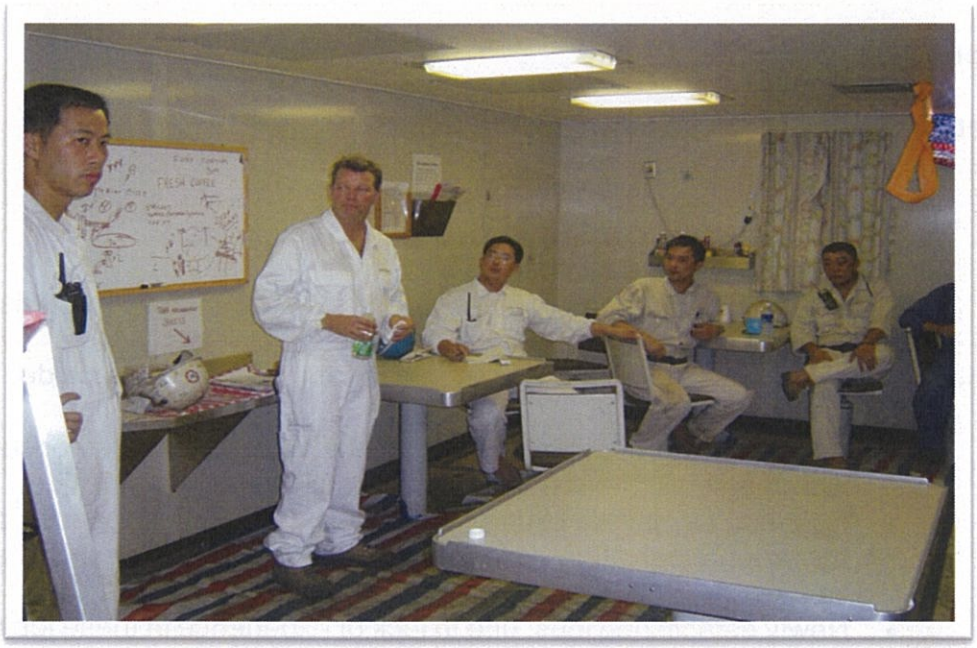
1. MANAGEMENT OF WORK SITE / SAFE WORKING PRACTICES

1.1 Toolbox Meeting

Tool box meetings can be a challenge. To help make it easier, the following meetings guides have been developed to provide a simple, clear format for conducting tool box talk these guides include information on specific safety topics that should help encourage safe work practices.

Tool box meeting shall be carried out in accordance with the procedures of safety management system for the purpose of managing risk, safely completing planned jobs, addressing all safety, health and crew management matters and finally securing work site.



The senior officers shall have a tool box meeting to discuss & plan the assigned jobs prior commencement of day work. The following should be considered and discussed as a minimum:

a. Risk associated with planned work activity, its existing and additional control measures and available time schedule
b. Ascertain need for formal risk assessment procedures or JHA procedures
c. Personal Protective Equipment
d. Use of work equipment and associated operation and safety procedures
e. Permits to work
f. Lock Out / Tag Out
g. Applicable rules and regulations
h. Communication and inter-relation of work activities or non-availability of required equipment
i. Availability of resources including equipment

j. Work and rest hours

Each responsible person for maintenance shall draw up a maintenance work plan for his own department, and make efforts to ensure the safe and smooth performance of maintenance work by keeping close contact among departments in relation to important work or work that concerns two or more departments.

2. Job Hazard Assessment

A job safety analysis (JSA) is a procedure which helps integrate accepted safety and health principles and practices into a particular task or job operation. In a JSA, each basic step of the job is to identify potential hazards and to recommend the safest way to do the job. Other terms used to describe this procedure are job hazard analysis (JHA) and job hazard breakdown.

Four Basic Steps

Four basic stages in conducting a JSA are:

- selecting the job to be analyzed
- breaking the job down into a sequence of steps
- identifying potential hazards
- determining preventive measures to overcome these hazards

Factors to be considered in setting a priority for analysis of jobs include:

- Accident frequency and severity: jobs where accidents occur frequently or where they occur infrequently but result in disabling injuries.
- Potential for severe injuries or illnesses: the consequences of an accident, hazardous condition, or exposure to harmful substance are potentially severe.
- Newly established jobs: due to lack of experience in these jobs, hazards may not be evident or anticipated.
- Modified jobs: new hazards may be associated with changes in job procedures.
- Infrequently performed jobs: workers may be at greater risk when undertaking non-routine jobs and a JSA provides a means of reviewing hazards.

Identify Potential Hazards

Once the basic steps have been recorded, potential hazards must be identified at each step. Based on observations of the job, knowledge of accident and injury causes, and personal experience, list the things that could go wrong at each step.

To help identify potential hazards, the job analyst may use questions such as these (this is not a complete list):

- Can any body part get caught in or between objects?

- Do tools, machines, or equipment present any hazards?
- Can the worker make harmful contact with moving objects?
- Can the worker slip, trip, or fall?
- Can the worker suffer strain from lifting, pushing, or pulling?
- Is the worker exposed to extreme heat or cold?
- Is excessive noise or vibration a problem?
- Is there a danger from falling objects?
- Is lighting a problem?
- Can weather conditions affect safety?
- Is harmful radiation a possibility?
- Can contact be made with hot, toxic, or caustic substances?
- Are there dusts, fumes, mists, or vapors in the air?

1. Eliminate the hazard

This is the most effective measure. These techniques should be used to eliminate the hazards:

- Choose a different process
- Modify an existing process
- Substitute with less hazardous substance
- Improve environment (ventilation)
- Modify or change equipment or tools

2. Contain the hazard

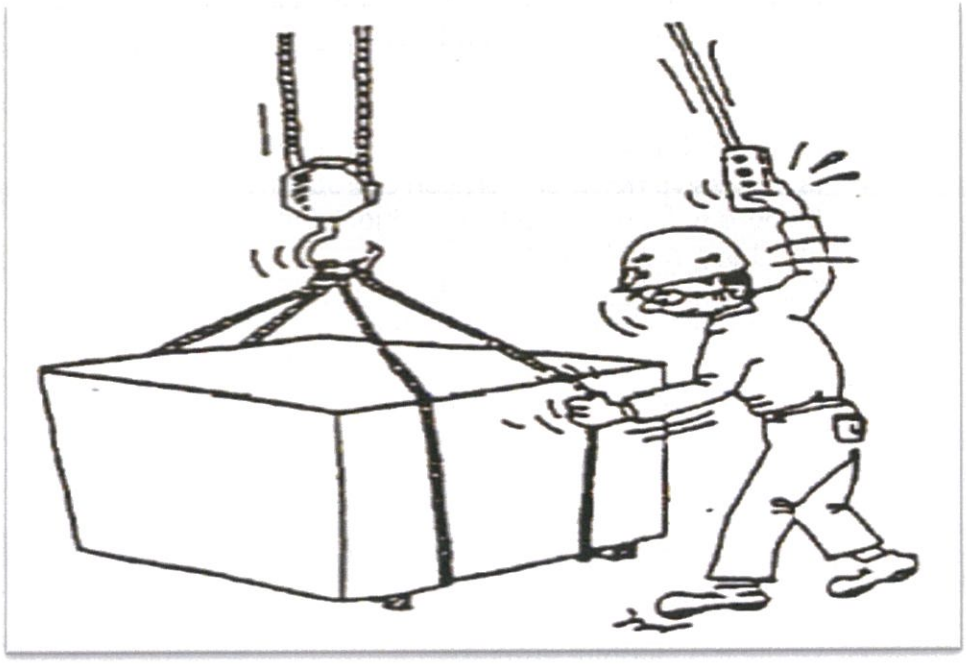
If the hazard cannot be eliminated, contact might be prevented by using enclosures, machine guards, worker booths or similar devices.

3. Revise work procedures

Consideration might be given to modifying steps which are hazardous, changing the sequence of steps, or adding additional steps (such as locking out energy sources).

4. Reduce the exposure

These measures are the least effective and should only be used if no other solutions are possible. One way of minimizing exposure is to reduce the number of times the hazard is encountered. An example would be modifying machinery so that less maintenance is necessary. The use of appropriate personal protective equipment may be required. To reduce the severity of an accident, emergency facilities, such as eyewash stations, may need to be provided.



Examples of Unsafe Act:

KYT (KikenYochi Training)

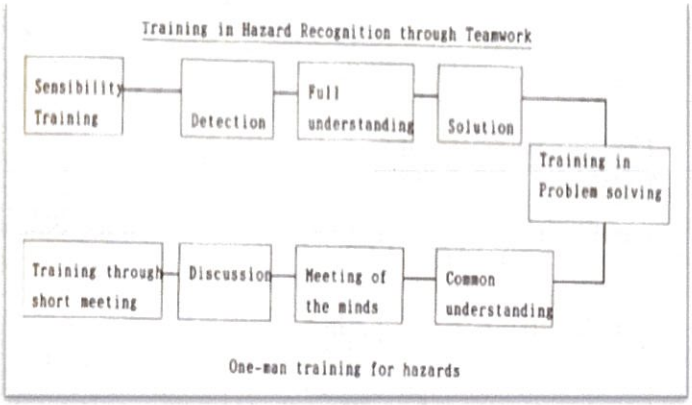
The Hazard Recognition Training (KYT) Concept

A. What is the hazard recognition training?

Hazard Recognition Training implemented under the Zero-Accident Campaign is safety anticipation training, through teamwork in the field, by everyone, quickly and correctly. It is also acceptable to carry out this teamwork training at the same time as one-man training.

The following three types of training are involved.
1. Sensibility Training
2. Training through Short Meetings
3. Training in Problem Solving

The following diagram illustrates the relationship among these three types.



B.Take Occupational Health and Safety in advance

1. To anticipate unsafe conditions, it is necessary to heighten the team's and the individual's sensibility to hazards.
Safety anticipation means preventing the development of accidents related to labor calamities in advance. In order to do this, it is extremely important to discover conditions which may cause accidents which are concealed in the workplace or within the work itself, and have a full understanding of these conditions before the work commences. The starting point of any safety activity is to realize that a hazard is a hazard.

If the ability to sense the underlying factors of a hazardous condition is labeled "sensibility" then it is necessary to heighten sensibility to hazards, and stress that the safety of everyone must be maintained by everyone, not only for the individual, but as a complete team. Hazard sensibility is heightened by repeated training in fact, accurate hazard recognition.
(Hazard Recognition Training is training for heightening sensibility in uncovering causes of hazardous conditions in workplace and working conditions, from individual level to the team level.)

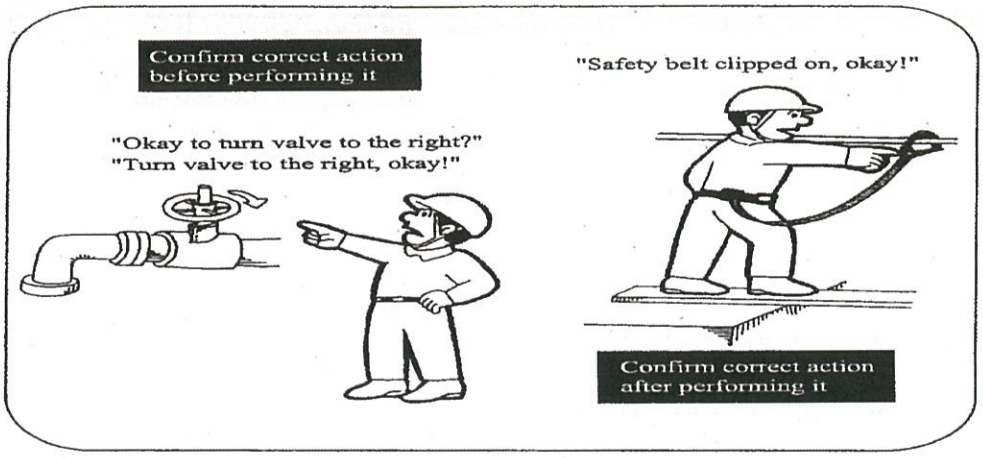
Kiken Yochi Training (KYT)

- Point and Call
- Point and Repeat
- Touch and Call

- "Point and call" is used to promote work safety and error-free work. It involves a worker identifying an object to be confirmed at each strategic point in work by pointing a finger at it and naming it by saying out loud, "[Such-and-such], okay! "
- It is essentially an act of confirmation performed individually.

OBJECTIVE OF POINT AND CALL

- Point and call is a specific method for preventing accidents caused by human error.
- It brings to the conscious level any "change of gears," making actions clear and regular, thereby improving work accuracy.



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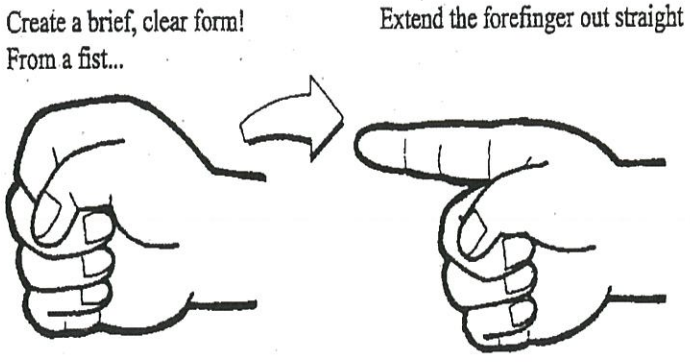
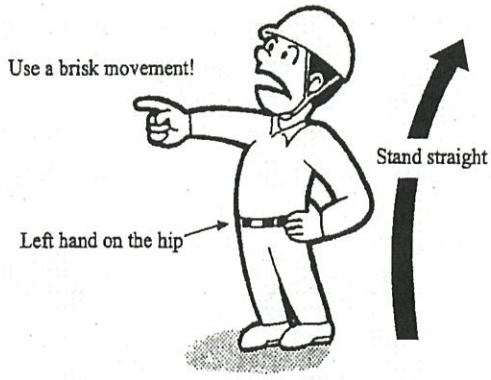
HOW TO POINT AND CALL

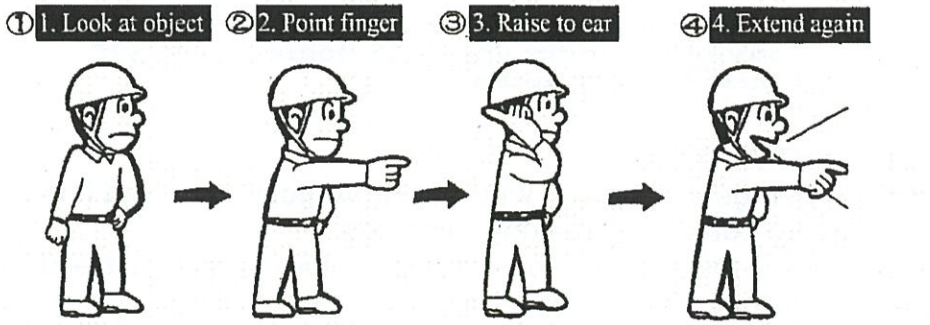
Carry out "point and call" at zero accidents meetings in the following manner:

- With the eyes: Look directly at the object to be confirmed.
- With the arm/finger: Place left hand on the hip. Extend the right arm, make a fist and extend the forefinger to point to the object. Lift the finger to the ear once, and extend it once more, saying "Okay! "
- With the mouth: In a clear voice, call out "[Such—and—such], okay!" For example,"Switch on, okay!" or "Valve open, okay!"
- With the ears: Listen to your own voice.



Make a fist, then extend the forefinger out straight to create a brief, clear form.





HOW TO MAKE POINT AND CALL EFFECTIVE

One person asking "[Such-and-such], okay?" with another person answering [Such-and—such], okay!" for mutual confirmation (or one person both asking and answering) is also effective in preventing accidents due to error.

Very important confirmation should be done by two people!

When working together, pointing and calling can be done by one person asking, "[Such-and-such], okay?" and the other person answering "[Such-and-such], okay!" Then the action is to be done, calling "[Such-and-such], okay!"

- To focus attention as closely as possible, it is better to call out "Temperature xx degrees, okay! " instead of "Temperature, okay!" or "Oxygen concentration xx percent, okay! " rather than merely "Oxygen concentration okay!"
- Callout the vital information in this way. Use variations according to the workplace and call out with as specific-and penetrating information as possible.

To focus attention, be specific in calling, saying "Ladder angle 75 degrees, okay!" instead of "Ladder okay!"

WHY USE POINT AND CALL?

- **Human beings are fraught with psychological flaws and it is no surprise that we are constantly making mistakes.**
- We must see this imperfection in human nature for what it is and try to somehow prevent mistakes from being made, or even if errors are committed, keep them from causing accidents.

At this point let us look at the necessity of point and call from the point of view of three human tendencies:

- Inattention
- Misperception

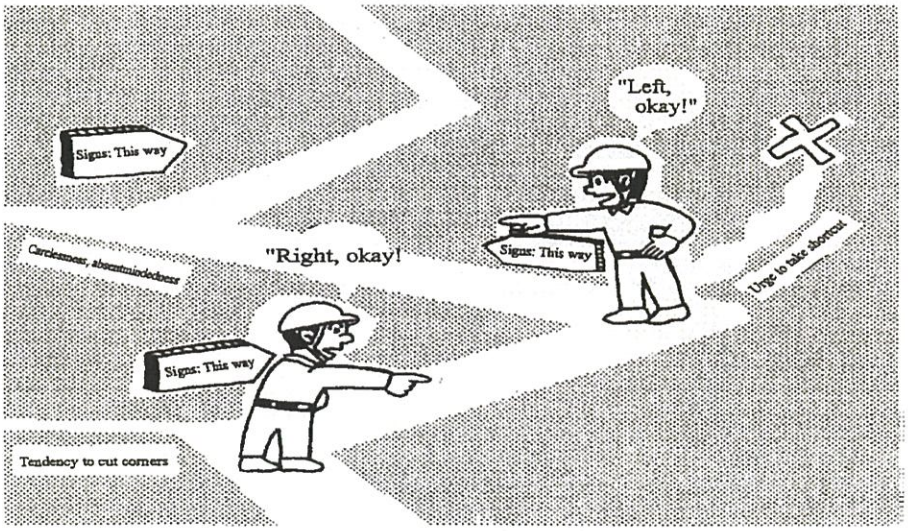
Tendency to cut corners or take shortcuts.

INATTENTION

To prevent the combination of hazard and inattention, at each strategic point in work the use of "point and call" will enable a person to "change gears" consciously, create a normal, clear state of mind, and confirm the action. It is essential for preventing carelessness, absentmindedness, and inattention

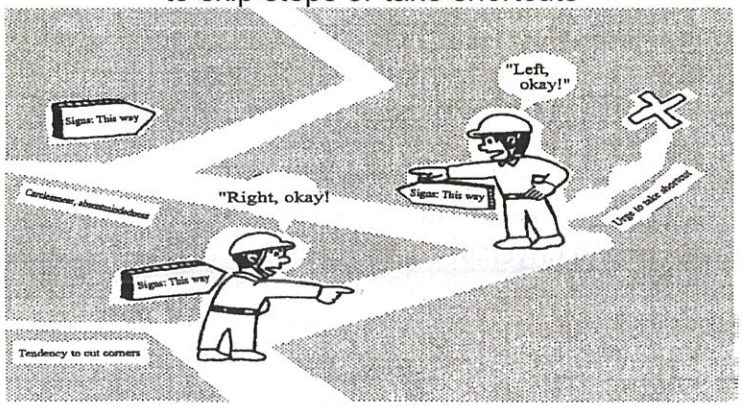
MISPERCEPTION

We need to understand fully that it is natural for human beings to make mistakes, and with that understanding proceed to work in a safe way. To avoid the mistake of confusing similar valves or switches, for example, in addition to proper labelling, it is necessary to employ the action of pointing and calling to bring the point or action to the conscious level, to create a normal, clear state of mind, and to enable the person to clearly identify the object.



Point and call is used to prevent accidents or incidents, and to make a habit of correct, safe action by having workers point and vocalize at each strategic point in their work.

- People often omit steps of a procedure that they are required to do, and have an urge to take shortcuts that are forbidden. Or, figuring that everything will be all right, they do something unsafe against-better judgment, or neglect to restore an unsafe situation to a safe one.
- **Pointing and calling** is an effective means of putting the brakes on such desire to skip steps or take shortcuts



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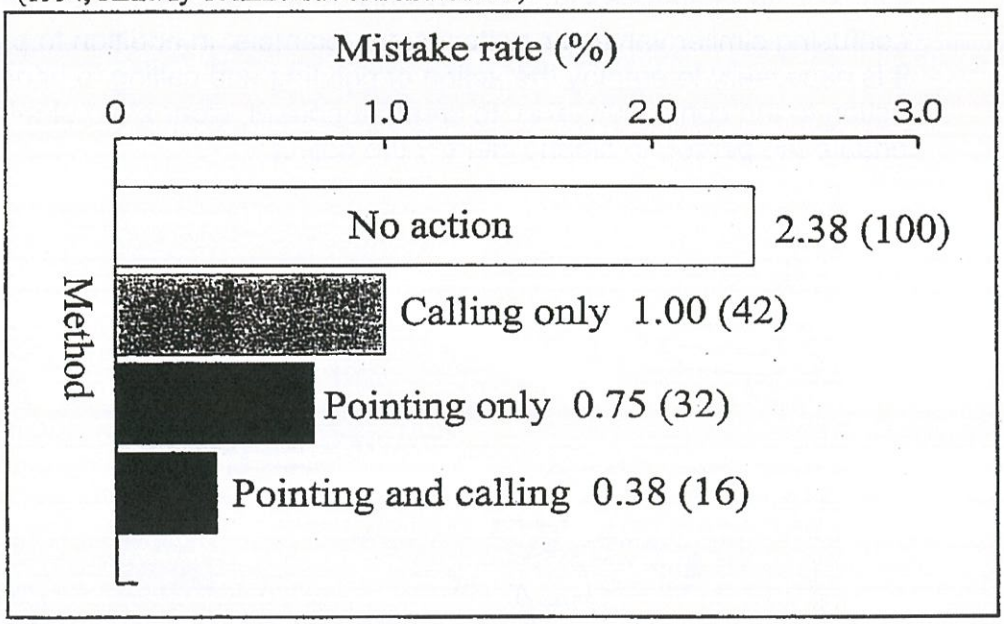
EFFECTIVENESS OF POINT AND CALL

Results of Official Effectiveness Trial of Point and Call System
(1994, Railway Technical Research Institute)



WHAT IS POINT AND REPEAT ?

- "Point and repeat" is a method by which everyone points to an object together and names it in unison. It aims to focus everyone's attention on the goal together and enhance the team's sense of identity and solidarity. This differs from "point and call."
  Generally, at the team meetings held to start and end the workday, a slogan is repeated in unison, such as "Every person is valuable. Okay!" Or it is used for calling out KYT items to confirm (hazard points, team action targets, etc.)

- **Method:**
- **As with point and call, the left hand is placed on the hip and one points at the object using the right hand. Everyone follows the leader and calls out "[Such—and—such] okay! " in unison.**

- ***WHAT IS TOUCH AND CALL ?***
- "Touch and call" is a type of point and repeat.
- Everyone is in physical contact through a part of the body.
- This enhances group identity and solidarity, and imprints a positive image on the paleo-cortex in the brain. The aim here is to promote safe actions even unconsciously, and to prevent careless, absent-minded behavior.
- It can be used for group repetition of slogans at team meetings held at start and end the workday, to mark the start and end of work, or to start and end training at a meeting.

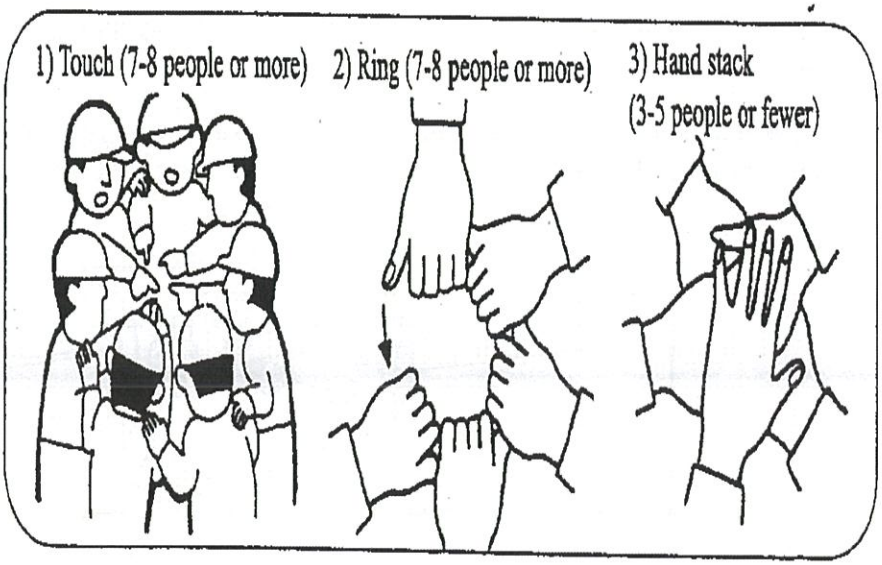
Touching left hands or placing them on one another's shoulders, call out in unison. Use this "touch and call" action to end a KYT activity.

- **THREE BASIC TYPES OF TOUCH AND CALL**

- **Touch:** Form a circle. Place your left hand on the shoulder of the person to your left,and using your right hand point to the center of the circle and call out in unison. This is suitable for 7~8 people or more.

Ring: Form a circle. Using your left hand, grab the thumb of the person to your left, forming a ring of hands. Use the right hand to point to the center of the ring and call out in unison. This is suitable for 5-6 people or more.

Hand stack: Form a circle. Everyone's left hand is put into the center, stacking one on another. Use the right hand to point to the stack of hands and call out in unison. The leader should support the stack of hands from below with palm facing upward. This is suitable for 3-5 people or fewer.



- **HOW TO PROMOTE POINT AND CALL**
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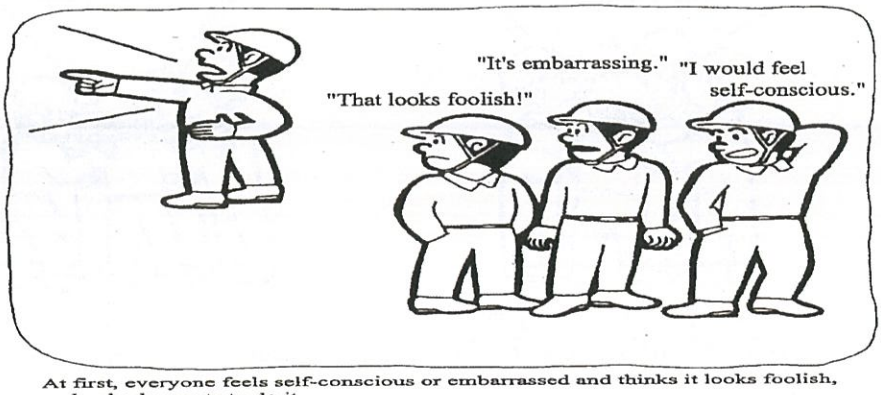
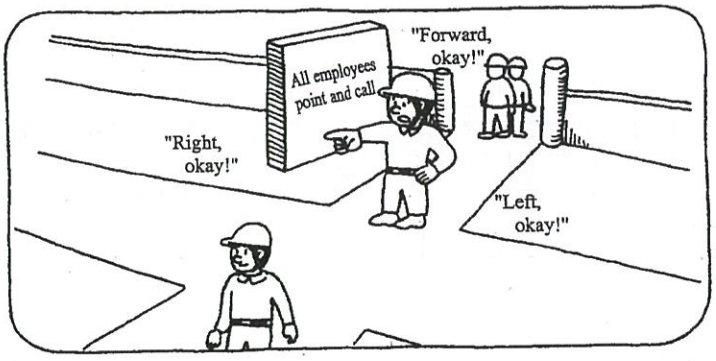


At first, everyone feels self-conscious or embarrassed and thinks it looks foolish, and nobody wants to do it.

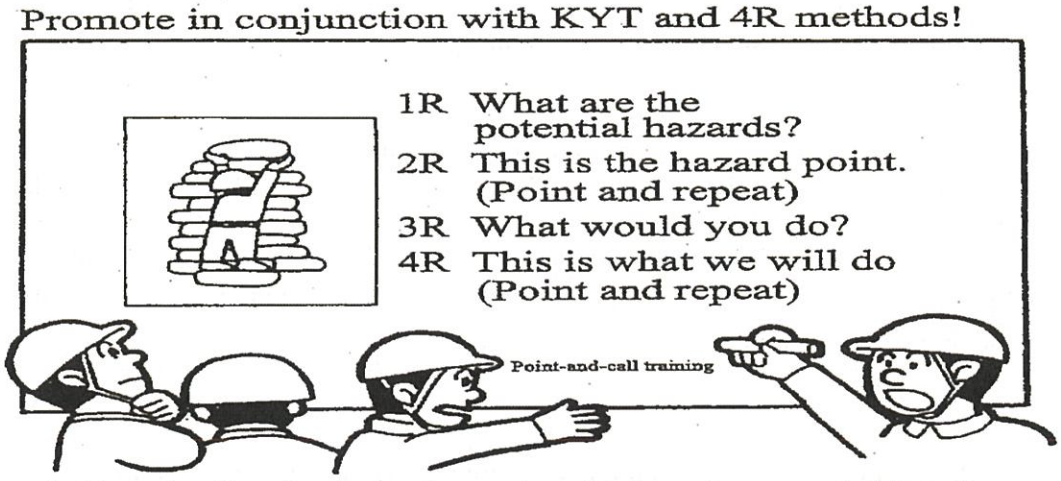
HOW TO PROMOTE POINT AND CALL

- **Executives should themselves point and call**, leading by example.
- **Supervisors should take the initiative** and call out in a loud voice. Point out that it is being carried out in every workplace and is an **essential part of the zero accidents campaign.**
- **Educate-workers** about the necessity and effectiveness of pointing and calling.
- **Train in a loud voice everyday** at the team meetings held to start and end the workday. It is also good to create training spots for everyone to practice pointing and calling together.
- **Rotate leaders every day** for training in pointing and calling. Decide on a point-and—call leader.
- **Analyze examples of past accidents or mis-operation or errors**, and impress on everyone the need for and importance of the point-and-call system.

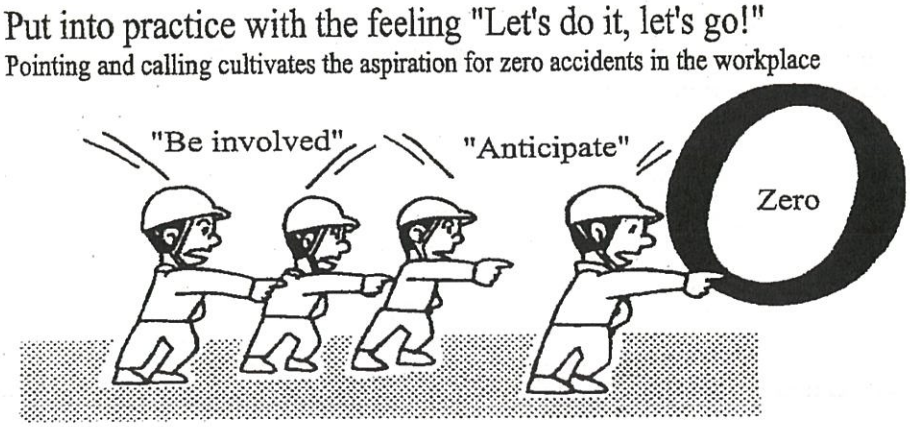


KIKEN YOCHI METHODS AT THE WORKPLACE

- At the start and end of work day, have everyone repeat together in a loud voice such slogans as 'Let's go for zero accidents, okay!'
- At Tool Box or Safety Meetings, conduct a Touch and Call session using such slogans such as 'Zero accidents, okay!'
- During work activity, identify hazards actively by using Point and Repeat in loud voice 'Hazard point, Because of such-and-such, this-this happens, resulting in that-that, okay!' – Verbally describe hazard and its effect!



Point-and-call and point-and-repeat methods are incorporated into the hazard prediction training four round method.



3. Near Miss

Dangerous Events and Irregular Look
Unsafe Acts and Unsafe Condition

The Importance of Near Miss Reporting

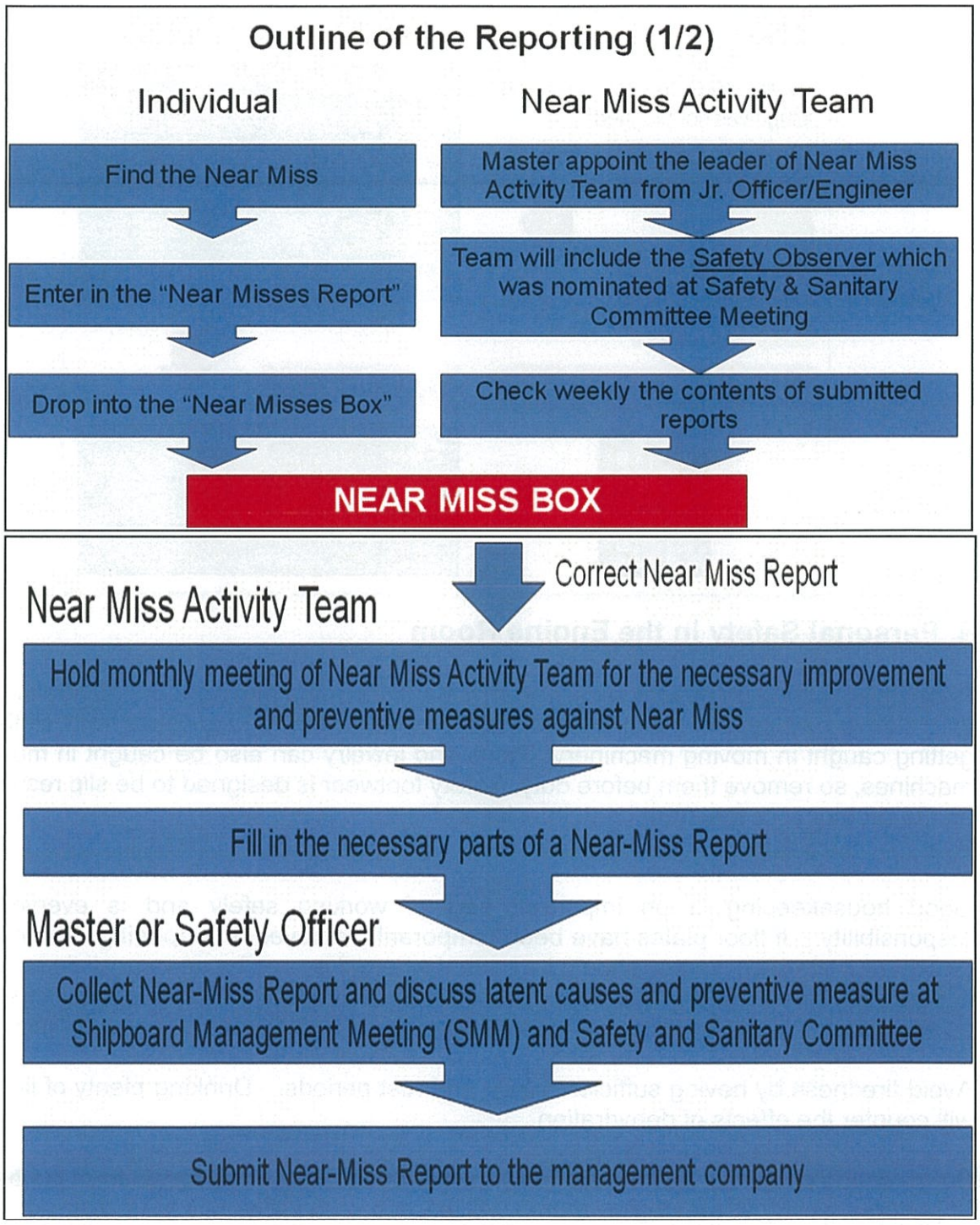
Reporting near misses is important to prevent accident by identifying situations that can lead to accidents and implementing corrective actions.
Objectives of near miss reporting

If one vessel will report a near miss, multiply that one vessel to the number of vessel in the fleet, then accidents will be prevented for the number in the fleet, for example, 1 near miss report times, send copy to the other 100 ships in the fleet, then 100 near misses of same nature was prevented. This is because the other vessels will be aware and will implement preventive actions, they became more safety conscious and aware of accident prevention.

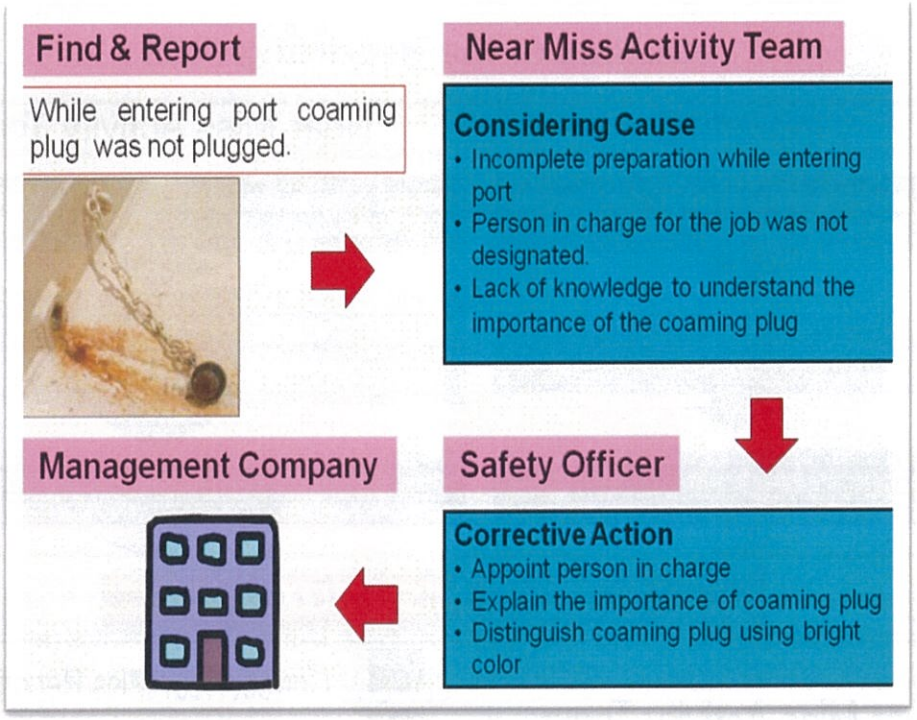
Examples of near miss that can be encountered on board while working:
1. One crew working with lathe machine and NOT wearing safety goggles.
2. One crew working with welding machine and NOT wearing the proper welding gloves.
3. One crew working in the engine room and NOT wearing a safety helmet.
4. The floor in the engine room lower flooring is slippery due to oil stain, therefore it may cause slipping hazard to those who will do a maintenance job in that area.
5. Some crew forgot to secure a couple of tools and left it on top of a boiler drum, making it a falling hazard to those who will work below that area.

After finding a near miss, a report should be written in a near miss report form, and to be submitted to the near miss activity team leader, to chief mate, or it can also be dropped in a near miss report box.

The following is a flow chart showing the procedure of reporting a near miss:



The flow chart below shows a sample flow for reporting:



4. Personal Safety in the Engine Room

Protective clothing is the first barrier against hazards in the engine room. Overalls with long sleeves will protect the skin against dirt and abrasion. A good fit prevents clothing getting caught in moving machinery. Rings and jewelry can also be caught in moving machines, so remove them before duty. Safety footwear is designed to be slip resistant and to protect your feet from heat, knocks and cuts.

Good housekeeping is an important part of working safely and is everyone's responsibility. If floor plates have been temporarily removed, the openings should be protected. Warning notices should be posted where they can be seen at all times until it is safe to remove them. Missing floor plates are dangerous. Replace them as soon as possible. If lifting handles are not available, use a sensible lever, not your fingers.

Avoid tiredness by having sufficient sleep and rest periods. Drinking plenty of liquids will counter the effects of dehydration.

Safe working practices, attention to training, and good housekeeping will form the basis of personal safety in the engine room. At the end of the day, it is your own skill and judgment that will take you safely home.

Main Personal Protective Equipment (PPE) Used Onboard Ship

Safety of self and co-workers is the prime priority kept in mind by a professional seafarer while working onboard ship. All shipping companies ensure that their crew follows personal safety procedures and rules for all the operation carried onboard ships.

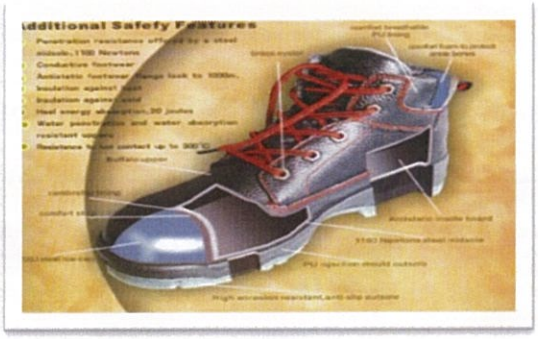
To achieve utmost safety on board ship, the basic step is to make sure that everybody wears their personal protective equipment's made for different types of jobs carried out on ship.

Following are the basic personal protective equipment's (ppe) that are always present onboard a ship to ensure safety of the working crew:

1) Protective Clothing: Protective clothing is a coverall which protects the body of the crew member from hazardous substance like hot oil, water, welding spark etc. It is popularly known as "dangri "or "boiler suit".

2) Helmet: The most important part of the human body is the head. It needs utmost protection which is provided by a hard plastic helmet on the ship. A chin strap is also provided with the helmet which keeps the helmet on place when there is a trip or fall.

3) Safety Shoes: Maximum of the internal space of the ship is utilized by cargo and machinery, which is made of hard metal and which make it clumsy for crew to walk around. Safety shoes ensure that nothing happens to the crew member's feet while working or walking onboard.



4) Safety Hand gloves: Different types of hand gloves are provided onboard ship. All these are used in operations wherein it becomes imperative to protect ones hands. Some of the gloves provided are heat resistant gloves to work on hot surface, cotton gloves for normal operation, welding gloves, chemical gloves etc.

5) Goggles: Eyes are the most sensitive part of the human body and in daily operations on ship chances are very high for having an eye injury. Protective glass or goggles are used for eye protection, whereas welding goggles are used for welding operation which protects the eyes from high intensity spark.

6) Ear Muff/plug: Engine room of the ship produces 110-120 db of sound which is very high for human ears. Even few minutes of exposure can lead to head ache, irritation and sometimes partial or full hearing loss. An ear muff or ear plug is used on board ship which dampens the noise to a bearable decibel value.

7) Safety harness: Routine ship operation includes maintenance and painting of high and elevated surfaces which require crew members to reach areas that are not easily accessible. To avoid a fall from such heightened area, safety harness is used. Safety harness is donned by the operator at one end and tied at a strong point on the other end.

8) Face mask: Working on insulation surface, painting or carbon cleaning involves minor hazardous particles which are harmful for human body if inhaled directly. To avoid this, face mask are provided which acts as shield from hazardous particle.

9) Chemical suit: Use of chemicals onboard ship is very frequent and some chemicals are very dangerous when they come in direct contact with human skin. A chemical suit is worn to avoid such situations.

10) Welding shield: Welding is a very common operation onboard ship for structural repairs. A welder is provided with welding shield or mask which protects the eyes from coming in direct contact with ultraviolet rays of the spark of the weld.

5. Proper Use of Tools and Measuring Instruments that are commonly used in Engine Room

The use of safety hand tools should be a key component of most industrial safety programs. An understanding of the hand tool's intended use and environment, combined with proper tool selection, maintenance and storage, will greatly reduce the risk of explosion and fire.

- Keep non-sparking tools clean and free from ferrous or other contaminants, which may impair the non-sparking properties.
- Do not use non-sparking hand tools in direct contact with acetylene, due to the possible formation of explosive acetylenes, especially in the presence of moisture.
- During normal use, all hammers and chisels will progressively develop some damage to the striking faces of hammers or the cutting edge and striking end of chisels.
- Do not store hammers and other hand tools fitted with wooden handles in places where the handles may dry out and shrink. This will increase the risk of the handle breaking or the head becoming loose.
- Avoid overstrikes, causing damage to the shaft. Supply replacement handles are often available from the manufacturer, and should be fitted by a competent operator, using an approved method of fitting and paying particular attention to the fitting of the wedges.
- Fiberglass handles can offer advantages over wooden handles in terms of breaking stress and tolerance for adverse environmental conditions. Fiberglass shafts fail progressively, rather than catastrophically, reducing the risk of sudden failure, injury or damage.
- When selecting a wrench, the jaw opening should have a close and tight fit on the head of the nut or bolt to which it is being applied. This is especially true with non-sparking tools, as they typically do not have the hardness of steel tools.
- Tools are designed for specific use. As with any tool, additional torque should not be applied through the use of "cheater bars." In addition to the probability that the tool will be damaged, this is a dangerous practice for the safety of the

operator. Wrenches should not be used as levers; nor screwdrivers as chisels, and so on.

- The accepted standards of safety and maintenance for common steel hand tools must also be adopted with non-sparking hand tools, in addition to any specific recommendations resulting from the alloys used.
- When sharpening non-spark safety tools, follow normal safety procedures, such as the provision of eye and face protection, adequate extraction and dust collecting facilities.

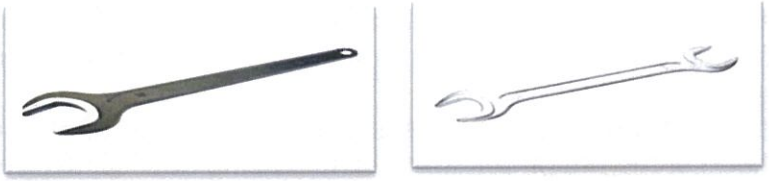
Kinds of Tools

Adjustable Wrench

Adjustable wrench is an adjustable tool for gripping hexagonal nuts, with adjusting screw in the head of the implement. But it is not applicable for fastening, it is lack of fitting measurement that a dedicated tool would have they also have a tendency to" round off "the corner of the fasteners itself due to a poor fitting.

Single open ended spanners/ Double open end spanners

It is a tool used to provide grip and mechanical advantage in applying torque to turn objects usually rotary fasteners, such as nuts and bolts or keep them from turning.



Straight Pipe Wrench

The pipe wrench is an adjustable wrench used for turning soft iron pipes and fittings with a rounded surface.

Solid Steel Bar Wrench

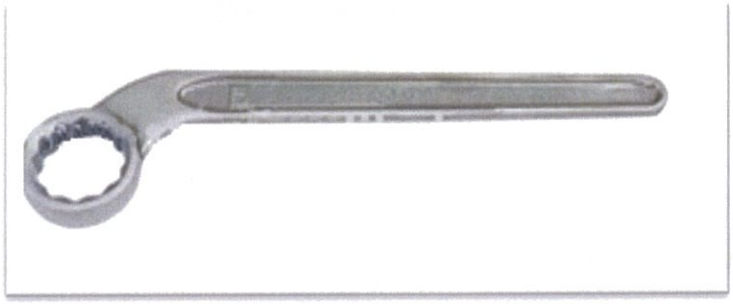
It is an old type of adjustable wrench with a straight handle and smooth jaws whose gripping faces are perpendicular to the handle.

Spud Wrench

A steel erecting tool which consists of a normal wrench at one end and a spike at the other, used for lining up bolt holes (typically when mating two pipe flanges).

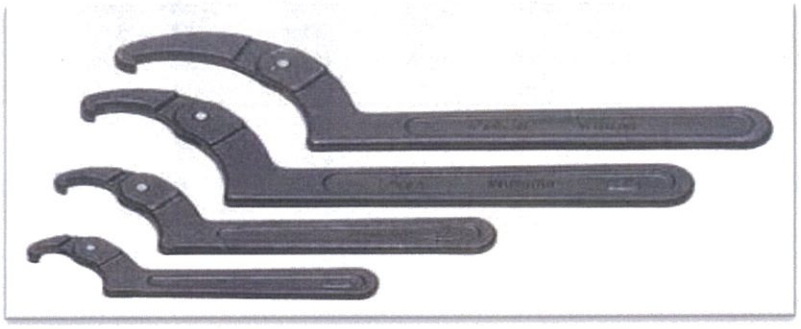
Single End Angle Wrench

This is a one-piece wrench with an enclosed opening that grips the faces of the bolt or nut and commonly use in angle position.



Hook Spanner Wrench

A wrench with one or several pins or hooks, designed to drive spanner head screws, threaded collars and retainer rings, shafts, and so on.

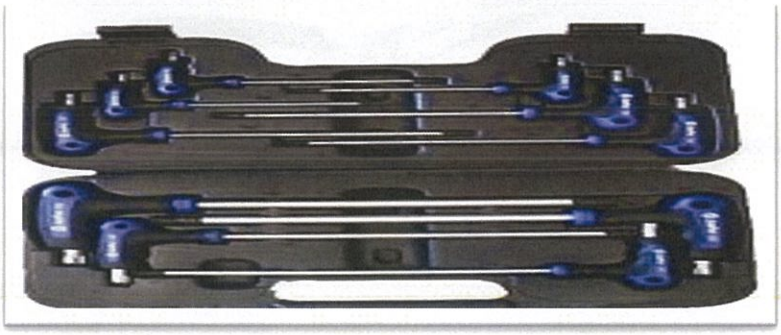


Socket Wrench

It contains a one-way mechanism which allows the socket to be turned without removing it from the nut or bolt simply by cycling the handle backward and forward.

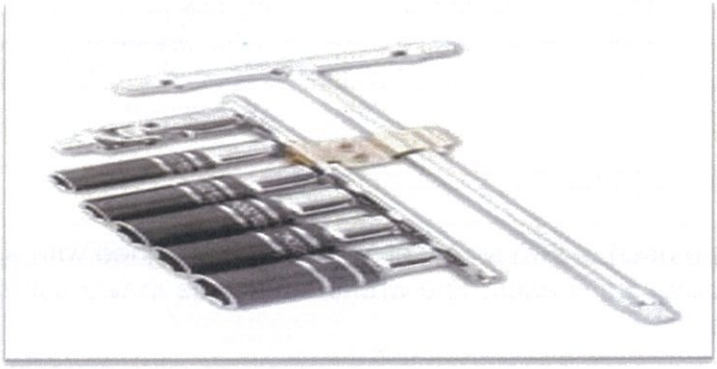
Hexagon Wrench (Allen Key)

A wrench used to turn screw or bolt heads designed with a hexagonal socket (recess) to receive the wrench. The wrenches come in two common forms: L-shaped and T-handles.



T- Wrench

A T-shaped wrench with a handle having a socket (either fixed or removable) which fits over a nut or bolt head.



Flat Nose Pliers

It is designed for making sharp bends and right angles in wire. Flat nose pliers can also grip flat objects and work well for straightening bent wire.

Combination Pliers

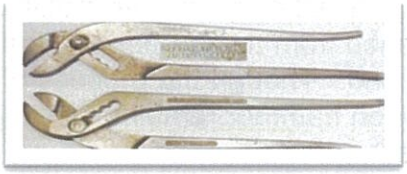
They have gripping jaws cutting edge and insulating handling grips that reduce (but did not eliminate) the risk of electric shock when contact with live wire.

Side- cutting Pliers

Side-cutting pliers, are used for gripping, wire splicing, wire cutting, insulation stripping, and for crushing insulation.

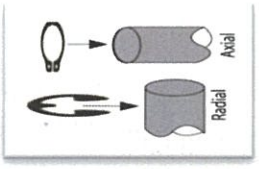
Water Pump Pliers

It is designed primarily for gripping objects by using leverage. These pliers aredesigned for numerous purposes and sometimes require different jaw configurations to grip, turn, pull, or crimp a variety of things.



Snap Ring Pliers

A tool used to forced open any retaining ring in shaft or in bores, it snap back into place to make a snug fit.





Hand Snip

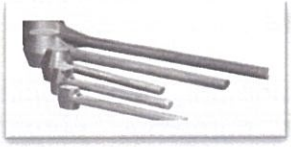
A toolwhich uses a compound leverage handle system to increase the mechanical advantage for cutting metal sheets, gaskets and it is similar to common scissors.

Tongs

It is a grasping device consisting of two arms that are joined, often at one end, as by a pivot or a scissor like hinge.

Hammer/ Lead Hammer

It serves to hit the object of soft or hard materials without damaging the component.

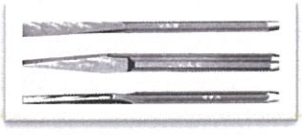


Ball Peen Hammer

Is also known as a machinist's hammer, is a type of peen hammer used in metalworking. It is distinguished from a point-peen hammer or chisel-peen hammer by having a hemispherical head. Though the process of peening has become rarer in metal fabrication, the ball-peen hammer remains useful for many tasks, such as striking punches and chisels.

Cold Chisel

It is a tool made of tempered steel used for cutting 'cold' metals, meaning that they are not used in conjunction with heating torches, forges, etc. Cold chisels are used to remove waste metal.



Hand Taps

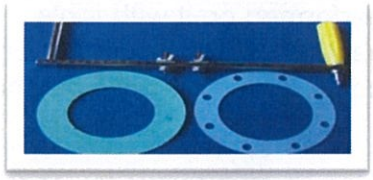
It is a cutting tools used to create screw threads, which is called threading. A tap is used to cut the female portion of the mating pair.

Dies

A die is used to cut the male portion of the mating pair.

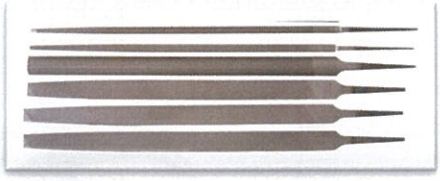
Gasket Cutter

It is a precision, hand-operated machine that cuts inside diameter and outside diameter, with speed and ease from all types of non-metallic sheet packing.



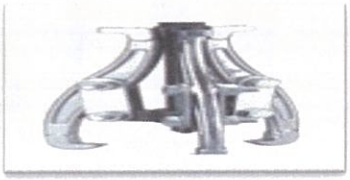
Machinist Files

Files come in far too many patterns and cuts to treat in detail here, but are generally either Machinists or Engineers Files for shaping, Saw or Sharpening Files for sharpening, Aluminum Files for that soft material, Rasps with coarse teeth for wood, Needle Files for small work or large Blacksmith Files.



Gear and Wheel Puller

Pullers are designed to be used in motor repair shops, shipyards, railroads, paper mills, steel plants and other process industries, for pulling frozen gears, bearings and couplings from shafts.

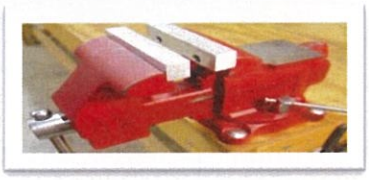


Pipe Cutter

A pipe cutter is a type of tool used on board to cut pipe. Besides producing a clean cut, the tool is often a faster, cleaner, and more convenient way of cutting pipe than using a hacksaw.

Bench Vice

It is a mechanical screw apparatus used for holding or clamping a work piece to allow work to be performed on it with tools such as saws, planes, drills, mills, screwdrivers, sandpaper, etc. Vises usually have one fixed jaw and another, parallel, jaw which is moved towards or away from the fixed jaw by the screw.



C-Type Screw Clamp

This type of device hold a wood or metal work piece, and are often used in, but are not limited to, carpentry and welding. These clamps are called "C" clamps because of their C shaped frame.

Screw Drivers

A screwdriver is a tool for driving screws or bolts with special slots, and sometimes for rotating other machine elements with the mating drive system.

-  The slot screw driver has a single slot in the fastener head and is driven by a flat-bladed screwdriver.
-  A cross-recess screw driver has two slots, oriented perpendicular to each other, in the fastener head; a slotted screwdriver is still used to drive just one of the slots. This type is usually found in cheaply made roofing bolts and the like, where a thread of 5 mm (0.20 in) or above has a large flattened pan head.
-  Phillips screw driver was purposely designed to cam out when the screw stalled, to prevent the fastener damaging the work or the head, instead damaging the driver. This was caused by the relative difficulty in building torque limiting into the early drivers.
-  The Frearson screw driver, also known as the Reed and Prince Screw driver, is similar to a Phillips but the Frearson has a more pointed 75° V shape. One advantage over the Phillips drive is that one driver or bit fits all screw sizes.
-  The Mortorq drive is a format used in automotive and aerospace applications. It is designed to be a lightweight, low-profile and high-strength drive, with full contact over the entire recess wing reducing risk of stripping.
-  The Pozidriv, sometimes misspelled Pozidrive, screw driver is an improved version of the Phillips screw drive. It is a set of radial indentations set 45 degrees from the cross recess.
-  A Robertson, also known as a square, or Scrulox screw driver has a square-shaped socket in the screw head and a square protrusion on the tool. Both the tool and the socket have a taper.
-  The Bristol screw driver is a spline with four or six splines. The grooves in the wrench are cut by a square-cornered broach, giving a slight undercut to the outer corners of the driver. The main advantage to this drive system is that

almost all of the turning force is applied at right angles to the fastener spline face, which reduces the possibility of stripping the fastener.

Hammering screwdriver

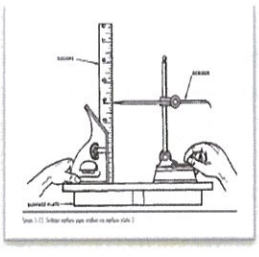
It is a tungsten alloy blades are pierced through a hard wooden handle the end is reinforced with a large nut that permits hammering.

Chain Hoist

Is a device used for lifting or lowering a load by means of a drum or lift-wheel aroundwhich rope or chain wraps. It may be manuallyoperated, electrically or pneumatically driven and may use chain,

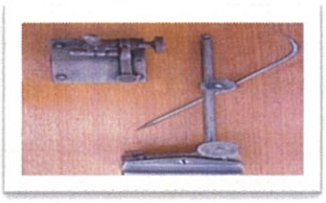
Surface Plate

Surface plate is a solid, flat plate used as the main horizontal reference plane for precision inspection, marking out (layout), and tooling setup. The surface plate is often used as the baseline for all measurements to the work piece; therefore one primary surface is finished extremely flat with accuracy up to .00001"/.00025 mm for a grade AA or AAA plate.



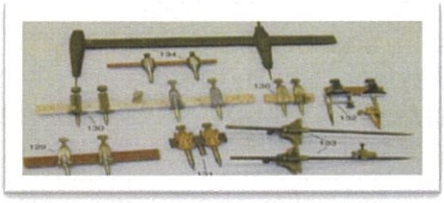
Scriber

A scriber is a hand tool used in metalworking to mark lines on work pieces, prior to machining.



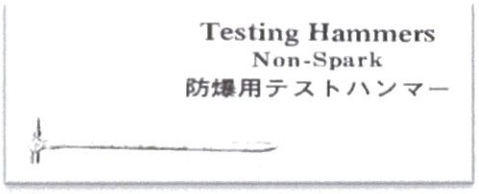

Trammel

This is used for scribing larger arcs and circles because of its sliding and adjustable heads.



Hammer test

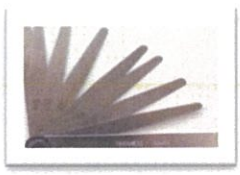
is done for the purpose of checking the integrity and tightness of the bolts and nuts. Hammer testing is done by striking the bolts or nuts at the counter clockwise direction or the loosening direction of the bolt or nut.
By hearing the sound and feeling the movement of the bolt or nut, you can distinguish if it is in good.



Feeler Gauge

Feeler gauge is a tool used to measure gap widths. Feeler gauges are mostly used in engineering to measure the clearance between two parts

They consist of a number of small lengths of steel of different thicknesses with measurements marked on each piece. They are flexible enough that, even if they are all on the same hinge, several can be stacked together to gauge intermediate values.

Dial Indicator

The dial indicator is a precision measuring tool that measures relative distances. Use to measure the difference in distance to two or more locations. The dial indicator is great for checking alignment and run out.

A plunger moves in and out from the body of the indicator and rotates the measuring needle on a dial face. Dial indicators usually have either a 1" or 2" range and are calibrated in increments of .001". A smaller dial reads each revolution of the larger dial in increments of 0.100".

The outer bezel rotates and turns the numeric scale with it so that you can set the indicator to zero at any plunger position. Most D/Is have two little movable markers on the outside of the dial face that can be used as reference points.

A dial indicator (DI) set up to center a bolt in a 4-jaw chuck. If the bolt is off-center, the DI plunger will move in and out as the chuck rotates. When the bolt is properly centered there will be little or no movement of the plunger and the needle of the DI will move only .001 or less.

Tools That Are Commonly Used in the Engine Room

The tools lessons will be found quite elementary in places, since they are prepared so as to be suitable for the beginning student, as just explained. They should be studied carefully, however, as this will enable all trainees to practice the art of study (which they may not have been doing recently) and will help them to master the more difficult engineering principles that follow in later lessons.

Good tools are essential if an engineer is to do his best work quickly, properly and accurately. Without the proper tools and the knowledge of how to use them, time is wasted, efficiency is reduced, and the person doing the work may injure himself.

Torque wrench - is a tool used to precisely apply a specific torque to a fastener such as a nut or bolt.

Proper use and maintenance of Torque Wrench

A torque wrench is a precision instrument designed to apply a specific amount of force to a fastener. Whether tightening head bolts on an engine, inspecting fastener tolerances on high-performance equipment, it is extremely important that proper care is used.

Guidelines are typically provided noting acceptable torque ranges, the order in which specific fasteners are tightened and the number of times a fastener must be tightened and loosened to ensure uniform torque application. Failure to properly torque fasteners can lead to equipment damage, personal injury or worse.

It is important to follow acceptable maintenance and use practices, such as:

1. Safety glasses or goggles should be worn at all times when using any hand too.
2. Always follow the manufacturer's directions regarding torque direction, proper force, torque pattern/sequence, use or non-use of lubrication on fasteners and torque "tighten/release" cycles.
3. Do not exceed the recommended working range of the torque wrench. Reliable measurements are based on a percentage of the working range. In general, most mechanical wrenches have a useable range from 20% to 100% of full scale. Most electronic wrenches have a useable range from 10% to 100% of full scale.
4. Do not use accessories or handle extensions unless specifically allowed by the torque wrench manufacturer.
5. Take time to inspect the tool and check for worn or cracked sockets. Properly lubricate and replace worn parts.
6. Avoid dropping or sliding a torque wrench. Dropping a torque wrench on a hard surface can cause the instrument to lose reliable calibration. If you suspect that a wrench has been dropped, have the tool inspected by the manufacturer or reputable calibration service.
7. Always store a torque wrench in a protective case and/or location when not in use.
8. Avoid exposure to temperature extremes, high humidity, fluid immersion and corrosive environments.
9. If using a click-type torque wrench, always store it at the lowest level on the scale.
10. Avoid marking, etching or placing labels on torque wrenches.
11. Use a torque wrench to apply a specific torque value during the final assembly process. Do not use a torque wrench as the primary means of tightening or loosening fasteners.

12. As most torque wrenches are length specific, always grasp the torque wrench in the center of the handle. If two hands need to be used, place one hand on top of the other.
13. Apply torque in a slow, methodical manner and avoid sudden, "jerking" movements.
14. When the wrench signals (by clicking, beeping or lights) that a specific torque has been reached, stop pulling immediately.

15. After 5,000 cycles or up to one year of use, whichever comes first, have your torque wrench inspected and recalibrated by the manufacturer or reputable calibration service. With proper care, a high-quality torque wrench should provide accurate measurements for many years.

Conversion of units of Measurement

Basic Equivalence of Units of Force:

1 N = 1 kgf•m/s^2
1 kgf = 9.81 N
1N = 0.102 kgf

Force = mass x acceleration
Gravitational acceleration (g) = 9.81 m/s^2
Therefore, N = kgf x g; N = kgf x 9.81 m/s^2
And, kgf = N ÷ g; kgf = N ÷ 9.81 m/s^2

For Torque Wrench:

1 N•m (Newton metre) = 0.102 kgf•m (kilogram-force meter)

Pressure Conversion:

1 Pa (pascal) = 1 N/m^2 (newton per square meter)

1 Bar	100 000 Pa (pascal)
	0.1 MPa (megapascal)
	1.019 kgf/cm^2 (kilogram-force per square centimeter)
	14.503 psi (pound per square inch)
	0.986 atm (atmosphere)

Example of how to convert units by manual calculation:
1. Prove that 100,000 Pa = 1.019 kgf/cm^2
Solution:
Note equivalents
100,000 Pa = 100,000 N/m^2; 1 kgf = 9.81 N; 1 m = 100 cm

Solve by elimination of units:

$= \frac{100{,}000\ N}{1\ m^2} \times \frac{1\ kgf}{9.81\ N} \times \frac{(1\ m)^2}{(100\ cm)^2} = \frac{100{,}000\ \cancel{N} \times 1\ kgf \times 1\ \cancel{m^2}}{1\ m^2 \times \cancel{9.81\ N} \times \cancel{10000\ cm^2}}$

$= \frac{100{,}000\ kgf}{98100\ cm^2} = 1.019\ kgf/cm^2$

Hydraulic Tightening

Hydraulic torque is a method used to tighten bolts rapidly and accurately with the necessary tension required. One of the advantages is that it is easy to operate; another is that hydraulic torque wrenches create no spark during operation and therefore it is an approved technique for oil and gas, underground mining and other industry applications.

Leak Testing for Hydraulic

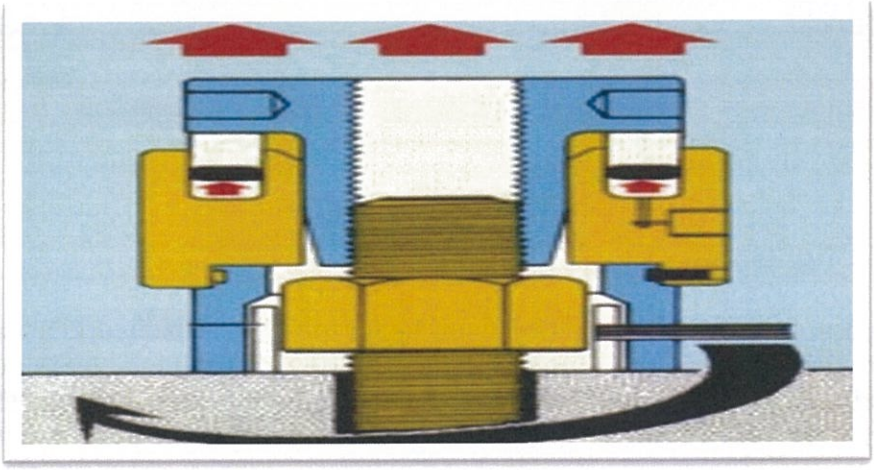
Leak testing or bubble testing is commonly performed after bolt tightening or flushing to ensure that there are no leaks in the system, and that the system is ready for operational use. Gas detectors and detergent are commonly used in performing the leak testing procedure. The testing will ensure that there are no leaks in the system that may cause an environmental issue, as well as ensuring that no contaminants enter the system whilst in operation.

Hydra tight has been at the forefront of the development of bolt tensioning systems for 30 years, and we've been responsible for the extensive uptake of this technology across the world in the oil and gas and power generation markets.

Bolt tensioners are suited to both topside and subsea applications. We have designed innovative features to increase the efficiency and speed of use across both these sectors.

The technology surrounding hydraulic bolt tensioners can either be very simple or extremely complex. Our wealth of experience is perfectly suited to cope with the wide

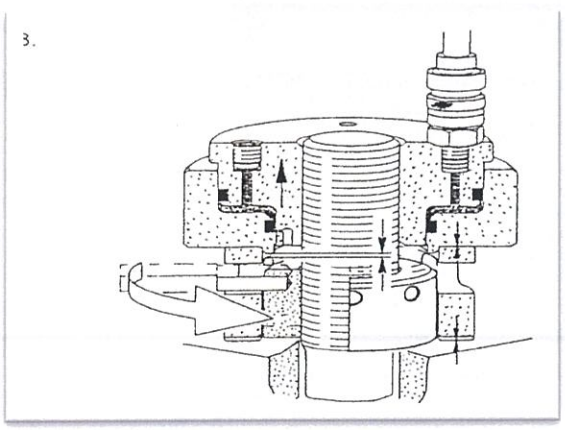
variation of requirements we receive. We design and manufacture tensioning products in-house at three Hydra tight locations, and our tension product group is focused on the continued development of the range as well as new product development.

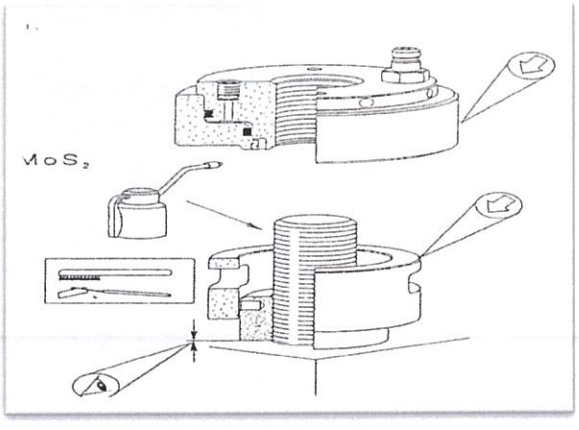


Direct: Tension is applied directly to stretch the bolt, so we don't need to fight against friction or losses.

Accurate: The applied load is controlled very accurately, because it is directly proportional to the pressure applied to the tensioner.

Calculated: The load transfer factor is calculable, helping to give the correct residual load.





Fast: Operation of tooling and improved accuracy reduces time required to retighten the load.

Versatile: Tensioning allows for loading multiple fasteners in a joint at the same time.

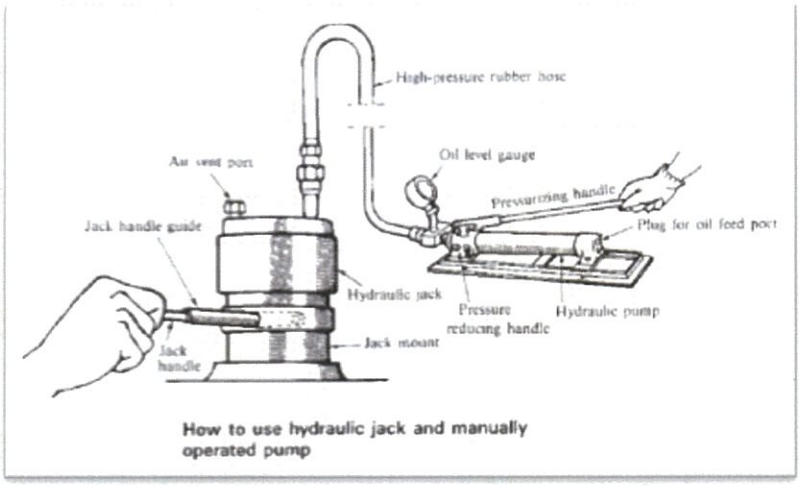
Reliable: Uniform bolt loading ensures a high level of accuracy by applying a consistent force.

Stress-free: Purely axial, tensile loading ensures no torsional stresses are introduced.

Use and Maintenance of Hydraulic Oil Jack: D/G

The hydraulic jack is used to tighten and loosen the following parts:

- cylinder head tightening nuts;
- connecting rod big-end tightening nuts;
- main bearing tightening nuts;
- sole plate; and
- Engine frame fixing nuts.



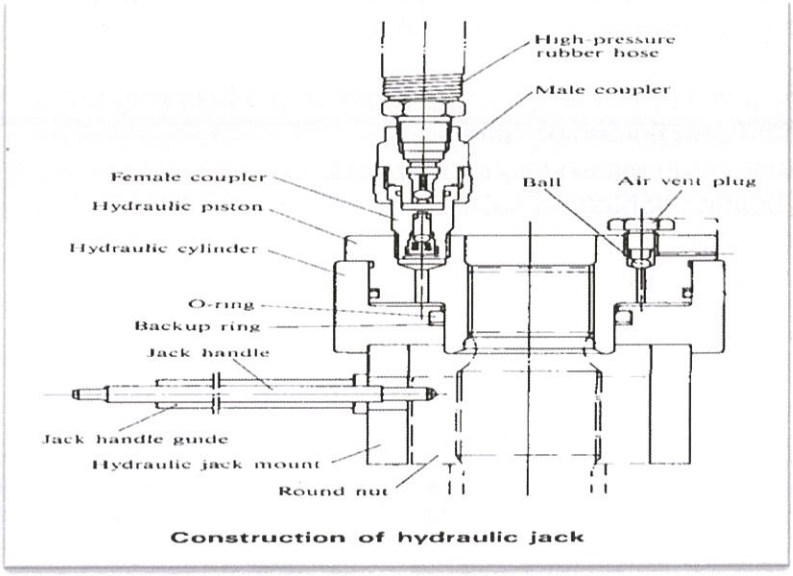
How to use hydraulic jack and manually operated pump

Maintenance Aux. Eng. Hydraulic Jack

1. O-ring and backup ring should be replaced with new ones over 4 ~ 5 years.

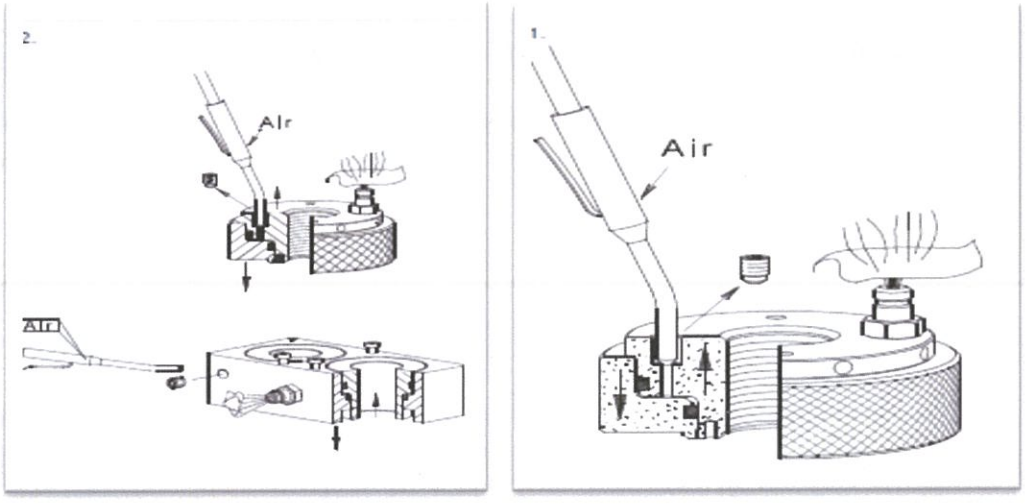
2. To overhaul jack, knock out liner by hitting bottom of hydraulic piston with wooden hammer. Take care not to damage exterior of piston and interior of liner.

3. When reassembling, take care not to damage O-ring and backup ring.



Construction of hydraulic jack

Hydraulic Tools Maintenance (Replacement of Sealing Rings)



1. The hydraulic jacks require no maintenance except replacement of defective sealing rings, each of which consist of an O-ring and a back –up ring fitted in ring grooves in the piston and cylinder.

The piston and cylinder are easily separated by taking out the bleed screw and pressing the parts apart with the help of compressed air

Note: Always use protective gloves and eye protection when working with compressed air.
Make sure there are no marks or scratches on the sliding surfaces of the parts. The presences of metal particles will damage the sealing rings.

Keep the sliding surfaces and threads coated with acid free grease or molybdenum disulphide grease.

2. The pistons and cylinders of the double jacks are separated in the same way as described for the single jack.

3. When changing the sealing rings, first mount the back-up ring and the o-ring.

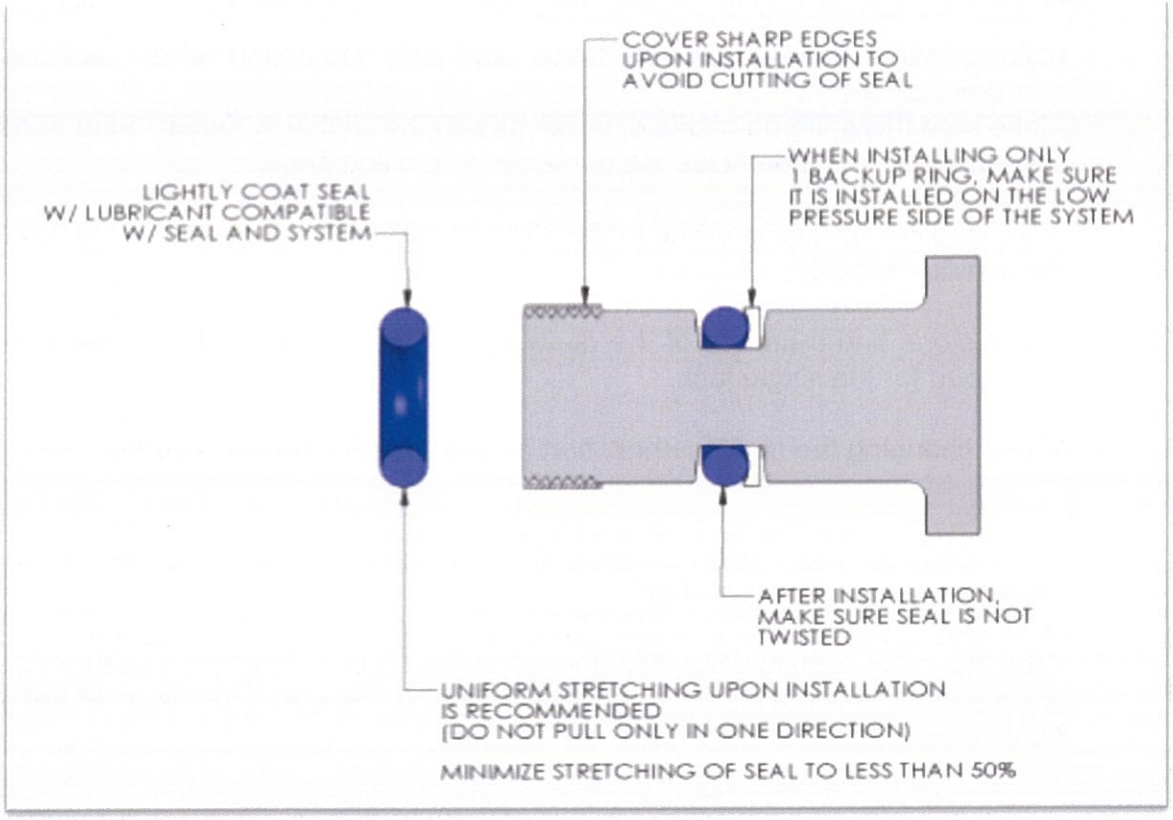
Note: Back up ring 1 must be away from the pressure chamber and the o-ring 2 close to the pressure chamber.

4. After fitting the sealing rings, coat the piston and cylinder with molybdenum disulphide grease and press the piston and cylinder together. See that the rings do not get stuck between the piston and cylinder.

O-ring Installation Guide:

The diagram below shows good tips on how to properly install an O-ring. The O-ring installation procedures are the following:

1. Lightly coat the O-ring seal with lubricant that is compatible with your system.
2. If necessary, cover any sharp edges upon installation to avoid cutting or damaging of the O-ring seal.
1. If you are installing a backup ring, a good tip is to make sure it is installed on the low pressure side of the system, that way the high pressure side of the system pushes the O-ring against the backup ring.
2. Upon installation of the O-ring, make sure there is uniform stretching of the O-ring and do not just pull only on one side of the O-ring.
3. Minimize the installation stretch of the O-ring to less than 50%.
4. After installation of the O-ring, make sure that the seal is not twisted in your O-ring groove or gland.

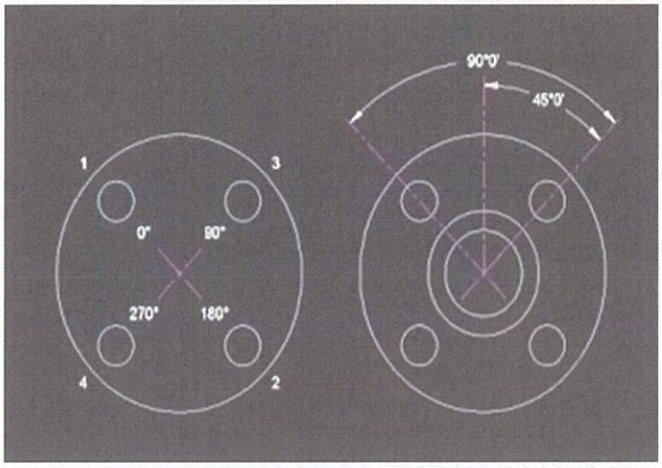


Bolt tightening Sequence Procedure

Start the tightening procedure by lubricating the nuts and bolts. Then hand tightened till they are snug against the flanges. If an air wrench is used make sure the pressure is set to the minimum. When tightening, always use the correct sequential bolt order for the flange.

4 and 8 Bolt Flanges

- First round - 30% of final torque (flange sequential order)
- Second round- 60% of final torque (flange sequential order)
- Third round - 100% of final torque (flange sequential order)
- One final time - clockwise or counter clockwise sequentially around the flange.



4 Bolt Tightening Sequence

- Sequential Order: 1-2, 3-4
- Rotation Order: 1, 3, 2, 4

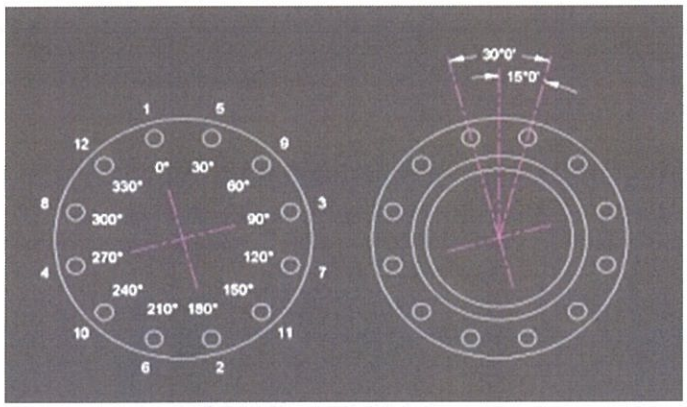
8 Bolt Tightening Sequence

- Sequential Order: 1-2, 3-4, 5-6, 7-8
- Rotation Order: 1, 5, 3, 7, 2, 6, 4, 8

12 Bolt Flanges and More

- First round - 20% of final torque (flange sequential order)
- Second round - 40% of final torque (flange sequential order)

- Third round - 80% of final torque (flange sequential order)
- Fourth round - 100% of final torque (sequential order)
- One final time - clockwise or counter clockwise sequentially around the flange.

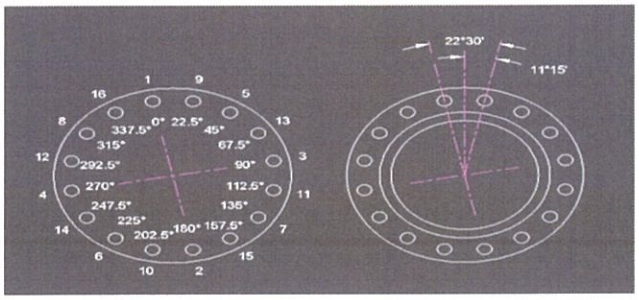


12 Bolt Tightening Sequence

- Sequential Order: 1-2, 3-4, 5-6, 7-8, 9-10, 11-12
- Rotation Order: 1, 5, 9, 3, 7, 11, 2, 6, 10, 4, 8, 12

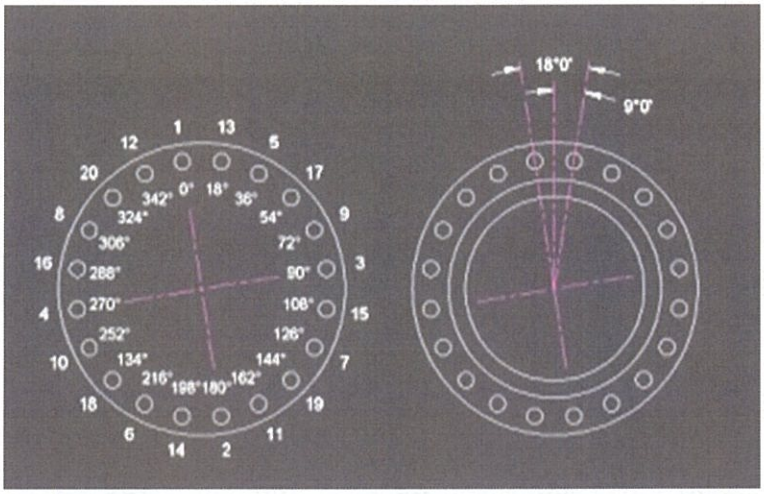
16 Bolt Tightening Sequence

- Sequential Order: 1-2, 3-4, 5-6, 7-8, 9-10, 11-12, 13-14, 15-16
- Rotation Order: 1, 9, 5, 13, 3, 11, 7, 15, 2, 10, 6, 14, 4, 12, 8, 16



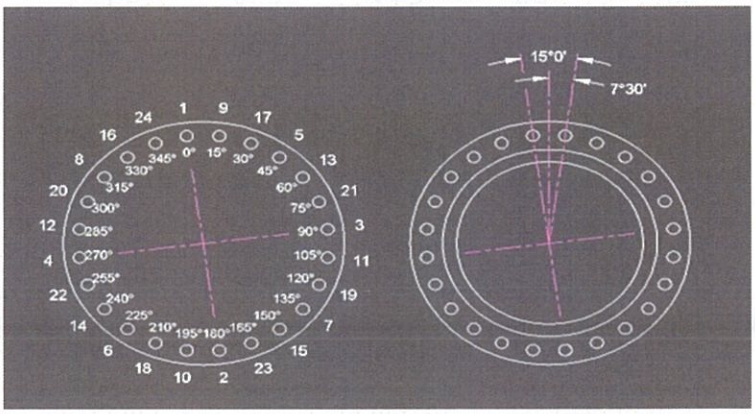
20 Bolt Tightening Sequence

- Sequential Order: 1-2, 3-4, 5-6, 7-8, 9-10, 11-12, 13-14, 15-16, 17-18, 19-20
- Rotation Order: 1, 9, 5, 13, 3, 11, 7, 15, 2, 10, 6, 14, 4, 12, 8, 16



24 Bolt Tightening Sequence

- Sequential Order: 1-2, 3-4, 5-6, 7-8, 9-10, 11-12, 13-14, 15-16, 17-18, 19-20, 21-22, 23-24
- Rotation Order: 1, 9, 17, 5, 13, 21, 3, 11, 19, 7, 15, 23, 2, 10, 18, 6, 14, 22, 20, 8, 16, 24



Torque Factor

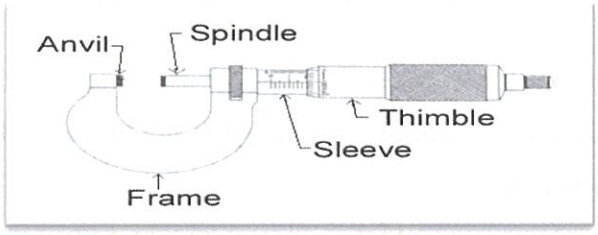
Pipe Size (NPS)	150# (ft-lbs)	300# (ft-lbs)	400# (ft-lbs)	600# (ft-lbs)	900# (ft-lbs)	1500# (ft-lbs)	2500# (ft-lbs)
1/2	45	45	45	45	150	150	
3/4	45	90	90	90	150	150	
1	45	90	90	90	240	240	
1 1/4							
1 1/2	45	150	150	150	368	368	
2	90	90	90	90	240	240	
2 1/2	90	150	150	150	368	368	
3	90	150	150	150	240	533	
3 1/2							
4	90	150	240	240	533	750	
5	150	150	240	368	750	1200	
6	150	150	240	368	533	1020	
8	150	240	368	533	1020	1650	
10	240	368	533	750	1020	3000	
12	240	533	750	750	1020	3300	
14	368	533	750	1020	1020	4770	-
16	368	750	1020	1020	1650	6600	-
18	533	750	1020	1650	3000	8800	-
20	533	750	1200	1650	3300	11580	-
22							-
24	750	1200	2250	3000	6600		-

Proper Use of Measuring Instrument

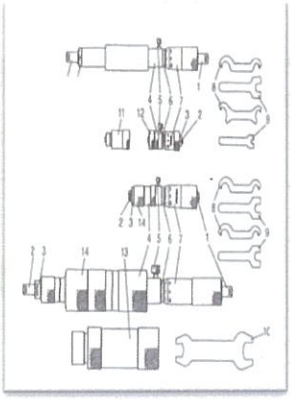
Micrometer

A micrometer allows a measurement of the size of a body. It is one of the most accurate mechanical devices in common use.

Outside Micrometer
Parts of Outside Micrometer

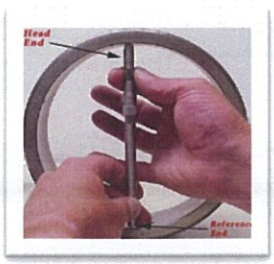


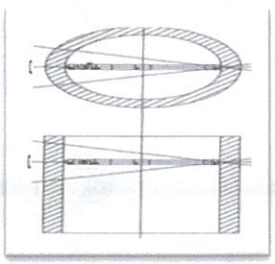
Inside Micrometer



Parts of Inside Micrometer

1. Anvil
2. Adjusting Anvil
3. Adjusting nut
4. Main Body
5. Clamp
6. Sleeve
7. Thimble
8. 10 Wrench
11. Extension Rod
12. Cap
13. Extension Pipe
14. Adjusting Rod

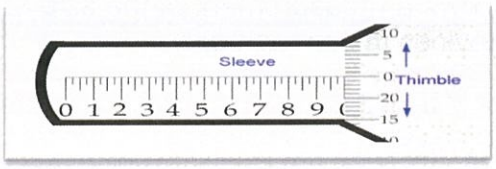




Setting the Reference Point

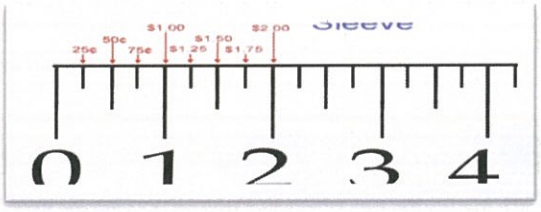
1. Clean the contact faces of the gauge and the measuring point.
2. Insert the gauge a little shorter to a work piece , set the reference point.
3. Move the thimble to the Measuring contact by moving back and forth until obtain the maximum point.
4. Lock then read the indicated value

To learn to read the mike you need to understand the Thimble and the Sleeve. Here we are going to learn to read the micrometer by figuring out the markings on the Thimble and the Sleeve.

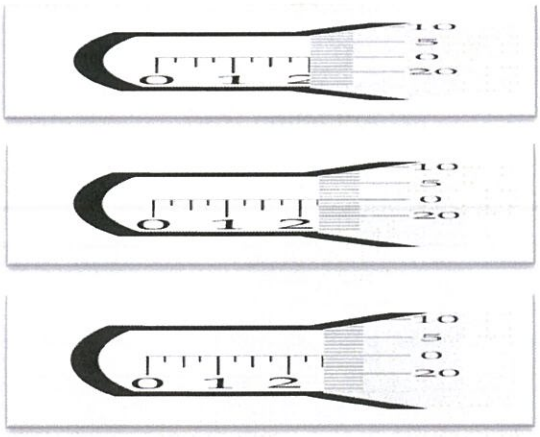


The sleeve does not move it looks like a ruler with ten numbers; the space between each is divided into quarters, as the thimble rotates around this sleeve it covers up or reveals the number marked on the sleeve.

It is easy to read micrometer if you think the marker of the sleeve as a dollar and quarters.



Now it gets a little easier to read the mike. For example, what are the readings on the micrometers shown below?



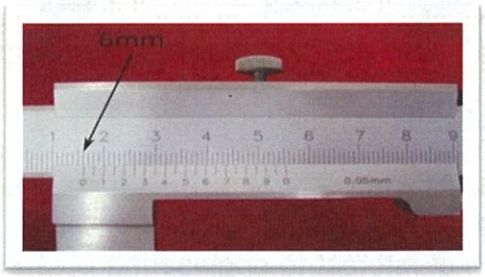
Vernier Caliper

The Vernier Caliper is a precision instrument that can be used to measure internal and external distances extremely accurately.

How to read vernier caliper?

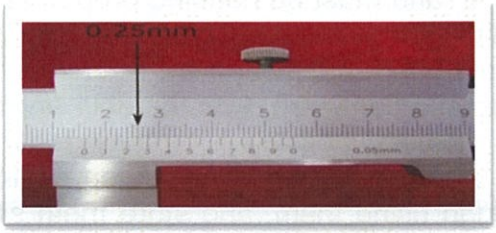
Read the centimeter mark on the fixed scale to the left of the 0-mark on the vernier scale. (10mm on the fixed caliper)

Find the millimeter mark on the fixed scale that is just to the left of the 0-mark on the vernier scale. (6mm on the fixed caliper)

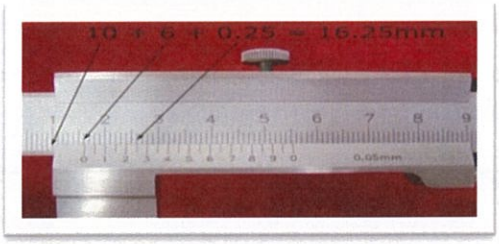


Look along the ten marks on the vernier scale and the millimeter marks on the adjacent

Fix scale, until you find the two that most nearly line up. (0.25mm on the vernier scale)



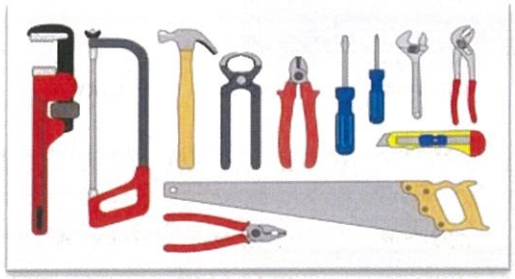
To get the correct reading, simply add this found digit to your previous reading. (10mm + 6mm + 0.25mm= 16.25 mm)



Proper Use of Tools

It will greatly reduce the risk of explosion or fire:

- Understand the Hand Tool's Intended Use.
- Proper Selection of Tools.
- Maintenance and Storage.



Proper Care of Basic Tools

The information in the lessons is extremely important to all who desire to be completely familiar with and well trained in the knowledge, care, and uses of hand tools. This also contain much of interest to engineering personnel who have picked up their knowledge of tools more or less by chance as their work required various tools to be used. Even engineers with long experience may gain valuable information that they had known about previously.

Good tools are essential if personnel are to do his best work quickly, properly and accurately. Without the proper tools and the knowledge of how to use them, time is wasted, efficiency is reduced, and the person doing the work may injure himself. Good tools are carefully made, and must be handled properly if they are to work and last as intended. They cannot take rough usage. This is especially important aboard ship where it may be impossible to procure a replacement when needed.

In such a good practice onboard, with the ship engineer and crew taking care of his tools, as valuable time and possibly lives may depend on the accomplishment of piece of work quickly and accurately. He will keep cutting tools sharp, grind them, if necessary, when through using them, and store them so that their edges will not be damaged or dulled by contact with each other or with other hard objects. He will handle delicate measuring instrument with care, and will not keep them where they might be damage by heavy tools.

Some tools can be used for several purposes, but the wrong tool may ruin not only it, but the work as well. If s screwdriver is used as a prying tool (informal used),it may bend or break. If a chisel is used instead of a wrench, an important part of the machinery may be scarred or broken. The way in which tools are handled, and the care given to

them, indicates the quality of workmanship and the kind of engineering to be expected in your department.

Tools handler Philosophy;

1. Used tools for their intended purpose acutely.
2. Clean the tools immediately after using them.
3. Keep tools in their proper places.
4. Always cover sharp pointed tools with cork.
5. Be sure are in good working condition before using them.
6. Handle and use tools property

Proper storage and correct location of tools needed during emergency Situation

As part of the Company safety campaign and Best practices onboard ship applied particularly in engine room, tools arrangement and location was made available for its intended use at every part or deck nearby where the machinery is located, e.g. tool board was made nearby the sea chest suction wherein all its necessary tools to be used during dismantling and cleaning are essentially available.

When work is being done, the necessary tools should be kept within easy reach, but not where they can fall and be damaged, or where they may fall and injure someone, as might occur from an upper level in the engine room. It is advisable to spread canvas along a grating, if tools are to be place on it, or if work is being carried on where tools might drop and fall through it. Opening in the engine or other equipment being worked on should be covered or plugged to prevent tools, nuts, bolts, etc., from accidentally falling through the openings. Such objects within the cylinder or crankcase of an engine, and not observed and removed before starting up, can cause considerable damage.

Tools should never be place on the finished parts of a machine, on the ways of a lathe, for example. Sharp tools should not be carried in the pockets of clothing or left protruding from work benches, as they may tear or puncture objects with which they come in contact, including the workman.

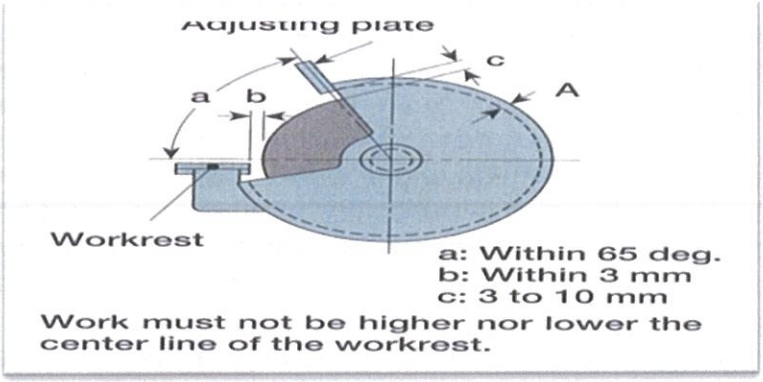
In general, every tool should be given its own place on a tool rack or tool board, or in tool box. Some tools should be kept close by the machine for which they are used. Other tools must be stored in the tool room. Tools should be cleaned after being used, should be oiled, in some cases, to prevent rust, and should then be returned to their respective places.

General Guidelines for safe practices in work site

1. Demonstrate knowledge of evacuation procedures
2. Identify and report dangerous situations
3. Use safety clothing and equipment (PPE's)
4. Demonstrate knowledge of fire prevention and control procedures
5. Maintain correct posture to avoid injury
6. Demonstrate knowledge of hazardous substances and associated procedures
7. Use ladders safely
8. Employ the safety tag system
9. Recognise responsibilities for providing, maintaining and using associated equipment for safety

Handling of Bench Grinder

- Adjust clearance between the grinding wheel and the work rest for approximately 3 mm or less.
- Adjust the height of the work rest to the centre of the grinding wheel.
- When the surface of the grinding wheel is uneven, flatten the surface with a dresser.
- Precaution when using a grinder: wear safety goggles, the side face of the grinding wheel shall not be use, check the condition of the grinding wheel for any crack.
- Check the tightening nut of the grinding wheel it is a left handed screw a safety precaution must be taken.

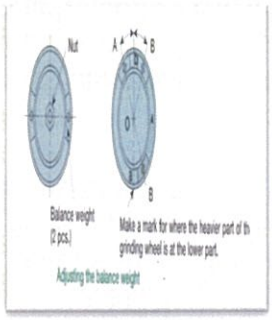


How to adjust if the grinder is in balance and vibrates during operation

- Adjustment when a balance weight is provided.

- Softy turn the grinding wheel by hand and the wheel will stop with a heavier part downwards, move the wheel to the opposite side namely to the top .repeat this procedures until the wheel stops randomly.
- Adjustment when a balance weight is not provided.

- Slightly tighten the nut, adjust the clearance between the shaft and the grinding wheel while rotating the wheel by hand. If it is not effective replace the grinding wheel with a new one.



6.General Works in Engine Room

Crack and Flaw Detection on Main Bearings

Cracks tend to form, spread and get worse as the heat, thermal stress, heavy loads, repeated bending and flexing, metal fatigue, pounding and vibration take their toll on the part. So if metal is pulling away from metal, it means an area is experiencing more stress than it can handle. That's why cracks form in the first place.

If critical parts are not inspected for cracks, there's no way to know if they will stand up to normal use and abuse. In the case of cylinder heads and blocks, you won't know if the castings can hold pressure until the engine has been assembled - which means you may have wasted a lot of time and effort if a casting turns out to be full of holes.
And it's not only cracks that you should be on the lookout for: other flaws such as porosity leaks in castings need to be identified so a decision can be made as to whether repair or replacement is the best option. With hard-to-find and high value cores and parts, the decision may hinge on the extent of the damage. If the part can be repaired economically and with a high degree of success, then it's probably worth fixing. But if it can't, you'll have to factor in the cost to replace it.

Even new parts aren't excluded: Cylinder heads, engine blocks, crankshafts, camshafts and connecting rods are just some of the components a savvy engine builder will check using nondestructive testing methods. There are a variety of techniques that can be used by themselves or in combination with other methods to find cracks in castings and other components.

Cracking Up

Cracks are quite common in late model cylinder heads and are often found between valve seats, in exhaust ports, between the spark plug hole and valve seats, around valve guides, between combustion chambers, and even on top of the head.

The blame is often placed on thinner castings and higher engine loads, but in many instances the underlying cause is engine overheating due to a cooling system failure (coolant leak, inoperative cooling fan, stuck thermostat, etc.), or a detonation problem (carbon buildup, inoperative EGR valve, too much ignition advance, etc.) or some other user (or builder) error such as incorrect installation (wrong torque on head bolts, dirty bolt threads, etc.).

One of the causes of cracking in cast iron heads is stress created when the valve seats are induction hardened. The concentrated heating process that hardens the valve seats also creates residual stresses in the head that may cause it to crack later - even if the engine has never overheated. The cracks typically form where stresses are highest, which is often between the valve seats.

Cracks typically form when a cylinder head undergoes too much thermal stress. Loss of coolant - severe overheating as well as sudden changes in operating temperature from hot to cold - can all create the conditions that can cause cracks to form.

Simply put, when metal is heated it expands. Aluminum expands at nearly twice the rate of cast iron, which creates a mismatch in expansion rates on bimetal engines with aluminum heads and cast iron blocks. While the heads are designed to handle a certain amount of normal expansion, elevated operating temperatures can push a head beyond those design limits, causing the metal to deform. This, in turn, may cause cracks to form as the metal cools and contracts.

Crack and Flaw Detection Techniques

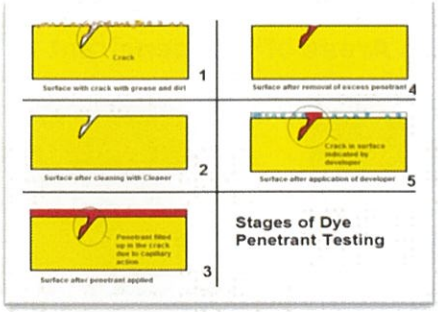
1. Dye Penetrant Inspection Procedures

Dye penetrant testing or liquid penetrant testing is one of the most common and cost effective techniques used in nondestructive testing.

Dye penetrant testing is used to detect the presence of surface cracks in components. The ideology to detect these cracks is by means of a dye usually highly colorful and less viscous that enables it to penetrate into cracks in the surfaces. This happens mainly due to the capillary action. The dye tends to remain inside the crack, which is made to surface out by the use of appropriate chemicals thus indicating the size and structure of the crack.

Here's how we practically carry out the dye penetrant testing. The dye penetrant kit basically constitutes of three chemicals in pressurized cans namely:

- Cleaner
-Penetrant
-Developer



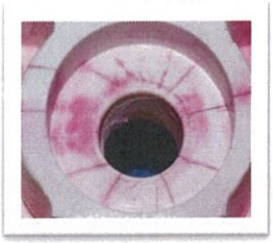
Testing Procedure:

Pre-cleaning:
This is the most important and vital stage of the dye penetrant testing. The surface to be tested is to be free from grease, oil, paints, etc. Dust particles covering the area can be removed by using pressurized air. The materials that have the capability to stick to the surface like grease, oil, gum, diesel, etc. can be removed easily by means of the cleaner. The cleaner disintegrates the sticky particles on the surface and carries away the same while flowing away. Any residual cleaner left on the surface tends to get evaporated all by itself. The area cleaned using the cleaner is to be left to dry for about 5 to 6 minutes.

Penetrant Application: The dye penetrant is now applied to the area where the cracks are to be determined. A dwelling period of about 10 to 15 minutes would be very much ideal for the penetrant to get itself settled inside the cracks present on the surface of the component.
Penetrant Removal: The excess *penetrant* that is present on the surface is removed using lint free clothing soaked with the cleaner. Care needs to be taken to ensure that the cleaner does not flow on the surface. The excess penetrant needs to be wiped out of the surface very carefully. This basically requires a good amount of expertise.
Developing: The *developer* is used to develop the penetrant present inside the cracks. Good amount of care needs to be taken by the user ensuring that no excess amount of developer is added to the surface. This may cause penetrant present inside the crack to be absorbed more quickly and distributed in the excess developer chemical. This can lead to an indication that no crack is present in the area.
Inspection: The developer used properly tends to indicate the areas where cracks are present. Cracks present are indicates a bright spots usually the color of the penetrant. The developer normally tends to provide a white background for the same enabling the inspector to identify the crack immediately.

Application Areas of Dye penetrant



Testing:
The dye penetrant testing is applicable in all areas where the surface finish tends to be quite good.

- for checking of cracks in roll formed sections
- surface crack detection in railway rails
- crack detection in gear teeth
- Detection of cracks in welding's particularly in boiler welding for detection of surface cracks.
- Detection of surface cracks caused by high speed grinding

Advantages:

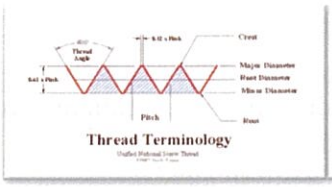
- Very low cost method for determination of surface cracks.
- portable kit enables easy carrying of the kit
- instant results can be obtained by the user and no highly trained personal required to interpret results

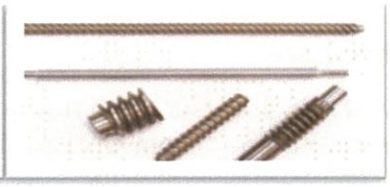
Disadvantages

- Only surface cracks can be detected. Any cracks below the surface or sub surface cracks cannot be detected
- Method works well only for surfaces that are machined or polished. Irregular or very rough surfaces tend to provide false results.

Proper checking of screw thread condition

1. Clean the thread with a wire brush.





2. Repair with file and die if it was found with slight damage.

Proper way of using thread lubricant
Types of Lubricant: Molycote Thread Lubricant
Solid lubricants - Mineral oil - Thickener - Powdered metal
How to Use:

- If possible, clean the thread and the bolt with a wire brush.
- Spread an adequate amount of the paste on the thread, right up to its root in order to obtain a good seal.
- In order not to alter the properties the paste, it must not be mixed with grease or oils.
- It is advisable to use the aerosol application to enable this product to be applied more quickly and cleanly to larger areas.

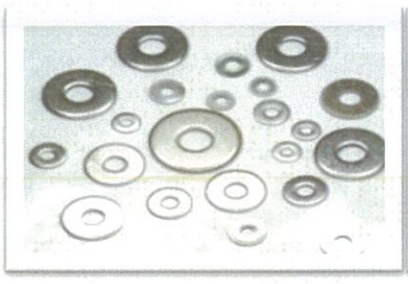
Importance of Lock washer

Washers

Nuts and bolts are common household fasteners that have a multitude of uses. While they may be effect by themselves, oftentimes the addition of a washer to one or both sides can increase their strength, appearance and efficiency. Different types of washers provide different advantages. Before reaching for a flat washer or a lock washer, it is important to know what you wish to accomplish.

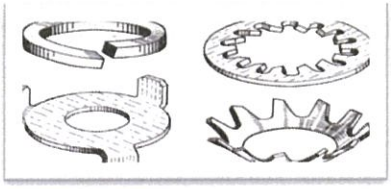
Types of Washers

Flat Washers
Flat washers are used to increase the surface area in order to more evenly distribute the force applied with tightening the fastener.




Lock Washers

Lock washers are used as a means of creating tension during tightening in order to help keep the nut from working loose later.



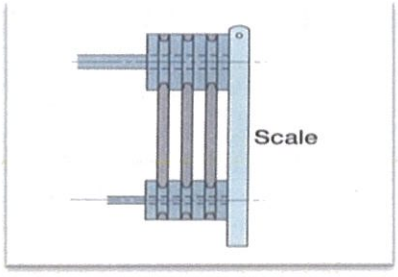
- Both flat and lock washers come in a wide variety of interior diameters, exterior diameters and thicknesses. Flat washers may be constructed from a variety of materials including brass, silicon bronze, stainless steel, zinc plated steel, chrome, rubber and many others. Lock washers may also be made from a number of different materials including stainless steel, zinc plated steel, silicon bronze, galvanized steel and many others.

Application and Uses of Washers

Flat washers may be used on the bolt side, the nut side or both sides of the fastener. Flat washers help to distribute the force of tightening the nut by increasing the surface area. They may also be useful as spacers when a bolt may be a bit too long for the job. Lock washers are typically used on the nut side of the fastener. The most common type of lock washer is the split coil washer. This type of washer creates tension as the coil is forced down by the tightening of the nut. This tension helps to keep the nut in place. Lock washers are frequently used in applications that involve vibration which may tend to work the nut loose.

Adjusting V- belt (with JOB CARD)

As shown in the figure, move the motor to adjust the tension of the V-belt while adjusting the parallelism applying a ruler (if not applicable, a string or a fine steel wire) to the pulley.



Proper tension of V-belt

- When you can pick and twist the v-belt with your fingers by approximately 90 degrees.
- When you can push the down the v-belt with your finger by approximately with its thickness.

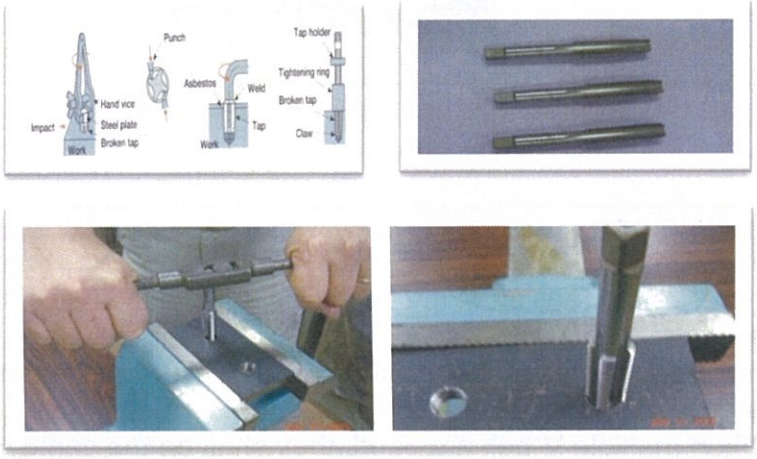
Handling Precautions

- Increase the tension of the belt if slipping noise is emitted at the start or during operation.
- Length of V-belt changes with operating time, proper interval of adjusting the tension of the V belt.
- When multiple V-belt are used, they shall be the same in length
- For renewal replace all the belts at the same time.
- The shape and the condition of pulley groove have a great influence on the life and transmission efficiency of the belt.
- If the pulley groove has been deformed or worn out replace with a new available spare, and send the old one to shore for recondition or repair.
- V-belt is structured so that the underneath surface does not move towards the groove bottom
- If ever it touches to the groove bottom, due to elongation or wear it is necessary to replace the V belt with new one.
- Oil sticking in the V belt is dangerous, check for any oil sticking in the belt.

Note: Angle of V-belt is 40 deg. Irrespective of the type (A, B, and C) while angle of the pulley differs (34, 36, or 38 deg.) according to the belt size and type.

How to remove a broken tap

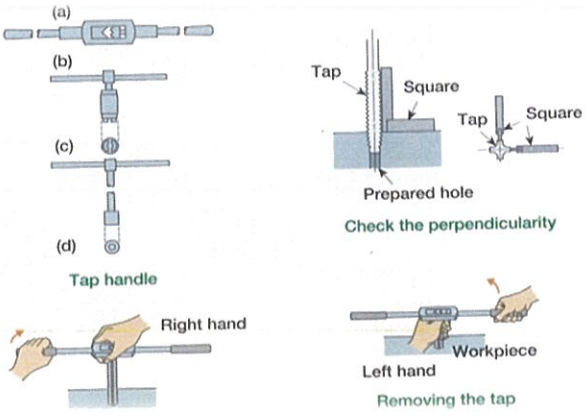
- Pinch the tip of the hand tap with a vice; slowly turn the vice while applying an impact on the work piece.
- Weld a steel piece on the tap to remove it
- If available, use a tap holder to remove the tap.



Proper use of tap and die

Making a prepared hole for a female screw

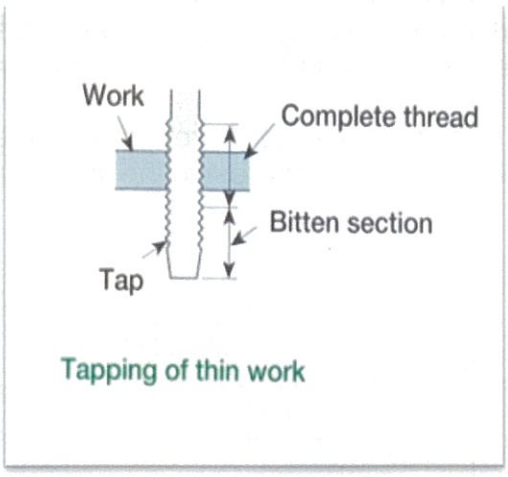
- To tap a female screw of nominal size M10, make a prepared hole with 8mm drill, although size of the prepared hole is 8.21mm according to the table.
- Relation between the nominal size of metric coarse screw thread and the inner diameter of female screw.
- It is desirable to make a prepared hole for a female screw at right angle to the base metal. Be careful of the perpendicular position, especially when a portable electric drill is used.
- For starting in making a hole in the work piece, start first with small size diameter drill then followed by the specified diameter drill.
- In the case of a blind hole, use a drill after making the required depth on it.



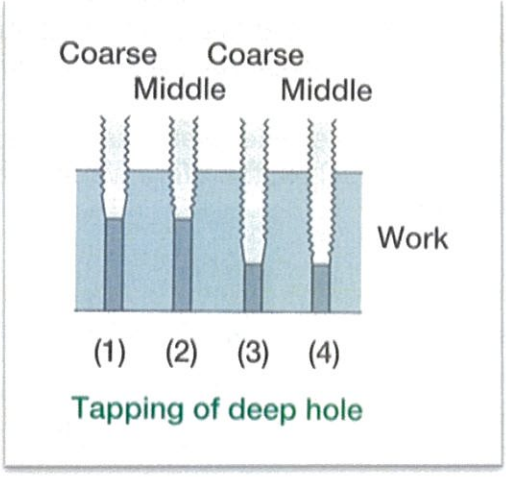
Normal size	Inner diameter of female screw	Normal size	Inner diameter of female screw
2	1.52	14	11.62
3	2.28	16	13.62
4	3.10	20	17.02
5	3.92	24	20.43
6	4.80	27	23.43
8	6.51	30	25.83
10	8.21	36	31.23
12	9.91	42	36.64

Tapping: 3 piece set hand tap

- Set a no.1 tap at the prepared hole perpendicular and slowly turn it clockwise until it bites the prepared hole, caring the tap does not tilt.
- When the tap nibbles the prepared hole, rotate the taps 2 turns and check for tilting.
- If tilting was observed removed and correct to perpendicular position.



Tapping of thin work



Tapping of deep hole

Turn the Handle

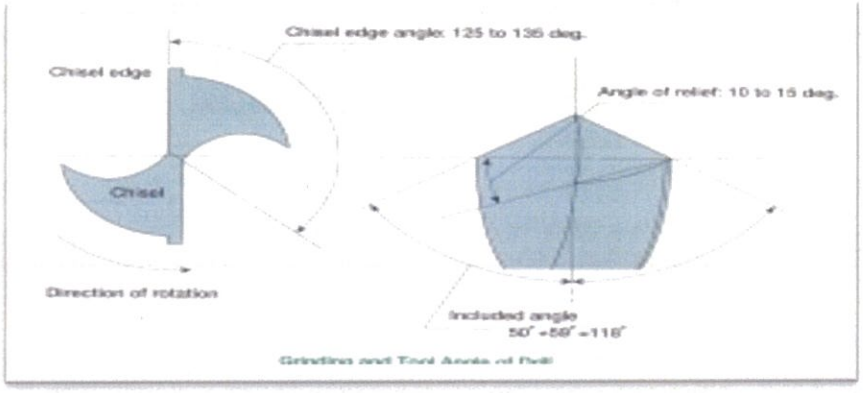
- When the tap is corrected and direction is determined, turn the handle horizontally and evenly by both hands.
- Return the handle by ¼ turn each time it is rotated by ¾ turn.
- Add oil at proper intervals, in the case of a blind hole; take the tap out of the hole to removed chips occasionally.

Note: If tapping is too hard that the tap is twisted when you apply a force on the handle, the prepared hole may be too small or the tap must be tilted against the hole. Remove the hand tap out of the hole and widen the hole with a round machinist file.

Grinding of Drill bit, and its Angle

1.1 Grinding of cutting edge

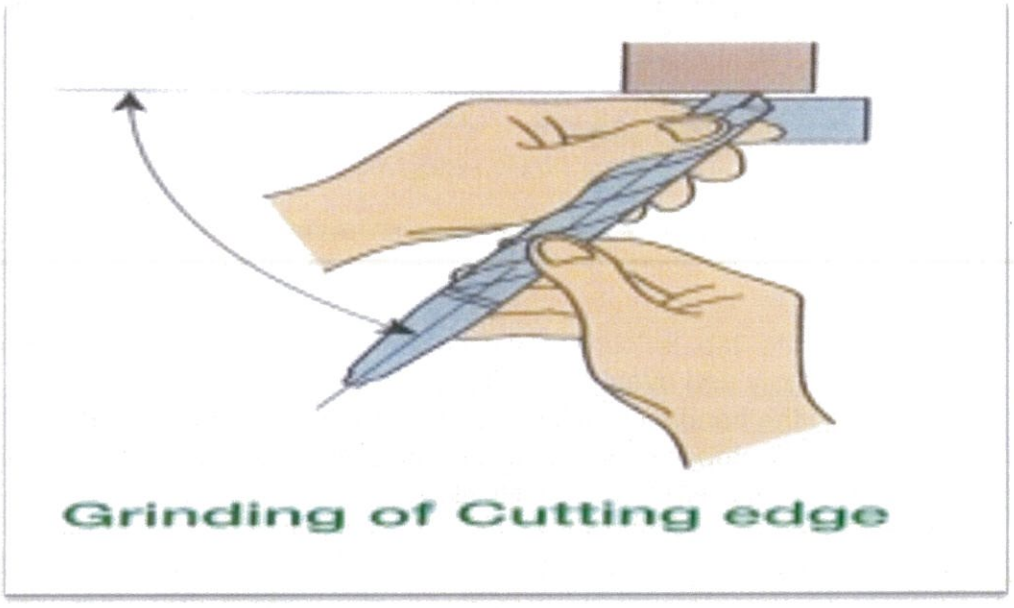
- As shown in the figure, hold the drill with your left hand placing on the tip side and right on the shank side.



With your left hand on the pedestal to keep a cutting edge horizontally, allow the edge to touch the periphery of the grinding wheel so that the included angle becomes 118 deg.

- Grind the end face of the drill while turning it by your right hand slowly as if you scoop up the grinding wheel and the end face shape the cutting edge in angle.

Note: The sharpness of your cutting edge have a great effect on the performance of your tool bit, therefore when grinding focus your interest to the tip of your tool bit cutting edge.



Importance of proper tightening a "Fastener" (bolt)

- use to hold or clamp two surfaces together.
- A correct amount of torque needs to be applied to the bolt In order for the bolt to properly perform this function.
- This applied torque will cause the bolt to stretch and act as a spring to clamp and hold the joint Together.

Primary causes of fatigue failure of bolted joints
Survey shows, failure of bolted assemblies are mainly due to:

- Not properly designed
- Wrong choice of components
- Tightening method
- Poor assembly

Why the need for correct tightening?

- To make the best use of the bolt's elastic properties.
- To work well, a bolt must behave just like a spring.

Purpose of Tightening
Depending on the application, the purpose of the tightening load is multiple:

- ensure the rigidity of the whole assembly and make it capable of supporting external loads due to traction, compression, bending moments and shear;
- prevent leakage at seals;
- avoid shear stresses on the bolts;

Purpose of Tightening

- resist spontaneous loosening effects.
- reduce the influence of dynamic loads on the fatigue life of the bolts.
- Furthermore, all components (bolts and assembly parts) must perform these tasks while remaining below the yield point of their respective materials.
- Bolt-tightening is optimal when the bolt is properly tightened.
- not too much, not too little!
- A bolt can fail just as often - and even more so - when it is not tightened enough, as when it is over-tightened.

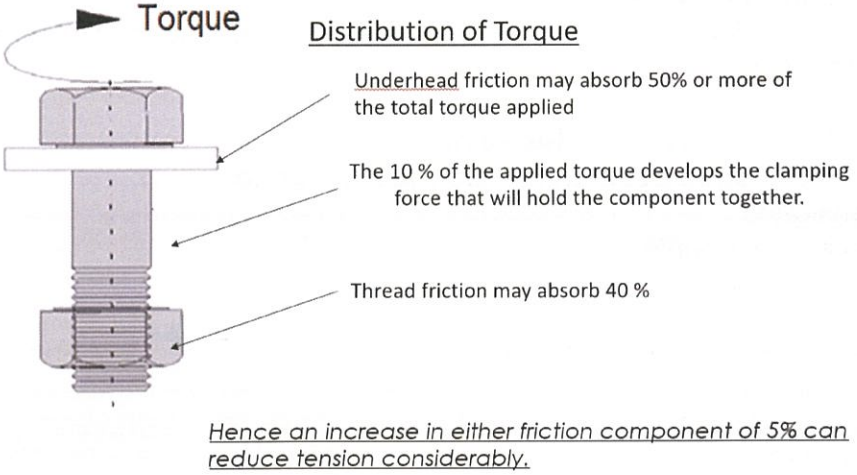
- ***Failure to properly torque fasteners can lead to equipment damage, personal injury or worse.***

(source: SKF bolt tightening handbook)

Other factors that affects the proper tightening and must always be checked by the operator (maintenance personnel)

Frictional drag on the shank or threads due to

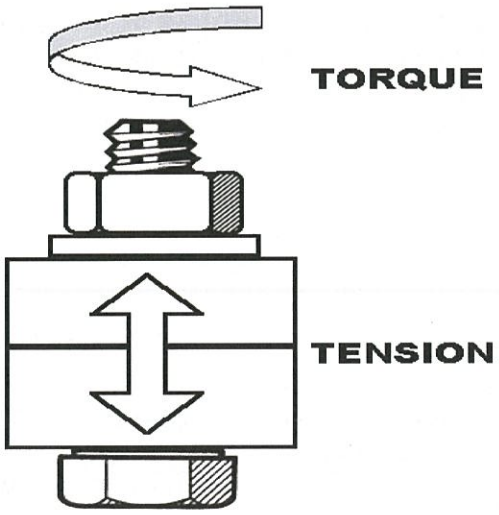
- the misalignment of the parts
- dirt on the threads,
- out of tolerance threads with unintended interference.



Hence an increase in either friction component of 5% can reduce tension considerably.

What is torque?

- Torque is a twisting force



The process of tightening a fastener involves turning (advance of the lead screw) and torque (turning moment) so that preload (tension) is produced in the fastener.

The desired result is a clamping force to hold the components together.

Terms

Proof load

- Is the published number that full size headed bolts are tested to.

Clamploaд

- is calculated at 75% of proof load.

Clamp load is only a estimated number, there maybe situations where the engineer calls for the bolts to be tensioned to a different value.

Proof load: For bolting specifications that do not have a published proofload, it is usually calculated at 92% of ultimate yield strength.
Clamp load: 75 of proof load to allow a safety buffer so that bolt does not get to close to proof load value.
If you exceed the proof load value when tensioning the bolt, you run the risk of bolt failure.

Clamping Force

Clamping force results from:

- Tension or stretch on bolts securing two pieces
- Springiness of a gasket between parts

Clamping force will change if threads are

- not clean and or damaged,
- unlubricated for lubricated fastener.
- Lubricated for non lubricated fastener.

Cleanliness is very important when assembling parts

Common method of Bolt tightening (Torque)

TORQUE PLUS ANGLE METHOD OF TIGHTENING (TURN OF NUT)

- Turn of nut: commonly used in structural applications, involves measuring the rotation of the nut relative to the point where the joint members were in solid contact (or snug fit)
- This method is for it is to get a more consistent stretch in the bolts. Since a torque wrench senses friction, there are a lot of variables that can affect proper tightening, especially as the torque spec increases.
- By only using the torque wrench for a small initial torque to seat the bolt, and then turning the bolt a certain number of degrees of rotation, a correct stretch will apply to the bolt. An example would be to tighten the bolt to 20 lb ft and then turn it an additional 90 degrees (1/4 turn).
- A degree of accuracy (up +/-25%) can be compromised due to a number of varying forces such as coatings, lubrication and surface texture.

- ❖ Tightening up fasteners using cheater bars ie pipes attached to sockets etc to give more leverage is dangerous and must not be used. It is not contest to see who can tighten the fastener up the hardest.

Understand the fasteners you plan to use, obtain proof load values, purchase a torque wrench &/or recalibrate your equipment, take into consideration all the variables such as lubricants etc and preload the assembly correctly.

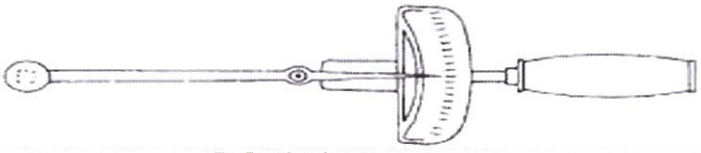
SNUG TORQUE
The torque required to pull plates together so that direct contact occurs; often used in angle control tightening.
The snug torque ensures that metal to metal contact occurs at all the interfaces within the joint.
It is only at this point that the required angle of rotation start in order that the bolt is tightened sufficiently.
The snug torque is usually determined experimentally on the actual joint.
SNUGGING
The process of pulling parts of a joint together,
most of the input turn during this process is absorbed in the joint with little tension being given to the bolt.

WHAT ABOUT TORQUE TO YIELD

- ❖ Torque to yield fasteners are stretched to the point that they are just about to "yield" or lose their springiness. These types of fasteners can only be used once and then must be replaced.

Proper Torque Wrench Use and Maintenance

- A torque wrench is a precision instrument designed to apply a specific amount of force to a fastener.
- It is very important that proper care is used.



Deflecting beam

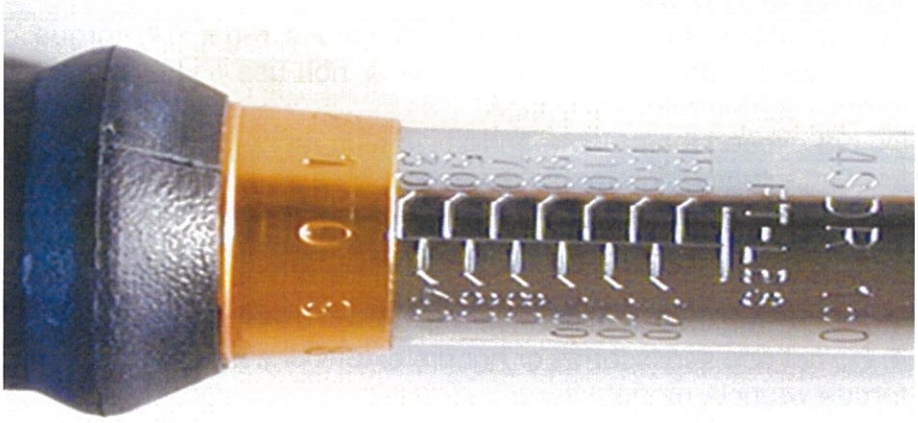
Rigid case dial indicator

Click type

Safety and Care

1. Always follow the manufacturer's directions regarding torque direction, proper force, torque pattern/sequence, use or non-use of lubrication on fasteners and torque "tighten/release" cycles.
2. Do not exceed the recommended working range of the torque wrench.
   Reliable measurements are based on a percentage of the working range.
   In general, most mechanical wrenches have a useable range from 20% to 100% of full scale.
3. Most electronic wrenches have a useable range from 10% to100% of full scale.
4. 4. Do not use accessories or handle extensions unless specifically allowed by the torque wrench manufacturer.
5. Take time to inspect the tool and check for worn or cracked sockets. Properly lubricate and replace worn parts.
6. Avoid dropping or sliding a torque wrench. Dropping a torque wrench on a hard surface can cause the instrument to lose reliable calibration. If you suspect that a wrench has been dropped, have the tool inspected by the manufacturer or reputable calibration service.
7. Always store a torque wrench in a protective case and/or location when not in use.
8. Avoid exposure to temperature extremes, high humidity, fluid immersion and corrosive environments.
9. **If using a click-type torque wrench, always store it at the lowest level on the scale.**
10. Avoid marking, etching or placing labels on torque wrenches.
11. Use a torque wrench to apply a specific torque value during the final assembly process. Do not use a torque wrench as the primary means of tightening or loosening fasteners.
12. As most torque wrenches are length specific, always grasp the torque wrench in the center of the handle.
13. If two hands need to be used, place one hand on top of the other.
14. Apply torque in a slow, methodical manner and avoid sudden, "jerking" movements.
15. When the wrench signals (by clicking, beeping or lights) that a specific torque has been reached, stop pulling immediately.
16. Have your torque wrench inspected and recalibrated by the manufacturer or reputable calibration service.

If using a click-type torque wrench, always store it at the lowest level on the scale.



- Most "Click torque wrench" are built with an internal spring mechanism that is compressed to against a lever.

Adjustable wrenches use springs that must meet a linear capability test.

After use, externally adjustable click wrenches should be turned back to minimum scale value.

This helps to preserve the linearity of the spring and calibration of the wrench.

All calibrated wrenches should be backed off to the minimum setting when stored.

Calibrated torque wrenches use a spring with a known linear range.

It is thought (and has been proven) that leaving a calibrated wrench at one setting impacts spring linearity, disallowing accurate use at other settings.

It does not happen every time, but over time linearity can be impacted causing error.

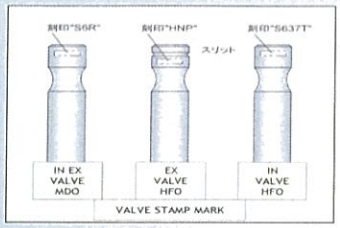
This is the reason for the recommendation to turn a wrench back to its minimum setting when not in use.

References:

- *Snap-on technical reference*
- *RS technologies, a division of PCB Load & torque, Inc.*
- *SKF bolt tightening handbook*

7. TROUBLES / Incidents
HUMAN ERRORS

Incorrect valve assembling



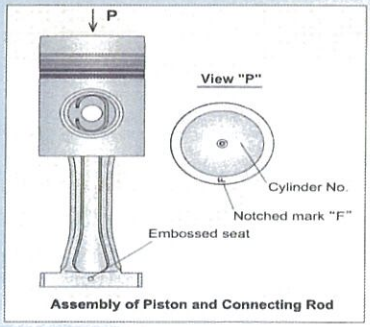
At DK,DC model engines, figure of exhaust and intake valves are common.

Incorrect assembling may cause troubles such as valve stamping.

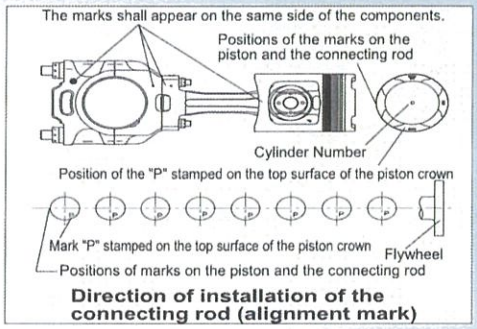
Identification mark is put on the top part of each valves.

DE-18 model engine adopts different figure of intake and exhaust valves in order not to assemble wrongly.

Incorrect piston assembling



Assembly of Piston and Connecting Rod

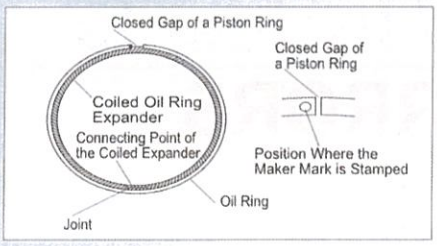


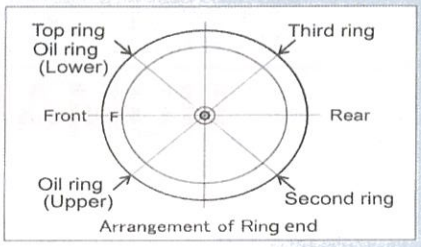
Direction of installation of the connecting rod (alignment mark)

Piston and connecting rod are assembled with their weight balance. When replacing a connecting rod to a new one, weight balancing is necessary.

In case of assembling wrong direction P-S of piston, intake and exhaust valves can contact
With the piston as lack of clearance. This may lead to valve breakage trouble.

Piston ring installation





When assembling oil ring, entangle the oil into the oil ring groove and insert the coil joint, so that the coil joint comes on the opposite side of the ring joint.

(Old model oil ring is with Teflon pipe. Engage coil through Teflon pipe and put the Teflon pipe at the ring joint to prevent coil to be between ring joint.

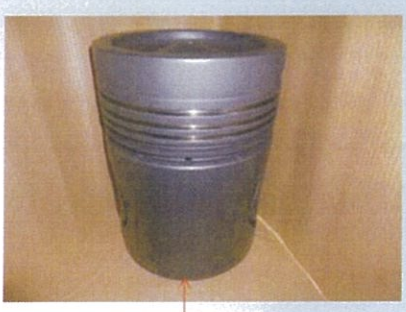
Install piston rings with Maker mark to up side (combustion chamber side).

In case of installing oil ring upside down, lubrication oil consumption increases.

Don't put piston ring and oil ring joint in line. Each ring joint has to be at the opposite side or with 90 degrees.

Piston body

Defric coating disappeared

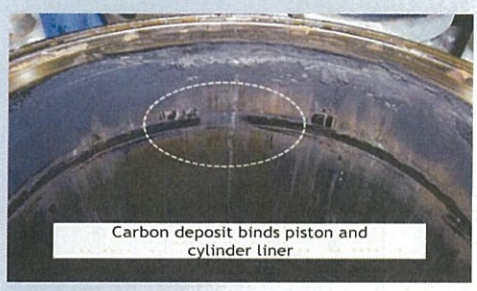


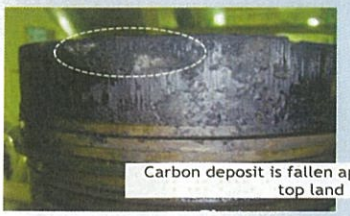
Newly defric is coated

Piston body is coated with "defric" and it has function of lubricity and anti-seizure. As running hour goes by, defric coating gets warn. When clean the piston, please notice below.

- Do not polish piston body with buff, sand paper or any hard material.
- Clean piston body with kerosene or washing oil.
- Small hit mark can be repaired partly but do not polish over all piston body.

Protect ring (Piston stick)


Carbon deposit binds piston and cylinder liner


Carbon deposit is fallen apart from piston top land

Accumulated carbon on the piston top land falls between piston and cylinder liner and binds them.

Prevention

· High load operation with MDO before long period non-operation.(Carbon removal with blow off operation)

· Hand or motor turning the engine for several minutes once a day. (Priming pump running when turning is recommended)

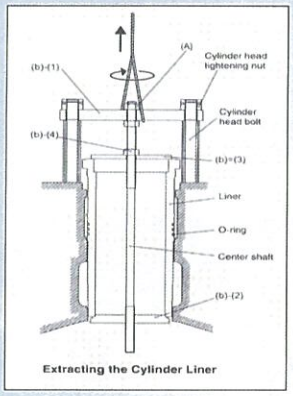
Countermeasure

· Opposite rotation turning

· Apply lubrication oil from nozzle hole of cylinder head to soften the carbon. Try turning a day after.

· Remove carbon with steam heater or carbon remover.

Cylinder liner extraction



Extracting the Cylinder Liner

Follow instruction manual when extracting cylinder liner and in case of not extracted for a long time, water scale or rust make difficult to extract.

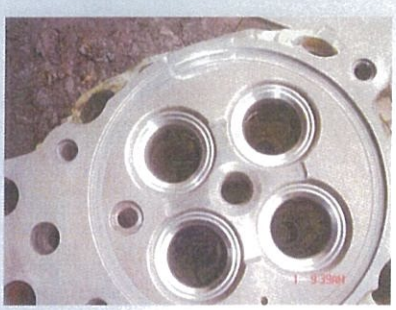
When it's difficult to extract, do not extract with force and try below as it may damage extraction tool.

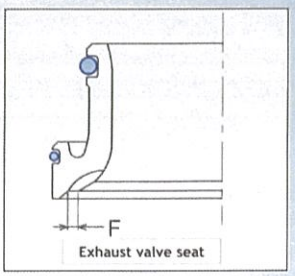
1,Lift tool (b)-(1)

2,Impact cylinder liner with plastic hammer.

3,Place oil jack on balance weight of crank shaft at top dead center position, jack up the cylinder liner from the bottom.

Water leakage from exhaust valve seat





Cooling water leaked from exhaust valve after cylinder head maintenance due to burning carbon on cylinder head to remove it.

Two o-rings are used in a exhaust valve seat and gets burnt in case of use fire.

The burnt o-ring looses its sealing function.

Do not use fire to remove carbon on cylinder head.

C.W. pump gear nut torque

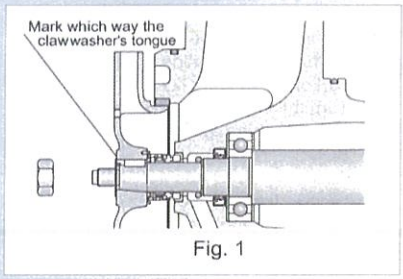
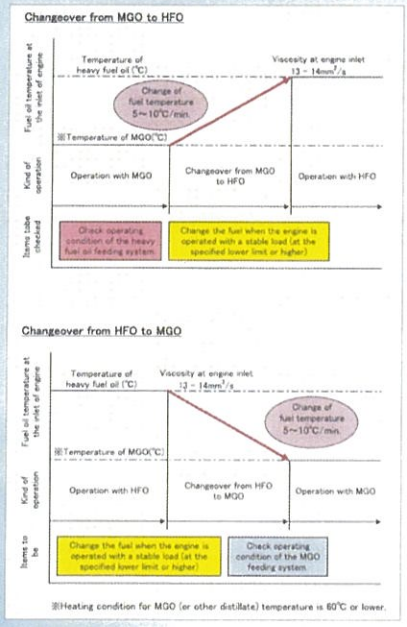


Fig. 1

When there is lack of torque on impeller nut or gear nut , key groove gets deformed and related parts such as gear, shaft, nut and so on gets damaged.

Apply Molykote and tighten with right torque to prevent accidents.

Fuel change over (plunger stick)



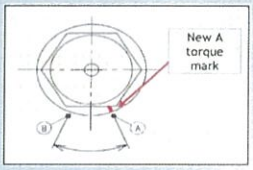
Fuel change over should be done under stable load (more than the minimum load) and keep the pace of 5-10℃/min.

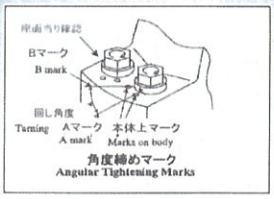
Do not heat MDO,MGO more than 60℃(flash point)

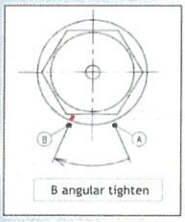
In case of change over is too quick, fuel injection pump plunger and barrel may get stuck or vapor lock occurs.

To prevent vapor lock, drain air in the fuel supply line instruments (heater, filter, tank etc)

Connecting rod bolt tightening







At the time of bolts replacement, tighten the bolts with running-in torque for 2-3 times. Once the running-in is done, tighten the bolts with A torque and put a new A torque mark on the bolts.

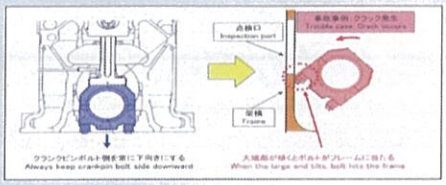
(When A torque mark on the bolts exceeds after use, tighten with A mark and put another new A mark on the bolts.

Tighten the bolts up to B angle after putting A mark on the bolts.

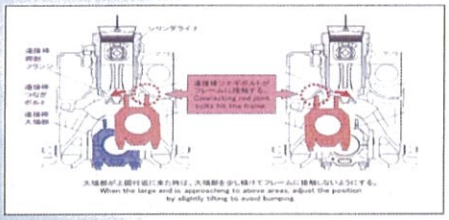
Apply molykote 1000 spray on bolt thread and seat.

Make sure that the torque wrench is corrected.

Connecting rod big end and frame contact



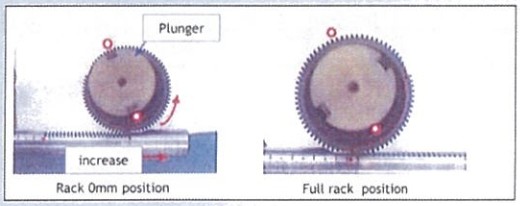
When turning cranks shaft remaining big end of connecting rod, pay attention that crank pin bolts are facing to the bottom all the time.



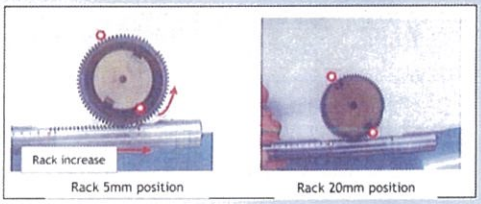
Turning crank shaft remaining connecting rod big end with connecting rod joint bolts, confirm safety and avoid contact of engine frame and the bolts by adjusting the position.

(For more safety, connecting rod joint bolts should be taken out)

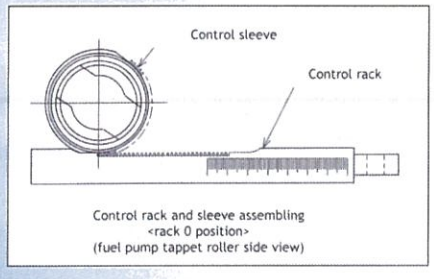
Fuel pump incorrect assembly



Right fuel rack amount and sleeve position



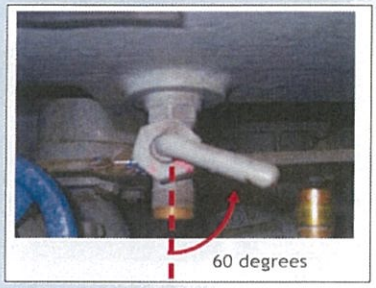
Assembling with opposite side of sleeve

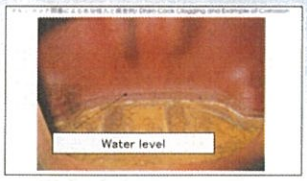


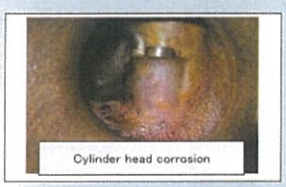
In case of assembling control sleeve from the opposite side, fuel rack becomes almost maximum at "0" position and fuel rack becomes almost zero at 20mm.

This wrong assembling lead to low RPM when normal running and became overspeed when tried to stop the engine.

Intake manifold water drain





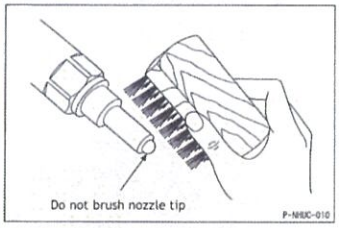


Open drain cock about 60 degrees of intake manifold to avoid acid corrosion. It's one of the reasons of cylinder head exhaust port side corrosion.

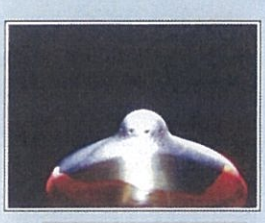
Also, please check below.

- Check air drain while running.
- In case of air is not coming from the cock, clean drain cock and secure air hole by iron wire.
- Cock lever 45 degrees stands for less than 1mm open. This may chokes the cock.

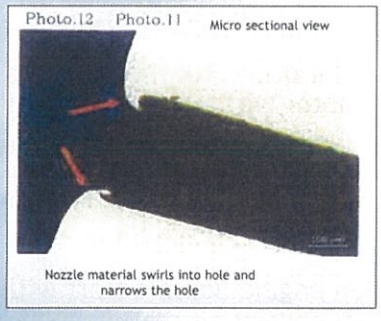
Fuel injection nozzle hole deformation



Nozzle tip before brushing



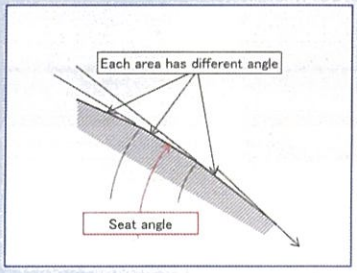
Nozzle tip after brushing

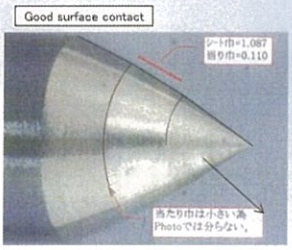


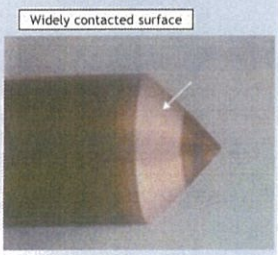
When cleaned nozzle hole with wire brush, material swirled into nozzle hole and narrowed the holes. This causes low out put due to lack of fuel or crack of nozzle body with too much internal pressure.

Carbon removal with wire brush has risk of causing trouble.

Fuel injection nozzle needle valve



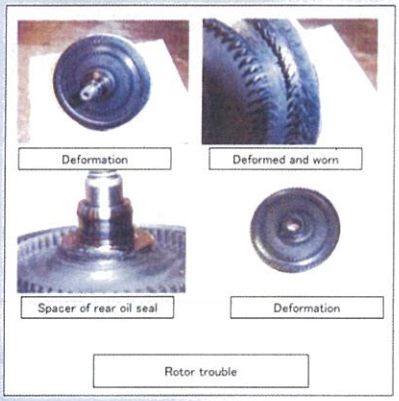




Needle valve has angles on its contact surface. When the angle is lost by polishing or so on, there will be malfunction on injection

When cleaning needle valve, just clean with kerosene and clothe.

Air starting motor over use



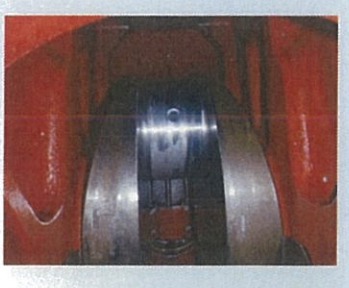
Trouble occurred when run the air motor with out cooling period.

Air motor requires some time to cool inner parts down to avoid overheat.

When engine doesn't start with 30 seconds of air motor running, retry after 150seconds.

Foreign material





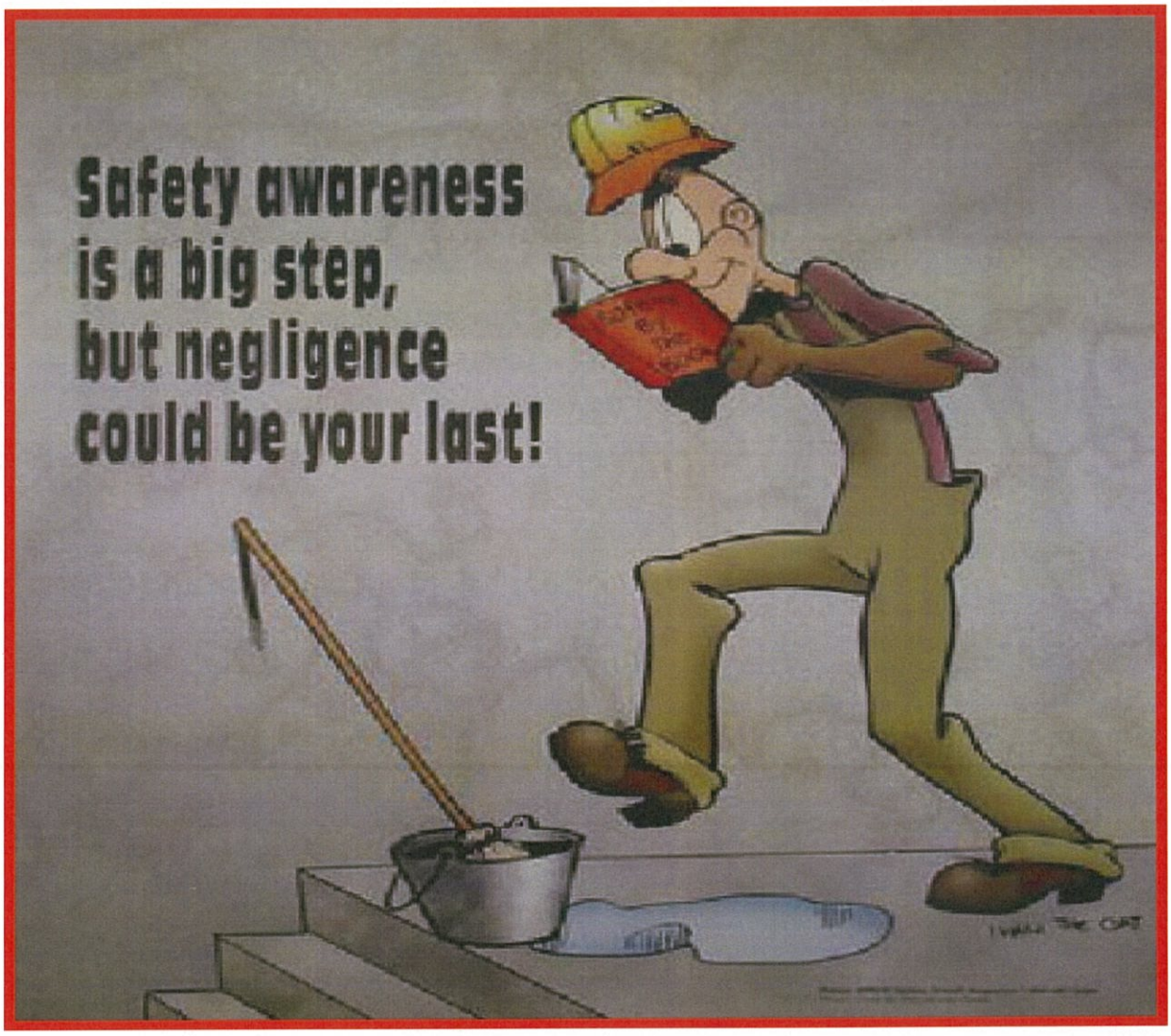

There was a overheat report of crank pin, a piece of cloth was found in the lubrication oil line after the investigation.

At the lubrication filter cleaning, lubrication oil pipe was covered with the cloth. This cloth was not taken out at assembling. It went into lubrication pipe line and stopped lubrication line.

8. General guidelines on Maintenance and inspection

Preparation:

- Develop a consistent routine.
- Use Common Sense Approach
- Consult Service Manuals
- Cleanliness
- Safety



Generally, machine / equipment maintenance should be suitably determined by judging it among others in following manner:
aa) running hours
bb) in service (running condition)
cc) efficiency
dd) Lubricating oil, Fuel oil, running output, etc (i.e for diesel engine)
ee) fluid handled (for pumps)
ff) Ambient

and together with engine status which is understood on the base of experience knowledge getting from the aforementioned condition and many other conditions in order to maintain the good condition of a particular machine / equipment for long time.

** When doing maintenance and inspection work, read the "Maintenance Manual (this includes the drawings)" and "Operating Instructions" beforehand, grasp the structure of the parts in question and the contents of work and fully understand the working procedure, and then set to work.

Why do we need to do first the above???
If the work is done with insufficient preparatory, not only it spends wasteful labor/ money but also lead to troubles and damages of the engine and personal injury / accident as well. The worst is whole ship might be place in jeopardy.

The parts in which damage is detected and or its using limit has been reached and will be reached until inspection as the result of inspection must be replaced with designated regular parts.

- If it is difficult to take measure against troubles onboard or on the spot, communicate with the maker service department and take suitable measures. <u>This matter must be firstly coordinated with your vessel manager.</u>

At all times for ready reference, keep the instruction manual and related documents (drawings, materials, etc) in a specified area at all times.

To prevent environmental pollution, do not dispose of the replaced parts or liquid waste without permission. Proper disposal should be done in accordance with existing laws / regulation.

Diesel Engine: Precautions for Disassembly, Maintenance, and Assembly

A. Prepare the spare parts for replacement, tools and measuring instruments in advance. (be sure to use only the specified tools) as for the spare parts use only genuine parts or parts specified by the engine maker
B. Gaskets, O-rings, split pins and wire ring wires must be replaced with new parts at every disassembly. Prepare the new parts according to extant of disassembly.
C. Block the openings resulting from disassembly with tape or clean cloth to prevent infiltration of foreign matters. After restoration, be sure to remove such tape or cloth.
D. Place the disassembled parts in neat order for prevention of the damage or loss, and improvement of the assembly working efficiency. (At overhauling.)

At overhauling, put suitable match or match marks as many as possible to avoid mistakes when reassembling.

E. Be sure to assemble the parts provided with the assembling position marks or matchmarks, such as the cylinder numbers and the bearing numbers, to their original positions. Further, when these parts are replaced, be sure to provide the new parts with the same marks as those provided on old parts.
F. Materials of the bolts and nuts used in high-temperature sections such as the exhaust manifold are heat-resistant. When reassembling the engine, therefore, be careful not to confuse them with ordinary bolts and nuts.
G. Tighten each bolts and nuts uniformly with the specified torque (or specified oil pressure, or specified angle).
H. When parts are required to be measured during maintenance, perform the measurement correctly, and rearrange the results of the measurement as the data for the reference on later days / next periodical inspection.
I. Before starting the engine after assembling back, restore the engine by fitting the removed protective covers and thermal insulation covers as they were.
J. Be sure to promptly replenish all the used spare parts.

Diesel Engine: Check items after disassembly, maintenance, and assembly

A. Check that all bolts and nuts are free from loosening and that specified lock washers are inserted securely. Particularly be careful when checking the inside of the engine where visual inspection is impracticable durng operation.
B. Turn the engine and prime each fluid to check that there is no problem such as interference of the working area, and leakage or clogging of each area.
C. After end of the work, check that the flywheel turning device and the turning bar used are in “disengaged” position .
D. Record the contents of the work executed and parts replaced in the engine log book.

Adherence to Safety:

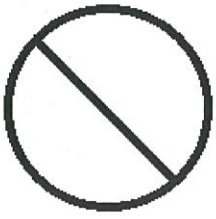
Symbol marks indicate the important descriptions concerning safety. Be fully careful and conduct the work with motto of "Safety first" in mind.

Some symbols marks

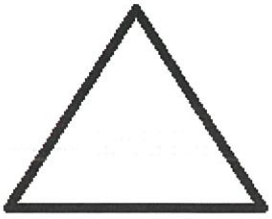
Warning" : Precaution related to the safety of personnel (Potential hazard which could result in death or serious injury)

"Caution" : Precaution related to safety of personnel (Potential hazard which may result in minor or moderate injury

"Prohibition" : Prohibited practice that can affect the safety of personnel and the machine.



Notice" : Information on handling of the machine / equipment to prevent damage.



"Obligatory acts" : Recommended practice or instruction to be followed to ensure safety of personnel and the machine / equipment

When maintenance or inspection work is to be carried out, watch your step so that trip up accident could be avoided.
*The floor in the engine room are slippery with oil adhering to them.
* Install steady footsteps as occasion demands.

Caution

When overhauling / working on piping system, keep all relevant valves "CLOSED" and release the pressure by loosening vent plugs, etc. gradually.
* If filters / strainers and pipe joints parts are to be overhauled, there is always the possibility the high temperature of fluid (oil / water) or sudden burst of flow due to the remaining / residual pressure.

CAUTION

DG OVERHAULING TRAINING

When overhauling / working machine parts with spring components, conduct the disassembly / assembly work very care fully, since the spring may jump out and cause injury to the worker.

CAUTION

*When overhauling parts (valves and other devices) with spring components, take care since there is a possibility of the spring to fly out.)

WARNING

When inspecting and electrical equipment / machine , be sure to turn “OFF” the power switch, and put up the appropriate sign tag e,g. “Under maintenance , do not Switch “ON”

WARNING

When handling liquid, strictly observe following instructions:

- fuel oil , lubricating oil: Flammable ……. Naked flame is strictly prohibited.
- Fresh water corrosion inhibitor, fresh water anti-freeze, mercury (thermometers) = Poisonous ……. Drinking is prohibited. Wash away, if in contact with skin.
- Battery electrolyte = Poisonous …….. Drinking is prohibited, wash away, if in contact with skin. Naked flames is prohibited.

WARNING

If work is to carried out on diesel engine:
After stopping the engine, do not open the crankcase side cover for at least 10 minutes, until the engine cools down sufficiently.
If fresh air should flow into the engine while it is not cooled down a risk of explosion may occur due to ignition of the oil mist.

Procedure of Tag-in/ Tag-out

The lock-out, tag-out procedure applies to any jobs involving stopping, isolation of device, equipment, machinery for the purpose of testing, routine maintenance, servicing. The purpose of this procedure is to ensure that the device, equipment, machinery is stopped, de-energized, isolated from all potentially hazardous energy sources and locked out before employees perform any testing, servicing, maintenance.

The use of these tags is not a substitute for other safety measures while working in hazardous machinery, but it could minimize the accident that is happening on board ship due to human error. It is important that there must be a lockout /tag out station on board that is accessible to all crew.

Lock Out Device

A device that uses a positive means (such as a key or lock) to seize an energy or isolate a device on a safe position.

Tag Out Device

It is a warning device, or a tag, that attached and fastened to an energy isolating device to prevent erroneous operation of certain machinery, Tags should be simple, durable and include legends such as "DO NOT START", "DO NOT OPEN", "DO NOT CLOSE", "DO NOT OPERATE", "ISOLATED" ,"MEN AT WORK".

Procedures:

The following standard lock out procedures shall be used for all corrective and preventive maintenance requirements:

a. When a requirement for lock-out/ tag-out has been identified, the Chief Officer or First Engineer (authorized officers) shall obtain permission from the Master and/ or Chief Engineer as per the job scope. Master and Chief Engineer shall be informed prior performing the lock-out.

b. Locks or Tags are to be attached such that they are apparent to anyone who may attempt to operate the component. DO NOT attach tags to breaker covers or valve caps which may be subsequently removed.
c. Notify all affected crew members regarding planned lock-out/ tag-out. The information shall also be repeated on PA system.
d. The authorizing officer shall identify the type and magnitude of the energy that the machine or equipment utilizes, shall understand the hazards of the energy, and shall know the methods to control the energy.
e. De-activate the energy isolating device(s) so that the machine or equipment is isolated from the energy source(s).
f. Lock-out the energy isolating device(s) with assigned individual lock(s)
g. Stored or residual energy (such as that in capacitors, springs, elevated machine members, rotating flywheels, hydraulic systems, and air, gas, steam, or water

pressure, etc.) must be dissipated or restrained by methods such as grounding, repositioning, blocking, bleeding down, etc.

h. Warning: Work shall not be permitted to start until Locks/Tags required for the protection of personnel or equipment has been attached in accordance with this procedure.

Restoration on Normal Procedures:

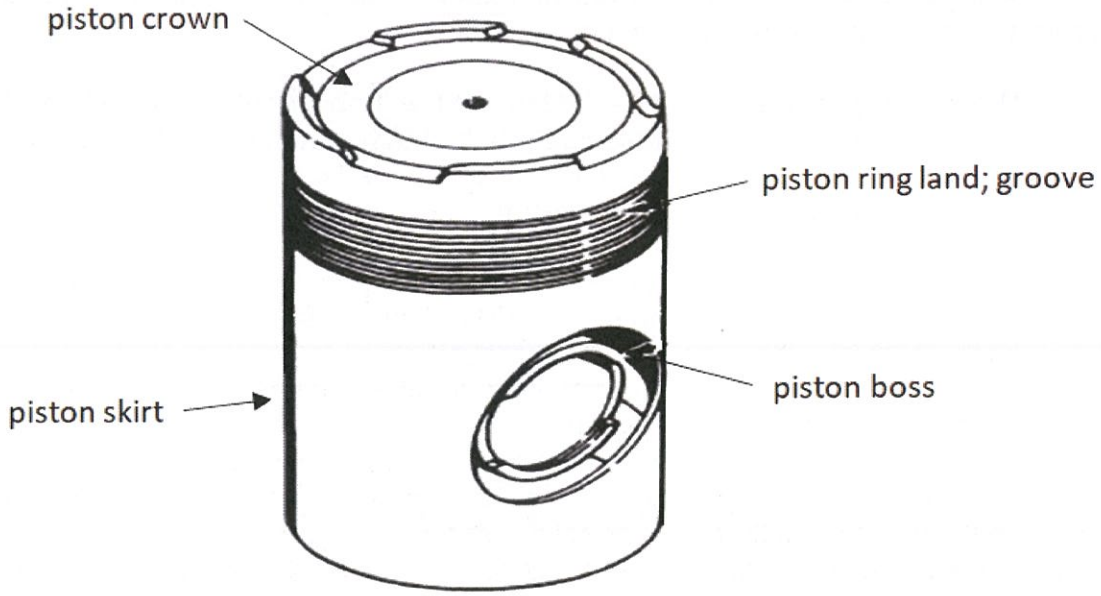
Before power is restored to the equipment, an authorizing officer shall inspect the work area to confirm:

a. It is safe to remove tags.
b. Equipment components are operationally intact and the work has been completed.
c. Personnel are physically clear of the work.

After all are confirmed as OK, each lockout/ tag-out device shall be removed by the authorizing officer.

9. Basic construction and operations (Diesel Engine)

Piston, Piston rings:



Piston:

Function - to transfer force from expanding gas in the cylinder to the crankshaft via a piston rod and/or connecting rod.

Material: The trunk piston comprises of piston crown and elongated skirt.

- Crown is made up of heat resistant forged steel alloy including chromium, nickel and molybdenum for heat and corrosion resistance without compromising on strength
- Skirt is

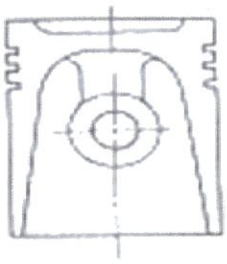
Two part of Piston:

a) Crown - made up of heat resistant forged steel alloy including chromium, nickel and molybdenum for heat and corrosion resistance without compromising on strength

b) Skirt - made up of nodular cast iron or forged silicon aluminium alloy which has the advantage of being light, with low inertia, reducing bearing loading.

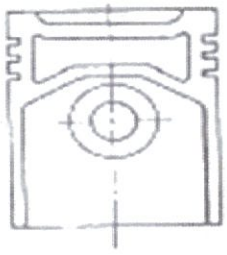
Crown is subjected to high temperatures and its surface is likely to be eroded / burnt away.
Skirt – in trunk type piston, skirt act as guide within the cylinder.

Cooling method:

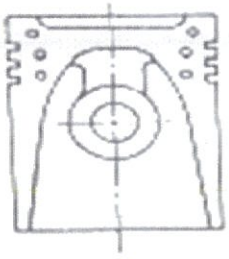


Splash

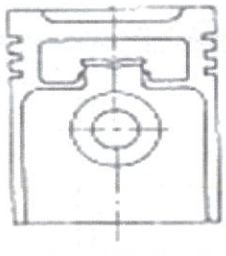
Spray



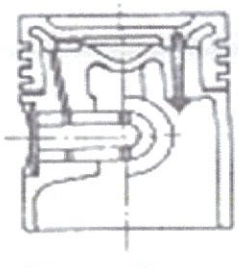
Chamber



Coil



Cocktail shaker



Two piece

Coolant used removing; either fresh water or Lubricating oil.
Water has more ability to eliminate more heat than lubricating.

Thermal stresses in piston crown:

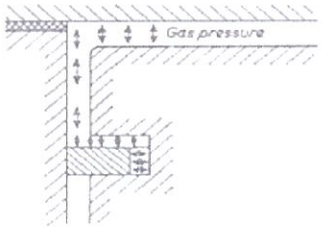
a) Mechanical stress
   Compressive and tensile stress caused by bending action cause by gas pressure. Inertia effect (movement up and downwards).
b) Thermal stress – piston is exposed to high temperatures during combustion.

Piston ring:

- function is to seal off gases generated in the internal combustion process,
- help with transferring heat t.o the cylinder wall and then to both lubricate and scrape down oil from it.

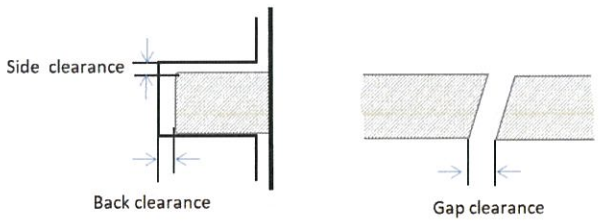
Piston ring sealing action:
Pressure of the gas in the clearance spaces forces the ring down on to the side of the groove and outwards on to the cylinder wall. Contact at these faces must be gas tight demanding smooth mating.

To make the piston assembled to the piston a ring gap/split is provided, gap in the piston ring also enable them to conform to the cylinder wall.
The gap / split.
Usually there are 3 or more piston rings.
Top piston rings mainly for sealing purposes other rings form dual function, dsealing and oil control.



Piston ring sealing action

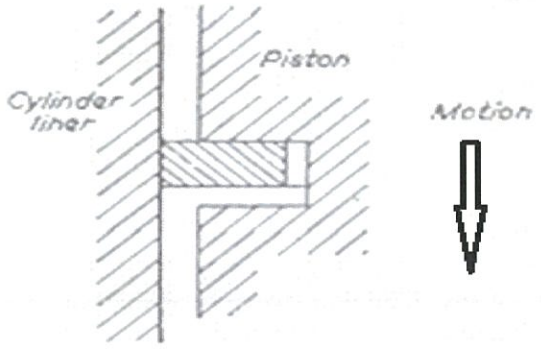
Clearances:



Gap Clearance: Wear of piston is greatest on the cylindrical face and is most easily assessed by the measuring the increase in the gap dimension when the ring is placed squarely in gauge consisting of a flat rigid ring with an inside diameter exactly equal to the nominal bore of the cylinder.

Side Clearance: Axial or side clearance of the ring in its groove is essential to ensure that is free to move relative to the piston in order to maintain contact with the cylinder bore. The clearance is best kept to the minimum that will serve this end for a number of reasons. A large clearance permits the ring to hammer the land below increasing the stress in the land and encouraging of the ring and the groove. Groove wear can be a problem with light alloy pistons.

Back Clearance: Any gasses occupying the clearance spaces round the ring are compressed during the high pressure part of the cycle by hot combustion gases entering the spaces. Large clearance spaces allow greater quantities of hot gas to enter and to raise the temperature of the groove with oxidation of the lubricating oil to form larger amount of undesirable carbonaceous deposits.
Pumping action: Piston rings tend to pump oil from the lower, well lubricated side to the upper, combustion chamber side where it is burnt. The compression rings are lubricated by this process but if it is excessive a high lubricating oil consumption will result together with carbon formation in the groove which interferes with the correct operation of the rings and is conducive to high rates of wear. During downward motion of the piston during the induction stroke the gas pressure on the ring is so low that it takes up a position at the top of the groove as (see fig. below). The oil film on the cylinder wall be comparatively thick below the ring as a result from crank chamber. The ring scrapes this oil film into the clearance space below and behind itself and then when the piston begins its upward motion and the compression of the charge commences then the ring is forced down on to the bottom of the groove and the oil is transferred around the back of the ring to its upper side
Excessive axial / side clearance increases the stroke of the ring in its groove which would result in large amount of oil beign transferred and consumed.



Piston ring pumping action

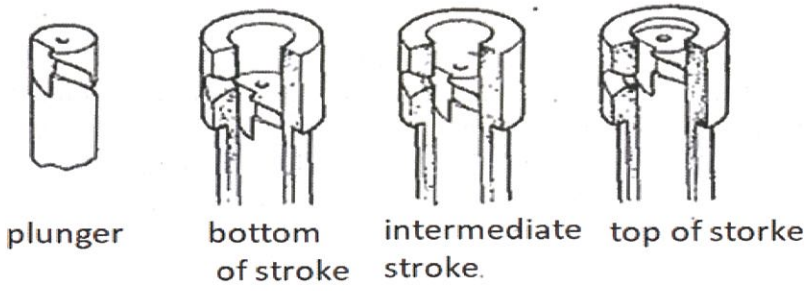
FUEL INJECTION PUMP, FUEL INJECTOR VALVE

Fuel Injection Pump:

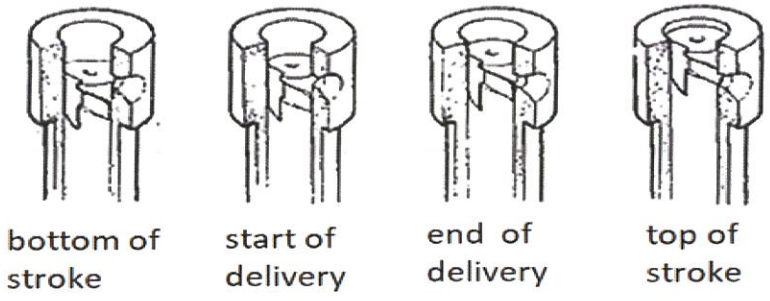
Function of fuel injection pump:

- pumps a metered amount of fuel in sufficient pressure to open the fuel injector in correct timing.

Fuel Pump:
It is actuated by a cam and roller tappet follower. When the follower is on the base circle of the cam the pump plunger is at the bottom of its stroke and the inlet port is open allowing fuel in the gallery to flow into and fill that portion of the barrel above the plunger. The plunger is a close fit in the barrel. As the cam rotates the plunger rises and seals off the inlet port at this point of the stroke the pumping action starts. By means of adjustments provided in the tappet follower this event can be timed in a precise relationship to the crank angle. Further upward movement of the plunger causes the fuel to be raised in pressure and expelled through the delivery valve to the injector.



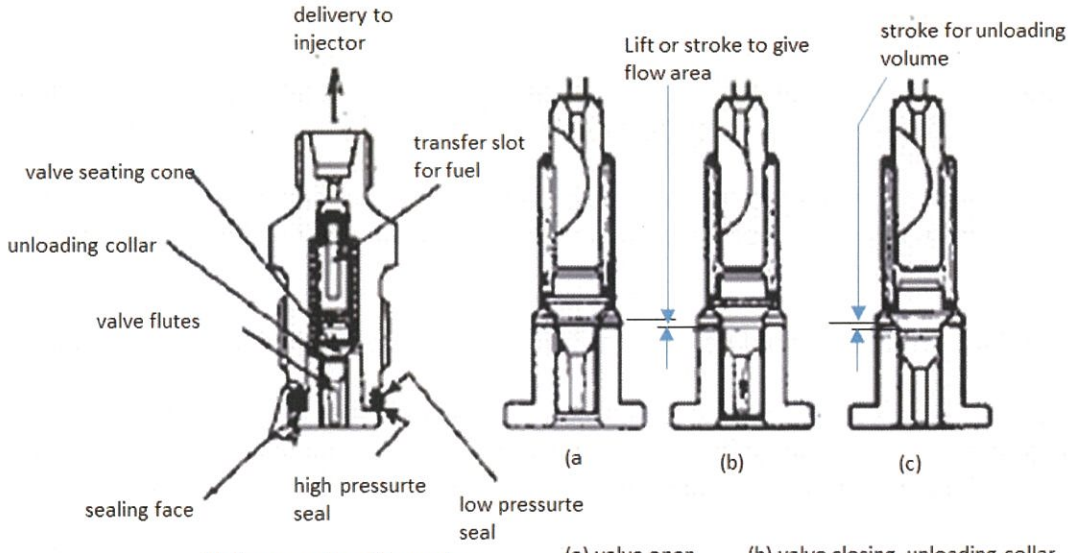
Plunger in position for no delivery
**vertical gash remains in communication with port throughout stroke*



Plunger in position for normal delivery

Delivery valve:
Function - unloading of unloading the pressure pipe as well as acting as non-return valve.

When the pump is delivering fuel the pressure of the fuel raises the delivery valve until the fuel can escape through the longitudinal flutes and over the face the piston and the valve seat and along to the injector nozzle. When the pump plunger releases the pressure in the barrel and the delivery valve snaps back on to its seat and doing so the small piston part of the valve enters the guide and increases the volume above the delivery valve by an amount equal to the travel of this piston before the valve seats itself. This action has the effect of suddenly reducing the pressure in the pipe and so causes the needed valve in the nozzle to snap back on to its seat quickly without dribble.



Volume unloading valve

(a) valve open against stop

(b) valve closing, unloading collar just entering bore

(c) valve closed, unloading collar at full stroke in bore

Fuel Injection Valve:

Function – to disperse the fuel throughout the compressed charge of air. To accomplish this, adequate degrees of penetration and fineness of spray droplets are required and achieved by passing the fuel at high velocity through small bore holes in the injector nozzle. The high pressure of the fuel necessary to do this must be created sharply at the commencement of injection and last must be just as sharply drop when injection ceases in order to avoid deterioration of the spray formation into a dribble or jets.

PNEUAMTIC SYSTEM:

Compressed Air Preparation:

Contamination

Examples can be found in practice where much importance is attach to the condition of the compressed air.

Contamination in the form of dirt or rust particles, excess lubricant, and humidity often lead to the disturbance in pneumatic equipment and damage to pneumatic components.

While coarse separation of condensate is effected in the separator after the recooler, fine separation, filtering, and other subsequent treatment of the compressed air in dealt with at the point of usage.

Particular attention should be paid to the moisture that is present in compress air.

Water (moisture) is introduced to the air network with the air drawn in by the compressor. The amount of moisture present depends primarily on the relative humidity which in turn is dependent on the air temperature and the weather condition.

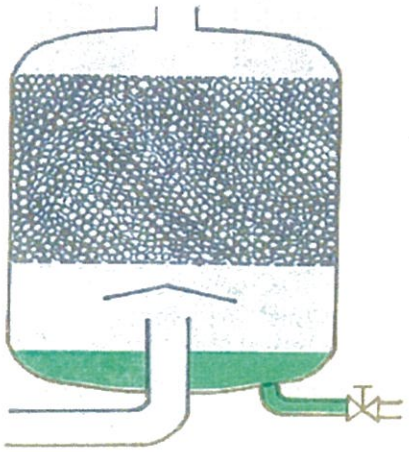
The absolute humidity is quantity of water which is contained in one cu.m. of air.

The saturation quantity is the quantity of water which one cu.m. can absorb at the temperature concerned. The relative humidity is then 100% ma. (dew point temperature)

$$\text{Relative Humidity} = \frac{\text{Absolute humidity}}{\text{Saturation quantity}} 100\%$$

Drying method:

a) Absorption drying – is purely chemical process. The compressed air is passed over a heat bed of drying agent. Water or water vapour comes into contact with the drying agent, a chemical compound is formed with the drying agent and it dessolves as a drying-agent/water compound.



Absorption Dryer

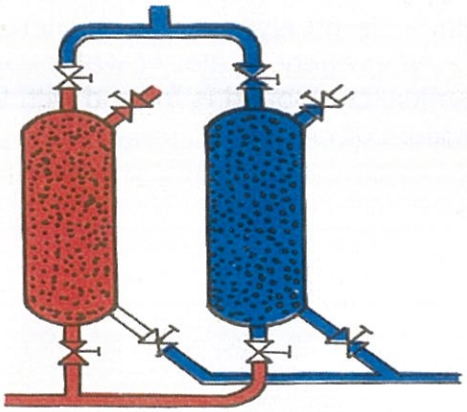
b) Adsorption drying

The adsorption process is based on a physical procedure. (Adsorb: substances are deposited on the surface of solids.) The drying agent is a granular material of sharp-edged shape of in bead form. This drying agent consist almost entirely of silicon dioxide. The term generally used for this "gel". The object of the gel is to adsorb the water and the water vapour. The moist compressed air is passed through the gel bed. The drying agent then forms a compound with the moisture in the compressed air.

The storage capability of such a gel with has natural limitations. If the drying agent is saturated, It is generated by simple means. Warm air is blown through the saturated gel bed and this adsorbs the moisture contaminated the drying agent.

The heat energy required for regeneration can also be provided by electric current or warm compressed air.

By connecting to adsorption plants in parallel, one plant can be connected for the drying process and warm air is blown through the second plant (regeneration).



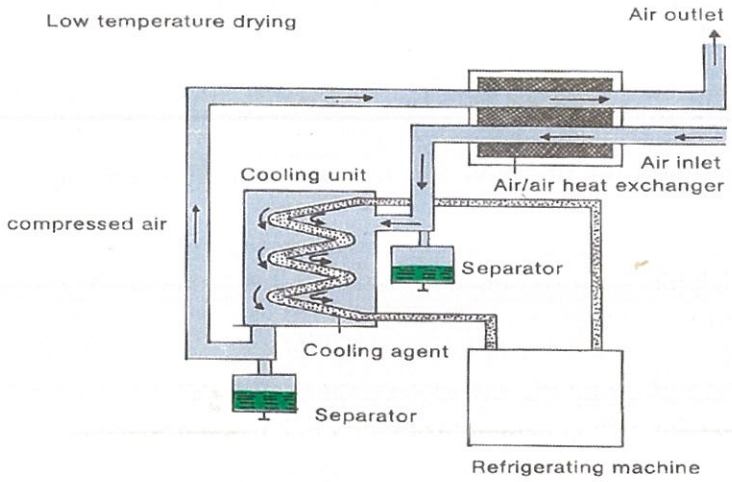
Adsorption dryer

c) Low Temperature drying

Compressed-air low temperature driers work on the principle of lowering the dew point temperature.

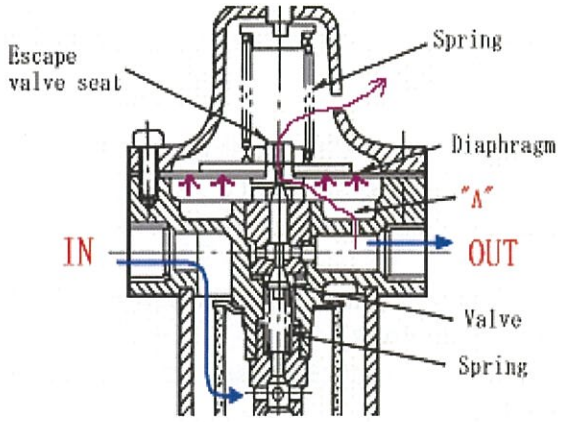
The dew point temperature is the temperature to which a gas must be cooled to dense the water vapour contained in the gas. The compressed air to be dried flows into the drier, First of all into the so-called air/air heat exchanger. The warm air which enters is cooled by cold dry air supply from a heat exchanger (Evaporator).

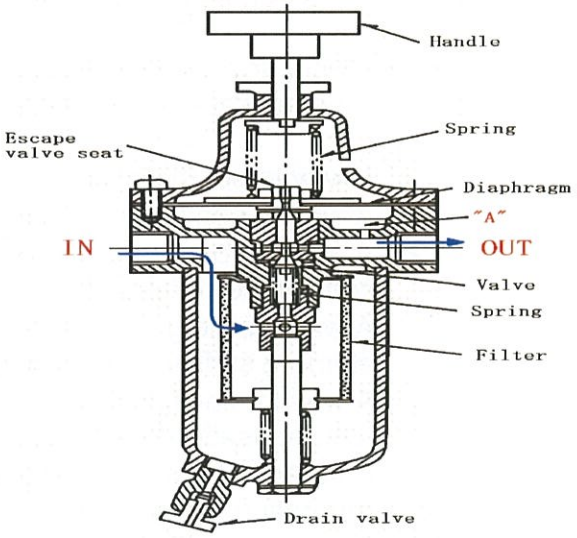
The oil and water condensate which occurs is removed by the heat exchanger. This precooled compressed air closed flows through the heat exchanger (evaporator) And is cooled further down to a temperature of approximately 274.7 K (1.7 ° C). During this process, water and oil condensate is removed for a second time from the air.



Control Air Regulator:

Air regulator provides a constant pressure of supply air to pneumatic instruments and control valves.
The outlet pressure is adjusted by the handle. The air, after reaching the area "A", applies force on the lower part of the diaphragm.
This force is compared with the spring force on the diaphragm to maintain the outlet pressure either by releasing or restricting the air escape through Escape valve.





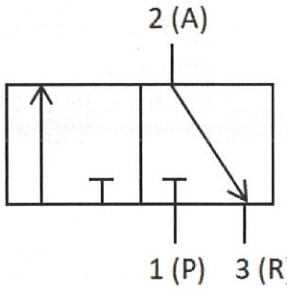
If the outlet pressure increases, the force due to air pressure on the lower part of the diaphragm overcomes the spring force and then excess pressure is released to atmosphere passing through the opening of the escape valve seat.

Pneumatic Directional Control Valves (Switching Valve):

Symbols

Connection coding:

Working lines	ISO 1219	ISO 5599
Working lines	A,B,C…	2,4,6…
Supply air	P	1
Drain, exhaust points	R,R,T…	3,5,7…
Leakage line	L	9
Control line	X,Y,Z	12,14,16..



3/2 Directional control Valve

Governing system:

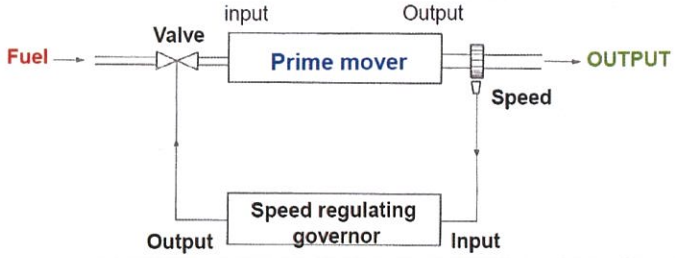
All power sources must be controlled in convert the power to useful work. The essential device which control the speed or power ouput of an engine, turbine, or other source of power is called governor. (Power source – a Prime mover, i.e. diesel engine)

Governor:
A device that senses the speed of prime mover and control fuel oil supply to keep required speed by the prime mover.
For example, driving a car, when you approach a slope, you will put on the pedal to accelerate the speed to keep the constant speed.
This is the same action as seen on the governor.

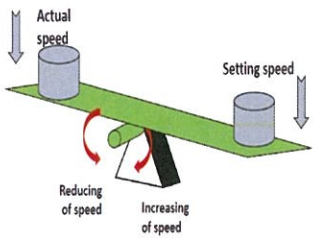
Every engine governing system must contain certain basic elements, whether the simple mechanical type or an electrical/electronic type.

- A way to set the desired speed (setting speed (reference) element)
- A way to sense the actual speed (speed sensing element)
- A way to compare the actual speed to the desired speed (An error sensing/correcting element)
- A way for the governor to change the fuel amount to the prime mover (power element sufficient to manage engine fuel controls)
- A way to stabilize the engine after fuel increase or decrease has been made. (compensation/resetting/stabilizing elemen
- A means of determining the method of operation…droop or isochronous mode (operating in parallel or alone)

The governor senses speed of the prime mover (input) and compare the actual speed and the setting speed. Operation of valve continue until the actual speed coincide with the setting speed.



Feedback is essential to control the prime mover precisely. Example, the balance scale, "weight of the actual speed" is compared with " weight of the setting speed" and when both are equal, then the scale is in balance.



Droop - Isochronous Relationship

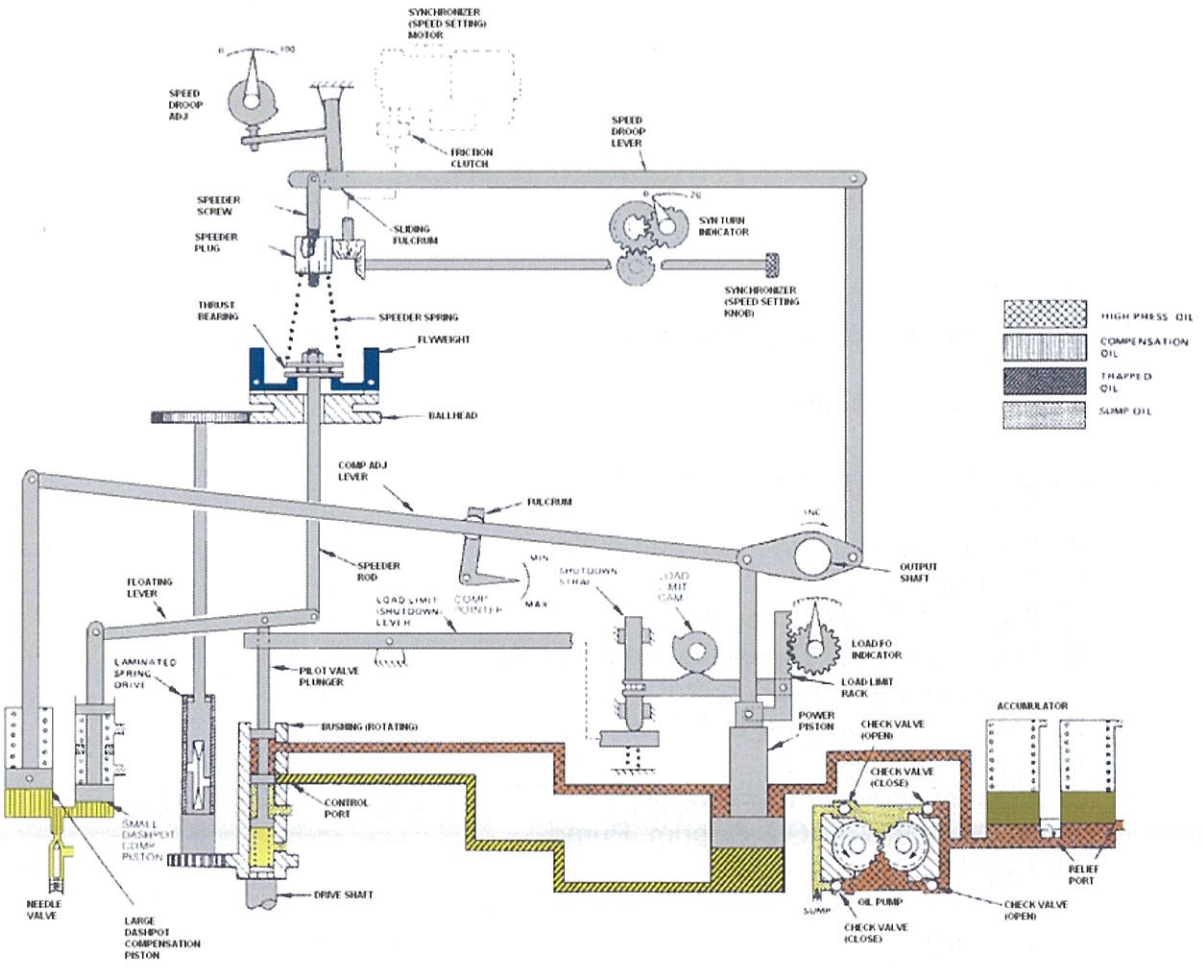
- Droop is defined as the percent change in speed as a unit goes from no-load to rated load condition. It can be expressed as:

Droop (%) = Speed Change * 100 / Rated Speed

Speed Change = no-load speed – full-load speed

- Isochronous means iso (same) chronous (time). Each engine revolution takes the same time… speed is constant.
- Unit must be in Droop mode when paralleled to the offsite power system. Unit is most desirably in Isochronous when carrying loads on emergency bus during the emergency situation.

Governor parts (Woodward Governor)



BASIC GOVERNING SECTION

This section consists of an oil pump, two accumulators, a speeder spring, a flyweight head and bushing assembly, a thrust

bearing, a pilot valve plunger, a buffer compensation system, and a power cylinder.
The governor drive shaft passes through the governor base and engages the flyweight head and bushing. The pump supplies pressure oil for operation of the basic governor section, the speed setting section, the load control system and all other auxiliary features or devices.

Maintenance of Auxiliary Machinery

Diesel Generator Overhauling

Check points prior D/G overhauling

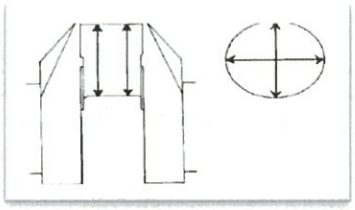
1. Secure starting air
2. Secure cooling F.W. inlet and outlet
3. Shut D.O. line
4. Shut L.O. inlet from purifier
5. Transfer L.O. to Diesel engine settling tank
6. Turn remote to local control
7. Turn operation level to "STOP"
8. Remove turning bar
9. Drain of cooling Fresh Water
10. STOP-LOCK-TAG L.O. prim. Pump
11. Tag D/G Panel at MSB

- **Crankshaft**

Items to Check and Measure

1. Scratches or dents on bearing surface, condition of fit-up, uneven or abnormal wear.

2. Fillet portion and lubricating oil hole in bearing (color penetrant testing method)
3. Soiling or clogging of lubricating oil hole
4. Loose balance weight fixing bolt
5. Crankshaft deflection
6. Contours of pin and journal



7. Surface hardness: if hardness degrades below the specified value, consult with the manufacturer.

Precautions for Disassembly and Reassembly

2) With sheeting, protect bearing part from damage during disassembly or reassembly.
3) Wash lubricating oil hole carefully and air blow dry.
4) Clean bearing surface thoroughly to keep it free from dirt.

- **Measurement of Crankshaft Deflection (Refer to JOB CARD instruction manual)**

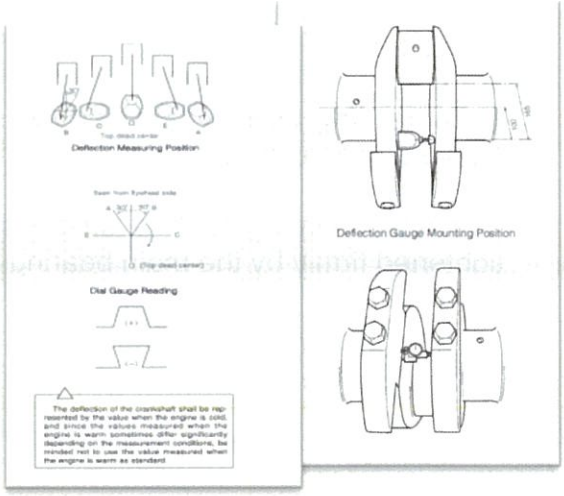
Excessive deflection may sometimes cause crankshaft breakage. Therefore, crankshaft deflection should be measured at installation and every six months after entering normal operation. Measure when crankshaft is cold.

Calculating Deflection

Calculate the deflection values as based on the measured values and in accordance with the following formula, and record he calculated values.

- Vertical (V) deflection: $dV = D - \frac{A+B}{2}$
- Horizontal (H) deflection: dH = C - E
- Positive/negative deflection: Open downward (+), closing downward (-)

A, B, C, D, and E represent the measured values respectively at each corresponding position shown in the figure on the right.



(5) Correction Limit for Deflection

a) The correction limit shall apply to whichever is larger of dV and dH as shown in the following table.

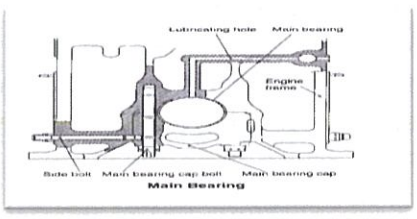
(Unit : mm)

	Adjusted value	Allowable limit	Direction
In case of direct connection : (One-side bearing generator)	0.03 or less	0.08	
	$\frac{1}{10,000}$ x stroke	$\frac{2.8}{10,000}$ x stroke	
In case of direct connection : (Both-side bearing generator)	0.03 or less	0.08	
	$\frac{1}{10,000}$ x stroke	$\frac{2.8}{10,000}$ x stroke	
In case of direct connection with flexible coupling:	0.09 or less	0.12	
	$\frac{3}{10,000}$ x stroke	$\frac{4}{10,000}$ x stroke	

- **Cylinder Head Maintenance and Inspection (Refer to JOB CARD)**
- **Piston Maintenance and Inspection (Refer to JOB CARD)**
- **Bearing**

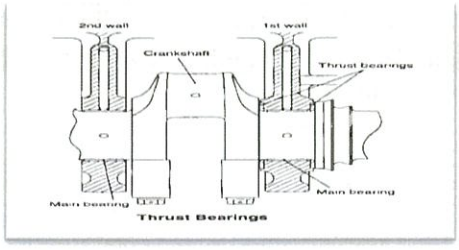
Main bearing and thrust bearing
General of Structure

The main bearing is of a suspension type. The main bearing cap is hydraulically tightened firmly by the main bearing cap bolts and the side bolts. The main bearing is



made of aluminum alloy having high wear resistance. The bearing upper and lower parts are positioned based on the claw. The main bearing is lubricated with oil supplied to the upper part thorough a drilled a hole in the engine frame.

The thrust bearing are also are made of aluminum alloy. They are mounted at the top and bottom on both sides of the first wall at the rear of the engine. Lubricating oil is supplied to them through the main bearing.

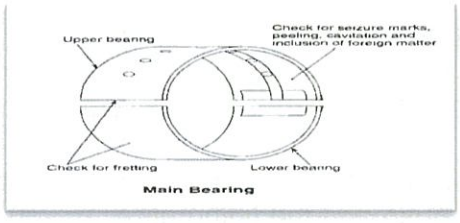


Thrust Bearings

Main Bearing

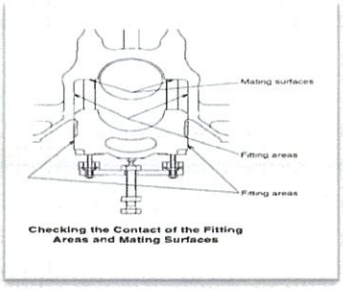
Normally, disassemble and inspect the main bearing without completely removing the main bearing without completely removes the main bearing cap. Lower the main bearing cap, and only the main bearing can be dismantled.

A. Check the bearing surface of the tightening nuts and on the cap. If the surfaces are rough repair them



Main Bearing

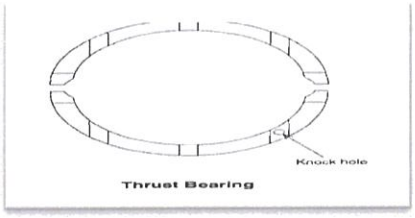
B. If the disassembled main bearing cap tightening nuts is loosened, tighten the nuts of other main bearings.
C. Check that the main bearing cap mating surfaces and the contact surface of the fitting areas are free from defects, such as fretting.
D. Check for flaws, hit marks and wear on the crankshaft surface



Checking the Contact of the Fitting Areas and Mating Surfaces

Maintenance of Thrust Bearing

A. Check the thrust bearing for seizure marks and inclusion of foreign matters. If minor defects are found, repair them with an oil whetstone.
B. Measure the thrust bearing thickness by using an outside micrometer, and record the measurement.
C. When the thrust bearing was worn heavily and the clearance between he thrust bearing and crank shaft (side clearance) (d) exceeds the limit for replacement, replace the thrust bearing with a new one. Replace the thrust bearing upper and lower parts simultaneously.

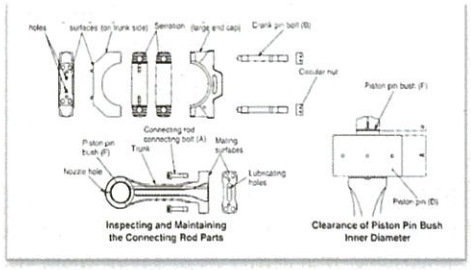


Nominal size (mm)	Standard Clearance (mm)	Limit for replacement (mm)
D = 83	d = 0.13-0.30	0.6

Inspection and Maintenance of Connecting Rod

A. Check the following parts, record their conditions and if defective parts found repair or replace them.
1. Check the contact of the piston pin bush (F) at the small end. Check for looseness and deviation of the bush and the fitting area.
2. Check for flaws and fretting on the mating surfaces of the trunk and the large end part.
3. Check for hit marks and peeling on the threaded portions and bearing surfaces of the connecting rod connecting bolts (A) and the crankpin bolts (B).
4. Check for wear and fretting on the serrated surfaces.
5. Check for hit marks and peeling on the contact surfaces of the large end cap with the circular nuts.
6. Check for hit marks and peeling on the threaded portions and bearing surfaces of the circular nuts (K).

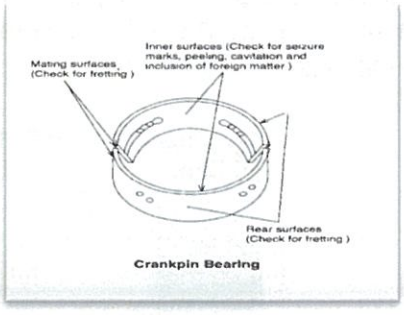
B. After cleaning the serrated surfaces, perform color check to check for flaws.
C. Blow air into lubricating holes through the trunk and the nozzle hole at the front to clean them.
D. Measure the inner diameter of the piston pin bush. Calculate the clearance based on the inner diameter and the measure outer diameter of the piston pin. If the clearance exceeds the limit for replacement, replace the bush with a new one.



Nominal size (mm)	Standard clearance (mm)	Limit for replacement (mm)
A= ø76	a= 0.04-0.12	0.25

Inspection and Maintenance of Crankpin Bearing

A. Check that the rear surfaces and mating surfaces of the crankpin bearing are free from fretting. Check that the inner surfaces are free from seizure marks, peeling, cavitations and inclusion of foreign matter. When defects are minor, repair the surfaces with an oil whetstone.
Note: The bearing is a thin- walled finish part, which is provided with appropriate interference (crush) and tension so that it can get into close contact with the housing surface. Therefore, do not repair the rear surfaces and mating surfaces with a file or scraper.

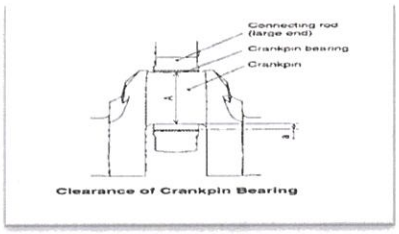


B. Clean the bearing, measure the bearing thickness with a spherical micrometer and record the thickness. Calculate the clearance based on the measured large end housing inner diameter bearing thickness and crankpin diameter. If the clearance exceeds the limit for replacement replace the bearing with a new one.

Nominal size (mm)	Standard clearance (mm)	Limit for replacement (mm)
A = ø 145	a = 0.08-0.17	0.3

Note:

5. Replace the upper and lower parts of the bearing at the same time.
6. While the bearing is used for a long time, the tension decrease, and the inner surface harden thereby causing cracking and peeling. Replace the bearing with a new one every 20,000 hours (4 to 5 years) even if the wear is less than the allowable limit.



Clearance of Crankpin Bearing

- **Fuel Injection Pump** **(Refer to JOB CARD)**
- **Fuel Valve Needle Condition** **(Refer to JOB CARD)**
- **Turbocharger Cleaning and Inspection** **(Refer to JOB CARD)**
- **Cleaning and Inspection of Filters and Strainers** **(Refer to JOB CARD)**

Filter & Strainer on Ship

Filter is a fine mesh screen which is used to remove impurities from oil, water and air on ship. Filters are mounted in pairs as a duplex system so that one can be used and other is kept on standby at a time. Filter can be used both in low pressure (suction) and discharge (high pressure) side of the system and is used to remove the smallest part of dirt which is carried away in the system. The cleaning frequency of filters depends upon the type of the filter and is decided by the manufacturer. The schedule is normally included in the planned maintenance system on board.

Strainer is a type of filter used mostly on low pressure or suction side and is used to remove large contamination particles from the system. This is because the mesh screen openings in the strainer are bigger in size and are similar to those of coarse filter. If the suction condition is critical, then the strainer can be fitted on the discharge side. This purely depends upon the make and recommendation of the

manufacturer. Normally strainers are cleaned whenever they are opened or when the pressure drop on the filter side is high.

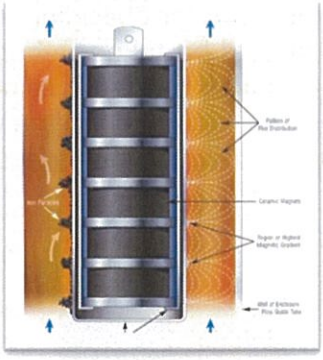
Type of Filters Used on Ship

Types of filters depending upon the Media

1) Hydraulic Filter: Hydraulic filters are very useful for removing solid contamination from lube and fuel oil systems of marine machinery. Without filters in the lube or fuel oil system, the machinery internal parts, bearings, piston, rings, liners etc. can get damaged, which will result in inefficient working of the machinery. Different applications of hydraulic filters are:

a) Fine Mesh Screen Filter: It is the most commonly used filter in lube and fuel oil systems on board. It can be used both on suction and discharge side of the system. It is normally used in cylinder lube oil line, main engine and auxiliary engine fuel oil line & diesel oil line, boiler fuel oil line and in different lube oil systems on board etc.

b) Magnetic filter: This normally consists of filter elements which are magnetic in nature and which help in catching fine metal or ferrous particles that run in the system. These elements are surrounded by a basket screen which also acts as a filter and simplifies the cleaning of the filter. Magnetic filters are used in lube oil system.

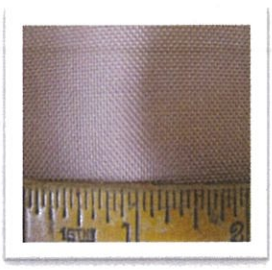


c) Auto Back Wash Filter: In auto back wash filters, when the pressure difference increases, an indication of filter getting clogged, the auto system cuts-off the filter and opens the bypass. The auto wash takes place with the help of an electric motor connected to a shaft which cleans the filter. During this operation, the drain of the filter gets open.

d) Centrifugal filter: As the name suggests, these filters work on the principal of centrifugal force removing high density fluids and impurity from the oil. It is normally used for lube oil systems. Most of the Auxiliary engines have attached centrifugal filters.

How to measure size of Mesh?

The chart below roughly converts between U.S. Mesh, microns, and fractions of an inch. There is no simple formula to convert between microns and wire mesh because it would have to account for changing wire diameter. To measure wire mesh properly, the mesh count should be taken in both directions. On coarse meshes, this can be accomplished by counting the number of openings per linear inch measuring from wire center to wire center. After taking the first count, a second count should be taken at a 90 degree angle to the original measurement. The mesh count of the cloth shown is 10x10.



Conversion Information U.S. Mesh to Micron Particle Size

COMPARATIVE PARTICLE SIZE

U. S. MESH	INCHES	MICRONS	U.S. MESH	INCHES	MICRONS
3	.265	6730	40	.0165	420
3-1/2	.223	5660	45	.0138	354
4	.187	4760	50	.0117	297
5	.157	4000	60	.0098	250
6	.132	3360	70	.0083	210
7	.111	2830	80	.0070	177
8	.0937	2380	100	.0059	149
10	.0787	2000	120	.0049	125
12	.0661	1680	140	.0041	105
14	.0555	1410	170	.0035	88
16	.0469	1190	200	.0029	74
18	.0394	1000	230	.0024	63
20	.0331	841	270	.0021	53
25	.0280	707	325	.0017	44
30	.0232	595	400	.0015	37
35	.0197	500			

16. Air Compressor

Gist:
Main Air Compressor Piston and Liner failures have been frequently damaged onboard vessel. A study was carried out and found that these failures were mainly due to failure and breakage of compressor valves and these broken parts in turn damaging the piston and liner while running.

Action required:

- **Carry out overhauling and inspection of compressor valves as per intervals stated in the PMS.**
- **Ensure overhauling intervals stated in PMS do not exceed the intervals as recommended by the maker.**

Recommendation during overhauling of compressor valves

- **Disassemble and clean all parts with soft cloth or brush.**
- **Renew springs / Spring plates and Valve during every overhaul (even if these parts are not worn out).**
- **DO NOT LAP THE VALVE PLATES.**
- **Valve seat (body) can be lapped and replacement of valve seat (body) must be in accordance with the maker's wear down limit.**

After assembling, test the valves by doing the following

- **Push the valve plate from the valve seat side using a screw driver and check action of spring. Put the screw driver in several place and check the action of spring.**
- **Test the valve for any leakage by filling water.**
- **Ensure adequate tightening of valve retainer by torque spanner, as many failures have happened due to improper tightening or due to over tightening.**

1st and 2nd Stage Suction and Delivery Maintenance and Inspection
(Refer to JOB CARD)

Connecting Rod Bolt Tightening (Refer to JOB CARD)
@250hrs:
1)Clean air filter
2)Check un-loader operation
3)If belt is provided for driving cooling water pump, check its tightness

@500hrs:
1)Change lubricating oil and clean sump.
2)Clean lube oil filter
3) Check and renew suction and discharge valves with overhauled one.

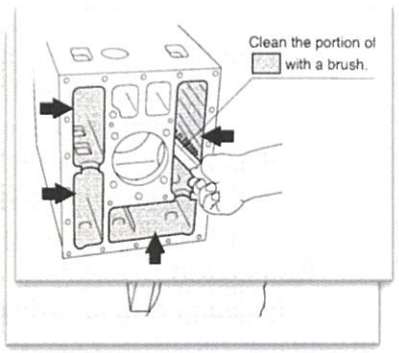
@1000hrs:
1)Crankcase inspection, main and big end bearing inspection
2)Relief valve overhauling

@4000hrs:
1)Piston and big bearing overhauling, piston ring renewal.
2)Intercooler cleaning
3)Motor overhauling

Other Parts for Maintenance
1. Inside of Cylinder
Check if cylinder inside is worn or proper quantity of oil is applied.
2. Water Jacket
a. Check if water dirt is stuck on the water jacket surface
(both 1st and 2nd stages.)
a. When water dirt is stuck, clean the portion shown below with the brush.
b.
3. Cooler
When air is compressed, temperature is considerably increase and affect the efficiency of the machine. Cooler is provided to maintain constant temperature of the air while it is being charged. To ensure cooler efficiency, Carry out periodical inspection and cleaning as recommended by the maker.

Remove the cooler covers of both 1st and 2nd stages.

a. Check if water dirt is stuck on the water jacket surfaces.
b. When water dirt is stuck, clean the portion shown in the figure with brush.

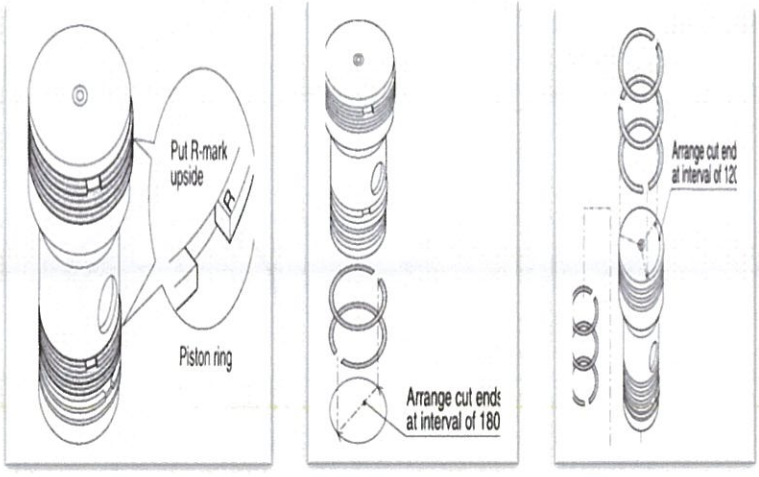


4. Piston

a. Remove the cylinder head.
b. Remove the rod cap from the connecting rod.
c. Screw in the piston removing tool at the top of piston, then extract the piston carefully so that the crank pin and the inside of the cylinder may not be scratched. At this time, connecting rod comes up together with piston assembly.

Caution:
* Carefully treat the piston since it is easily scratched.
* Use a ring mounting tool when reassembling the ring.
* The piston should not be clamped by vise or hit by hammer.
* Piston ring has sharpened edge. Be careful not to injure your finger.

1. Outside the Piston
 a. Check that oil is properly applied.
 b. When quantity of oil applied is insufficient, first readjust the lubricator then replace it when it was found to be damaged or fault.
2. Piston Rings
 a. Three piston rings are set on the 1st stage and three piston rings are set on the 2nd stage.
 b. Check direction of the ring (face and back) and extent of wear.
 c. If the direction of the ring is wrong, mount it correctly.
 d. Replace the worn piston ring.
 e. When setting piston rings into piston ring grooves, put the R-mark side of each ring upside and arrange the cut ends at interval of 120° so that all the cut ends will not be aligned.
 f. As each ring is narrow shaped and easily deforms, handle it with care.

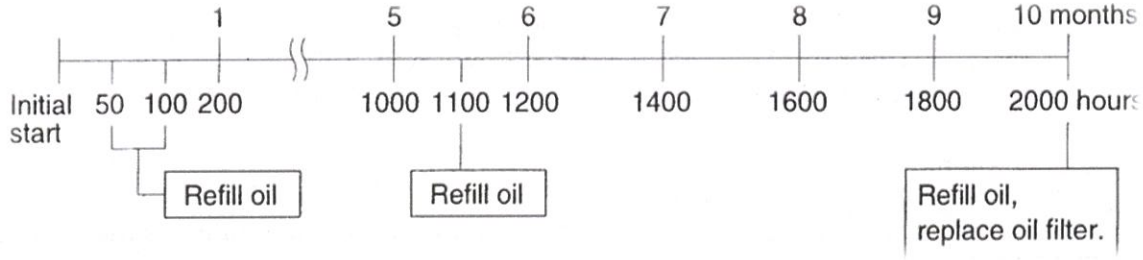


5. Oil Scraper

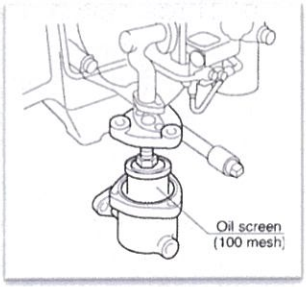
a. Two oil scraper rings are set on the piston skirt.
b. Check direction of the ring (face and back) and extent of wear.
c. If the direction of the ring is wrong, mount it correctly.
d. Replace the worn scraper ring.
e. When setting scraper rings into piston ring grooves, put the R-mark side of each ring upside and arrange the cut ends at interval of 180° so that the cut ends will not be aligned.
f. As each ring is narrow shaped and easily deforms, handle it with care.

Oil System

Replace the oil according to the time table.

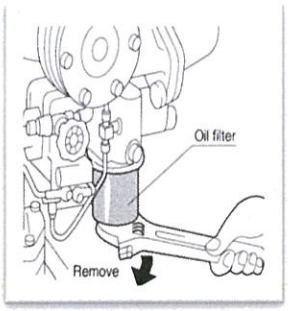


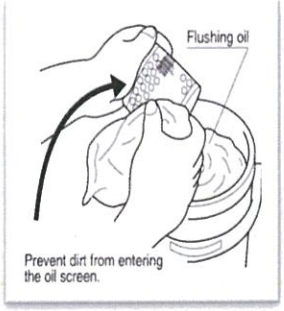
1. Oil Screen
Oil screen blocks coarse dirt.



a. Clean the oil screen when replacing the oil.
b. Cover so that no dirt enters the oil screen, remove the stain with soft cloth, and wash with clean flushing oil.
c. Replace the oil screen if it is broken.

2. Oil Filter
a. Oil filter filters minute dirt.
b. Oil filter is cartridge type.
c. Replace oil filter with a new one at every two times of replacement.

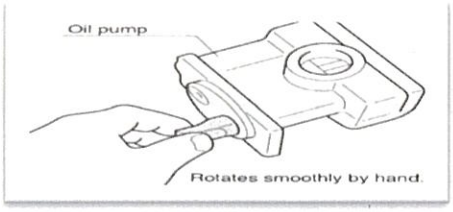




3. Oil Pump

a. Inspect oil pump every 8000 hours of operation.

b. After removing the bolts, replace the connecting piece suppressor as shown in the figure below. Shift the connecting piece toward the oil release valve body side using a minus screwdriver, then remove the oil pump.



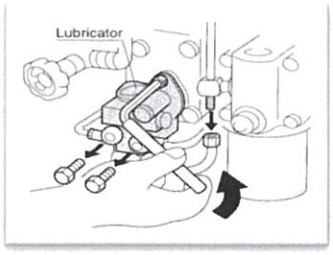
4. Make sure that the pump can be rotated freely by hand. If it cannot be rotated by hand or resistance is large, disassemble and clean. Replace if necessary.

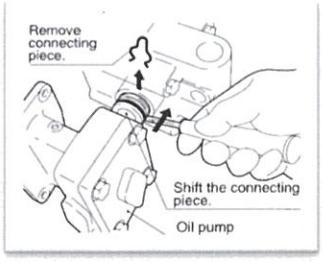
5. Lubricator (works for the lubrication of 1st stage cylinder)

a. Replace the lubricator at every 8000 hours of operation.

b. Replace the lubricator as illustrated in figure below.

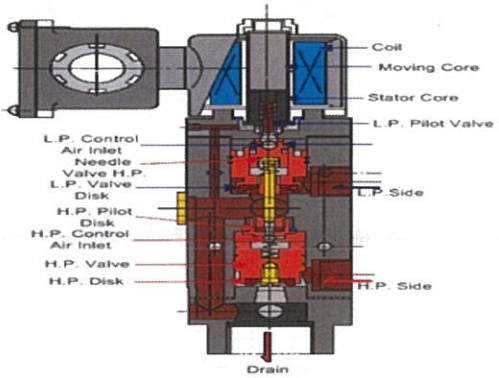
c. As quantity of oil supply has been adjusted to appropriate quantity before shipment, basically do not change it. But when reconditioning becomes necessary ask for its details to compressor manufacturer.





Magnetic Un-loader Valve

A device used to load/unload the air compressor during starting and stopping to reduce the operating torque, controlled by a solenoid valve and by a timer relay in the control panel. The magnetic un-loader valve is in open position during starting and will close automatically within 10 seconds maximum setting (depending on the setting of timer relay) from the point of starting and load operation begins. When stopping the magnetic un-loader valve will open until to the point of starting to release the remaining air pressure in the compressor system.



When the solenoid coil is energized, the L.P. Pilot valve and H.P. needle valve is forced by the spring to open the pilot line to the atmosphere. The air from the air compressor casing 1st (L.P.) and 2nd (H.P.) stage is released to the atmosphere by forcing to open the L.P. valve and H.P. valve. When the solenoid coil is de-energized, the control air from L.P and H.P. Control Air will force to close L.P. and H.P. Valve thus, compressor is in load operation.

Auxiliary Boiler

The common auxiliary boilers used onboard are the composite Boiler-economizer. Two main classification are used the water tube where water heated inside the tube and fire/smoke tube where the water is heated outside the tube.

Safety Devices

Ship's Name: _____

AUX. BOILER ALARM TESTING RECORD

PLACE:
TEST DATE: TESTING INTERVAL-6M

	DESCRIPTION	ALARM	TRIP RESULT		TEST METHOD
1	SOURCE FAILURE			GOOD	BREAKER OFF
2	FLAME FAILURE			GOOD	OFF FLAME EYE
3	F.D. FAN STOP			GOOD	CUT NBR
4	F.O TEMP. TOO LOW	LOW T	80 deg.C	GOOD	THERMOCOUPLE OFF
5	DRUM LEVEL TOO LOW	LOW L	N.W.L. - 180mm	GOOD	BLOWDOWN
6	BURNER MOTOR STOP			GOOD	BREAKER OFF
7	FLAME EYE ABNORMAL			GOOD	OFF FLAME EYE
8	SUPPLY AIR PRESS.LOW PRIMARY	LOW P	4.9 Kpa	GOOD	AIR HOSE DISCONNECT
9	SUPPLY AIR PRESS.LOW SECONDARY	LOW P	0.98 Kpa	GOOD	AIR HOSE DISCONNECT
10	DRUM WATER HIGH LEVEL	HIGH L	N.W.L. + 200mm	GOOD	FILL-UP MANUALLY
11	DRUM WATER LOW LEVEL	LOW L	N.W.L. - 150mm	GOOD	BLOWDOWN
12	F.O HEATER OUT HIGH TEMP.	HIGH T	145 deg.C	GOOD	THERMOCOUPLE HEAT-UP
13	F.O HEATER OUT LOW TEMP.	LOW T	90 deg.C	GOOD	THERMOCOUPLE OFF
14	DRUM STEAM PRESSURE LOW	LOW P	0.45 MPa	GOOD	MANUAL DUMPING STEAM
15	F.O. TEMP. LOW (PUMPCONTROL)	LOW T	110 deg.C	GOOD	THERMOCOUPLE OFF

CHIEF ENGINEER 3RD ENGINEER

Boiler Rotary Cup Burner Maintenance (JOB CARD)

MAINTENANCE

1. Check the main shaft lubrication.
2. Clean the rotary cup burner.
3. Inspect each screws connection and fixation.
4. Check the rotating body for vibration and abnormal noise.
5. Grease up rotating parts and sliding parts.

a. The frequency of each maintenance item shown above is a standard: change appropriately by understanding the actual method adopted in the ship concerned.

b. Pay special attention to the items relating to soot fire.

c. Completely understand the descriptions not only in this list but also in the instruction manual.

Cleaning

If a sufficient amount of circulating water is continuously supplied and the water quality is controlled in a proper condition, no problem will occur. Scales adhering to the inner surface can only be removed by a professional's chemical cleaning.

Types of Boiler Burner

a. Pressure Jet Type Fuel Oil Burner

A pressure jet oil burner forms a simple robust unit, widely used in marine boilers. The basic assembly consists of a steel tube, or barrel, to which are attached swirl and orifice plates; these are made of a high grade or low alloy steel, and are held in place by a cap nut. The complete unit is clamped into a burner carrier attached to the boiler casing. This both holds the burner in its correct position relative to the furnace, and also permits the supply of fuel through an oil tight connection.

The oil is supplied to the burner under pressure and, as it passes through, the burner performs two basic operations. First it imparts rotational energy to the oil as it passes through angled holes in the swirl plate. The rotating stream of oil thus formed is then forced under pressure through a small hole in the orifice plate which causes the jet to break up into fine droplets. This latter process is termed as atomization, although each individual droplet of oil is formed of vast numbers of atom. As the final result of these operations a hallow rotating cone, formed of fine particles of oil, leaves the burner tip.

In all pressure jet burners, however, a minimum supply pressure in the order of 700 kN/m^2 is necessary to ensure efficient atomization is maintained. At the same time various practical considerations limit the maximum pressure to about 7000 kN/m^2. The control over the throughput of oil is obtained in two ways; by varying the oil supply

pressure and/or by changing the diameter of the hole in the orifice plate. Whilethis system is convenient for manual operation, it is not suitable for automatic control due to the need to change orifice sizes when the oil supply pressure reaches its upper or lower limits.

Safety Precautions:

- The burners must be kept clean and care should be taken during this operation not to damage or scratch the finely machined surfaces of the swirl and orifice plates. The latter should be renewed as the orifice wears beyond a certain amount. This should be checked at regular intervals by means of a gauge.
- After cleaning make sure all the various parts are correctly assembled.
- Any oil leaks must be rectified as soon as possible as they can lead to fires in the air register or double casing of the boiler.
- Burners not in use should be removed, otherwise the heat from the furnace will cause any oil remaining in the burner barrel to carbonized.

b. Steam Blast Jet Type Fuel Oil Burner

This type of burner atomizes the oil by spraying it into the path of high velocity jet of steam or air. Although either medium can be used, steam is usually both more readily available and economical at sea. Compressed air is therefore seldom used, except when lighting up from cold.

In this the steam flows along the central passage, and is then expanded through a convergent divergent nozzle, where its pressure energy is converted to kinetic energy resulting in a high velocity jet of steam. Oil sprayed into this jet is entrained by it, being torn to shreds and atomized in the process.

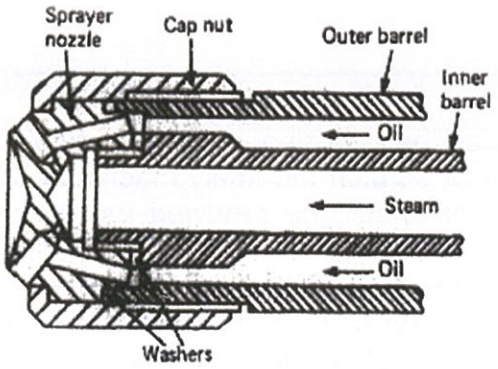
The oil supply pressure ranges from about 140-2000 kN/m^2, with corresponding steam pressures of 140-1500 kN/m^2.

Safety Precautions:

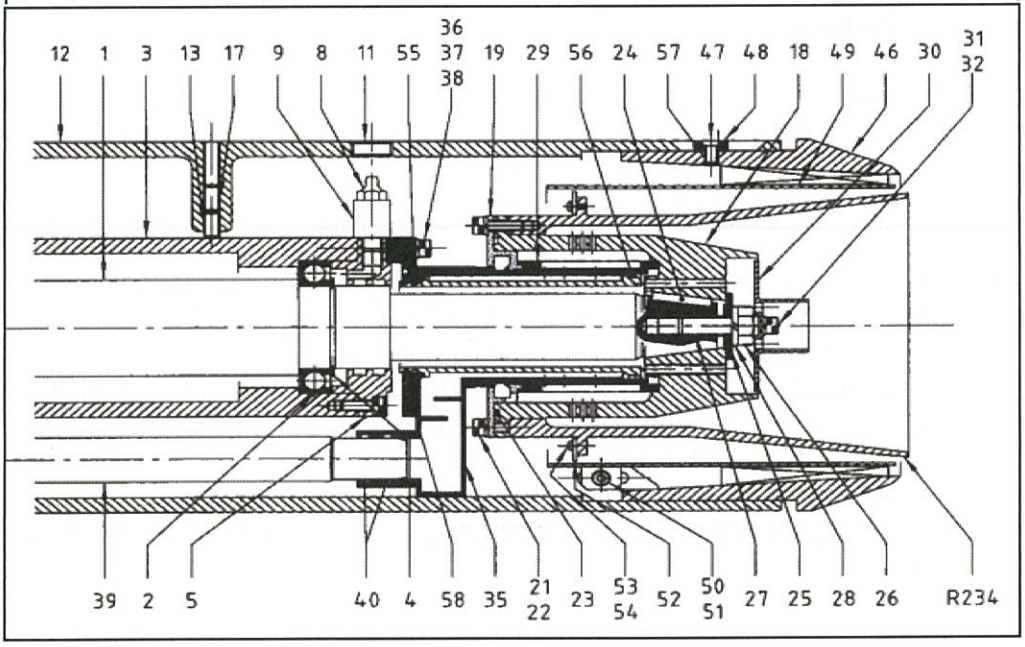
- Care must be taken to use only dry steam, any water present having a chilling effect which could cause flame instability. The steam may be obtained directly from the boiler, the pressure being dropped to the required value by passing it through reducing valves. Alternatively it may be obtained from an auxiliary source such as a steam to steam generator.
- Excessive use of steam can be caused by incorrect setting of the burner or by leakage across the joint faces in the atomizing head of the burner, and in some versions gaskets are fitted to prevent this.
- Steam is left on all the time the burner is in operation, even when the oil is turned off, in order to cool the burner and prevent any remnants of oil in the burner passages from carbonizing.
- Safety shut off valves are fitted to the burner carrier; these are opened by projections on the burner so that oil and steam are automatically shut off when the burner is removed.

Maintenance of Burner

Rotary Cup Type Fuel Oil Burner



MARK	NAME OF PARTS	Q'TY	REMARKS	MARK	NAME OF PARTS	Q'TY	REMARKS
30	DIFLECTOR	1		R234	ROTARY CUP MANTLE	1	
29	HUB SLEEVE	1					
28	WASHER	1		58	RETAINING RING	1	
27	HELI-COIL MID-GRIP INSERT	1		57	HELI-COIL MID-GRIP INSERT	4	
26	LOCK BOLT	1	M12 P=1	56	O-RINFG	1	
25	MAIN SHAFT END DISC	1		55	O-RINFG	1	
24	ROTARY CUP SHAFT KEY	1		54	LOCK WASHER	3	
23	O-RINFG	1		53	SLOTTED HEAD SCREW	3	M4 x 6
22	LOCK WASHER	8		52	RESTRICTION RING	1	
21	ALLEN CAP SCREW	8	M6 x 25	51	LOCK WASHER	4	
19	ROTARY CUP HUB COVER	1		50	ALLEN CAP SCREW	4	M5 x 10
18	ROTARY CUP HUB	1		49	NOZZLE SLEEVE	1	
17	ALLEN SET SCREW	3	M10 x 25	48	LOCKING PRISM	4	
13	CENTERING SCREW	3	M10 x 25	47	COUNTER-SUNK ALLEN HEAD SCREW	4	M6 x 15
12	PRIMARY AIR TUBE	1		46	PRIMARY AIR NOZZLE	1	
11	LUBRICATION PLUG	1		40	O-RINFG	2	
9	GREASE NIPPLE EXTENSION	1		39	FUEL OIL TUBE	1	
8	GREASE NIPPLE	1		38	COUNTER-SUNK SCREW	2	M6 x 20
5	FRONT BEARING COVER	1		37	LOCK WASHER	4	
4	RETAINING RING	1	6010Z	36	ALLEN CAP SCREW	4	M6 x 40
3	MAIN SHAFT BEARING HOUSING	1		35	FUEL OIL DISTRIBUTOR	1	
2	MAIN SHAFT BALL BEARING	1		32	LOCK WASHER	1	M5
1	MAIN SHAFT	1		31	ALLEN CAP SCREW	1	M5 x 15



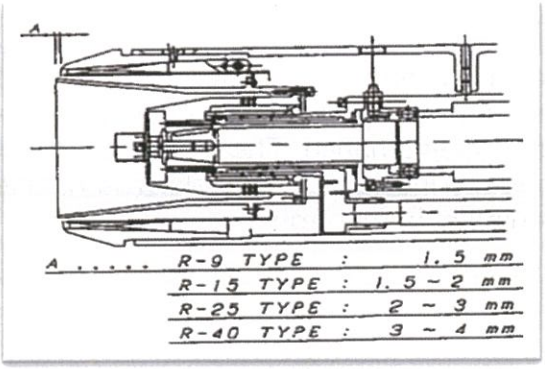
The rotary cup burner is attached to the burner front door and can be opened without removing air/oil piping and electric wiring. With the burner opened, all burner parts can be seen for inspection and maintenance. The secondary air register is made of steel plate and does not require insulation materials. The register can be removed for maintenance from opening at burner front.

Table: Maintenance and Interval

No.	ITEM	JOB ITEM	INTERVAL	REMARKS
1.	F.O. Pressure	Visual check	All times	Set-press. for ship: 0.6 MPa
2.	Rotary-cup in-side	Cleaning & check	Weekly	Cleaning of inside and confirmation of mounting posit
3.	Rotary-cup hub & distributor	Disassembling & cleaning	Monthly	Depending on the dirt condition, the interval to be changed
4.	Ignition burner	Cleaning & check	Week/twice or more	Confirmation of electrode mounting position, visual check of electrode glace
5.	Flame-eye glass	Cleaning & check	Weekly	Confirmation of electric resistance (600~20kΩ)
6.	Strainer screen	Cleaning	Weekly	Depending on the dirt condition, the interval to be changed
7.	Burner belt	Visual check	Weekly	Adjustment of tension and check of consumption
8.	Air/oil linkage	Visual check	Monthly	Check of each bolt and screw
9.	Bearing	Audible check	Monthly	Check of abnormal sound of bearing for burner main shaft & each motor
10.	Heater element	Cleaning & check	Yearly	Cleaning of heating surface; Electric type: check of terminal wiring connection
11.	Electric parts	Visual check	Monthly	Check of terminal wiring connection

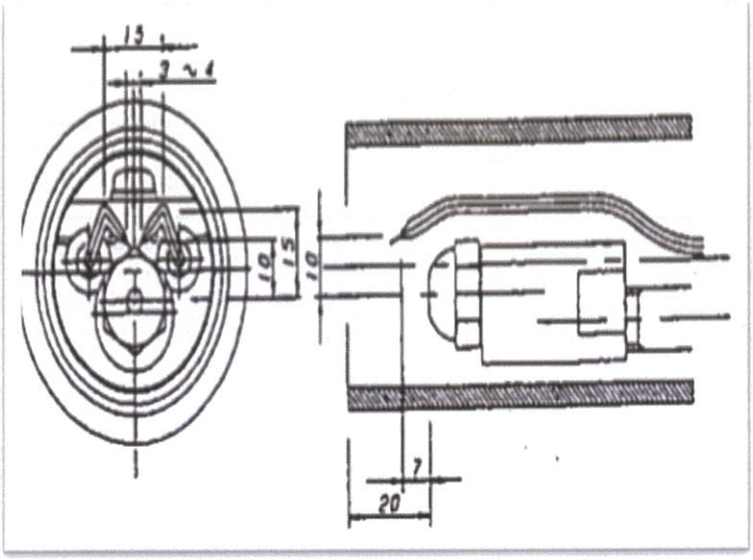
Clearance for rotary cup type fuel oil burner:

A = clearance from the tip/end of the rotary cup mantle (R234) to the tip/end of the primary air nozzle (46)



Take note of the clearance end required for the burner and this should be maintained or follow up on assembly.

Clearance for ignition burner:



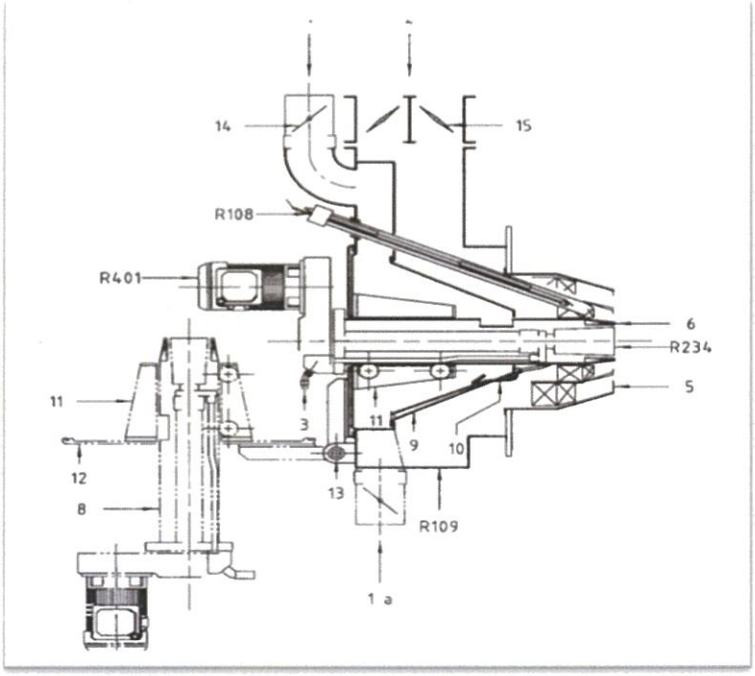
Others

1. Re-adjust tension of the burner belt after initial operation for 50-100 hours. Set the belt tension so that the belt sinks about 15mm when it is pushed with a force of about 20N. Pour grease of 4-5 g to the main shaft5 bearing every 1,000 hours. Use grease for wide temperature range.

The rotary cup can be cleaned without removing it from the main shaft. However, after long-term operation, it is necessary to clean the rotary cup after removing the primary air nozzle, cut, distributor.

ROTARY CUP BURNER GENERAL ARRANGEMENT

1	PRIMARY AIR ENTRY	12	BURNER FRONT DOOR
1 a	DITTO ALTERNATIVE LOCATION	13	HINGES
2	SECONDARY AIR ENTRY	14	PRIMARY AIR DAMPER
3	FUEL OIL ENTRY	15	SECONDARY AIR DAMPER
6	PRIMARY AIR NOZZLE	R108	IGNITION BURNER UNIT
8	PRIMARY AIR TUBE	R109	BURNER WIND-BOX
9	PRIMARY AIR HOUSING	R237	ROTARY-CUP
10	AUTOMATIC SHUTTERS	R401	BURNER MOTOR
11	SPOOKED BRACKET WITH ROLLERS	R510	SECONDARY AIR REGISTER



Reference:
Daihatsu Diesel Engine – Instruction Manual / Operation Manual
Sunflame burner – Maintenance Manual
Introduction to Pneumatics – FESTO DIDACTIC
WOODWARD GOVERNOR MANAUL
Machinery space.com
Piping-designer.com