Looseness, coming off	Vibration

(Maintenance Handbook)

Fig. 2-5

2	Daily Inspection of Pumps
2-3	Contents of daily inspection
2-3-1	Categories of responsible areas between operation and maintenance depts.

Troubles caused during pump running include mechanical ones and those related to performance. Therefore, in the daily inspection of pumps, it is necessary to conduct inspection based on sound, heat, or vibration, lubricating condition check, and status monitoring of changes in the pressure and flow rate. Furthermore, in addition to these, minor maintenance work such as retightening of fastened sections or gland, lubrication, etc. is also included in a daily inspection.

Table 2-3 shows the OSI*1 items conducted by the maintenance department and the daily inspection area overlaps with a daily inspection conducted by the operation department; however, inspection intervals and areas that each department takes charge of are decided as appropriate.

Type	Item	Method (inspection equipment)
Daily inspection	● Checking each part for abnormality based on appearance ・Unusual noise ・Vibration ・Retention heat ・Oil condition (color, quantity, etc.) ・Leakage ● Operating condition abnormality	・**Five senses** ・Monitoring instruments ・Listening rod, etc. ・Simple vibration meters, etc. Daily inspection by operation dept.
Condition surveillance	● Vibration trend measurement control ● Detection of unusual sound (Bearing damage)	・Vibration meter ・Bearing monitor ・Listening rod, measuring instrument for condition surveillance, etc.
Precision diagnosis	● Vibration abnormality ● Sound abnormality ● Oil properties Check & inspection by maintenance	・Spectrum analyzer ・Sound spectrograph ・Ferrography ・Spectrometric oil analysis program (SOAP) ・Measuring instrument for condition surveillance, etc.

Based on five senses
Qualitative (> quantitative)

Use of inspection equipment
Quantitative

(CES)

Table 2-3

***1: OSI (On-stream inspection)**

This is an inspection conducted during operation. It grasps changes in operating equipment or a deterioration status based on five senses or using inspection instruments to detect the sign of change, abnormality, etc. at an early stage.

Note: There are cases where a daily inspection is not included in OSI.

2	Daily Inspection of Pumps
2-3	Contents of daily inspection
2-3-2	Daily inspection items and methods

The daily inspection of pumps has been described in various forms up to now and the following summarizes daily inspection items:

[Inspection item] [Method]

① Bearing temperature............................. Touching with hand
② Leakage from shaft seal .... Eye observation
③ Amount of lubricant in bearing .... Eye observation
④ Vibration and unusual noise .... Touching with hand or listening by ear
⑤ Suction and discharge pressure .... With a pressure gauge, vacuum gauge, or compound pressure gauge
⑥ Motor load .... Ammeter

Inspection area	Inspection item	Inspection method
・Casing ・Shaft seal ・Bearing ・Oil level gauge ・Bed ・Nameplate ・(Coupling)	Leakage Unusual sound Vibration Temperature Odor Corrosion Wear Crack Fouling Lubrication status	● Five sense-based inspection ・Sense of sight ・Sense of hearing ・Sense of touch ・Sense of smell ・(Sense of taste) ● Simple instrument-based inspection ・Listening rod ・Monitoring instrument ・Simple vibration meter, etc.
・Change in performance	Pressure change Current value change	Pressure gauge reading Ammeter reading

Table 2-4

In a daily inspection, a lubrication status check is added to inspection making sound, heat, and vibration as the base to make minor maintenance work such as retightening of fastened areas and pump gland, lubrication, etc.

I It is important to grasp an equipment condition accurately by properly observing with eye (sense of sight), properly listening by ear (sense of hearing), and touching with hand (sense of touch). In addition, gas or liquid leakage or oil burning caused by bearing temperature rise, etc. can be detected by smell (sense of smell)..

<table>
<tr><th>Item</th><th>Point</th><th>Method</th></tr>
<tr>
<td>Vibration

Sound</td>
<td>1. Vibration
・Check the degree of vibration by the impression of sound and touching with hand.
In centrifugal pumps, vibration or unusual sound is the most simple and effective means for grasping an equipment status. However, five senses-based diagnosis is a qualitative diagnosis in which judgment on the presence/absence of an abnormality is made by a sense of “different from usual” and it is very difficult to make judgment on whether it is normal or abnormal. If you feel a sense of “different from usual,” check sound and vibration using a listening rod or simple vibration meter and if a measured vibration value exceeds the reference value, it is necessary to contact the maintenance department to have appropriate actions taken.

Rotating machines always vibrate!

All rotating machines always vibrate even if the equipment concerned is in good condition. Increased vibration means that mechanical trouble has occurred.

[Vibration from pump]
Vibration includes mechanical vibration and hydraulic vibration (such as surging).
* Causes of the occurrence of mechanical vibration
An unbalanced rotating body caused by wear, breakage, etc., contact in the casing, alignment failure, poor foundation, distortion caused by piping load, etc.
* Causes of the occurrence of hydraulic vibration
Cavitation, surging, air suction, etc.

* General permissible standard of centrifugal pumps (displacement)

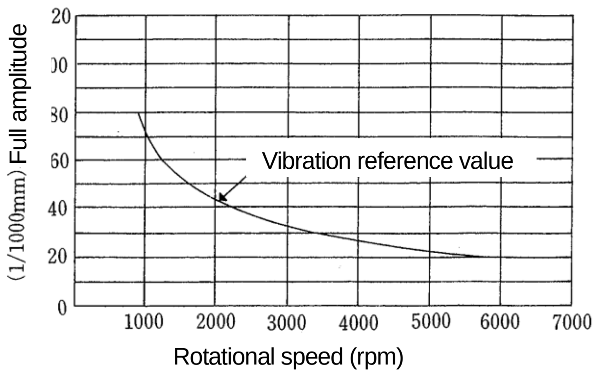



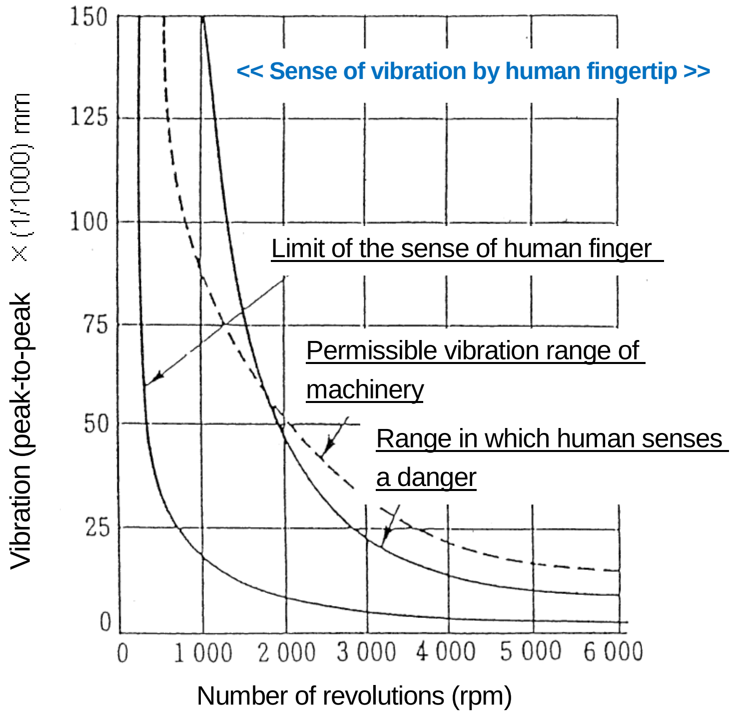
Fig. 2-12</td>
<td>Touching with hand

Sound listening

Vibration measurement

Conduct vibration measurement by determining a fixed point. This is also true for measurement of vibration from a motor.</td>
</tr>
</table>

2	Daily Inspection of Pumps
2-4	Points of daily inspection
2-4-1	Bearings and lubrication (2/2)

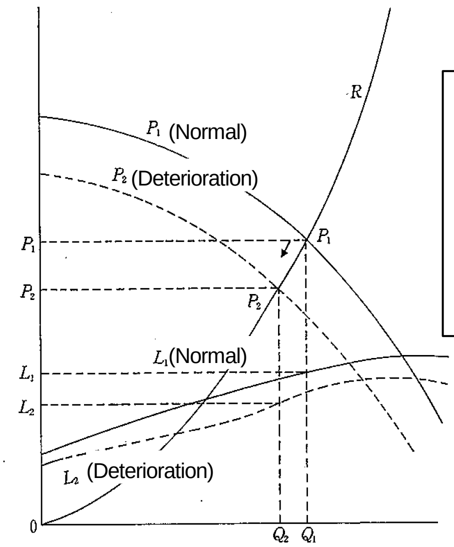
Item	Point	Method
	* Sense of vibration by human fingertip  [Source] S.J.Shuey : Power Engineering Vol.77,No.5 **Fig. 2-13** [Precautions in measuring vibration] When measuring vibration, it is necessary to recognize the purpose of measurement first. That is, it is important to select the appropriate measurement mode (displacement, velocity, or acceleration) according to the diagnostic purpose. General mechanical vibration (such as unbalance or miss-alignment), fluid pulsation, etc. occur in a range of the neighborhood of 10 Hz to a few 100 Hz; it is good to measure vibration of displacement or velocity. Gear vibration, damaged rolling bearing, cavitation, etc. occur in a relatively high vibration range of a few 100 Hz to several 10 kHz. Therefore, they are generally measured by acceleration vibration. In a low frequency range, the sensitivity of displacement is high and as the frequency increases, the sensitivity target moves to velocity and then to acceleration. Up to a frequency of a few 100 Hz, vibration is measured by displacement or velocity, while at frequency higher than that, it should be measured by acceleration.	Use the three physical quantities of vibration: Displacement Velocity Acceleration suitably.

2	Daily Inspection of Pumps
2-4	Points of daily inspection
2-4-2	Performance check (1/3)

Whether a pump is demonstrating specified performance can be determined by the following three items:

① Suction/discharge pressure
② Motor's current value
③ Specified discharge quantity

Generally, pump's performance can be judged by monitoring a pressure gauge and if a large change occurs in the pressure, a motor current is measured or comparison between the performance characteristic curve (performance test records) and data is made to judge the presence/absence of an abnormality.

Item	Point	Method
Pressure change Current value Flow rate change	1) Performance degradation ① Reduction in pressure, flow rate, and axial power If the impeller has worn out and its outer diameter has been reduced, the impeller's peripheral speed decreases, causing the pressure, flow rate, and axial power to be reduced. This phenomenon is also observed if the liner ring has worn out, causing clearance from the impeller to increase or if foreign matter is caught in the impeller.  The point of intersection of the resistance and pressure curves changes from P_1 to P_2, causing the pressure to drop. The flow rate and axial force also decrease from Q_1 to Q_2 and L_1 to L_2, respectively. **Fig. 2-21** ② Pressure rises and the flow rate and axial force decrease If piping resistance increases due to the adhesion of scale, etc. on the piping inside (on discharge side), the pressure rises and the flow rate and axial power decrease. ③ Pressure drops and the flow rate and axial power increase If piping resistance decreases due to wear on the flow-rate regulating valve or piping, the pressure drops and the flow rate and axial power increase. * The characteristic curves of the cases ② and ③ above are given on the next page.	Visually

2	Daily Inspection of Pumps
2-4	Points of daily inspection
2-4-2	Performance check (2/3)

<table>
<tr><th>Item</th><th>Point</th><th>Method</th></tr>
<tr>
<td>Pressure change

Current value

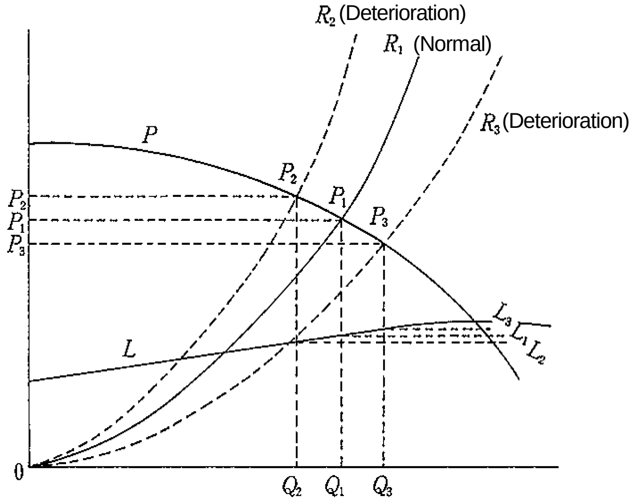
Flow rate change</td>
<td>


Fig. 2-22

② In the case of increased piping resistance
The point of intersection of the resistance and pressure curves changes from P1 to P2, causing the pressure to rise. The flow rate and axial force decrease from Q1 to Q2 and from L1 to L2, respectively.
③ In the case of reduced piping resistance
The pressure decreases from P1 to P3, while the flow rate and axial force increase from Q1 to Q2 and from L1 to L2, respectively.

④ Increase in the axial power
If the resistance of a rotating body increases due to damaged bearing, excessive tightening of gland packing, etc., only the axial force increases and the flow rate and pressure remain almost unchanged.

Those items can be summarized as shown in the table below:
<table>
<tr><th></th><th>Pressure</th><th>Flow rate</th><th>Axial force</th><th>Judgment</th><th>Cause</th></tr>
<tr><td>①</td><td>➘</td><td>➘</td><td>➘</td><td>Degraded performance</td><td>・Worn-out impeller (reduced O.D.)
・Liner ring worn-out</td></tr>
<tr><td>②</td><td>➚</td><td>➘</td><td>↘</td><td>Increased piping resistance</td><td>・Adhesion of scale on piping inside</td></tr>
<tr><td>③</td><td>➘</td><td>➚</td><td>↗</td><td>Reduced piping resistance</td><td>・Worn-out flow-rate regulating valve or piping</td></tr>
<tr><td>④</td><td>↘</td><td>↘</td><td>➚</td><td>Increased rotating resistance</td><td>・Increased resistance of a rotating body due to worn-out bearing, excessive tightening of seal, etc.</td></tr>
</table>
(➔: Large change, →: small change)
</td>
<td>Visually</td>
</tr>
</table>

2	Daily Inspection of Pumps
2-4	Points of daily inspection
2-4-2	Performance check (3/3)

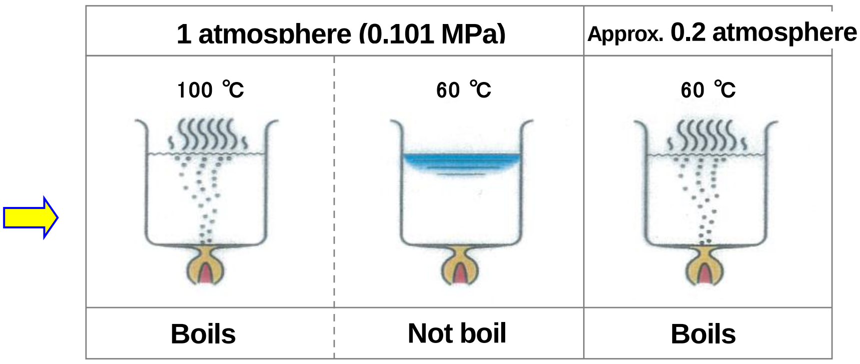
Item	Point	Method
	2) Characteristic change by temperature For liquid, the specific gravity, viscosity, and steam pressure changes with temperature change; a large temperature change causes effect on the performance of a pump. Therefore, when liquid of high temperatures is used, it is necessary to grasp the liquid characteristics sufficiently to prevent a temperature change. ・Specific gravity change: Specific gravity increases with decrease in temperature. **Increased pressure or axial power** ↓ **Motor is overloaded.** ・Viscosity change: Viscosity increases with decrease in temperature. **Increased friction loss in a pump** ↓ **Flow rate, pressure, and efficiency decrease.** **Axial power increases.** ・Steam pressure change: Steam pressure increases with increase in temperature. **Reduced NPSHav** ↓ **Cavitation occurs.** **For clear water of 40°C or less, change in the specific gravity, viscosity, or steam pressure caused by a temperature change is so small that the performance of a pump is not almost affected. Thus, a characteristic change by temperature is generally ignored.**	

3	Performance of Centrifugal Pumps
3-1	Cavitation
3-1-1	Cavitation and NPSH (1/4)

Water boils at 100°C; however, this occurs under the standard atmospheric pressure (1 atm = 0.1013 MPa) and if the pressure decreases, a boiling phenomenon occurs even at temperature less than 100°C. Liquid has a saturated steam pressure according to its temperature and if liquid pressure falls below the saturated steam pressure, it evaporates and generates foams. Also in the pump inside, in cases where the inlet pressure is low or the flow velocity is locally high, etc., if the pressure decreases partially and falls below the liquid's saturated steam pressure, the same phenomenon may be caused. This is known as pump's cavitation.

The table below shows the saturated steam pressure with respect to each temperature of water, liquid most familiar to us. As understood from the table, water boils at approx. 0.02 MPa at 60°C. Therefore, in the case of a pump pumping warm water of 60°C, if the pump's inlet pressure decreases to a point close to 0.02 MPa, cavitation is caused.

Temperature (℃)	Saturated steam pressure (Mpa)
0	0.00061
10	0.00123
20	0.00234
30	0.00424
40	0.00738
50	0.01234
60	**0.01992**
70	0.03116
80	0.04736
90	0.07011
100	**0.10133**



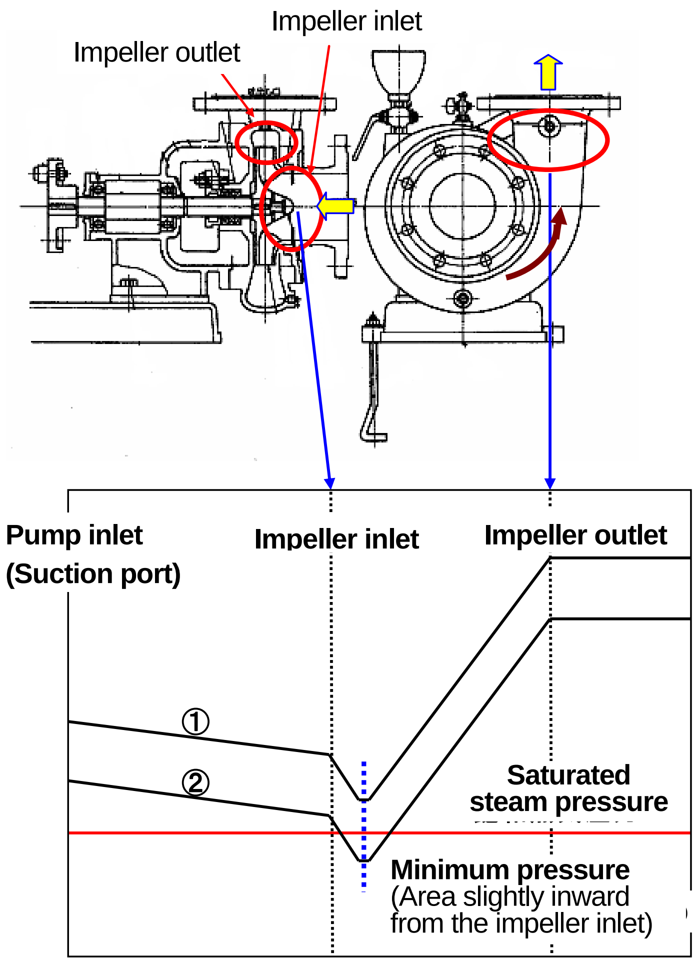
The occurrence of cavitation causes noise and vibration to develop, resulting in reduced pump performance. In the severe case, the pump may be disabled from pumping. The use of a pump in cavitation-caused condition for long hours may result in damage (material surface is hollowed in pit form) on an area of the impeller or casing where the cavitation has occurred due to impact caused when bubbles break. This is known as cavitation erosion.

* In an early stage, a small number of air bubbles are formed and noise and vibration occur somewhat. No particular change is observed in terms of the performance and appearance. However, as the cavitation progresses, there develops a larger crunching sound caused by the formation and breakage of air bubbles, disabling a planned flow rate from being achieved and the efficiency from decreasing and causing the impeller, etc. to be damaged.
Note that term "cavity" has the meaning of a hole or empty space.

The occurrence of cavitation is most harmful to pump operations; it must be prevented.
The next page shows the mechanism of the occurrence of cavitation.

3	Performance of Centrifugal Pumps
3-1	Cavitation
3-1-1	Cavitation and NPSH (2/4)

[Mechanism of the occurrence of cavitation]



In status ①, the minimum pressure is more than the saturated steam pressure; no cavitation is caused. If the liquid condition enters status ②, the minimum pressure falls below the saturated steam pressure, cavitation occurs.

Pump's internal pressure drops
↓
Pressure falls below saturated steam pressure.
↓
Boils (evaporates)
↓
Air bubbles are formed.
↓
Air bubbles break at the impeller's high-pressure area.
↓
Vibration and noise are caused.
↓
Impeller and casing are damaged.

At the beginning, dissolved gases are separated to form air bubbles.

Pressure becomes the lowest at the impeller inlet.

Air bubbles pass through the impeller and break to disappear as the pressure rises.

When air bubbles break, high impact pressure is exerted and the repetition of this causes the impeller or casing to be damaged.

3	Performance of Centrifugal Pumps
3-1	Cavitation
3-1-1	Cavitation and NPSH (3/4)

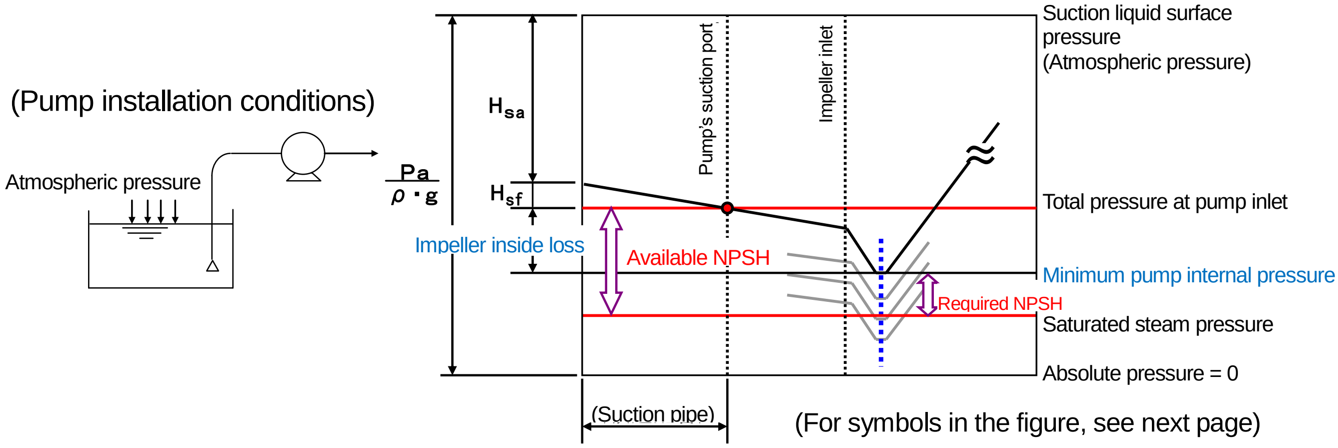
Cavitation is caused if liquid pressure falls below the saturated steam pressure; to prevent cavitation from occurring, actions must be taken so that there is no area where the liquid pressure becomes less than the saturated steam pressure. For this, it is necessary to specify a suction head at the suction port of a pump.

This suction head is known as net positive suction head (NPSH) and there is a distinction between available and required NPSHs.

● Available NPSH
- The available HPSH represents how high the total pressure (absolute pressure) of liquid flowing into a pump is from the saturated steam pressure (absolute pressure) of the liquid at its temperature. It is expressed in head.
- It is a value on the user side that is determined from the pump's installation and usage conditions.
- It is generally represented as "NPSHav." (JIS-based representation: NPSHA)

● Required NPSH
- The required NPSH is the minimum suction pressure required to prevent cavitation from occurring that is expressed in head.
- This is a value specific to a pump (on the manufacturer side) that is determined from the pump's design and manufacturing conditions.
- It is generally represented as "NPSHre." (JIS-based representation: NPSHR)

The figure below shows the relationship between the available NPSH and required NPSH.



(For symbols in the figure, see next page)

* The area where the liquid pressure is lowered most in a pump is a location slightly inward from the blade inlet of the impeller. From the pump's suction port to this location, there occurs a reduced pressure head due to the loss of head in the suction nozzle, increased velocity head caused by a reduction in the cross-sectional area of the stream, increased local velocity head caused by blade action, etc. To maintain the minimum pressure in the pump higher than the saturated steam pressure of the liquid, the pressure at the suction port must be held higher than the saturated steam pressure by the portion of a pressure drop caused during this distance. The pressure head equivalent to the portion of this pressure drop is the required NPSH and is specific to the pump. Note that the required NPSH changes with a different discharge rate or different rotational speed even in the case of the same pump.

To prevent a pump from causing cavitation, it is required that the available NPSH > required NPSH is established. In petrochemical or general chemical plants, a margin of approx. 30% is generally allowed for.

Available NPSH > 1.3 × required NPSH

3	Performance of Centrifugal Pumps
3-1	Cavitation
3-1-2	Cavitation and NPSH (4/4)

The available NPSH is obtained by the following equation:

$$H_{sv} = \frac{Pa}{\rho \cdot g} - \frac{Pv}{\rho \cdot g} - H_{sa} - H_{sf}$$

where

Hsv	: available HPSH (m)
Pa	: atmospheric pressure (absolute pressure) （Pa）…kg/(m•s^2)
Pv	: saturated steam pressure …kg/(m•s^2)
ρ	: liquid density (kg/m^3)
g	: gravity acceleration(m/s^2)
Has	: suction height (m) * "+" is given if the pump's reference plane is above the suction liquid surface or "-" is given if it is below the suction liquid surface.
Hsf	: Loss of head in the suction pipe (m)

Measures for preventing cavitation

① Lower the installation location of a pump to shorten the suction head.
② Use a vertical pump to immerse the impeller into water.
③ Lower the pump's rotational speed to reduce a suction specific speed.
④ Use a double suction pump.
⑤ Use two or more pumps to increase the discharge rate.
⑥ If the loss of head in the suction pipe or the loss of head caused by a valve, pipe joint, etc. provided for the suction pipe is large:
- Increase the diameter of suction pipe and reduce the numbers of valves, pipe joints, etc.
- Remove clogging from strainers.
- Lower the liquid surface of a suction tank.
- Lower the liquid temperature.

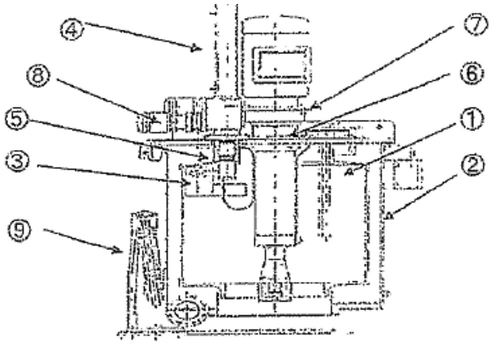
⑦ Do not regulate the flow rate using a valve on the suction side.

Centrifugal daily Inspection sheet

Daily inspection sheet for equipment　(　　　　Plant)

equipment No	F-405
Name of equipment	Centrufugal for JKY
Inspection interval	1time／Month
Inspection timing	FY2014 1st half

Type	The bottom discharge type
Material	SS400
Lining	SUS 304
Size	48inchs
Maker	Tanabe well tech



Inspec position	Position　NO	Inspection item	Interval	／	／	／	／	／	／	／
Inside	①	Corrosion and lining detaching	1time／M	It's put into effect before the inner situation driving starting. Lining damaged presence of the body and a baske						
Outside（Body）	②	Corrosion and liquid adhesion　Leaking	1time／M	Check leakage from body flunge、bolt looseness						
Scrach blade	③	Corrode and chip.	1time／M	Checking befor starting. Scratch blade corrosition 、missing、bolt drop down						
Turning and lifting apparatus	④	Abnormal noise	1time／M							
Bellows	⑤	Damage and bolt looseness	1time／M	Checking befor starting. Bellows bolt drop down						
Pillow	⑥	Abnormal noise oil leakage	1time／M	Grease leakage from oil seal、Vibration check、Temparature check on pillow、check by Auscultation stick						
	within 2.8m/ s	Vibration　(m/ s) Max	1time／3Ｍ							
	Ambient temperature＋within 40℃	Temparature（℃）Max	1time／3Ｍ							
Main motor	⑦	Abnormal noise oil leakage	1time／M	Grease leakage from oil seal、Vibration check、Temparature check on pillow、check by Auscultation stick						
	Withun 2.8m/ s	Vibration　(m/ s) Max	1time／3Ｍ							
	Ambient temperature＋within 40℃	Temparature（℃）Max	1time／3Ｍ							
	Rating　135A	Ammeter（A）	1time／M							
Cylinder for turning	⑧	Abnormal noise 、Air leakage	1time／M	Check air leakage、abnormal noise, Defective performance						
Cylinder for lifting	⑧	Abnormal noise 、Air leakage	1time／M							
The body stand and the prop part	⑨	Corrosion	1time／M	Corrosion、Abnormal						
Lubrication oil（●;renewal　□：supply　△：Sampling)			1time／M							
Remark		Inspector								
		Leader								
		Manager								
		Equipment control								

1． Record method　normal：○　abnormal：×and coment

Control Equipment Note Point out and countermeasure in Patrol

Equipment Name：No.2Deaeration container water supply pump
Machine No.:
Group : B

Kind of Oil・Grease
Motor（MultempSRL）
Pillow（TA-46）

	FY2016		FY2017		FY2018	
Manager						
Acting chief of a section						
Head						
Inspector						
	July	Nov	July	Nov	July	Nov
Running or Stopping	R S	R S	R S	R S	R S	R S
①Rust Dirty Loosen fundation bolt	Good No good	Good No good	Good No good	Good No good	Good No good	Good No good
②「Oil」 Quantity・Dirty・Leakage	Good No good	Good No good	Good No good	Good No good	Good No good	Good No good
③「Control mark」 Oil-level indicator・Pressure Gauge	Good No good	Good No good	Good No good	Good No good	Good No good	Good No good
④「Indication tag」 Miss, damage and pollution	Good No good	Good No good	Good No good	Good No good	Good No good	Good No good
⑤「Shaft seal」 Grand・Mechnical etc	Good No good	Good No good	Good No good	Good No good	Good No good	Good No good
Dudgment after countermeasure	Good No good	Good No good	Good No good	Good No good	Good No good	Good No good
Submittion for repair	Have No have	Have No have	Have No have	Have No have	Have No have	Have No have
	Submitting	Submitting	Submitting	Submitting	Submitting	Submitting
Note To indicate on the measure contents and the contents of no judgment. (Sample)②item.For an oil level decline Supply oil to upper level of cotrol mark ⑤item. Groud packing have many leakage. We don't have adjustment. Submit repair report.						
Sign						

Remark

Inspection sheet of Chemical Equipment

Leader	Inspector	Acting	Manager

Inspection date Y M D

Inspector ＊Inspection interval：1time/Month ：Safekeeping time: 3yaers

Inspection Item	
①	Would you like a tank and a ground of rotating equipment?
②	Isn't there leaking a tank, a heat exchanger, laying of the pipes and a pump?
③	Isn't there abnormal vibration equipment and laying of the pipes?
④	Isn't there abnormality the oil level withstanding,vibration and an allophone of the rotating equipment?
⑤	Would you like keeping warm of equipment and painting?
⑥	Are sign kinds maintained and are they in the fixed place?
⑦	Isn't there abnormality in a liquid level meter, a thermometer, pressure gauges and a measuring instrument?
⑧	Isn't there leaking in a safety valve, breather valves and a safety device?
⑨	Aren't there a crack and transformation in equipment, a container, laying of the pipes and support, etc.?
⑩	Isn't there leaking first valve and flange?
⑪	Isn't it OK seiri,seiton

C：Chemical Equipment S：Specal Chemical Equipment Cnt:Control Special chemical Equipment
P：Poison play thing handling equipment（St：Storage facility） D：Dangerous goods equipment

Equipment No	Equipment Name	Result of Inspection	Action	Equipment

Sparemachine Maintenance

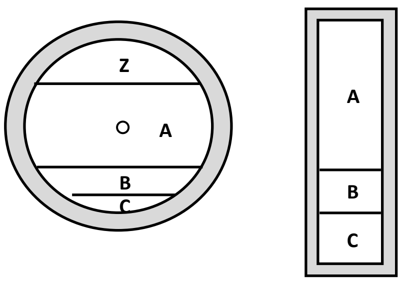
cheif	Inspe	Actin	mana

	M/C No	Type	Liquid	Interval	Action	Date	Name	Unlock after action	Remark	Coment of Machine G	Charge
			4HW	1time/M	Test run 20sec				Close discharge valve and Start	Don't have that in particular.	
			8HW	1time/M	Test run 20sec				Close discharge valve and Start	Don't have that in particular.	
		Plunger	Liquid	1time/M	Inching motion：Plunger piston go back more 1time				Close discharge valve and Start	Same as left	
		Furgal・big	WT	1time/M	Odd month change and even numbered month hand turning				Contact to power section before（in house2441）	Don't have that in particular.	
			CW	1time/M	Test run 20sec				Change Auto to Manual at 2nd Electric room 2FL	Don't have that in particular.	
			7HW	1time/M	Test run 20sec				・Change Auto to Manual at 2nd Electric room 2FL ・Close discharge valve and Start. ForI/L	Even hand turning is possible (As soon as work is taken.)	
			NaOH	1time/M	Test run 20sec				Close discharge valve and Start	Even hand turning is possible	
			Reaction liquid	1time/M	Hand turning					Don't have that in particular.	
			DPC	1time/M	Hand turning					Don't have that in particular.	
			HW	1time/M	Test run 20sec				Close discharge valve and Start. For safety valve		
			CW	1time/M	Test run 20sec				Change Auto to Manual at control panel in 4th elentriv room. ・Close discharge valve and Start		
			DHW	1time/M	Test run 20sec				Close discharge valve and Start		
			Willpower transportation	1time/M	Hand turning					Even hand turning is possible	
		Magnet	NaOH	1time/M	Chage A→C 30min run				1st No3 run→No1 stop	Don't have that in particular.	
		Magnet	NaOH	1time/M	Change A→B 30min run				1st Ni2 run→No1 stop	Don't have that in particular.	
			Drainage	1time/M	Test run 20sec				・Supply seal water and start ・Close discharge valve and Start	If we have abnormal of out put pressure Pickling	
			HW	1time/M	Test run 20sec				Close discharge valve and Start	Even hand turning is possible	
		Frugal・Multistage pump	Boiler water	1time/M	Test run 20sec				Close discharge valve and Start	Even hand turning is possible	
			CW1	1time/M	Test run 20sec				Close discharge valve and Start	Even hand turning is possible	
			CW2	1time/M	Test run 20sec				Close discharge valve and Start	Even hand turning is possible	
			CW2	1time/M	Test run 20sec				Close discharge valve and Start	Even hand turning is possible	
			DMW	1time/M	Hand turning					Even hand turning is possible	
		Turbo blower	Local exhaust	1time/M	Test run 20sec				Open Suction valve ・Close discharge valve and Start	Even hand turning is possible	
		Turbo Comp	Air	1time/M						From Instraction book	
				1time/M	Run no load				Supply water seal water heat exchanger CW and Start		
			Air	1time/M	Run no load				Select Main →「test run」・Select load→No2「0%」Start		

Section　 Oil level Inspection sheet　1−①

CLR							
Inspection date	Inspector	Oil level	Cleaness of oil level	machine No	Position	Section use	Remark
		Z・A・B・C	Good ・Not		Pillow		Under control daily report without ordinary
		Z・A・B・C			Pillow		
Inspection date	Inspector	Oil level	Cleaness of oil level	machine No	Position	PCR2 section use	Remark
		Z・A・B・C	Good ・Not				
		Z・A・B・C	Good ・Not		ｸﾗﾝｸｹｰｽ		
		Z・A・B・C	Good ・Not				
Inspection date	Inspector	Oil level	Cleaness of oil level	machine No	Position	PCR2 section use	Remark
		Z・A・B・C	Good ・Not		ｷﾞｱﾎﾞｯｸｽ		Start●is oil level control C because we can't watch oil level
		Z・A・B・C	Good ・Not				
Inspection date	Inspector	Oil level	Cleaness of oil level	machine No	Position	Section use	Remark
		Z・A・B・C	Good ・Not		Pillow		
		Z・A・B・C	Good ・Not				
		Z・A・B・C	Good ・Not		Oil recovery equipment		
		Z・A・B・C	Good ・Not		Motor east		
		Z・A・B・C	Good ・Not		Motor west		
		Z・A・B・C	Good ・Not		Oil tank		Under control daily report without ordnary
		Z・A・B・C	Good ・Not				Suspended equipment
		Z・A・B・C	Good ・Not		Pillow/Gear		
		Z・A・B・C	Good ・Not		Pillow		Suspended equipment
Inspection date	Inspector	Oil level	Cleaness of oil level	machine No	Position	Section use	Remark
		Z・A・B・C	Good ・Not		Oil bath		
		Z・A・B・C	Good ・Not				
		Z・A・B・C	Good ・Not		Oil bath north		Open oil cap 2place at east side and check oil in inside.
		Z・A・B・C	Good ・Not		Oil bath south		
		Z・A・B・C	Good ・Not		Oil bath north		Open oil cap 2place at east side and check oil in inside.
		Z・A・B・C	Good ・Not		Oil bath south		
		Z・A・B・C	Good ・Not		Oil bath		
		Z・A・B・C	Good ・Not				
		Z・A・B・C	Good ・Not		Oil bath		
		Z・A・B・C	Good ・Not				
		Z・A・B・C	Good ・Not		Oil bath		
		Z・A・B・C	Good ・Not				
		Z・A・B・C	Good ・Not		Crank case(common		
		Z・A・B・C	Good ・Not				
		Z・A・B・C	Good ・Not		Oil bath		Suspended equipment
		Z・A・B・C	Good ・Not				
Inspection date	Inspector	Oil level	Cleaness of oil level	machine No	Position	Section use	Remark
		Z・A・B・C	Good ・Not		Pillow stand		
		Z・A・B・C	Good ・Not				

※When we can't watch oil level replace to SG/LG new one.



Oil level
Round type：Z・A・B・C
Verical type：A・B・C
Please inspect

Z:Too much
A:Proper
B：a Little
C:Too little

Air serbo unit don't have oil level site.
Please inspect oil leakage

Section Motor Grease Supply List

	Equipment No	Position	Maker Brand	Quantity (g)	Interval	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		Left hand	ENEOS	50	6m		○						○				
		Front side	MultinocSDX	50	6m		○						○				
		Left hand	ENEOS	50	6m		○						○				
		Front side	MultinocSDX	50	6m		○						○				
		Left hand	ENEOS	50	6m		○						○				
		Front side	MultinocSDX	50	6m		○						○				
		Left hand	ENEOS	35	6m		○						○				
		Front side	MultinocSDX	30	6m		○						○				
		Left hand	ENEOS	35	6m		○						○				
		Front side	MultinocSDX	30	6m		○						○				
		Left hand	Kyoudouyushi	100	4m				○				○				○
		Front side	MultitempSRL	60	4m				○				○				○
		Left hand	Kyoudouyushi	55	4m				○				○				○
		Front side	MultitempSRL	60	4m				○				○				○
		Left hand	ENEOS	115	6m		○						○				
		Front side	MultinocSDX	115	6m		○						○				
		Left hand	ENEOS	115	6m		○						○				
		Front side	MultinocSDX	115	6m		○						○				
		Left hand	ENEOS	45	12m						○						
			MultinocSDX														
		Left hand	ENEOS	45	12m						○						
			MultinocSDX														
		Left hand	Kyoudouyushi	55	4m				○				○				○
		Front side	MultitempSRL	55	4m				○				○				○
		Left hand	ENEOS	80	6m		○						○				
		Front side	MultinocSDX	60	6m		○						○				
		Left hand	Showa Shell	100	4m				○				○				○
		Front side	AlbaniaS2	110	4m				○				○				○
		Left hand	Showa Shell	100	4m				○				○				○
		Front side	AlbaniaS2	110	4m				○				○				○
		Left hand	ENEOS	45	12m						○						
			MultinocSDX														
		Left hand	ENEOS	45	12m						○						
			MultinocSDX														
		Left hand	ENEOS	45	12m						○						
			MultinocSDX														
		Left hand	ENEOS	45	12m						○						
			MultinocSDX														
		Date supply grease															
		Person supply grease															

Daily maintenance record sheet

This document is the manufacturing department of Mitsubishi Chemical Corporation Kurosaki Plant
It is an example of a form related to daily maintenance being used.

Daily inspection related reference material

1. Spare machine Maintenance
2. Control Equipment Note Point out and countermeasure in Patrol
3. Inspection sheet of chemical equipment
4. Spare machine Maintenance
5. Oil level Inspection sheet
6. Motor Grease Supply List