B. Know the correct operating pressures. Always set and check pressures with a gauge. How else can you know if the operating pressure is above maximum rating of the components? The question may arise as to what the correct operating pressure is. If it isn't specified on the hydraulic schematic, the following rule should be applied:

> The correct operating pressure is the lowest pressure which will allow adequate performance of the system function and still remain below the maximum rating of the components.

Once the correct pressures have been established, note them on the hydraulic schematic for future reference.

DEVELOPING SYSTEMATIC PROCEDURES. Analyze the system and develop a logical sequence for setting valves, mechanical stops, interlocks, and electrical controls. Develop a cause and effect troubleshooting guide similar to the charts starting on page 3. The initial time spent on such a project could save hours of system down-time.

RECOGNIZING TROUBLE INDICATIONS. The ability to recognize trouble indications in a specific system is usually acquired with experience. However, a few general trouble indications can be discussed.

A. Excessive heat means trouble. A mis-aligned coupling places an excessive load on bearings and can be readily identified by the heat generated. A warmer than normal tank return line on a relief valve indicates operation at relief valve setting. Hydraulic fluids which have a low viscosity will increase the internal leakage of components resulting in a heat rise. Cavitation and slippage in a pump will also generate heat.

B. Excessive noise means wear, misalignment, cavitation or air in the fluid. Contaminated fluid can cause a relief valve to stick and chatter. These noises may be the result of dirty filters, or fluid, high fluid viscosity, excessive drive speed, low reservoir level, or loose intake lines.

MAINTENANCE. Three simple maintenance procedures have the greatest effect on hydraulic system performance, efficiency, and life. Yet, the very simplicity of them maybe the reasons they are so often overlooked. What are they? Simply these:

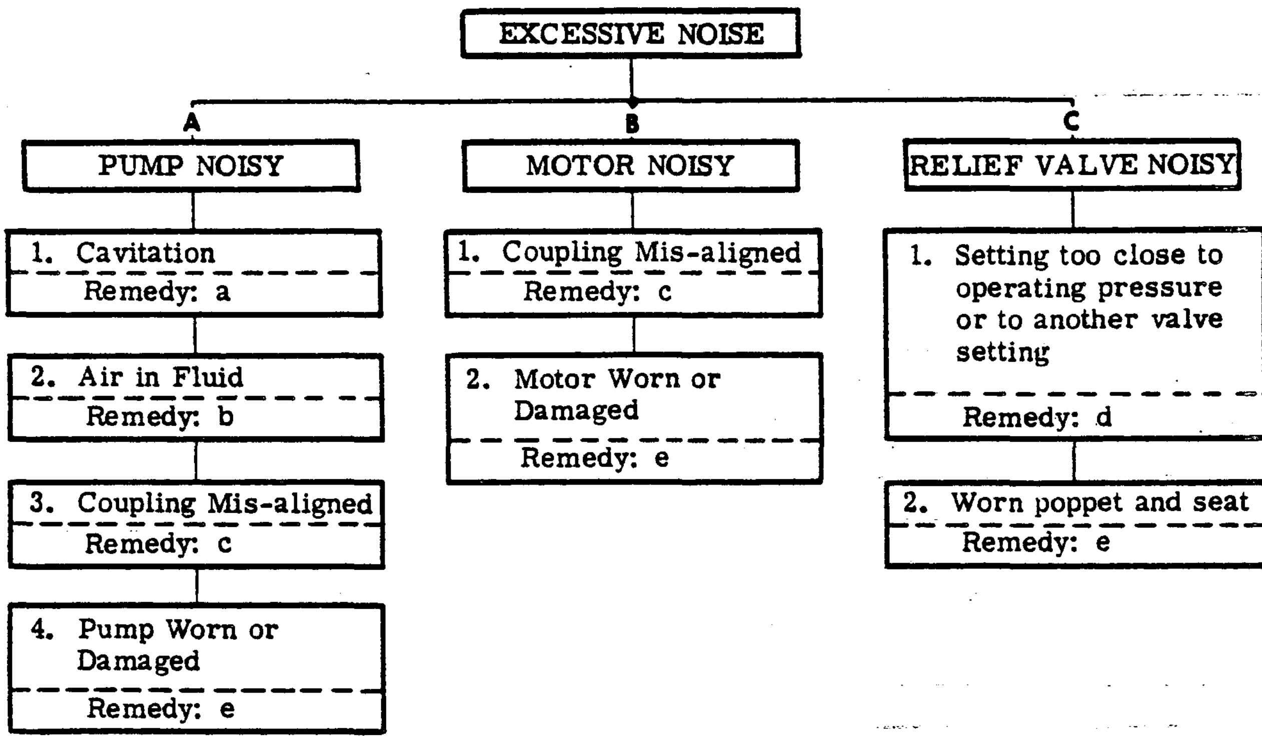
A. Changing filters and strainers

B. Maintaining a clean sufficient quantity of hydraulic fluid of the proper type and viscosity.

C. Keeping all connections tight, but not to the point of distortion, so that air is excluded from the system.

The following charts are arranged in five main categories. The heading of each one is an effect which indicates a malfunction in the system. For example; if a pump is exceptionally noisy, refer to Chart I titled EXCESSIVE NOISE. The noisy pump appears in Column A under the main heading. In Column A there are four probable causes for a noisy pump. The causes are sequenced according to the likelihood of happening or the ease of checking it. The first cause is cavitation and the remedy is "a". If the first cause does not exist, check for cause number 2, etc.

**Chart I , Excessive Noise**




REMEDIES:

a. Any or all of the following: Replace dirty filters - Clean clogged inlet line - Clean reservoir breather vent - Change system fluid - Change to proper pump drive motor speed - Overhaul or replace supercharge pump

b. Any or all of the following: Tighten leaky inlet connections - Fill reservoir to proper level (with rare exception all return lines should be below fluid level in reservoir) - Bleed air from system - Replace pump shaft seal

c. Align unit and check condition of seals and bearings

d. Install pressure gauge and adjust to correct pressure

e. Overhaul or replace

## Chart II, Excessive Heat

**EXCESSIVE HEAT**

**A — PUMP HEATED**

1. Fluid heated — Remedy: See column D
2. Cavitation — Remedy: a
3. Air in fluid — Remedy: b
4. Relief or unloading valve set too high — Remedy: d
5. Excessive load — Remedy: c
6. Worn or damaged pump — Remedy: e

**B — MOTOR HEATED**

1. Fluid heated — Remedy: See column D
2. Relief or unloading valve set too high — Remedy: d
3. Excessive load — Remedy: c
4. Worn or damaged motor — Remedy: e

**C — RELIEF VALVE**

1. Fluid heated — Remedy: See column D
2. Valve setting incorrect — Remedy: d
3. Worn or damaged valve — Remedy: e

**D — FLUID HEATED**

1. System pressure too high — Remedy: d
2. Unloading valve set too high — Remedy: d
3. Fluid dirty or low supply — Remedy: f
4. Incorrect fluid viscosity — Remedy: f
5. Faulty fluid cooling system — Remedy: e
6. Worn pump, valve, motor, cylinder or other component — Remedy: e

REMEDIES:

a. Any or all of the following: Replace dirty filters - Clean clogged inlet line - Clean reservoir breather vent - Change system fluid - Change to proper pump drive motor speed - Overhaul or replace supercharge pump

b. Any or all of the following: Tighten leaky inlet connections - Fill reservoir to proper level (with rare exception all return lines should be below fluid level in reservoir) - Bleed air from system - Replace pump shaft seal

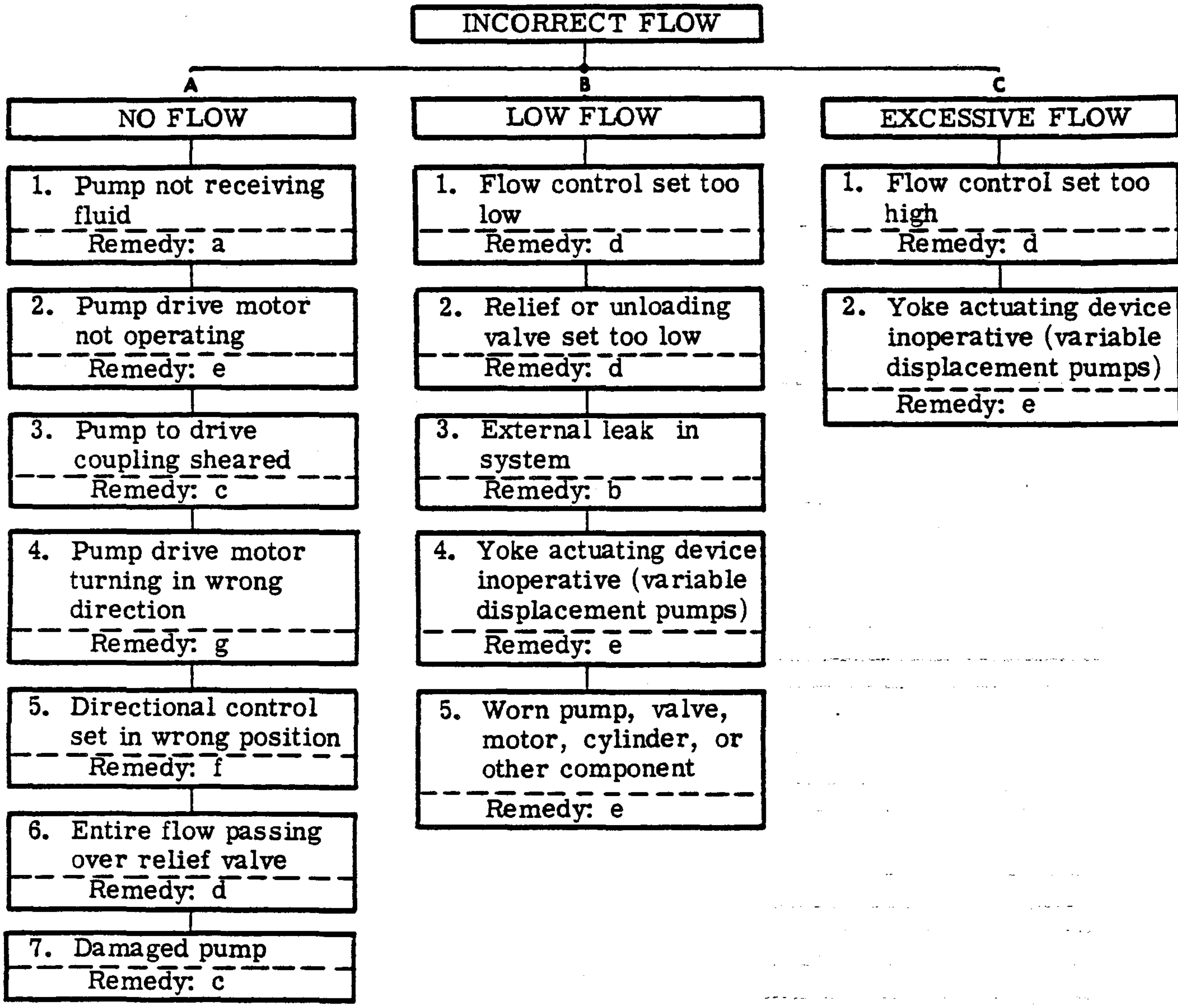
c. Align unit and check condition of seals and bearings - Locate and correct mechanical binding - Check for work load in excess of circuit design

d. Install pressure gauge and adjust to correct pressure

e. Overhaul or replace

f. Change filters and also system fluid if of improper viscosity - Fill reservoir to proper level

## Chart III, Incorrect Flow




REMEDIES:

a. Any or all of the following: Replace dirty filters - Clean clogged inlet line - Clean reservoir breather vent - Fill reservoir to proper level - Overhaul or replace supercharge pump

b. Tighten leaky connections - Bleed air from system

c. Check for damaged pump or pump drive - Replace and align coupling

d. Adjust

e. Overhaul or replace

f. Check position of manually operated controls - Check electrical circuit on solenoid operated controls

g. Reverse rotation

## Chart IV, Incorrect Pressure

**INCORRECT PRESSURE**

**A. NO PRESSURE**

1. No flow
   - Remedy: See Chart III, column A

**B. LOW PRESSURE**

1. Pressure relief path exists
   - Remedy: See Chart III, column A and B
2. Pressure reducing valve set too low
   - Remedy: d
3. Excessive external leakage
   - Remedy: b
4. Pressure reducing valve worn or damaged
   - Remedy: e

**C. ERRATIC PRESSURE**

1. Air in fluid
   - Remedy: b
2. Worn relief valve
   - Remedy: e
3. Contamination in fluid
   - Remedy: a
4. Accumulator defective or has lost charge
   - Remedy: c
5. Worn pump, motor or cylinder
   - Remedy: e

**D. EXCESSIVE PRESSURE**

1. Pressure reducing, relief or unloading valve misadjusted
   - Remedy: d
2. Yoke actuating device inoperative (variable displacement pumps)
   - Remedy: e
3. Pressure reducing relief or unloading valve worn or damaged
   - Remedy: e

REMEDIES:

a. Replace dirty filters and system fluid

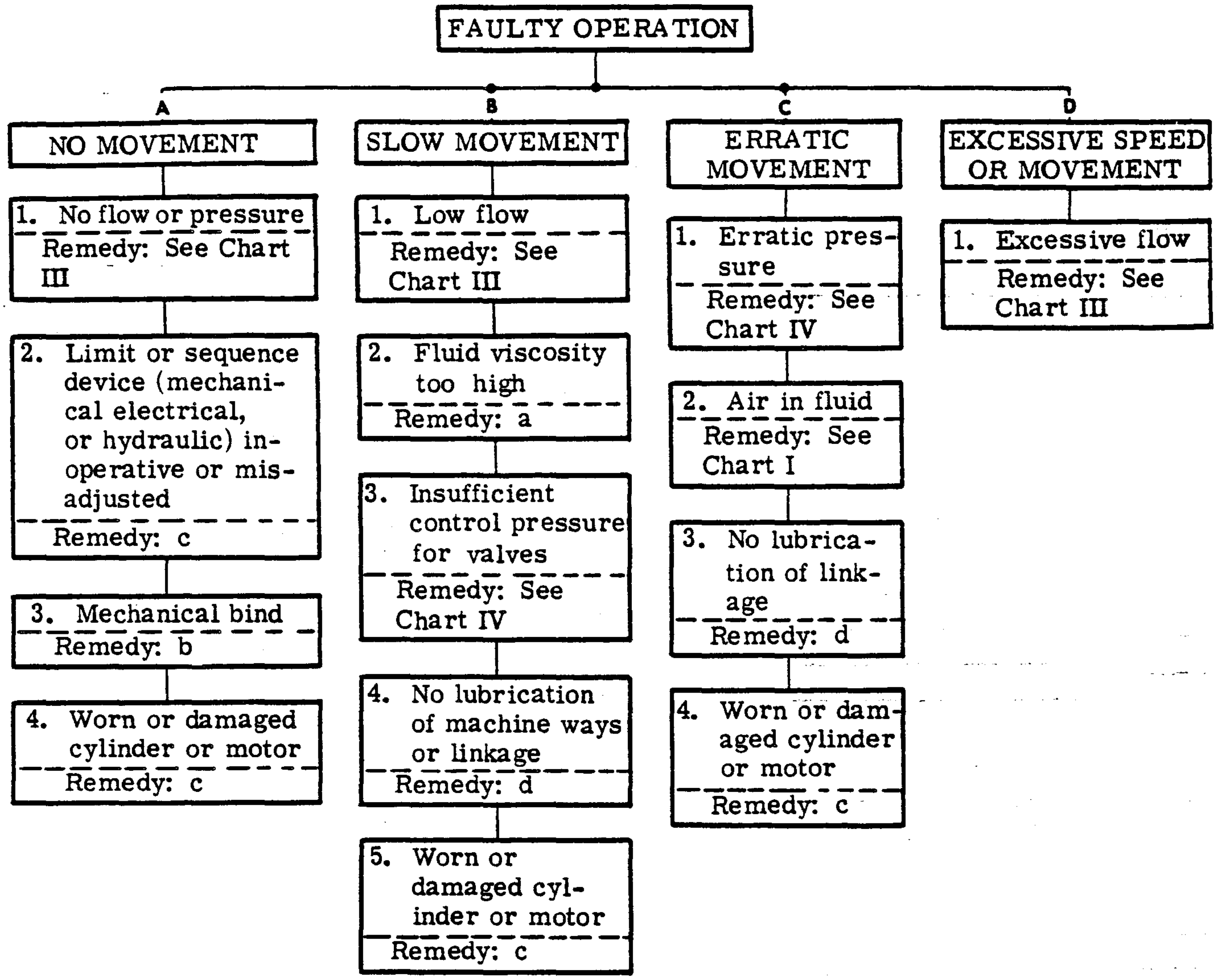
b. Tighten leaky connections (fill reservoir to proper level and bleed air from system)

c. Check gas valve for leakage - Charge to correct pressure - Overhaul if defective

d. Adjust

e. Overhaul or replace

## Chart V , Faulty Operation




REMEDIES:

a. Fluid may be too cold or should be changed to clean fluid of correct viscosity

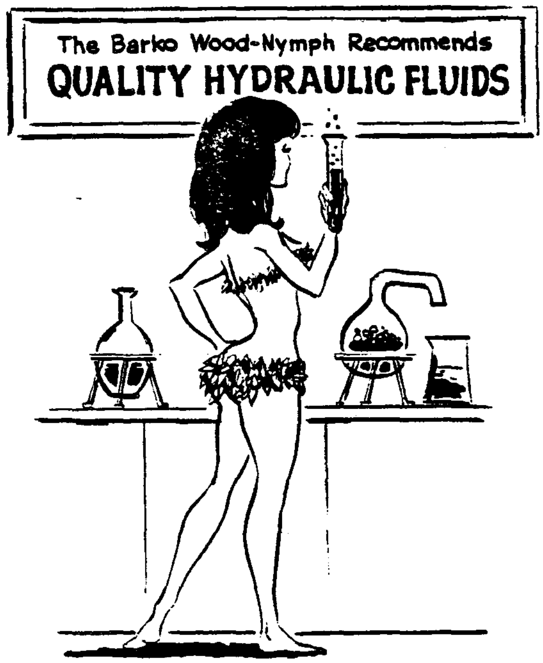
b. Locate bind and repair

c. Overhaul or replace

d. Lubricate

# HYDRAULIC HINTS

**BARKO HYDRAULICS**




Today's hydraulic fluid has to be tougher, to provide peak pressure and instant power through many hours of constant operation. It must stand up day after day in all types of systems. It has to be ready-to-go on cold winter mornings and not let down on hot summer afternoons. This means more oil punishment and need for built-in quality.

## Quality Hydraulic Fluid Needs:

1. Anti-wear properties to prevent scuffing and excessive wear at high-speeds and high pressure operation.

2. High stability to resist oxidation and prevent varnish formation and deposits that foul systems.

3. Rust resistant additives to prevent rust formation from moisture condensation.

4. Anti-foam agents to break up air bubbles in the fluid and prevent "foaming" that causes sluggish and erratic operation.

5. Good viscosity index for easy flow at low temperatures without thinning out at high temperatures after hours of use. (recommend MS 10W for system operating temperature range of $0^{o}$F to $180^{o}$F). See Vickers new hydraulic fluid recommendation for more complete information.

6. Seal conditioner properties to prevent cracking or excessive swelling of seals that can result in fluid leaks.

Many vehicles today especially on power steering application use a common automatic transmission type "A" hydraulic fluid. Mobile fluids require an extreme pressure additive, to provide adequate protection for the hydraulic units. During the past few years, we have found evidence of reduced unit service life in systems using automatic transmission type "A" hydraulic fluids. This is because most fluids of this type contain no anti-wear additives. Some type "A" have anti-wear additives, but the majority do not.

These are potential hazards to the hydraulic system, emphasizing the need for quality fluid. Just any fluid won't do the job in modern hydraulic systems, and the wrong fluid is a sure road to trouble. MS (most severe) hydraulic fluids are specially formulated to meet the need of most hydraulic system components.

On test runs of many types of vehicles, changing to M.S. fluid increased the service life of the system components. In addition to increased service life, using MS oils will result in a cost saving. MS oils are readily available from all major oil companies.

# HYDRAULIC HINTS

**BARKO HYDRAULICS**

## RECOMMENDED CLEANLINESS PRACTICES

### SYSTEM CLEANLINESS

Today's high system pressures and speeds make clean systems mandatory. A common source of trouble in a system is dirt. Dirt may enter at any time from receipt of the components, to new vehicle delivery or its repair. Scheduled maintenance and good assembly practices will result in prolonged service life of the hydraulic components.

The following practices have been -- and always will be -- good, sound manufacturing, preventative maintenance, and servicing procedures. They are not costly to institute, but can be highly beneficial to the vehicle manufacturer and to the user.

### GOOD HOUSEKEEPING

The most obvious and essential point in stressing cleanliness is good housekeeping. The manufacturing plant or service facility that keeps the working area clean also encourages their employees to apply these practices in their own work habits. Regularly scheduled cleaning, sweeping and washing of assembly and service areas reduce the presence of environmental contamination.


### ASSEMBLY AREAS

As part of the good housekeeping practices, the location of the assembly and service area is very important. This area should be separated from welding, sanding and painting operations. It should also be relatively clear of any outside doors which may be open allowing dust or dirt to be blown into the assembly area.

### STORAGE AND HANDLING OF UNITS

All hydraulic components should be stored in a clean dry place. Units and components should not be unpacked unless there is an immediate need for them. Stock should be rotated regularly so that the oldest units are used first. The units must be stored with ports plugged. Port protection such as plastic plugs or shipping plugs should not be removed until circuit components are ready for installation.

## REJECTED MATERIAL

Defective material should be promptly tagged with the specific reason for rejection, its ports plugged, then removed from the work area for repair or replacement. This prevents rejected or defective parts from being used in error. Dirt must be prevented from entering the unit and causing contamination. System components can be ruined if dirt is allowed to enter through open ports. It is as important to protect a rejected unit as much as a new unit; otherwise the real reason for rejection may not be evident if the unit is further damaged or contaminated.

## FITTINGS AND HOSES

Fittings and hoses which have not been equipped with shipping caps, or have been removed for rework of hydraulic components, must be thoroughly cleaned. Flush fittings or hoses with mineral spirits and air dry. Check forged steel or cast fittings for burrs, foundry sand or casting fins. Failure to remove defects of this nature could result in an early malfunction or component failure. All welded or silver brazed piping should be pickled. It should be neutralized, dried, and oiled with a preservative to prevent rusting. Openings should then be sealed until use at assembly. Mobile Bulletin M-1221-S which covers "Preparation of Pipes, Tubes and Fittings" should be referred to.

## RESERVOIR

In the operation of hydraulic systems, the reservoir is one of the greatest sources of contamination. Reservoirs should be designed so that they can be completely cleaned after welding. This can only be accomplished with adequate clean-out plates. Cleaning the reservoir interior, then welding the remaining opening closed is not good hydraulic practice.

Welding spatter and scale are always a factor when reservoirs are manufactured. The best way to remove scale is by sandblasting. Sand left by this operation is best removed by a heavy-duty industrial vacuum cleaner. Another method is steam cleaning and drying in a heated atmosphere. It is good practice to paint the interior of the reservoir with non-bleeding engine enamel.

After cleaning, all openings should be sealed until just prior to use. The finished reservoir should not be stored outside. Tape or material covering the openings could be damaged by the elements, resulting in a contaminated reservoir. The reservoir should be carefully inspected to be certain it is clean just prior to use.

## FILLING THE RESERVOIR

After thoroughly cleaning the reservoir, care should be exercised to maintain cleanliness when filling the hydraulic system. It is suggested to pump the hydraulic fluid through a 10 micron filter to prevent contamination from entering the system. Vickers OFM series filters are excellent for this type of duty. In addition, the nozzle of the filling hose should be wiped clean with a lint-free paper towel or cloth prior to use.

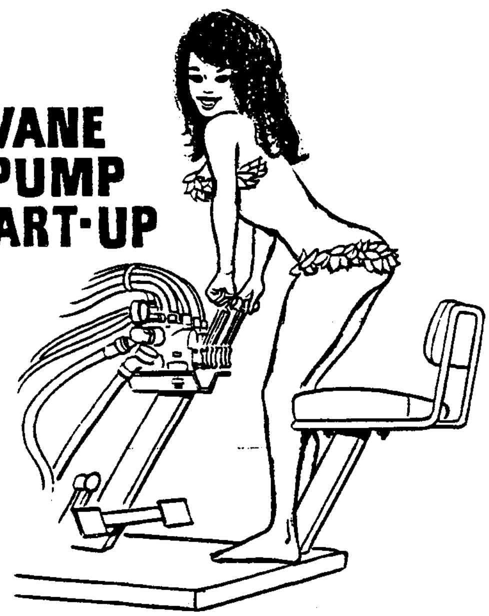
## CONCLUSION

Modern mobile hydraulic systems are becoming more complex with each passing year. A small amount of extra effort in system cleanliness will result in better service life of the hydraulic components. This in turn will result in less maintenance cost, less down time, and more reliable availability of each machine.

# HYDRAULIC HINTS

BARKO HYDRAULICS

## VANE PUMP START-UP



Some important requirements we share in the Mobile Industry are reliability, increased service life and elimination of vehicle downtime. In addition to standard, periodic maintenance, good start-up procedures can help keep equipment working efficiently. High speeds and pressures require careful system start-up.

Air must be expelled at start-up or the pump will not prime. Air in the pumping chambers can cause pump failure. Following these recommended practices can be a big step toward trouble-free pump operation.

### START-UP AT THE FACTORY

1. To minimize air and contamination in systems, mount the pumps, motors, cylinders and valves. Fill all hardware with clean fluid from clean containers before installing lines, being sure that pump and motor are full of fluid.

2. Flush out and clean the reservoir and lines before mounting. Fill the reservoir with new, clean fluid. Put all control valves in neutral position.

3. Crack open a pressure line fitting at the pump outlet port, or at the inlet of the valve for removing air from the system.

4. Install a pressure gauge (gage) as near to the pump pressure outlet port as possible.

5. At this point we are ready to start the engine. Jog the starter several times--for about one minute. Then start the engine and run it to a speed of about 800 rpm (avoid high speed start-up). With the pump primed, air and fluid will bleed out through the loose fitting. After the air is bled from the system, a solid stream of fluid will come out. When this happens, tighten the fitting.

6. With no load on the system, work the directional valve handles back and forth several times. If the relief valve is adjustable, back it off. If there are cylinders, do not permit

travel to the end of the stroke. Keep working the levers back and forth until the pump noise from the air has diminished.

7. Work the valve lever until the piston of the cylinder bottoms out, and observe the pressure. Reverse the handle several times to remove air from the cylinder.

If the circuit has a hydraulic motor such as a winch or auger, they must be dead headed. Do this by attaching the line to a beam or pole.

Adjust the engine speed to about 1200 rpm and relief valve just under its normal setting for the work requirement. It will be necessary for the cylinder piston to travel to the end of its stroke. Use a tachometer to determine if the governor is set at the proper speed and adjust setting if necessary.

Speed the engine up to maximum rpm and set the relief valve for its full-flow maximum pressure setting. There will be a difference in pressure from the point where the fluid starts to flow or cracks over the relief valve, and when the engine is at maximum speed. Thus, we have a difference between cracking pressure and full-flow pressure. If the pump is quiet, the vehicle is ready to test under rated load.

## INITIAL, ON-VEHICLE START-UP

There are three steps that should be followed before the initial, on-vehicle start-up. First, always be sure the system is filled with a good grade of hydraulic fluid. Second, check all lines, fittings and components in the system. Keep them as clean as possible. And third, vent the air out of the system. A good job of eliminating air will pay big dividends in efficient operation, and longer equipment service life.

1. Fill all pump and motor housings with hydraulic fluid through the inlet ports. If the unit is mounted so that the inlet port cannot be used, fill through the outlet port or drain port. Obviously this will have to be done prior to installing inlet and outlet connections. The inlet and outlet connections should remain plugged until the connections are ready to be made.

2. When the system is completely "plumbed up" fill the reservoir.

3. Break the inlet connection loose on all pumps and hold cracked open until air in the inlet line is purged and solid oil runs out. Tighten connection.

4. Loosen connections at check valves, motor outlet, heat exchanger outlet (providing heat exchanger is above oil level in reservoir. Turn the engine over on the starter--do not start the engine. Tighten each connection in turn as a solid stream of fluid starts to be expelled.

5. When all connections are tight, and system has expelled as much air as possible, start the engine. Engine speed should be in the low rpm range for the next few minutes when each component in turn is operated.

6. Check fluid level in reservoir and add if necessary.

7. Check system for leaks. Be

sure inlet to pumps are tight and not leaking air into system. Air leaks into system can be detected by air bubbles in the reservoir.

8. Examine fluid in reservoir. On initial start-up there may be some air which should come out as bubbles on the surface of the fluid. The fluid in the reservoir should clear up in a short time. (Length of time is dependent on how much air was removed from the system prior to start-up.)

## COLD WEATHER START-UP

It's very important in cold weather to follow a daily start-up procedure. We all accept the fact that cold water must not be added to the cooling system of a car when the engine is hot. A cracked cylinder block may result from thermal shock. In the same light, when a vehicle is started in cold weather, the hydraulic system must not be subjected to shock.

1. Jog start the engine and run it to a speed of about 1200 rpm (avoid high speed start-up).

2. Actuate cylinders and control valves repeatedly for warm up. Do not allow cylinders to travel to the end of their stroke, or pressure to build up to the relief valve setting. Cold fluid makes relief valves sluggish in operation. It can add 500 to 1000 psi to the maximum pressure setting of the relief valve. When all components are warm to the touch, the vehicle can be placed in service.

## LUBRICATION DATA

When operating at temperatures below freezing, the use of MS 10W oil is recommended. If temperatures fall below zero, 5W or 5W20 should be used.

A new vehicle should be shipped with a light weight oil. When the vehicle is made ready for use, change to a heavier weight oil if the temperature is high enough to require it. During warm weather, use 20-20W oil. For best results, change to light oil in the fall, heavier oil in the spring.

## CORRECTING PUMP AND MOTOR FAILURES

Contamination is a cause for pump or motor failures. To correct this situation, remove failed units, then drain and discard the fluid from the reservoir.

1. Flush and clean the reservoir and system to remove all metal chips and other contamination.

2. Install new filter cartridges in system.

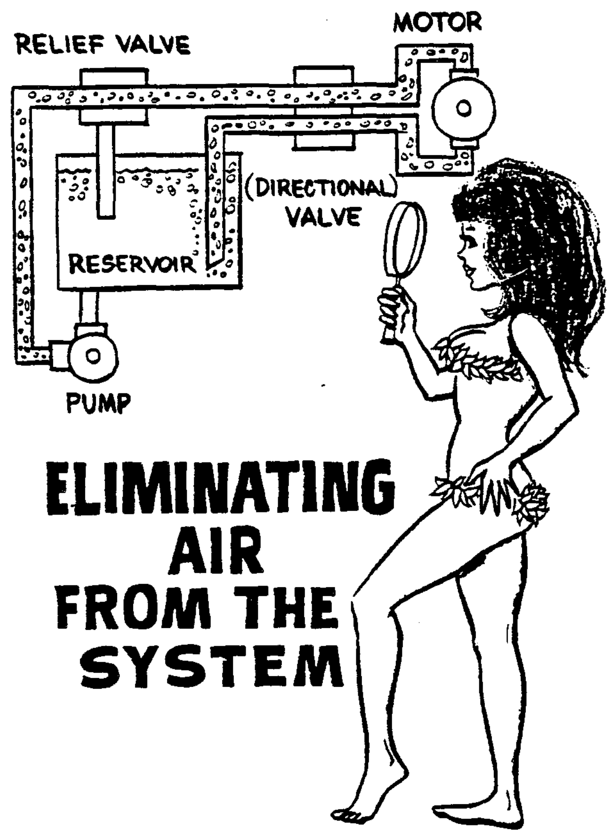
3. Install auxiliary low micron rated filters.

4. Start the system as described earlier.

5. After 40 to 45 hours, remove the auxiliary filters.

# HYDRAULIC HiNTS

BARKO
HYDRAULICS




## ELIMINATING AIR FROM THE SYSTEM

All hydraulic fluid contains some dissolved air, usually about 10% by volume. Under increased pressure, the fluid will absorb much more air. Aeration in a hydraulic circuit is the presence of free air in places where there ought to be only fluid. Usually the air will be in the form of bubbles dispersed through the fluid.

Difficulties with aeration will occur more frequently as flow velocities increase in hydraulic components. This bulletin covers some of the causes of air being introduced into a system and the suggested practices to effectively reduce and eliminate this problem.

### CAUSES

The most common places for air to be introduced into a hydraulic system or for aeration to occur are listed below:

1. Damaged inlet line; loose or defective fittings or seals at any component.

2. Damaged return line; loose or defective fittings or seals at any component.

3. Damaged or worn cylinder rod, packing or seals.

4. Cracked junction blocks, tees or piping.

NOTE: Because fluid acts as a sealant at atmospheric pressure, when system drops below atmospheric pressure air may be drawn in where fluid will not necessarily leak out.

5. Fluid level too low. This can cause vortexing at pump inlet in reservoir, thus drawing in air.

6. Air trapped in filter with no means of bleed off.

7. Return fluid discharged above fluid level in reservoir. Poor baffling in the reservoir can also cause turbulence and resultant introduction of air.

8. Air trapped in system during original filling, or when adding fluid for makeup.

## DAMAGE TO SYSTEM

The conditions listed in the previous paragraph all contribute to inducing air into a hydraulic system or what is commonly known as aeration. Excessive aeration can cause pump damage, resulting in immediate failure or contribution to later failures. The two causes of damage to components by aeration is lack of lubricity and overheating. In addition, aeration can cause jerky and uneven movement in pumps or motors which, in combination with the causes previously mentioned, will cause failure.

Loss of lubricity in a hydraulic component will eventually result in seizure and subsequent pump failure. Overheating is caused by a breakdown of hydraulic fluid as a result of oxidation. Oxidation of fluid leads to sludging and varnish formation. Operating a system with aeration can oxidize the whole charge of fluid and eventually sludge and varnish will cause the motor or pump to overheat excessively and cause failure.

## HOW TO AVOID AERATION

Regular inspection and regular maintenance are the best ways to prevent air from being introduced into a hydraulic system. Keeping all connections and fittings tight is the easiest way to avoid the introduction of air.

Return fluid entering the reservoir will create aeration if it is discharged above the main body of the fluid in the tank. To prevent this condition, maintain sufficient fluid in the tank to keep the return line submerged. The pump intake line should always be below the fluid surface for the same reason.

In starting a new system, or after a system has been completely drained and flushed, a tendency for the fluid to aerate may exist until all air is purged from all line and components. To correct this condition, a thorough purging of the entire system should be performed.

If air is being trapped in the reservoir filter, a bleed device should be installed in the top of the filter or inlet air breather.

In general, there is a great deal more service life built into hydraulic equipment than is now realized in many cases. Improved service life depends on maintaining proper conditions within the system.

# HYDRAULIC HINTS

BARKO HYDRAULICS


## GENERAL

The main causes of air being introduced into a hydraulic system are loose connections and fittings. This not only creates aeration in the fluid but also provides the risk of contamination entering the fluid and components with the air. The easiest way to effectively reduce and possibly eliminate this problem is to use an adequate pipe thread sealer at all connections and fittings.

In the past, Vickers has been asked by customers to recommend a pipe thread sealer. This bulletin provides information on the properties and applications of pipe thread sealer.

## DESCRIPTION

While other pipe thread sealers may meet Vickers specifications, the compound which Vickers has experience with is John Crane Plastic Lead Seal #2. It may be obtained from the Crane Packing Company, Morton Grove, Illinois, or their distributors.

## QUALITIES

The sealer will form a flexible, non-hardening seal that can be easily broken at any time without stripping the threads or damaging the pipes or fittings. It will also provide a non-shrinking bond that will inhibit rust or corrosion in the threads and will not gall, seize, or block the threads.

The sealer is homogeneous, free from lumps or any foreign matter, non-hygroscopic, and will not harden in the container during use. It is non-toxic and will not dissolve in petroleum products. The sealer covered by this bulletin also conforms to MIL-G-12376.

## APPLICATION

The pipe thread sealer is intended for use on threaded steel pipe in fixed installations. It can be easily applied by brush or paddle at temperatures ranging from -50° to +140°F. This sealer is intended for use with petroleum fluids only. Apply sealer sparingly and leave the first two threads near the end of the pipe or fitting bare.

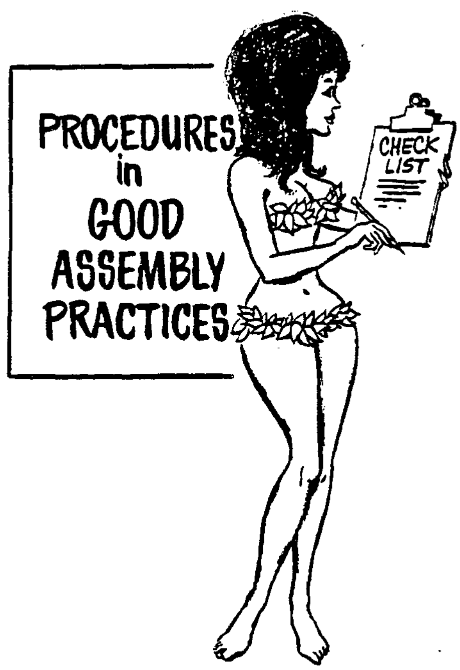
## CONCLUSION

Vickers recommends the use of pipe thread sealer on all exterior pipe plug threads and pipe fittings. Vickers uses John Crane Plastic Lead Seal #2; however, other compounds which meet the requirements outlined in this bulletin may be used. As stated previously, effective use of pipe thread sealer can reduce aeration and contamination, thus increasing reliability and service life and reducing maintenance and vehicle downtime.

# HYDRAULIC HINTS

**BARKO HYDRAULICS**

## GOOD ASSEMBLY PRACTICES




There are a number of procedures that can be used during assembly that help to ensure system reliability and long service life.

1. Most important--cleanliness.

2. All openings in the reservoir should be sealed after cleaning.

3. No snag grinding or welding operations should be done in areas where hydraulic components are being installed.

4. All cylinder, valve, pump, and hose sub-assemblies should be sealed and/or capped until just prior to use.

5. Mineral spirits should be kept in safety containers.

6. Air hoses (filtered and dry) should be used to clean fittings and other system components.

7. Examine pipe fittings and hose assemblies prior to use to be certain that burrs, dirt and/or scale are not present.

8. All pipe and tubing ends should be reamed properly to prevent restriction and turbulent flow.

9. When using teflon tape or compound on pipe threads, always leave the two first inside threads bare.

10. Do not use teflon tape or compound on straight thread fittings.

11. When installing pumps or motors, always align coupling halves as closely as possible, within 0.007 inch.

12. When using flexible couplings, follow the manufacturer's recommendations or allow 1/32 to 1/16 inch clearance between the coupling halves.

13. Do not drive couplings on pump or motor shafts. They should be a slip fit, or shrunk on using hot oil.

14. Always use grease on splines when installing. This adds to the life of the splines.

15. When using double universal joint couplings, the shafts must be parallel and the yokes must be in line.

16. When installing V-belt pulleys on pumps or motors, line up both pulleys as closely as possible. Always install the pulleys with a minimum amount of overhang as close to the pump or motor face as possible. This increases bearing service life.

In your own specific assembly process, you may see additional procedures that should be added. By doing this, you could form your own assembly check-list. Additionally, our Hydraulic Hint Bulletins cover other procedures that contribute to good assembly practices. They are:

* Recommended Cleanliness Practices
* Vane Pump Start-Up
* Eliminating Air From the System
* Quality Hydraulic Fluids
* Pipe Thread Sealer
* Oil Storage and Handling

# HYDRAULIC HINTS

**BARKO HYDRAULICS**

## GENERAL

A number of the Mobile Hydraulic Hints outline methods for reducing contamination in the system at assembly and after the system is running. Following these procedures is absolutely necessary to the proper operation of any hydraulic system or component. <u>But none of these procedures will do the job if contaminated fluid is added to the system to begin with.</u>

Refiners of hydraulic oils take particular care to prevent contamination of any sort from entering the oil up to the time of delivery. It is <u>just</u> as important to exercise care in <u>preventing</u> contaminants from entering <u>after</u> its delivery, and during storage and handling. This bulletin provides instructions for this purpose.

## STORAGE

Care must be taken from the minute oil is delivered to keep it clean. The first step is selecting a clean, dry spot for storage. Store the drums on their sides and cover them to prevent dust accumulation.

To avoid condensation in storage, drums must be protected against sudden temperature changes and should be kept full. Water collecting on the top of a drum will seep through the plug and into the oil. Water in hydraulic oil will reduce reliability and service life, regardless of the manufacturer's claims of the oils ability to function with water contamination.


## HANDLING

Before opening a drum, wipe the top carefully so that dirt will not fall into the oil. If, by chance dirt does get into the oil, make sure the oil is cleaned before using. Most large particles can be removed by straining through a 100-mesh screen. Remove the remaining dirt by allowing it to settle in the oil. Using only the clean oil from the top of the container may waste some oil, but it could prove to be very worthwhile in keeping the system clean.

If equipment is available, filter or centrifuge the oil. Remember, however, that active earth types of filters (such as Fullers Earth) remove oil additives. Consult your oil company representative or filter manufacturer if you're not sure.

When drawing oil out of storage, make certain it is carried from storage point to use in clean, covered containers. If the oil drawn out of storage is not used immediately, make sure it is kept tightly covered.

## FILLING

Before removing filler cap to add oil to a hydraulic system, wipe off the fill plug and the filler nozzle with a clean, lint-free cloth. The safest way to pour oil from a container into a reservoir is to use a 10-micron filter on the filler nozzle. It is especially important at this point to watch for metallic chips, bits of waste, and other contaminants that may cause damage to the hydraulic system. The reservoir should be tightly closed after filling the system.

## CONCLUSION

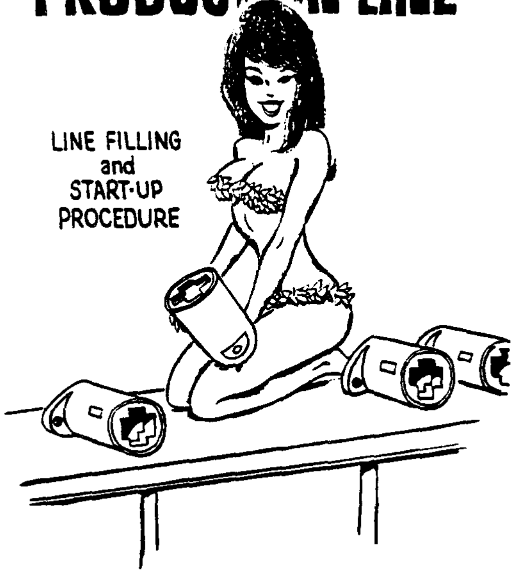
Dust, water, lint or contaminants of any kind can seriously impair the operation of a hydraulic system. Following the simple rules outlined in this bulletin can prevent such material from contaminating hydraulic oil. A preventive maintenance program aimed at keeping oil clean can pay off.

Vickers equipment is designed to prevent dirt from entering the hydraulic system during operation. Nevertheless, it is to your advantage to study your own operating conditions and initiate practices to ensure contamination-free system operation.

# HYDRAULIC HINTS

**BARKO HYDRAULICS**

## PRODUCTION LINE




This procedure is written specifically for the high-production O.E.M. user, and can be adapted to mass production. In some cases, the procedure may be the same as procedures published before. This one has been changed as needed to provide a faster, more workable method.

Filling and start-up procedures are not limited to the assembly line alone. The specified steps cover the product all the way from the receiving dock to off the end of the line. And since each element of a hydraulic system is dependent on the others, they are all covered.

### RECEIVING

Production units are usually packaged in multi-unit shipping containers. These should be stored in a clean, dry place. The stock should be rotated regularly so that the oldest units are used first. Use care to avoid dropping or damaging containers when moving the stock.

Units and components should not be unpacked unless there is an immediate need for them. Port protection such as plastic plugs or shipping plugs should not be removed until circuit components are ready for assembly.

The following items should be checked at the receiving inspection:

1. Model Numbers - Be sure that correct model number has been received.

2. Date Stamp - Vickers uses a date code to identify manufacturing dates for warranty purposes. Every effort should be made to use older stock first. Also, lot shipments of a given run should be used in batches. This permits easier isolation if a service problem should develop during a particular production run.

3. Check critical installation dimensions, i.e., shaft diameters, pilot diameters, mountings, etc. as shown on Vickers installation drawing.

4. Check plugged ports to determine if units are sealed. If plugs are missing, replacements should be provided prior to storage.

5. Check fittings, lines, tubing and hose for cleanliness and freedom from burrs. These parts must be clean and sealed with protective plugs prior to storage.

6. Check reservoirs for leaks, remove welding slag, and apply rust preventive to interior. All openings should be covered.

7. Fluid - Bulk oil deliveries should be checked for adherence to oil specification. Viscosity control and anti-wear protection are essential for modern hydraulic systems and must be maintained within specified limits. Storage facilities must be designed to preclude contamination by dirt and water. Condensation must be considered as a source of water.

8. Service Parts - Check part numbers. Inspect critical surfaces for nicks and scratches which may have occurred in shipment. These should be removed by light stoning prior to use.

## ASSEMBLY LINE TECHNIQUES

A primary cause of hydraulic system failure is contamination. It is far better for a system to start with clean components than to depend on filtering or flushing procedures after assembly.

Since a particle smaller than 0.0016-inch cannot be seen, visual checks for contamination are not good enough. A form of magnification should be used. Refer to Mobile Bulletin MH-4 for other recommended cleanliness practices.

Here are the basic assembly line procedures that should be followed:

1. Install couplings on pump or motor shafts using a device that will not damage bearings or other parts. Avoid using pressure devices or hammers that cause such damage. When splined shafts are used, lubricate splines before operation.

2. Align pump and motor mountings within the adjustment limits of the coupling used.

3. Leave protective plugs in position until ready to assemble the lines.

4. Be sure assembly areas are located well clear of dust producing operations such as welding, sanding, painting or open doors.

5. Install and tighten fittings to specified torque levels.

6. Maintain recommended bend radii on all hoses and lines. Installing these at smaller radii can cause early fatigue failure of pressure lines, kinking of hoses, restricted inlets and cavitation.

7. Avoid forcing tube lines into position. This creates bending stresses that can cause line failure. Clamp all lines securely to minimize vibration, and to prevent rubbing on any other part.

8. At this point the system is ready for either filling or flushing. If unsure of cleanliness, flush the system.

When flushing the system, the contaminant particles must be picked up and carried by the oil stream. It is necessary to maintain a turbulent flow of about 25 feet-per-second through the system. Fluid used for flushing should be the same fluid used for filling. Because of this, continuous filtration at 10 microns is essential to flushing the circuit. The use of magnetic traps can extend filter life by trapping ferrous particles. Flushing time can best be established by test and will depend on the size of the system and amount of contamination present.

9. Use a pressure filling technique to fill the system. Oil should be pumped from the storage tank through a 10 micron filter before introduction into the system. In most cases it is desirable to introduce oil into the circuit, and back-fill the reservoir. Since the reservoir is usually the highest point in the system, this permits trapped air to escape through the reservoir. If any circuit element is constructed in such a manner as to create an air pocket, the use of a bleed plug is recommended to remove the air.

The pressure fill technique should be designed to fill all hydraulic cylinders in the circuit. This requires sufficient pressure to extend the cylinders under no-load conditions. Continue to fill the circuit until the necessary oil level in the reservoir is attained. Remember to allow for any cylinders which have not filled.

## FINAL TEST TECHNIQUES

Start the hydraulic system under no load, or minimum load conditions. With an engine driven pump, the pump should be rotated with the engine starter until output movement is observed. In systems with vane pumps it will be necessary to start the engine as these units will not function at cranking speed. After initial movement is observed start the engine and run at low idle until the hydraulic system is running smoothly. If cylinders are used, bleeding may be required to eliminate air. With proper fill techniques the system should run smoothly almost instantaneously.

Use caution if the system is to be started under cold weather conditions. Refer to Mobile Bulletin MH-5 for additional start-up procedures.

Include the following in the final test sequence:

1. Run the system at its maximum working load through all operating modes. Check the engine speed, output speed and force levels, and control function. Also check for fitting leakage and unusual noise and vibration levels.

2. Run the system at its maximum hydraulic pressure to check the high-pressure relief valves.

## ADJUSTMENT

With the system running smoothly at low idle, adjust the control linkages as necessary. Listen for unusual noises and cavitation. Check the reservoir for proper fluid level, signs of aeration, surface agitation, foaming and air bubbles. If the oil is aerated, or the pump is cavitating, check the inlet lines for leaks.

## PAINTING

When painting the vehicle, mask off critical areas such as pumps and motor shaft, seals and bearings, control valve spools, cylinder piston rods, electrical connectors, reservoir breathers, etc. Avoid painting rubber hoses as paint solvents may attack the rubber. When solvent is used for cleaning, or when baking is used to dry paint, check the effects on hydraulic system components.

## VEHICLE STORAGE

Since it is common practice to store completed vehicles outdoors, seal the hydraulic system, especially if it will be long-term storage. This eliminates the problems of introducing contamination such as airborne dust, or water in the system caused by condensation. A rust preventative should be applied to all moving or sliding surfaces. Vickers recommended oil viscosities should be used as determined by the temperature.

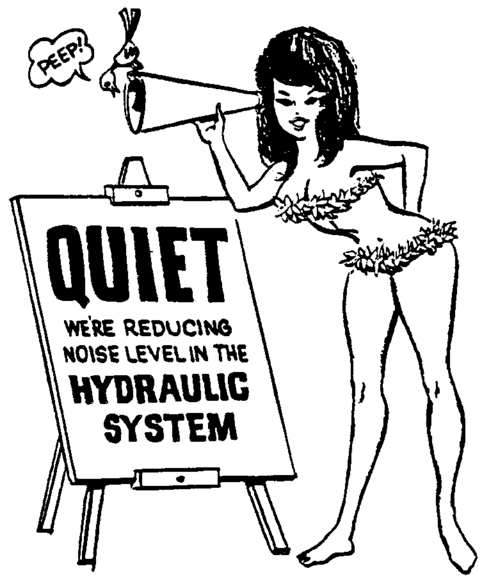
Vehicles with hydrostatic transmissions should not be towed unless wheels are disengaged from the hydraulic motor. When towing valves are provided they should be activated. Towing speeds with tow valves should be maintained at no more than 1/4 maximum vehicle speed. If vehicle must be towed for long distances, special provisions may be required.

Before starting the vehicle, again refer to Mobile Bulletin MH-3 for detailed starting instructions. Following these procedures should help provide the long life and unit reliability which has been engineered and manufactured into your Vickers hydraulic components.

# HYDRAULIC HINTS

BARKO HYDRAULICS

## REDUCING NOISE LEVEL




A lot has been learned in the field of noise control over the past several years, especially in machinery applications. We know that some of these basic principals can be used to quiet down mobile hydraulic systems as well.

Some very effective noise control modifications can be made by changing the vehicle design. The following procedures, however, effect the hydraulic system only.

### HYDRAULIC PUMP

One of the main sources of noise in a system is the pump. Remember that a large pump operating at low speed is generally quieter than a small pump operating at high speed. A fixed-displacement pump is quieter than a variable-displacement pump. And, finally, pumps mounted on standard mounting flanges, attached to light frameworks, with low-cost shaft couplings and solid pipework are usually very noisy.

The best way to install a pump for noise control is on rubber isolation mountings. For best noise control it is desirable to install an insulated baffle enclosure over the pump.

### TANK AND INLET LINE

The reservoir must be arranged to feed fluid, free of air bubbles, into the inlet line. This means baffles in a reservoir. All lines should enter or leave the reservoir well below the lowest fluid level to be used.

The inlet line, including strainer if fitted, must permit the maximum flow demanded by the pump at the minimum working temperature, with an inlet pressure depression at the pump of not more than five inches Hg. Less than five inches Hg. is preferable, and a positive head of oil at the pump inlet is best. The final three feet of inlet line before the pump should be flexible.

### PRESSURE LINE

The pressure line should be flexible for three feet next to the pump to isolate pump vibration.

## CASE DRAIN LINE

Where a case drain line is used, it should be flexible for three feet next to the pump. With pressure compensated pumps, the diameter of the flexible line used should be one size larger than the case tapping to minimize transient case pressure rise during rapid off loading.

## SHAFT COUPLINGS

The motor shaft and the pump shaft should be aligned as closely as possible. All metal shaft couplings tend to transmit torsional vibration from the pump. Couplings with a lower torsional stiffness reduce noise. The type which transmits the torque through a rubber ring shaped like a car tire has the lowest noise level.

## PIPEWORK

Even with a flexible pipe at the pump delivery port, pressure pulsations are transmitted to the pipework. Pipework should be isolated from structures by rubber mountings wherever possible, particularly where bulkheads and other flat surfaces are present.

## STRUCTURE

The complete structure should be free of flat surfaces that can resonate with applied vibration. Where this is impossible the resonant parts should be stiffened or damped.

## ACOUSTIC FILTERS

In specific cases these can be applied in the delivery and inlet lines. They are, however, "tuned" to a particular installation and cannot be made available off the shelf.

# HYDRAULIC HiNTS

BARKO HYDRAULICS

## AVOIDING PUMP FAILURES


Many things can happen to a hydraulic system that will cause pump failure. By practicing certain preventive maintenance procedures, frequency of pump failures can be cut down. Pump failure can be avoided if tell-tale symptoms are discovered and checked out when they occur.

The main symptoms to watch for are excessive system temperatures and noise. These usually indicate a defective pump. Also watch the overall performance of the system. If the equipment operates a little slower, less powerfully, or is less responsive, it's time to check the system for flow rate and pressure. This check should be made with the engine at speed, and under load.

Any excessive or unusual pump noise should be investigated immediately. Pump noise generally indicates cavitation caused by restricted inlet supply, excessive fluid aeration, or worn internal parts.

If a pump stops suddenly, it is almost certain that a major internal pump part has failed. The only solution to this, of course, is to examine the pump and rebuild or replace it as necessary.

After the pump has been repaired or replaced, don't operate the system until you have drained it, flushed it and refilled it with new fluid. This should do away with any particles from the failed part that could damage the newly repaired system.

Some other items that can cause poor performance and eventual pump failure are listed here. These should be checked periodically.

1. Reservoir - Check the fluid level at reasonably close intervals to be sure it is up to the full mark. If the level is going down faster than usual, there's probably a leak somewhere in the system.

2. Inlet Line - A bit of debris may have plugged the inlet pipe preventing sufficient fluid from reaching the pump. Frays and kinks in the inlet line can also restrict the fluid supply. Be sure the inlet line is secure and leak proof.

3. Return Line Filter - The return line filter should be checked frequently and cleaned or replaced as necessary. This is especially true when the vehicle is operated in dusty work locations. If it is found that the filter needs frequent cleaning or changing, it may be better to install a larger and higher capacity filter in the system. This should be checked with the manufacturer's representative.

4. Oil Viscosity - Be careful not to use fluid that is too thick. This should be determined by local temperature conditions and component manufacturer recommendations. Also, fluid may thicken through oxidation or contamination. Refer to oil sheet M-2950-S.

Remember that heat, high pressures and contamination all speed up oxidation. This results in gum, sludge, plugged valves and excessive wear on the pump, cylinder and valve parts. The answer is to always use the proper grade and amount of fluid, and to perform regular preventive maintenance.

# HYDRAULIC HINTS

**BARKO HYDRAULICS**

## PREPARATION FOR SHIPMENT - MOBILE VEHICLES


The final step in the production of vehicles using mobile hydraulic equipment is painting and preparation for shipment. Paint is essential to protect the surface of the vehicle, and can also be distinctive and eye-appealing.

Before painting, the vehicle must be thoroughly cleaned and prepared. If these operations are improperly performed, damage to hydraulic system components could result. This bulletin outlines procedures to prepare mobile vehicles for painting and shipment.

### MASKING

All exposed piston rods including those on power steering boosters and steering cylinders should be masked with protective tape on exposed surfaces. Paint on extended piston rods will cause damage to the sealing elements in the cylinder cap. This could cause leakage when the rods are retracted.

Hydraulic motor and pump shafts should also be masked with protective tape. Because in many cases the shaft seal is outboard of the thrust bearing, it is extremely important to make sure the seal is also protected before painting. Leakage may occur as a result of end play if the seal is painted.

All control valve spools must be masked before painting. If spools are painted, seal damage and leakage can result when valve spools are pushed inward during operation. If spools extend through open caps, the bottoms of the spools should be masked. On closed end caps, mask the drain hole before painting to prevent clogging.

### PRE-SHIPMENT LUBRICATION

Prior to painting a vehicle, all traces of dirt, oil, and grease must be removed. Cleaning is usually done with a volatile mineral spirit which is sprayed on and dries before painting. While this is a necessity, it may create problems for the hydraulic system.

Valve spools and pump and motor shafts are left dry. This may cause rust and corrosion due to unfavorable climatic conditions. Because mobile vehicles are usually stored outside, it is advisable to coat all unpainted surfaces on valve spools and ends, and pump and motor shafts with protective grease. It is also recommended to thoroughly grease all controls before shipping.

## CYLINDER PROTECTION

Most mobile cylinder control valves have a circuit characteristic of the inlet open to the reservoir, in the neutral position and cylinder ports blocked. Unless the valve has cross port relief valves or the cylinder has internal relief valves, this creates a problem.

Oil left in cylinders is incompressible. If it is subjected to a mechanical shock load, these pressures could result in cylinder damage. Hardwood blocks should be used to prevent any movement of the piston rod during shipment to avoid damage to the cylinders.

# HYDRAULIC HINTS

**BARKO HYDRAULICS**

## KEEP IT CLEAN


Without doubt, the most common of hydraulic system ailments is contamination. Dirty fluid can be the result of dirty plumbing. In this bulletin, the term plumbing will include the reservoir, tube, hoses, and fittings. Clean fluid cannot be expected to do an adequate job if it has to travel through dirty plumbing before reaching the work.

Cleanliness at installation is the primary consideration in hydraulic plumbing. This bulletin outlines the steps and precautions to be taken at installation and provides a detailed procedure for flushing a hydraulic system.

### RESERVOIR

The reservoir should be thoroughly cleaned and painted before installation in the system. Inside, the reservoir should be painted with a sealer to minimize oxidation which can be caused by condensation. The sealer must be of a composition that will not react chemically to the hydraulic fluid. Some fire-resistant fluids require special sealers other than that used for standard mineral-based fluids. Suitable sealers usually can be recommended by the fluid supplier.

### PLUMBING AND FITTINGS

All lines should be smooth and clean on the inside. If the line is threaded, be sure to ream the end until the inside burr is removed. Burred edges not only obstruct flow but also may break off and contaminate the fluid later. When applying sealer compound, the two end threads are kept free of compound to avoid contamination. Sand blasting, de-greasing and pickling are recommended for thoroughly cleaning lines prior to installation. Limit sand blasting to pieces where there is no danger that sand particles might remain lodged after the piece is flushed clean.

If possible, blow compressed air through the lines to evaporate the solvent and remove any dust that may have collected. For safety reasons, when blowing with compressed air, always make sure the air isn't blown into open machinery or at people. Once a tube or fitting has been cleaned, open ends should be capped and plugged immediately and left covered until installation. Rags or waste should not be used for this purpose, because they may deposit harmful lint which can cause severe damage in a hydraulic system.

## MAINTENANCE

A good preventive maintenance program includes periodically draining and cleaning the reservoir and flushing with a solvent compatible with the hydraulic fluid being used. Periodic inspection and sampling of fluid will dictate whether flushing the system is required.

A sample of fluid that is representative of that in circulation should be taken (not from the bottom of the reservoir). If it is cloudy, off-color, contains suspended sediment, or if on standing, shows separate sediment or liquid layers, then changing the fluid charge is recommended. Prior to installation of a new fluid charge is an ideal time to clean and flush the system.

## RESERVOIR CLEANING

The reservoir in a hydraulic system is a settling basin for any contamination. Although there are other places in the plumbing where contaminants may accumulate, the reservoir is usually where the majority of them will settle. If inspection shows that the fluid is in poor condition, the fluid should be drained and the reservoir cleaned.

Remove all accumulated sediment or other forms of contamination from the bottom of the reservoir. Wipe down the interior of the reservoir to remove any further impurities. After the reservoir is thoroughly cleaned, the system can be refilled with new fluid.

While on the subject of reservoirs, the inside of large reservoir covers is often one of the most neglected parts of a system. Although not many mobile applications require a reservoir of this size, if one is used in a mobile application, it can be the source for rust contaminating the system. A large cover is subject to condensation and vibration; thus, as rust forms, it flakes off into the hydraulic fluid.

Be sure to thoroughly clean and then paint the underside of a cover before reinstalling it. In severe cases, an aluminum cover may be the answer. Self tapping screws to hold covers in place are "taboo" unless they go into blind holes.

## FLUSHING SYSTEM

If contamination is evident in fluid samples, then chances are accumulation has occurred somewhere within the plumbing. The only way to effectively remove accumulated contaminants and thoroughly clean the entire system is by flushing. This is done by circulating a small percentage of special petroleum solvent cleaner with the fluid charge long enough to loosen and remove the deposits. The fluid should then be drained while it is hot, the reservoir cleaned manually as previously outlined, and the system flushed.

The most effective way to clean a hydraulic system is to first drain the dirty fluid from the system; then clean the reservoir and add clean fluid with the solvent added. Flushing is usually most effective at about 150° F. The fluid should remain in the system from 10 to 50 hours depending on the condition. A careful watch on the filters will indicate when the system is clean.

After removing the flushing liquid used for cleaning, it is recommended to flush the system first with clean hydraulic fluid to pick up the remaining cleaner. Then drain the system again and check filters and the bottom of the reservoir.

## SOLVENTS

Fluid suppliers are the best source for recommended solvents. Solvents such as alcohol, kerosene, carbon tetrachloride and others should not be used.

Because it is impossible to remove all of the cleaning solvent from the system, these low viscosity materials tend to reduce the viscosity of the new fluid. Another thing to remember is that a low-viscosity solvent may not hold in suspension the contaminants it washes off a surface. The contaminant then settles in another part of the system and may not flush out.

## CONCLUSION

For prolonged service life, contamination must be periodically removed from hydraulic systems. Most of this effort can be saved if adequate steps are taken to prevent contaminants from entering the system in the first place. New systems not properly installed may be contaminated.

Once the system is in operation proper periodic cleaning will prevent component failure and prevent system downtime. Remember, hydraulic components are more costly than fluid.

# HYDRAULIC HiNTS

BARKO HYDRAULICS

## DIAGNOSIS AND CORRECTION OF AERATION AND CAVITATION

Aeration and cavitation are two distinct phenomena that can occur in hydraulic systems, causing noisy operation, erosion of metal and accelerated wear. While their effects are similar, they have different causes and require different corrective action.

### AERATION

Aeration is the presence of free air in the hydraulic fluid. Practically all commercial fluids contain up to ten percent air in solution and can dissolve more air under increased pressure.

Free air in the fluid can make it spongy, which will make pressure erratic and reduce the effectiveness of the fluid as a lubricant. In addition, it may accelerate breakdown of the fluid as the bubble implodes with great force.

Aeration may be accompanied by foaming in the reservoir. Aeration damage is most severe in the pump. It causes erosion marks on the end plates between the ports (see figure 1). In addition, loss of lubrication often causes severe vane tip wear (figure 2). Aeration bubbles may make the vanes bounce as the rotor turns and the result is a rippled ring as shown in figure 3. In addition to these signs, aeration sometimes can be diagnosed by the characteristic sounds as if the pump is pumping marbles and by presence of foam in the reservoir. On prototype vehicles, hydraulic reservoirs should have windows and a clear plastic inlet line to the pump to be certain that no free air enters the pump.

### CAUSES OF AERATION

Excess air can be taken into the fluid in several ways. Most common is where the fluid level in the reservoir is too low to fully cover the intake opening. Any time a whirlpool can be seen at the intake, air is being pulled into the pump with the fluid. Restrictions in inlet piping can create pressure drops that allow free air to form and be taken into the pump inlet. Air will mix with oil in the reservoir under the following conditions:

1. If the return line opens above the fluid level.
2. If the flow in the reservoir is turbulent.
3. If filter check valves open above the fluid level.
4. If shrouds over filter cartridge are not sealed.

Other possibilities are a leaking shaft seal on the pump, leaking cylinder rod seals, or any leaking connection in the inlet line that isn't submerged. These leaks often can be found by squirting oil around the possible leakage points and listening for changes in pump noise. The oil will temporarily seal the leak and the pump will run quieter when the leak is located and eliminated.

Obviously the cause of aeration should be found and corrected to prevent premature failure of the pump or breakdown of the fluid's lubricating ability. Baffles and diffusers will help to prevent free air in reservoirs.

## CAVITATION

Cavitation is a vacuum in the fluid. Cavities occur when the components don't completely fill. It can also occur in motors or cylinders where the load overruns the delivery from the pump. Cavitation is prevalent in the pump when the inlet conditions are critical. The characteristic sound of cavitation is a high pitched "scream" and this noise increases with the degree of cavitation and with increased operating pressure. This is caused by the implosion of the cavities or voids in the fluid.

## CAVITATION EFFECTS

Typical effects of cavitation are eroded end plates (as shown by pitting between the inlet and outlet port). A rippled ring with the vanes worn flat on the ends and pitting around the ports in the inlet quadrant of the cam ring (see figure 4). In short, the effects are much the same as aeration.

## CAUSES OF PUMP CAVITATION

Pump cavitation may be caused by a restricted inlet line, by sharp bends in the inlet line; by a clogged inlet filter; by fluid that is too high in viscosity and by excessively long inlet lines. Also if the pump inlet is too high above the fluid level in the reservoir, the "lift" required may be too much to allow the pump to fill. One other possible cause is a vacuum in a non-vented reservoir caused by the oil shrinking in volume as it cools. This can be avoided by momentarily cracking the reservoir cover whenever the machine is started up cold. Cavitation from fluid that is too thick sometimes is avoided by operating at reduced pump speed until the fluid is warmed up and becomes less viscous.

Whenever cavitation is detected, it should be corrected or the life of the pump will be shortened. When cavitation is suspected, a vacuum gauge should be installed at the pump inlet to determine if corrective action is required.

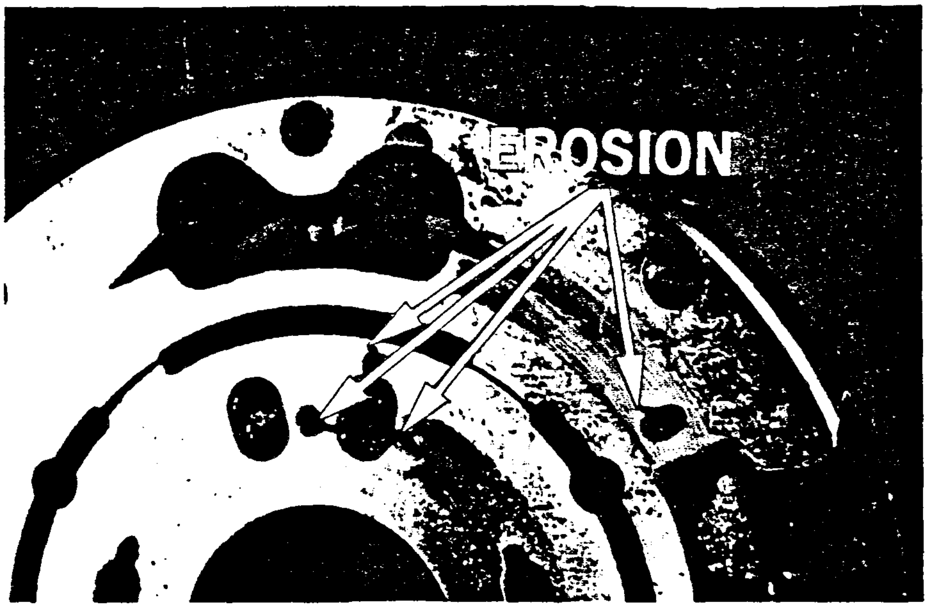



Figure 1

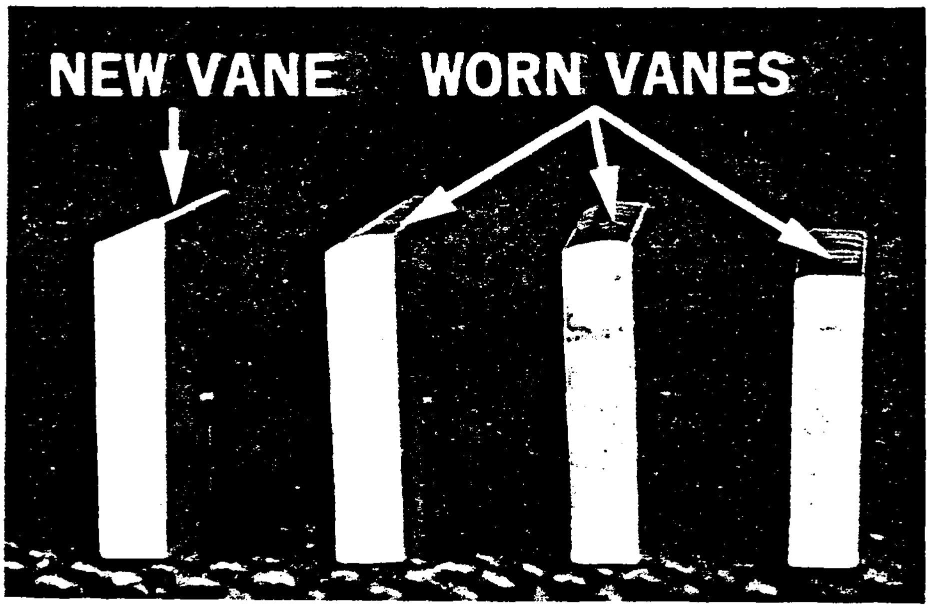



Figure 2

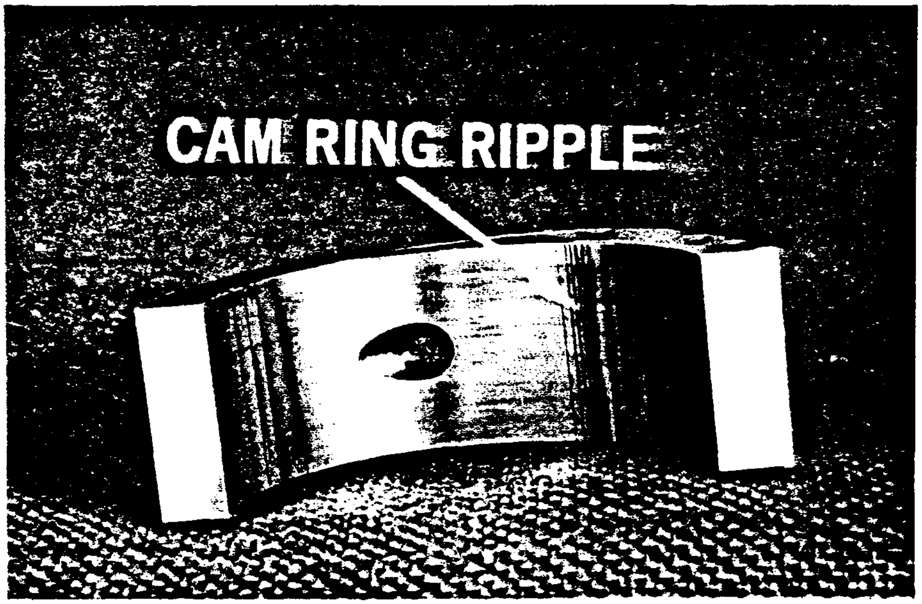



Figure 3

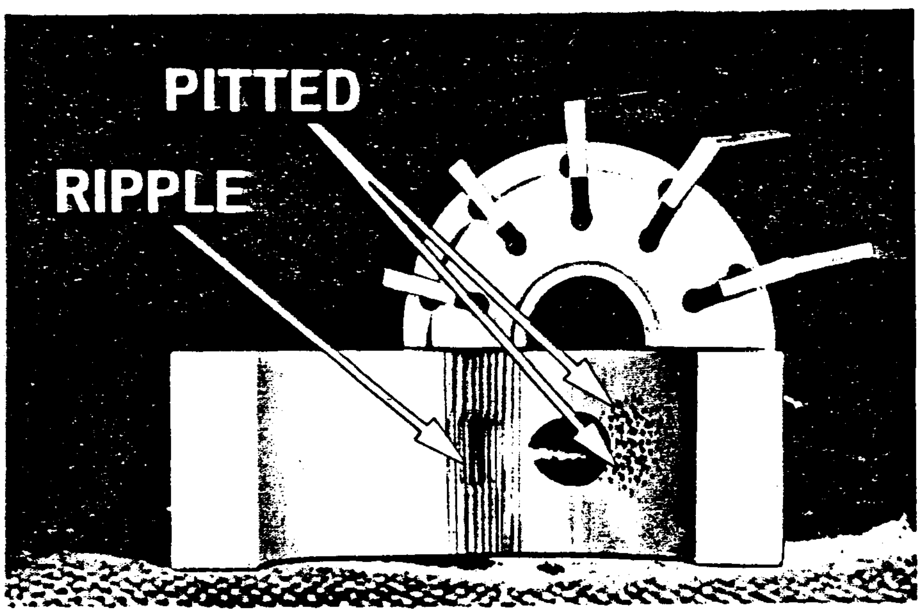



Figure 4