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Safe maintenance of hydraulic systems

June 2019

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Safe maintenance of hydraulic systems

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The DGUV or the FBHM or the translator shall not be liable for any incidental or consequential damages in connection with or arising out of the use of this safety information on hydraulic maintenance and its rules.

The committee of experts FBHM is composed of representatives of the German institutions for statutory accident insurance and prevention (Berufsgenossenschaften), federal authorities, social partners, manufacturers and users and subdivided into subcommittees.

The DGUV Information 209-071 is based on experience gathered by the FBHM and its subcommittee in the field of hydraulic equipment of machinery and plants. It should help to specify the safe maintenance procedures of hydraulic equipment that are used in machinery and plants, and that are included in the scope of the European Machinery Directive. The particular provisions for different applications (e .g. in the mining industry or similar) have to be considered.

The present document DGUV Information 209-071 “Safe maintenance of hydraulic systems” is the English translation of the German DGUV Information 209-070 “Sicherheit bei der Hydraulik-Instandhaltung”, edition Juni 2019, and it replaces the former English edition DGUV Information 209-071 of March 2015. The provisions according to individual national laws and decrees in other countries remain unaffected by this translation of the German information DGUV Information 209-070. The requirements of the individual national legal rules and of manufacturers instructions (including manuals) apply without reservation. In order to get detailed information it is necessary to read the relevant wording of the national rules and instructions.

Preliminary remark

Since 1950, more and more hydraulic components have been produced as modular elements and used in systems or machines to meet widely varying requirements.

The particular advantage of hydraulic systems is their high energy density, i. e. small components can be used to generate high outputs.

At the beginning, hydraulic control elements were exclusively operated manually. In the course of the technical development, the combination with electric or electronic parts has been promoted increasingly. Today, for example, automated production systems consist of numerous linked, complex assemblies.

The possible applications of hydraulic systems are very diverse. They range from the micro area via machine and systems engineering up to the aerospace industry.

In the field of hydraulics energy is transferred via a hydraulic fluid that is used to generate movements or forces. In general mechanical engineering, pressures up to 350 bar and in special cases, e. g. for static forming technology, pressures up to 5,000 bar are used.

This information addresses persons who plan and carry out maintenance work on machines and systems with hydraulic equipment.

As maintenance procedures on machines often require the intervention in areas that are not accessible during normal system operation, this work requires the implementation of special protective measures (see also DGUV Informa-

tion 209-015 “Instandhaltung – sicher und praxisgerecht durchführen”, Maintenace work – safe and practice-oriented execution).

This information mentions descriptions of hazards and measures for preventing them and gives advice for implementing maintenance work on hydraulic equipment in a safe manner. This information provides support for identifying and assessing risks and deriving suitable measures in accordance with German general technical rules for operating safety TRBS 1112 „Instandhaltung“ (Maintenance) with regard to the specific hazards in maintaining hydraulics. This information describes measures that must be taken into account when carrying out maintenance work on machines and plants with hydraulic equipment. Apart from the description of planning and carrying out maintenance work, this information also deals with troubleshooting and re-commissioning after repairs were carried out.

1 Maintenance of machines, systems, and vehicle attachments with hydraulic equipment

1.1 General

For all works on hydraulic systems and equipment, the information given by the machine or system manufacturer regarding knowledge and qualification, as well as commissioning and maintenance procedures have to be observed.

Spare parts have to meet the specifications of the machine manufacturer. This means that all parts to be installed have to be selected especially in accordance with the maximum operating pressures and suited for the hydraulic fluid used in the system.

Hazard warnings and safety measures, among others from the safety data sheet of the hydraulic fluid used, have to be incorporated and implemented into the operating instructions (see section 2.1).

Remodeling machines and systems can constitute a substantial modification in the meaning of the German Product Safety Act, at which additional safety requirements and further measures may have to be taken into account. Thus, the manufacturer should be contacted before any remodeling works.

Note

Remodeling a machine may require a new assessment of conformity.

1.2 Qualification of maintenance technicians

Maintenance technicians have to be familiar with the design of hydraulic components and systems through their professional training, occupational experience, and activity. They should have finished their vocational training, e. g. as

- industrial mechanic,
- mechatronics technician,
- systems mechanic,
- automobile mechanic,
- agricultural machine mechanic or
- have passed advanced training as hydraulics technician.

Furthermore, the maintenance technician has to be instructed regarding the possible hazards and the resulting protective measures. Fundamental obli-



Fig. 1
Maintenance technician during maintenance work

gations of the employees result from the DGUV Vorschrift 1 “Grundsätze der Prävention” (Principles of Prevention), see Annex 1 letter F.

For planning and implementing maintenance works, it is required to understand at least

- the operating instructions (including notes on maintenance),
- the functional and wiring diagrams on hydraulics and, where appropriate, on electronics,
- the operating modes,
- the machine sequences, and
- the connections to other technologies (mechanic, electric, electronic).

The application of the methods of systematic troubleshooting has to be known.

If the knowledge mentioned above is insufficient, system-specific information have to be requested from the machine manufacturer.

The work on electric parts of machines and systems is associated with special hazards. Thus, this work must only be conducted by persons who are technically trained and instructed in electrotechnology, e. g. electricians.

1.3 Hazards when working on hydraulic systems

A hazard analysis has to be conducted for maintenance work and documented together with the resulting protective measures (see also TRBS 1112, section 4, paragraph [2]). The risk assessment for the maintenance technician must be conducted by the head of the maintenance department.

For recurring, identical maintenance work (e. g. replacement of hose assemblies, valves or cylinders), it may be sufficient to carry out risk assessments once and use this as a basis for operating instructions and regular instruction.

> ***Note:***
> *In case of particular hazards (e. g. due to reciprocal effects with other work or at new, unknown places of operation or in the premises of customers), a risk assessment must also be conducted before maintenance work is started and, if necessary, it may have to be coordinated with the responsible safety and health coordinator of the customer.*

Working on hydraulic systems can lead to the following hazards:
- **uncontrolled leakage of the hydraulic fluid,**
- **accidental machine movements,**
- **risk of burning at hot surfaces or hot hydraulic fluid,**
- **parts coming off or bursting,**
- **skin diseases,**
- **noise.**

Uncontrolled leakage of the hydraulic fluid

The leakage of hydraulic fluid has to be expected if lines rupture, if connection elements that are still pressurized become loosened, if hydraulic hose assemblies (see figure 2) are damaged, or if inadmissibly high forces are applied. The consequences can be:
- damage to the eyes,
- intrusion into the skin (intoxication),
- scalding by hot hydraulic fluid,
- risk of fire, if there are ignition sources (e. g. oils on hot surfaces),
- slipping danger on work stations and traffic paths,
- hazards due to accidental machine movements,

- environmental hazards, (e. g. intrusion into or release to the ground/ groundwater).

Inadmissibly high forces can occur due to
- improperly set pressure valves,
- modifications, e. g. on pressure relief valves,
- improperly rated valves (switching too fast),
- loads applied externally,
- accidental pressure intensifications on cylinders.

Accidental machine movements can be triggered by
- accidental operation of command or control devices, such as buttons, levers, controlling light barriers, proximity switches, manual overrides, as well as interferences by magnetic fields,
- errors in the control system,
- energy separation, energy supply, residual energy,
- parts failure,
- contamination of the hydraulic fluid.



Fig. 2
Bursted hydraulic hose assembly

Residual energy in a system can be present if
- accumulators (hydraulic/pneumatic) exist in the system,
- loads are maintained in elevated positions,
- clamping forces exist,
- there are tensions between parts.

Parts failure can result from e. g.
- excessive system pressure,
- wear and tear and material fatigue (e. g. valve springs),
- stuck valves,
- overload due to excessive dynamic pressure peaks,
- improper or contaminated hydraulic fluids.

Risk of burning on hot surfaces and hot hydraulic fluids by:
- machine parts that are hot during operation, such as line assemblies, pumps, motors and
- escaping hydraulic fluid, e. g. when lines are opened or components are removed.

Parts coming off or bursting can be the result of
- overloaded components, e. g. due to excessive operating pressures or pressure peaks,
- material fatigue,
- parts selected improperly.

This also comprises whipping hydraulic hose assemblies ruptured on one end.

Contact with hydraulic fluids can lead to **effects hazardous to skin** (see section 2). Vapors of hydraulic fluids can cause airway irritations when inhaled.

Noise emissions are not only caused by the pump unit, even the noise of machines generated during operation can cause a substantial level of noise, e. g. during troubleshooting, test operation and others. Thus, the maintenance technician of the hydraulic system has to wear ear protection in case of noise emissions hazardous to health.

Depending on the maintenance work, one or more hazards can occur simultaneously. Thus, several protective measures have to be used. The most important protective measures are explained in the individual sections of this information brochure. If required, references are made to other DGUV information brochures.

Note:
Should the risk assessment of maintenance work identify explosion hazards, the Technical Rule for Operating Safety (TRGS) 1112 Part 1 "Explosionsgefährdungen bei und durch Instandhaltungsarbeiten – Beurteilungen und Schutzmaßnahmen" (Explosion risk arising during and due to maintenance work – assessment and protective measures) must be applied.

1.4 Electrical hazards

Working on electric parts of machines and systems can result in special hazards, such as
- direct and indirect contact with live or conducting parts,
- shock currents,
- electric arcs/discharges,
- voltage diversion, (e. g. with improper grounding),

and especially hazards due to working in confined spaces, which also comprise the interior of machines and metallic vehicle superstructures.

Thus, this work must only be conducted by persons technically trained and instructed in electrotechnology, e. g. electricians.

1.5 Planning the works

Accidents most often occur because of no or insufficient organizational preparation of the maintenance works. Implementing the works when being pressed for time is another reason. Furthermore, often only repair work is performed instead of determining and remedying the reasons for the failure. Moreover, years of routine can lead to overestimation of one's own capabilities or to misinterpretations, if the practiced way of working is no longer challenged.

A precondition for safe maintenance works is planning the works thoroughly, including the execution of a risk assessment and considering or preparing maintenance instructions.

Planning comprises:
- the scope and the course of the maintenance procedure,
- required protective measures according to the risk assessment,
- the selection of maintenance technicians according to their qualification,
- the required number of maintenance technicians according to the extent of the work to be performed, and
- the work equipment to be used, such as tools and devices.

When determining the work steps, possible hazards have to be minimized by protective measures. If new hazards occur during the works, they have to be minimized as well by risk assessment and additional protective measures.

The maintenance instructions should include at least the following:

- notices on systematic troubleshooting (see section 3),
- provision of components that may need to be replaced, special tools, and aids,
- securing the circuit breaker of the energy supply, for example electrical, hydraulic, pneumatic,
- reduction of residual energies (in connected parts as well),
- supporting elevated loads,
- method(s) for depressurizing the system,
- checking the depressurized condition,
- if required, further protective measures to be taken (see Annex 1 letter B).

Safe access to the points of contact and to safe standing surfaces has to be provided for performing the maintenance works, e. g. work platforms, other platforms.

The most important safety measures for maintaining hydraulic systems can be summarized in the **five-finger rule of fluid power technology:**

Note

Five-finger rule of fluid power technology

1. Interrupt energy supply.
2. Prevent unintentional re-closing (figure 3).
3. Depressurize the system, including all existing accumulators, lower or support elevated loads, reduce residual energies.
4. Check depressurization.
5. Prevent hazards caused by adjacent systems.

If several persons work together during the maintenance work on a hydraulic system, one of them has to be held responsible for determining, monitoring and coordinating the work and the protective measures.



Fig. 3 Securing against unintentional re-closing by lockable ball valves.

Along with the direct hazards caused by the hydraulic system, secondary hazards have to be taken into consideration as well, e. g. risks of falling from heights.

In order to improve occupational safety for maintenance works on a systematic basis

- the causes of faults and failures should be documented and evaluated,
- the implementation and effectiveness of measures taken should be checked,
- work implemented should be documented,
- risk assessments and maintenance instructions should be checked and updated, if required, and
- any technical modifications implemented should be recorded in the documentation of the machine or system.

2 Handling hydraulic fluid

2.1 Skin protection

Maintenance technicians for hydraulic systems are used to having „dirty hands“ at work. The intensive daily skin cleansing procedure is tolerated apparently without any problems, so that normally, only little thought is given to the question whether the skin – the largest human organ – tolerates this without being damaged in the long run. The alloy components and additives contained in the oils and fats can have allergizing or sensitizing effects.

A lack of consciousness for the aforementioned is one reason why skin diseases range amongst the most frequent work-related diseases in metal-working companies.

The organ skin is the link between the human immune system on the one hand and the „external world“ on the other hand. Especially the fats on the external skin layer form an efficient but vulnerable protection against harmful influences. Frequent washing, especially with substances solving the fats, damages this protective layer. If the body is no longer able to repair these damages within the work breaks, the result is dry skin with formation of ruptures and redness, shortly, the „wear eczema“. Secondly, often an “allergic eczema” additionally „engrafts“ during the further course, as substances potentially causing allergies can intrude into deeper regions of the skin organ more easily if the skin is already damaged. Depending on the personal disposition, such reactions can occur a relative short time upon the first skin exposures or upon many years or decades of executing skin exposing activities.

If a work-related allergic skin disease has established, the consequences – professional and private – are often serious. As contact with substances causing allergies normally cannot be prevented completely, losing the job is possible.

No.: 000 Sample

Operation:

Field of application:

Workshop, warehouse

Operating instructions according to §14 GefStoffV

(German Ordinance on Hazardous Substances)

Date: 27.01.2012

Hydraulic oils

Hydraulic oils with high viscosity: Highly refined mineral oils with additives

Hazards for human beings and the environment

Hydraulic oils are flammable. In connection with air, vapors emitted during strong heating and atomized sprays can form explosive mixtures. Clothes soaked with oil are subject to an ignition hazard.

Frequent or long-term contact with the products, also through clothes soaked with oil, can cause skin diseases such as inflammation, skin rash, petroleum acne for example.

Products subject to high temperatures while being used can accumulate harmful substances.
Leaking hydraulic oil is hazardous to waters.

Protective measures and rules of conduct



Store and fill hydraulic oils above drip pans only, avoid splashing.
Do not overfill drip pans with containers and do not use drip pans to store other materials.
Keep away from ignition sources, do not smoke. Do not atomize lubricants.
Keep containers closed and protect against heating.
Store soaked cleaning cloths in non-inflammable, closed containers.
Replace cleaning cloths on a regular basis.

Label filled containers, replace faulty labels.

Never use food containers or containers that could possibly be confused with them.



Hand protection: for long-term, use resistant gloves protecting against chemicals

Skin protection: see skin protection scheme

Avoid contact with skin and clothes.



Take off soaked clothes immediately and only re-wear them upon cleansing.

Do not put used cleaning cloths into the pockets of the working clothes.
Upon handling the materials wash your hands and apply care creme.
Do not use any solvents, thinners, benzine or others for skin cleaning purposes.

Behaviour in case of danger (emergency telephone: see placard)



Upon leakage immediately soak up using oil binder (.....) and place into waste container; ventilate room thoroughly. Caution: Slip hazard due to slippery floor.

Fire extinguisher for fire class B, no water. .....

In case of fire there is the danger of bursting of closed heated containers.

Leave oil warehouse in case of danger.

Escape route: see identification of the escape routes and emergency exits





First aid (first aider: see placard)



Upon skin contact:	Wash thoroughly using soap and water, take off soaked clothes beforehand.
Upon eye contact:	With open palpebral fissure and in direction of the external palpebral fissure flush for 10 minutes with running water, contact eye specialist.
Upon swallowing:	**Do not stimulate** vomiting, contact a doctor.
Upon oil injection:	E. g. upon subcutaneous intrusion of oil **contact doctor immediately!**

Appropriate disposal

Collect wastes in labeled, non-inflammable containers (.....); keep waste containers and empty containers closed, empty containers at the end of the shift at the latest or remove from the work area.

Date, Signature: .....

Fig. 4 Sample of operating instructions for hydraulic oil

What can be done?

There are many options for maintaining a mostly healthy skin even during strongly contaminating activities. Firstly, the most important precondition is that everybody develops the proper understanding for the vulnerability of his or her own skin.

The entrepreneur is responsible for regulating skin protection within the company, e. g. using a skin protection scheme (see figure 4). In doing so, specialists (company physician, supervisor) should be integrated and corporate experience should be taken into consideration.

2.1.1 Work clothes

No special protective clothes are specified for the maintenance technician for hydraulic systems. Work clothing worn and contaminated in addition to or to protect the private clothes have to be cleansed on a regular basis. There should be at least two, better three overalls for every maintenance technician, in order to provide for immediate replacement even in case of unforeseeable contaminations with hydraulic fluids.

Note

Contaminated clothes have to be taken off immediately.

Contaminated cleaning rags must not be put into the trousers.

Naturally, the hands have the most intensive contact with the possibly harmful substances. Appropriate protective gloves provide best protection (see figure 5). Appropriate means that they are especially resistant regarding the substances they are supposed to protect against. For handling hydraulic, machine, motor, and transmission oils, gloves consisting of the following materials are considered appropriate:

- acrylonitrile butadiene, rubber, nitrile rubber, nitrile latex (NBR),
- chloroprene rubber (neoprene) (CR),
- isobutylene isopropene rubber (rubber) = butyl rubber, butyl (IIR).



Fig. 5
Personal protective equipment for oil change

Different tasks for maintenance works require the normal protective clothes to be supplemented, e. g.
- **overhead works:** gloves with cuffs,
- **troubleshooting and leakage tests:** helmet with visor,
- **component replacement:** one-way trousers type 4.

Note

No gloves must be worn in the vicinity of rotating parts.

2.1.2 Skin agents

This generic term comprises:
- skin protection agents,
- skin cleansing agents, and
- skin care agents.

The harmful substances to be expected are substances insoluble in water. Some statutory accident insurers and skin care agent manufacturers developed skin protection schemes differing in content and color in dependency on the effects of individual harmful substances. The yellow skin protection scheme, shown in figure 6, lists a selection of appropriate skin protection agents, skin cleansing agents, and skin care agents to be used in case of contact with substances insoluble in water.

Basically, the objective should be to clean the skin as gently as possible, as well as to provide the skin especially with fat and moisture after work, along with the appropriate skin protection agent. Using appropriate skin protection agents or protective gloves as consequently as possible reduces or prevents contamination of the skin and thus allows for using more gentle skin cleansing agents.

		Skin protection and hygiene scheme „maintenance“			
		Gloves	Skin agent for		
			Skin protection	Skin cleansing	Skin care
					
Skin contact to hydraulic fluids that cannot be mixed with water		Sahara 100 Dextram 376 Contact NB20C SolVex 37-675	Lindesa O Liga pro Herwesan Olio Sansibon pr 88 Travabon	Lindapur plus Ivraxo soft B Herculan Topscrub pr clean plus Praecutan plus	Lindesa Ligana HPC Herwe Cura Cura Soft pr 2000 Stokolan
Products taken from: DGUV Information 209-022 “Hautschutz in Metallbetrieben”, (Skin protection in metal processing companies) 11/08 (The list makes no claim to be complete)					

Fig. 6 Skin protection and hygiene scheme

2.1.3 Use of skin agents

Skin agents can only achieve the desired success if all three skin agents (skin protection, skin cleansing, and skin care agents) are used

- on a regular basis (daily, before starting to work, before and after breaks, and after work), and
- properly (see manufacturer’s instructions).

2.2 Leaking hydraulic fluid

Leakages of hydraulic fluid have to be prevented, as oiled work surfaces and treads on machine platforms, as well as oiled workshop floors bear slip dangers, tools could slip more easily on wrench surfaces or parts, and fire hazards could be the result. As personal protection equipment worn gloves have to be kept free of hydraulic fluid or replaced.

In order to avoid wetted machine platforms or vehicle treads, appropriate drip pans are useful. This also includes adapted pans for maintenance work on the mobile hydraulic system outdoors or on construction sites. Removed hydraulic components such as pumps or valves still contain residual amounts of hydraulic fluid and have to be stored intermediately in sufficiently dimensioned pans.

Inserting drip pans into the workshop floor below the machines prior to their installation provides for efficient protection against slip dangers on workshop floors.

If required, oil binders, sweeping equipment, and disposal containers have to be taken to the danger spot immediately, in order to hold leaked hydraulic oil and thus eliminate slip hazards. Oil absorbing cloths help to remove residual oil in machine parts.

Note

Leaked hydraulic fluids have to be removed immediately and completely.



Fig. 7
Trolley for transporting oil binders

In order to reduce leakages of hydraulic fluids, some machine manufacturers permit using vacuum pumps (see figure 8) generating a slight vacuum in the hydraulic tank upon closing all tank air vents using a connection via special tank covers.

In case of a fire hazard, oil binder shall only be used, if it is appropriately removed directly after use.

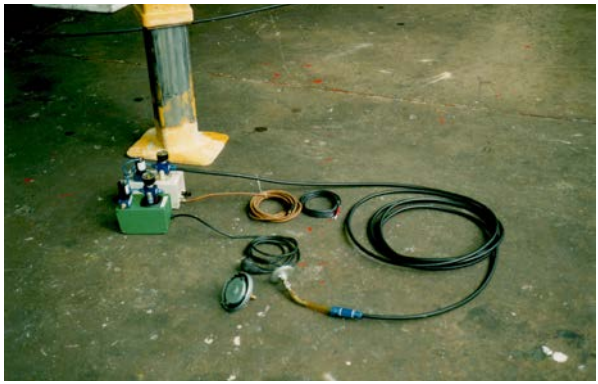


Fig. 8
Vacuum pumps for mobile hydraulic tank in 24 VDC and 230 VAC design

2.3 Searching for leakages

Searching leakages on machines has to be conducted systematically at reduced system pressure, if possible, and with personal protection equipment, e. g. gloves, protective rubber clothes, goggles, or helmet with visor, and by using aids such as blotting papers.

It has to be taken into account that the hydraulic fluid leaking from the leakage points (cracks, fissure) under high pressure causes very serious injuries or intoxications when coming into contact with the human body! Even the use of protective clothes, including protective gloves, does not provide for complete protection.

Note

In any case, keep away from possible leakage points.

2.4 Replacing the hydraulic fluid

The hydraulic fluid used has to comply with the provisions of the machine manufacturer or the system or component manufacturer. In this, the materials of the sealing elements used have to be taken into consideration.

When replacing the hydraulic fluid attention has to be paid to the fact that no contamination enters the tank or other parts of the hydraulic circuit. In order to achieve the desired cleanliness class, freshly delivered hydraulic fluid has to be filtered as well.

3 Troubleshooting

Naturally, preventive maintenance and repair measures, especially checking the oil cleanliness on a regular basis, are the best method to minimize errors and failures in the run-up already. Nevertheless, errors and failures can occur when operating a hydraulic system or machine, which impair the general operational sequence but also the safety of the hydraulic system or machines.

Apart from the impairment of the product quality, this can lead to hazards (see section 1.3) which no longer ensure safe working with the machine.

Thus, it is important that the machine operator reports all failures and errors to the supervisor or the maintenance department immediately. These persons decide whether it is possible to continue work with the machine or whether the machine has to be repaired immediately.

Note

Errors in hydraulic systems or machines have to be reported to the supervisor immediately.

Before starting troubleshooting, the procedure has to be determined. Along with planning the proper troubleshooting, this also comprises the measures for securing the work area (i. e. the danger and effective range), as well as the required protective measures.

Note

Troubleshooting and repair works must only be conducted by trained personnel.

At the beginning of troubleshooting, the required technical documents and information should be available, e. g. operating instructions, circuit and electrical diagrams, including measuring points and a list of items. If no hydraulic circuit diagram can be found for older systems, a circuit sketch should be established on the basis of design, signposting, and labeling of the parts.

The machine operators should be questioned regarding error behavior, failures, and reactions of the machine and system. If a maintenance book or log exists, it should be used to investigate if this or similar failures have already occurred. Furthermore, the error lists in the operating instructions of the manufacturer have to be taken into consideration.

Note

For troubleshooting, the technical documents of the system/machine have to be available.

If troubleshooting requires working methods which deviate from those applied for normal operation, e. g. test runs, setting, start-up, or is it necessary to run one cycle or several cycles with the defective machine in order to localize the errors, it has to be ensured that safeguarding equipment (movable safeguarding equipment, two-hand control devices, light barriers) on the machine is active in this phase as well. On the basis of the error that occurred, further machine-specific measures (and organizational measures) may have to be taken in order to avoid employees being endangered during troubleshooting (wide area safety fence using chains, instruction plates, reduced speed, and reduced pressure).

During troubleshooting, operating modes should be applied in which individual functions are operated outside the automatic operation at reduced speed, in tip operation (hold-to run control device), with enabling switch, or in the operating mode „Set-up/Hand“.

Attention must be paid to the fact that dangerous follow-up movements are triggered when passing position switches, e. g. also for automatic program-controlled tool or work piece change, start-up of accessory devices.

Note

Troubleshooting must only be conducted with activated safeguarding equipment.

If required, further organizational measures are necessary.

If troubleshooting also can be done with the machine turned off or if the machine is turned off for error correction upon localizing the error, the five-finger rule mentioned in section 1.5 has to be observed.

Note

Observe the five-finger rule of fluid power technology.

If the control system is not a purely hydraulic system, but the hydraulic system is operated as part of an electro-hydraulic control system, it may be necessary to have the troubleshooting procedure conducted by a specialist electrician. In case of complex systems operated with electronic control systems, it may also be necessary to call a specialist for electronic hardware or software. In this case, if several persons work on the machine for troubleshooting purposes, it is imperative to provide for sufficient coordination of the activities on the machine. This especially holds true if the machine operator has to be incorporated into the activities.

Furthermore, hazards caused by adjacent systems or hazards to persons working on adjacent systems have to be prevented.

Note

For electro-hydraulic systems, a specialist for electrical engineering or electronics has to be called.

Activities of several persons have to be coordinated.

Even when pressed for time, following a systematic and targeted procedure is imperative, as a random and rash disassembly or adjustment activities could result in the fact that the initial error cannot be identified anymore.

It is recommended to document the implemented work steps, adjustment values, as well as their modifications. All modifications to the system have to be documented in a traceable manner, e. g. in the machine documentation and, if required, in a maintenance book or log.

A list of eliminated failures and error causes supports troubleshooting procedures in the future.

Many hydraulic system manufacturers have developed comprehensive service information in which they describe systematically possible malfunctions and their causes or possible sources and measures for eliminating them as the technical reasons for errors and the measures for their elimination can vary considerably.

Annex 1 letter A shows a general troubleshooting tree for hydraulic components.

Typical errors include for example:
- clogged hydraulic filters,
- stuck valves due to contaminations,
- unexpected start-up of the machine due to tipping/triggering position/stop switches
- failure of valves due to spring rupture.

The reason for part failure should be determined.

Notes:
If the hydraulic energy has to be maintained for troubleshooting or due to other reasons, the provisions of the manufacturer have to be observed.
Regarding the re-commissioning procedure, further safeguarding measures have to be observed, see sections 5.1.2 and 6.1.9.

4 Working on hydraulic components

4.1 General

When working on different hydraulic components, numerous safety-relevant aspects have to be considered by the maintenance technician. Sections 5 and 6 deal with the particularities for certain machines and systems, and those for the mobile hydraulic system.

Basically, only spare parts approved by the manufacturer should be replaced or installed.

It is imperative to observe provisions and notices of the manufacturer regarding special knowledge or training of the maintenance technician.

The hydraulic system has to be protected against contaminations introduced from the outside as far as possible. Flushing provisions specified by the manufacturer have to be observed. Spare parts to be installed have to be free of contaminations.

All parts installed by the maintenance technician have to be selected in accordance with the operating pressures and hydraulic fluids.

Due to the partially relatively large masses or the installation position and the position of the center of gravity of hydraulic components, suitable lifting gear and lifting accessories must be provided for disassembly and assembly and for transportation.

If it is possible to confuse line connections, these have to be marked clearly by the maintenance technician before being disconnected.

It is imperative to observe the provisions of the manufacturer regarding commissioning after completed maintenance works.

4.2 Pipelines

Pressurized fittings of pipelines must not be opened.

If pipelines are replaced, standardized seamless cold-drawn precision steel pipes have to be used. When selecting these pipes, the requirements of the machine manufacturer with regard to material characteristics, wall thickness, cross sections and the admissible operating pressures have to be observed (see parts list).

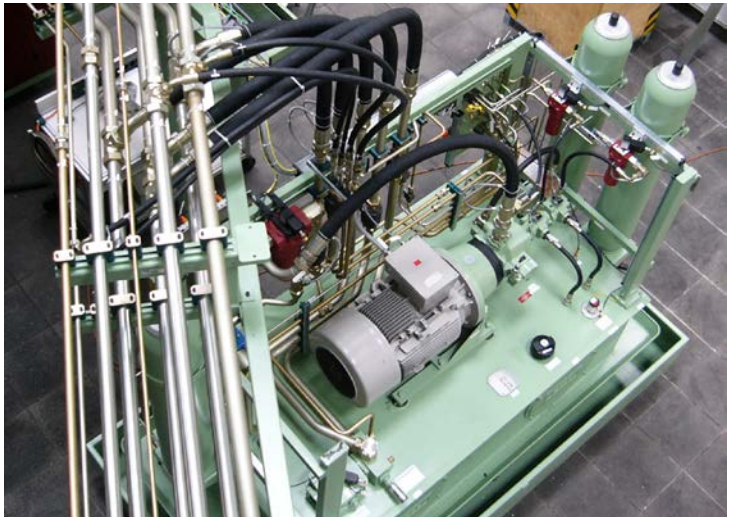


Fig. 9 Central hydraulic system at commissioning

Some connection element manufacturers rate the nominal pressures in deviation from the standards. Thus, parts having the same dimensions can be characterized by substantial differences regarding the nominal pressures. Similar thread sizes of different systems (metric/imperial) must not be confused!

Note

When procuring spare parts attention must be paid to the fact that parts having the same dimensions can be characterized by different nominal pressures and thread types!

If pipelines have to be re-routed within the framework of maintenance work, they have to be attached by pipe clamps in an adequate manner.

The following distances are recommended:

External pipe diameter	Recommended spacing[1] between two pipe clamps (according to DIN EN ISO 4413)		
	From a pipe connection	Between two supports in the case of a straight pipe	From a pipe bend
up to 10 mm	0.05 m	0.6 m	0.1 m
over 10 mm to 25 mm	0.10 m	0.9 m	0.2 m
over 25 mm to 50 mm	0.15 m	1.2 m	0.3 m
over 50 mm	0.20 m	1.5 m	0.4 m

[1] Reproduced by permission of DIN Deutsches Institut für Normung e. V. For applying the DIN-standard, the recent issue which can be obtained from Beuth Verlag GmbH, Burggrafenstraße 6, 10787 Berlin, Germany is decisive.]



Fig. 10 Proper attachment of pipelines with pipe supports

In doing so, it has to be observed that the pipeline is not damaged, e. g. attaching it by welding is inadmissible. No other parts must be attached to pipelines.

The pipe elbows have to be bent taking into account the details regarding the bending radii and the use of appropriate devices (e. g. pipe bending machine). The pipes must not be buckled when they are bent. Pipes subjected to heat treatment have to be cleansed and descaled.

Before being installed, pipeline components always must be deburred, cleansed, and installed in accordance with the provisions of the fitting suppliers.

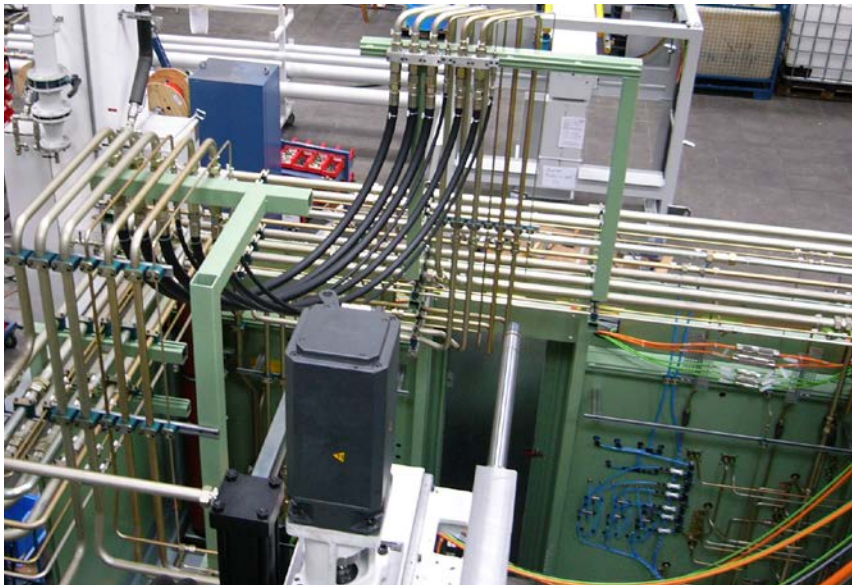


Fig. 11 Pipeline routing in a large machine

If line connections can be confused, they have to be marked clearly and permanently by the maintenance technician before being disconnected.

During assembly, the newly installed connections have to be tightened in accordance with the manufacturer's instructions, e. g. using the torque wrench or according to specified angle of twist, in order to avoid shear forces and tensions.

Pipelines and fittings have to be checked for leaks up to maximum operating pressure before they can be approved.

If pipeline fittings show leakages, these have to be remedied. For this, depressurized condition has to be established first. Afterwards, the following measures can be implemented:

- Checking the tightening torques of fittings,
- checking the tightening torques of flange connections,
- replacing the seals.

4.3 Hose assemblies

4.3.1 General

Hose assemblies are only used on machines and vehicles, if hydraulic connections are required between moving parts of a hydraulic system or if an easier replacement of power units (e. g. auxiliary power units on earth-moving and farm machines) is wanted (see figure 12). Using hose assemblies can also reduce pressure peaks in the hydraulic system or compensate vibrations between individual parts.

In general, hoses consist of an elastomer compound of internal and external rubber layer and pressure carriers consisting of one or several layers.



Fig. 12
Hydraulic hose assemblies on an excavator

Plastic hoses are used as well having technological advantages and disadvantages (see also section 4.3.9).

The term hose assembly describes the assembly and the unit of hose and fitting mounted afterwards.

Hose line = Hose + Fitting

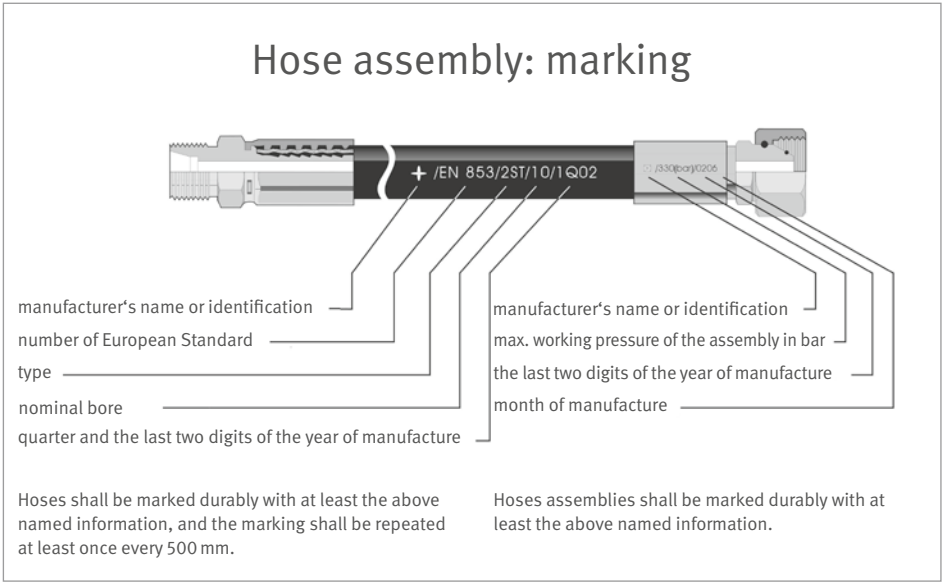


Fig. 13 Structure and labeling of a hose assembly

Faulty integration, ageing, and mechanical damage can result in the hose assemblies bursting. Thus, corresponding care should be exerted when selecting, assembling, mounting, and operating hose assemblies.

A hose has to be labeled consecutively and durably as follows, see DGUV Regel 113-020 “Hydraulik-Schlauchleitungen und Hydraulik-Flüssigkeiten – Regeln für den sicheren Einsatz” (Hydraulic hose assemblies and hydraulic liquids – Rules for safe use):

- manufacturer sign,
- hose type,
- nominal width,
- date of manufacture (quarter and year), as well as the
- number of the relevant hose standard.

A hose assembly has to be labeled durably as follows:

- manufacturer’s name or short sign,
- maximum operating pressure with indication of the unit,
- date of manufacture (year/month), see also DGUV Regel 113-020 or DIN 20066 “Fluidtechnik – Hydraulikschlauchleitungen” (Hydraulic fluid power – Hose assemblies – dimensions, requirements).

Note

Hoses and hose assemblies of unknown origin and/or with incomplete marking must not be used!

4.3.2 Selection of hose, fitting, and hose assembly for replacement

In principle, hoses have to be replaced in accordance with the manufacturer’s instructions. If no manufacturer details are available, the following procedure has to be followed:

Hose, fitting, and hose assembly have to be selected in such a way that

- the admissible maximum operating pressure of the individual components is not exceeded for the operating conditions to be expected taking account of pressure peaks,
- the operating pressures for which the control system has been designed are taken into account,
- the thermal resistance is ensured,
- changes in lengths and outside diameters of the hoses were taken into account,
- the minimum bending radius is adhered to (depending on hose type and nominal width),
- abrasion characteristics are considered,
- the cross-sections are sufficiently dimensioned, so that no inadmissible dynamic pressures are generated that for example could impair the free return flow to the tank,
- the compatibility of hose and sealing materials with the hydraulic fluid used is given,
- only parts are used that comply with the requirements of European or international product standards, such as EN, ISO, SAE standards,
- designs of hose assembly fittings consisting of a (drilled) pipe socket with olive are not used, as they do no longer correspond to the state-of-the-art and led to accidents due to slipping tools in the past.

Note

It has to be checked, if the hose assembly is suitable for the intended use regarding pressure and flow.

4.3.3 Creating a hose assembly

It is recommended to purchase hose assembies as fully assembled parts.

If a hose assembly is self-made, it has to be observed that the selected parts (hose and fitting) are compatible regarding their dimensions, shape, and pressure stage. For this, it is imperative to observe the provisions of the manufacturers of hose and fitting. Proof of safe function must be furnished by an appropriate test procedure (see section 4.1.2 of DGUV Regel 113-020).

If the integration is self-conducted, only equipment and devices approved by the fittings manufacturer must be used for this purpose (see figure 14). A safe hose integration furthermore implies detailed knowledge of the integration procedure, the devices, and parts. Conducting the integration without this knowledge and without these devices is negligent and inadmissible from a safety point of view.

The so-called “improvised cobbling together” of hose assemblies on the bench vice is negligent!

Note

Hose assemblies should only be purchased from the hose assembly manufacturer in pre-assembled state.



Fig. 14 Device for pressing hose fittings

Fig. 15 Hose assemblies in natural position on a test cell

4.3.4 Installing the hose assembly

In order to ensure the functionality of hose assemblies and to not shorten their lifetime due to additional loads, the following has to be observed.

1. Hose assemblies have to be installed in a way that their natural position and movement is not impaired (scour marks have to be avoided), see also figure 15.
2. Hose assemblies must not be subject to tensile, torsional, and compression loads caused by external influences during operation.
3. The smallest bending radius of the hose specified by the manufacturer must not be fallen below.
4. If possible, hose assemblies have to be protected against damage caused by external mechanical, thermal, or chemical influences.
5. Varnishing hose assemblies should be avoided since the outer hose layer may be impaired in its properties of use due to reactions with varnish and the detectability of the marking and possible cracks may be prevented. Hose assemblies should be protected prior to varnishing the machine parts by masking off or a film cover.
6. Possibly present safeguarding measures on the machine have to be re-attached upon installation of the hose assemblies, e. g. safeguarding covers. The initial protected installation position has to be restored.

DGUV Regel 113-020 or DIN 20066 provides an overview of essential installation criteria.

Note

When installing hose assemblies, it is imperative to observe the installation instructions of the hose manufacturer, e g. minimum bending radii.



4.3.5 Regular check of hose assemblies

Due to ageing, wear and tear, and damage the hose assemblies have to be checked on a regular basis.

For this, the hose assemblies have to be checked for external deficiencies (visually) by an authorized person (see also TRBS 1203) at least once a year; see also DGUV Regel 113-020. Related specified provisions of the manufacturer have to be observed.

Further notices regarding authorized persons (formerly known as technical experts), tests, and test intervals, see section 7.

These tests have to be documented together with the date in a test log, e. g. when testing the machine (see also TRBS 1201).

The test criteria are:
- leakages on the hose, the hose assembly, or the fitting,
- the hose coming out of the fitting,
- damage or deformations to fittings reducing the functionality and strength of the fittings or of the connection fitting-hose,
- damage of the external layer up to the insert (scour marks, cuts, cracks),
- embrittlement of the external layer (formation of cracks in the hose material),
- deformations not corresponding to the natural shape of the hose assembly, in pressurized or depressurized condition or when being bent, e. g. layer separation, formation of bubbles, pinch points, knees,
- corrosion of the fitting reducing the functionality and the strength,
- Can the hose assemblies still move freely or are there pinch, shear, or scour points caused by attaching new parts of the system or power units?
- Is it ensured that hose assemblies do not project into traffic paths, even when the power units connected via hose assemblies are driven to their respective end positions?

- Have hose assemblies been varnished (explanation: cracks and labeling cannot be seen!)?
- Have the storage periods and the lifetime been exceeded?
- Have all covers been re-mounted after the test?
- Are additional stripping protections provided or are they required?

Note

Hose assemblies have to be checked at regular intervals.

Hose assemblies shall not be patted by hands when being checked

4.3.6 Faulty hose assemblies

If deficiencies regarding the safe condition of a hose assembly are detected during the test, the relevant hose assembly has to be replaced. Figure 16 shows some faulty hydraulic hose assemblies. Hose assemblies must not be repaired and must not be assembled from old parts.

If several hose assemblies are replaced simultaneously, it has to be ensured that the connections cannot be confused, e. g. by marking them.

Note

Faulty hose assemblies have to be replaced immediately!



Fig. 16
Examples of failed hydraulic hose assemblies

4.3.7 Lifetime of hose assemblies

Basically, hoses and hose assemblies are subject to a natural ageing process even if they are stored properly (according to section 4.6.2 of DGUV Regel 113-020) and operated under admissible loads. This ageing process reduces the performance of the hose assemblies. Thus, the lifetime of a hose assembly is limited.

The possible lifetime (i.e. period of use) of hose assemblies especially depends on the operation and environmental conditions. Due to the wide range of applications for hose assemblies, it is thus not possible for technical reasons to specify a binding, maximum admissible lifetime in safety rules and regulations and standards.

The instructions of the hose and hose assembly manufacturers regarding the maximum storage time have to be observed. When producing the hose assembly, the hose should not be older than four years.

When determining the lifetime for the corresponding hose assemblies used on a machine, the user first and foremost has to base his decision on the replacement intervals recommended by the machine manufacturer, but also on his or her own experience regarding the individual operating conditions. This especially holds true when the lifetime recommended by the manufacturer is exceeded. Prolonging the lifetime is possible if

- corresponding test values and experience on part of the machine manufacturer, the operator or the hose and hose assembly manufacturers are available,
- a risk assessment has been conducted and documented by the operator that considered secondary safeguarding measures against hazards caused by hose assembly failures as well, and
- the test for safe condition is carried out at appropriate and fixed intervals and by an authorized person.

For the recurring test it should be clarified, if the preconditions that lead to the determination of a certain lifetime have changed, e. g. higher system pressures, changed location of installation. In this case, a risk assessment has to be carried out.

It is absolutely recommendable to shorten the test intervals, e. g. to biannually or quarterly (instead of at least annually), when prolonging the lifetime.

Unless there are other specifications regarding the lifetime of hydraulic hose assemblies, six years are recommended as reference value, see also DGUV Regel 113-020.

4.3.8 Securing the environment in case of hose assembly failures

In general, hose assemblies perform their task without any problems when they are designed and selected properly, produced carefully, and installed correctly.

However, it has to be considered that failures of hose assemblies, e. g. near work stations and traffic paths, can lead to hazards, e. g.:
- leakage of hydraulic fluid at high pressure,
- lashing, and
- fire hazard.

Thus, additional measures for safeguarding the environment in case of hose assembly failures have to be taken at those points, e. g. by means of additional stripping protection or screening (see figure 17).

Special protective hoses for hydraulic hose assemblies can, if properly dimensioned and installed, contribute to a reduction of risks caused by ejected hydraulic fluid jets. The protective hoses must not be closed on both ends in order not to impair their protective effect. The cross-section has to be sufficient. This makes the protective hose to function as intended.

Safeguarding measures against hose assembly failures are not imperative if there is no hazard, e. g. by hose assemblies routed within machine enclosures.

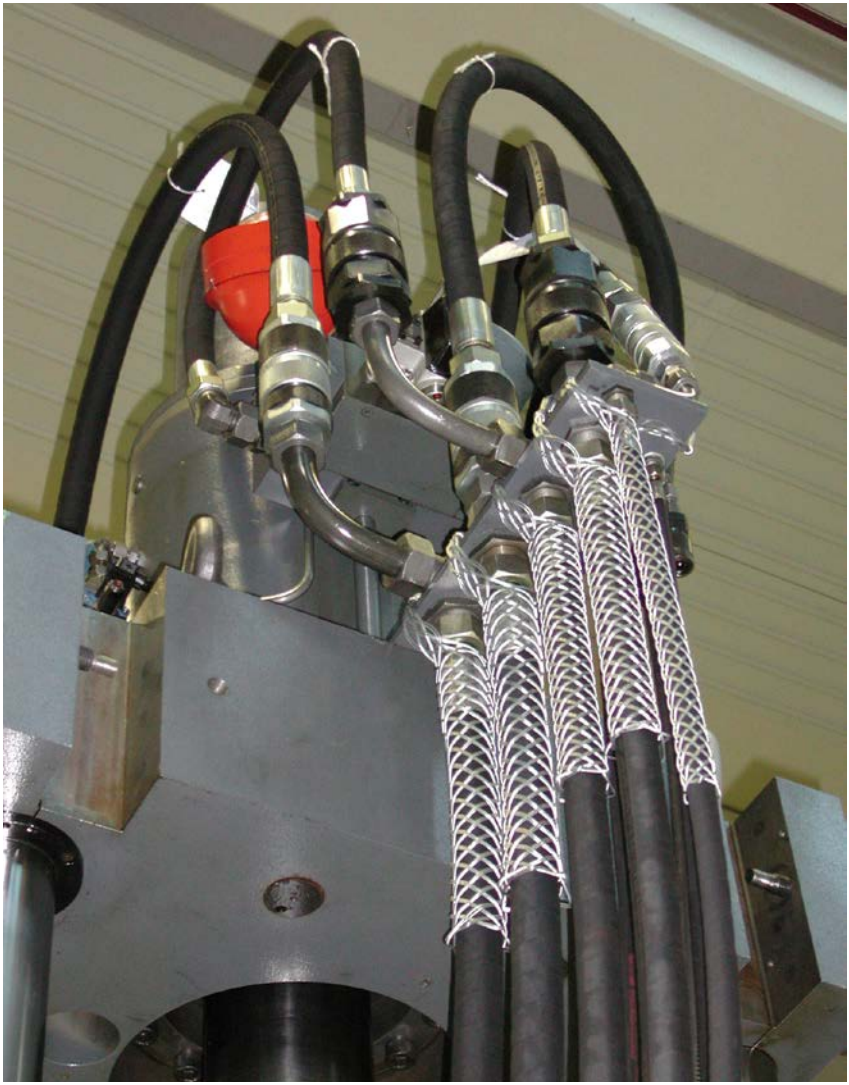


Fig. 17 Stripping protection on hose assemblies

4.3.9 Particularities of plastic hose assemblies

Plastic hose assemblies are used more and more on machines with confined installation conditions, on mobile devices, and in the chemical industry.

Some technological **advantages** of the plastic hose assemblies can be:
- 20 to 30 % weight reduction,
- reduced external diameter and minimum bending radius,
- higher milling and abrasion resistance,
- good resistance against diverse chemical substances, as well as
- low sensitivity regarding water-containing cooling lubricants,
- no or only low influence of ageing during storage time before use,
- relatively low price, especially for small nominal widths.

Some technological **disadvantages** of the plastic hose assemblies can be:
- higher breathing volume,
- higher loss of elasticity after longer periods of use,
- lower torsional strength, thus twisting possible during installation,
- higher sensitivity regarding mechanical damage, especially if pressure carriers consist of plastic yarn meshwork,
- higher sensitivity regarding UV radiation, thermal radiation, and liquid metal, e. g. welding beads,
- higher sensitivity of the external layer regarding cutting oils (however, depending strongly on the material).

The above mentioned advantages and disadvantages of plastic hose assemblies have to be taken into consideration during design, selection, and installation. Regarding lifetime, replacement, and installation, section 4.3.7 applies.

Possible exclusions regarding the use on the part of the manufacturers have to be observed.

4.4 Hydraulic cylinders

Before starting to replace hydraulic cylinders, they have to be free of all forces, e. g. caused by elevated loads. Furthermore, it has to be paid attention to the fact that depressurization is implemented on both the piston and the rod side (see figure 18).

The technical data of replacement cylinders have to comply with those of the types to be replaced.

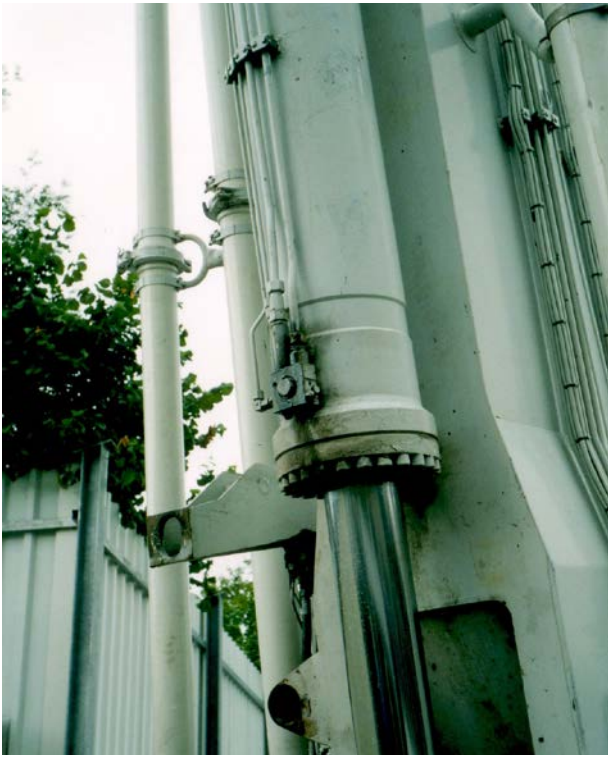


Fig. 18
Hydraulic cylinder with pilot-operated check valve

In order to prevent unforeseeable sudden parts movements caused by residual air in the cylinders, the latter have to be filled with hydraulic fluid and vented by several extracting and retracting procedures in idle in the service workshop or via the system hydraulics before they are installed. If this is not implemented automatically, the ventilation has to be implemented manually on the piston and rod side. In doing so, possibly existing bleeding screws have to be used. The fittings must only be re-tightened when the leaking oil is free of bubbles.

If sealing plugs are used after the hydraulic cylinders have been filled, it is important to remove them before installation. This is particularly important on the piston rod side, in order to avoid pressure transmissions.

If travel sensors or proximity switches exist at the cylinders, the electrical cables have to be connected properly. If electrical cables run the danger of being confused, they have to be marked before they are disconnected.

Sealing sleeves of leaky hydraulic cylinders must be replaced in accordance with the provisions of the manufacturer only.

When replacing the hydraulic cylinder, a possibly existing piston rod protection, e. g. sleeve or sheet metal cover, has to be re-installed after installation.

After having replaced a cylinder of a clamping device in particular, the machine or the system must be approved for the operator after sufficient test runs only.

In order to attach cylinders, parts approved by the manufacturer must be used only (such as screws in the required property class). The details regarding thread design and screw-in length have to be observed. When working on parts of a hydraulic cylinder, including seals, cleanliness has to be top priority.

4.5 Pumps and hydraulic motors

When replacing hydraulic pumps and motors, large quantities of hydraulic fluid can leak out. In order to prevent the slip hazard, appropriate collection containers (see figure 19) have to be kept at hand.

Connections and attachments of the depressurized hydro pump or the hydro motor have to be loosened in accordance with the manufacturer's instructions. In order to avoid confusions, connections and lines have to be marked before disconnecting them. Openings of lines and motor-side flanges have to be protected against contaminations.

Installing, filling, starting-up, venting, and adjusting hydraulic pumps and motors should be carried out in accordance with the manufacturer's details in the operating instructions. The direction of rotation of the pump has to



Fig. 19 Mobile hydraulic pump in an oil drip pan

be observed during the installation procedure. When installing the electric motor, care must be taken to ensure the proper electric connection (rotating field).

When assembling pump, suction line, and tank care must be taken that the suction filter is installed properly.

The safeguarding equipment has to be re-installed before commissioning.

4.6 Valve blocks

In order to prevent confusions, the individual connections of the valves or stacking assemblies of valve blocks have to be numbered or marked before being disassembled (see figure 20).

Valves must be installed and demounted exerting the utmost care and cleanliness only. During the installation, the O-ring sealing elements within valve stacking assemblies have to be checked for proper seat. Defective seal elements must be replaced immediately.

All technical data (including wiring symbols and settings) of replacement valves have to comply with the provisions of the manufacturer or with the data of the type to be replaced.

The valves/valve blocks have to be assembled observing the order of the stacking assembly. In doing so, the installation position specified by the manufacturer has to be observed. The selected attachment screws have to comply with the dimensions and strength classes specified in the valve data sheet. The screws have to be tightened evenly and exactly to the torque specified in the valve data sheet as well.



Fig. 20 Marking hydraulic valve blocks

When replacing faulty switching solenoids on valves, the required voltages and performance details have to be observed.

Solenoids for 24 Volts operation do not execute the switching function when operated with 12 Volts, for example.

When installing replacement valves of other manufacturers, the electric pin assignments of the connection plugs have to be observed. These can be found in the related valve data sheet.

4.7 Accumulator systems

Accumulators are devices the manufacturer has to meet special safety provisions for. Furthermore, the operator of work equipment has to observe the provisions for the tests in accordance with the Ordinance on Industrial Safety and Health (see section 7).



Fig. 21
Warning note on accumulator system

As maintaining and filling accumulators with gas, measuring pressures, and testing upon commissioning require special knowledge, work on accumulator systems must only be conducted by especially trained maintenance technicians or by the manufacturer. It is imperative to observe the provisions of the manufacturer in the operating instructions.

Before working on the accumulator, the pressure in the accumulator has to be reduced, along with the pressure of the system hydraulics. This is implemented either automatically or via a manual pressure reduction feature at the accumulator safety block. A pressure indicator, e. g. pressure gauge, has to be used to check the efficiency of the depressurization procedure. It has to be observed that the accumulator may be under high pressure on the gas side. It may be required to reduce this pressure as well. Before the accumulator is removed from the system, both the fluid and the gas side must be fully unloaded.

Note

Due to risk of explosion, it is imparative not to use oxygen or air to fill accumulators.

New or repaired accumulators on oil-hydraulic systems may be delivered pre-charged with nitrogen (at low pressure of, e. g. 2 bar) on the gas side in order to protect the accumulator bladder against in-transit damage.

Before commissioning, these accumulators have to be charged to the charging pressure specified in the hydraulic circuit diagram using nitrogen.

When replacing the gas-side filling valve in the accumulator, only valves specified by the manufacturer (only genuine spare parts) may be used.

It is imperative to observe the notices in the operating instructions for filling the accumulator with nitrogen. The accumulator filling device comprises

- pressure reducing valve, connection line from the gas bottle/central gas supply to the accumulator with corresponding connections,
- accumulator-side port with pressure gauge,
- appropriate tools.

Neither welding nor soldering works and no mechanic processing may be implemented on accumulators.

On the basis of the special safety-relevance, accumulators have to be checked for mechanical damage.

After installation of the accumulator, the accumulator safety block has to be attached correctly and the accumulator (see figure 22) and possibly existing protective guards against external damage have to be re-installed properly.

4.8 Filters

Filtering the hydraulic fluid in a reliable manner is an imperative precondition for trouble-free function and long lifetimes of all hydraulic components and thus of the overall machine or system.

Filters have to be checked on a regular basis and replaced in accordance with the maintenance scheme or the clogging indicator. Figure 23 shows a filter unit with clogging indicator.



Fig. 22 Hydraulic accumulators

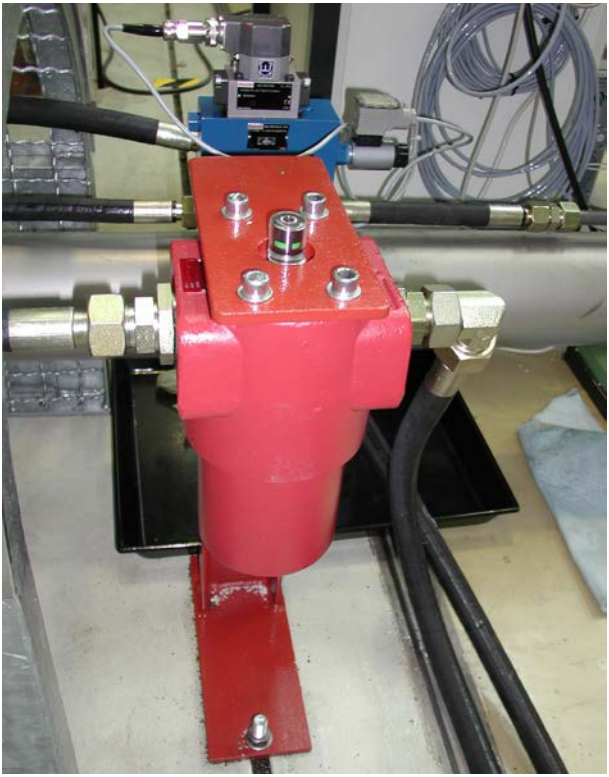


Fig. 23
Hydraulic filter with clogging indicator

Note

The check and replacement intervals of the filter systems have to be observed!

When changing filters, the pressure reduction, the risk of scalding by hot hydraulic oil, the prevention of dirt and water entering the system, the condition of seals and system bleeding must be observed.

In case additional filters are installed at a later point in time, they have to be installed in an easily to be maintained manner outside of the danger areas and must meet the requirements of DIN EN ISO 4413 (e. g. clogging indicator).

5 Working on machines and systems

5.1 General

Basically, the manufacturer's provisions in the operating instructions have to be observed.

Along with the basic general safety instructions for maintenance work and for handling hydraulic components (see section 4), the following section contains further notices for the safe hydraulic maintenance on stationary machines and systems (see figure 24).

5.1.1 Reducing hydraulic energy

Before starting to work, the hydraulic energy in the system has to be reduced. Re-closing of the system has to be prevented. If individual hydraulic circuits of the hydraulic system are separated from the common pressure supply, it has to be checked if the correct connection has been disconnected.

Furthermore, the accumulators connected to the hydraulic system have to be disconnected from the system or depressurized (see figure 25). The depressurization must not lead to new hazards, e. g. loosening of clamping devices. The complete pressure reduction has to be checked (see "five-finger rule" in section 1.5).

Despite the energy supply being switched off, hydraulically elevated loads, e. g. machine parts, work platforms, hydraulic vertical axes, cause a substantial pressure in parts of the hydraulic system. On more complex machines and systems, this pressure can transfer to further parts of the system. Thus, elevated loads, e. g. material to be conveyed or machine parts, have to be lowered, secured using existing locks, or supported in a safe manner before starting the maintenance work.



Fig. 24 Hydraulic power unit on stationary production facility

After reduction of all pressures supplied into the hydraulic system, it is possible that residual pressures still exist in trapped heads of fluid between valves and other parts. They have to be reduced as well, e. g. by operating the valves several times or in accordance with the manufacturer's provisions.



Fig. 25 Depressurized hydraulic accumulators with closed pressure lines

The opening of the screwed connections on hydraulic lines should proceed at first slowly and carefully after the depressurization took place. The further loosening of the screwed connections should be done carefully as well, in order to realize possible hazards caused by the still existing pressure of the hydraulic fluid in time (slightly knocking on the screwed connection is helpful) and to take protective measures. If pressure is still present, the screwed connection must not be loosened further. The depressurization in the system has to be repeated and the effects of this procedure have to be re-checked.

5.1.2 Re-commissioning

Upon completion of troubleshooting and correction of faults, the connections and parts have to be checked for compliance with the specifications of the circuit diagram. All loosened screws, line connections (see figure 26), and electric plug-and-socket connections have to be tightened and checked.

After completion of maintenance work, it must be observed that tank lines be re-opened, if they were closed before.

The following measures have to be taken to prevent hazards caused by possibly occurring machine malfunctions after completion of the repair work:
- Protective guards have to be brought to their protective position or activated.
- Protection by means of distance

After completion of the maintenance or repair work on the hydraulic parts these have to be filled and vented. The running-in and adjusting specifications have to be observed for the pumps in particular. Hydraulic pumps mostly are self-priming.

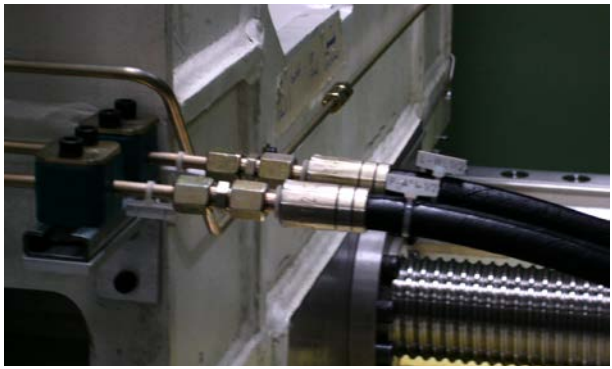


Fig. 26
Markings on pipe and hose side

Adjustment work on the pressure relief valves must only be conducted by the manufacturer or in accordance with the manufacturer's specifications, e. g. according to the pressure measurement sheets. It is imperative to adhere to the sequence of the procedure contained therein.

Incomplete venting procedures may lead to failures and hazards in machines and systems caused by suddenly starting movements. Venting the system completely prevents unforeseeable sudden movements of hydraulic cylinders and motors, e. g. stick slip.

After bleeding of the hydraulic system, all hydraulic functions have to be checked. In doing so, the specifications regarding safety have to be observed, e. g. reduced system pressure, screenings. When testing the hydraulic functions, it is important to keep sufficient distance as regards to reaching danger areas. It has to be ensured that neither the maintenance technician nor other persons stay below elevated loads or in danger areas.

All functions of cylinders have to be tested separately, if possible, at reduced speed and without loads.

Supports and safety measures for elevated loads must be removed only when the load is held safely by the hydraulic system again.

5.2 Working on machine tools

5.2.1 Clamping cylinders

Machine tools may have hydraulic clamping devices, the structure of which can be very complex in some cases (see figure 27). These clamping devices can clamp "actively" by hydraulic pressure and be supported by a hydraulic accumulator or they operate according to the closed circuit current principle

and generate the clamping force by spring tensioning. For releasing the clamped parts in the case of the closed circuit principle, spring tensioning is overcome through the use of a hydraulic cylinder. With this functional principle sudden pressure drops, e. g. due to hydraulic line failure, or a deadlock of the clamping system loosening suddenly as a result of the spring force can lead to pinch hazards for operators and maintenance technicians.



Fig. 27
Complex clamping module of a transfer line

5.2.2 Vertical slides on machine tools

Machine tools may have hydraulically elevated vertical axes or other axes loaded by gravity that are held in their position by means of hydraulic brake and holding devices. These vertical slides have to be considered in the same way as the elevated loads (see section 5.1.1).

5.3 Working on hydraulic presses

In accordance with the European Machinery Directive presses are classified as particularly dangerous machines. Thus, press manufacturers have to equip the machines with comprehensive safety technology. On the basis of this comprehensive safety technology the maintenance technicians for hydraulic systems have to familiarize with the particularities of these machines before starting any maintenance work.

Before starting any maintenance work the drive has to be switched off and an existing turn-off device has to be operated.

When working on hydraulic presses below elevated loads, e. g. upper die, the device has to be brought into the protection position against retraction of the slide at first. Normally, such devices are installed on presses with a bolster plate depth of more than 800 mm and a stroke of more than 500 mm. If the press is not equipped with such a device a support (see figure 28) has to be used that is able to accept the forces present when the drive is switched off.

Notices to the aforementioned can also be found in section 3.6 of chapter 2.3 (Presses in metal processing) of the DGUV Regel 100-500 and 100-501 “Betreiben von Arbeitsmitteln” (Operating work equipment).



Fig. 28
Slide support on a hydraulic press

5.4 Working on hydraulic scissors lifts

Industrial and mobile hydraulic scissors lifts, lifting tables, and lifting platforms are equipped with maintenance supports. When conducting work on the hydraulic system that cannot be carried out with the platform lowered completely, the maintenance support (see figure 29) has to be used. From the engineering point of view this support is designed in a way that it is able to accept all weight forces of the parts in a safe manner and in doing so is secured against slipping. This is to prevent improvised measures, e. g. with squared timbers or the like.

When installing and removing the maintenance support it has to be ensured that the elevated work platform is held safely by hydraulic means or with appropriate load-carrying equipment.



Fig. 29
Installed maintenance support on hydraulic scissors lift

6 Working on the mobile hydraulic system

Along with the general safety instructions regarding maintenance work and handling the hydraulic components (see section 4) the following sections have to be considered in addition to the manufacturer's specifications in the operating instructions (including maintenance and repair instructions) when maintaining the mobile hydraulic system.

6.1 General

In addition to the notices described already for the hydraulic system of stationary machines (see section 5.1) further aspects have to be taken into consideration for mobile hydraulic work equipment. Maintenance work is often conducted outside workshops, e. g. for self-propelled machines used on construction sites or off roads. In doing so, tools and aids are often available to a limited extent only.

Different operating pressure levels have to be observed for implementing maintenance work. Starting with approximately 60 bar for low pressure hydraulic systems for farm and harvesting machines, they range up to pressures of over 400 bar for earth-moving machines.

6.1.1 Securing the vehicle

In principle, vehicles should be positioned on firm ground when conducting maintenance work. This especially holds true for maintenance work on vehicles that can tilt or swivel attachments or superstructures, e. g. booms, hydraulically tiltable cabs, conveyor belts.

Before starting to work on the hydraulic system, the vehicles have to be secured against:
- rolling due to uneven ground,
- rolling due to force effect caused by the maintenance work,

- tilting caused by changes to the position of the center of gravity (also when working with hoisting platforms).

Elevated parts or superstructures of vehicles have to be lowered to the ground, e. g. loading device, boom, or the required mechanical locks such as locking pins, cylinder support, and the like have to be used. Furthermore, all required locks have to be put in place, e. g. articulated steering lock for vehicles with articulated steering (see figure 30).

The support areas for possibly extracted supports have to be able to accept the forces present.



Fig. 30
Installed articulated steering lock

For drive-on platforms the wheels have to be secured by means of stop-blocks. When positioning the vehicles on column lifts with small centered platform the vehicle has to be lashed to the platform or wired (see figure 35).

Note

Vehicles must not be accessed in lifted condition.

6.1.2 Depressurizing

Before starting any work the following has to be conducted:
- mobile hydraulic systems have to be depressurized,
- vehicle drives have to be switched off,
- hydraulic systems have to be switched off,
- hydraulic accumulators have to be closed on the pressure side and depressurized.

Note:
Caution with residual pressures caused by trapped fluid volumes, e. g. between valves and cylinders. They have to be depressurized by operating the control lever or the valve. The depressurization has to be checked, e. g. by means of a pressure gauge.

6.1.3 Collection container

When disassembling hydraulic components, drip pans of suitable shape and size (see figure 31) have to be positioned below the corresponding parts in order to collect possible leaking quantities of residual oil.



Fig. 31
Oil collection pan

6.1.4 Hose assemblies

Connections and attachments have to be loosened in accordance with the specifications of the manufacturer (see sections 4.2 and 4.3). If there is the danger of confusing the connections of the lines in the confined space of the vehicle (see figure 32), they have to be marked before being loosened or removed.

Before replacing hose assemblies, the depressurization of the mobile hydraulic system has to be checked in any case.

Damaged hose assemblies have to be removed wearing protective gloves as projecting metal wires from the meshwork pose a risk of injury.

Frequently changed attachments such as adjustment devices of the forks or swiveling devices mostly are equipped with quick couplers sealing both connection parts (attachment and line side) automatically after the line has been interrupted. When changing over to quick couplers, the specifications of the manufacturer have to be observed.

Fig. 32
Hose assemblies on a mobile hydraulic system

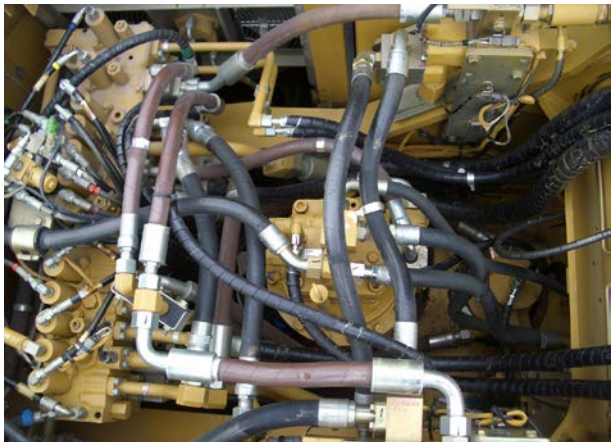


Fig. 32
Hose assemblies on a mobile hydraulic system

6.1.5 Disassembling heavy parts

Substantial forces can be present on the lifting cylinders of the vehicle superstructures. Before working on cylinders, these forces have to be accepted, e. g. by lowering the attachments or superstructures. If mechanical blocking by means of a bolt locking mechanism is not provided, the use of support frames is recommended (see figure 33).

Numerous hydraulic components, e. g. traction drives, main pumps, boom cylinders, are characterized by high dead loads and off-center position of the center of gravity. Thus, replacing these components has to be conducted with the help of lifting gear attached to the designed attachment points.

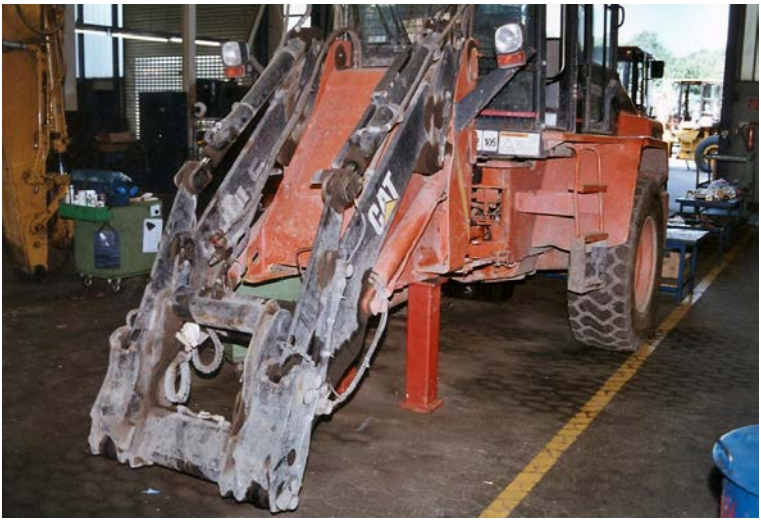


Fig. 33 Support frame when working on wheel-type loaders

6.1.6 Replacing the hydraulic fluid

Mobile suction devices used to empty the tank are suitable for replacing the hydraulic fluid (see figure 34). Replaced filters can drain with the help of a hopper device.

Mobile filling devices with integrated leakage protection/collection pan are particularly suitable for filling the system with new hydraulic oil.

When changing the hydraulic fluid, care must be taken that no contamination enters the tank or other parts of the hydraulic circuit. To achieve the desired cleanliness class, also freshly supplied hydraulic fluid must be filtered.



Fig. 34
Aid to dispose of old hydraulic oil

6.1.7 Fire hazards

Hydraulic fluid may ignite at hot surfaces, e. g. exhaust manifold, turbochargers. Insulating materials have a wicking function when contaminated with hydraulic fluid, which makes them easily inflammable.

Measures for reducing the fire hazard are:
- removing leaked hydraulic fluid completely (see section 2.2) and wiping parts dry,
- renewing soaked insulation material, e. g. noise protection lining,
- avoiding external ignition sources, e. g. cigarettes,
- covering hot surfaces.

6.1.8 Working while drive is running

Basically, repair work must only be carried out with the drive standing still. If work can only be conducted with the drive running, e. g. for testing and adjustment work, hazards have to be taken into account caused by:
- unprotected mechanical drives with rotating parts,
- hot surfaces of parts,
- noise.

The work must only be conducted by trained and experienced maintenance technicians. When conducting these works corresponding technical and personal protective measures have to be taken, e. g. safety by means of distance, covers, hearing protection, and further personal protective equipment, if required.

6.1.9 Re-commissioning

After completion of the maintenance work, including the ready-to-operate filling and venting of the hydraulic system, the drive and work functions have to be tested individually and if possible at low speeds and load-free. This should be carried out either behind screenings or from the safe distance.

The following procedure is recommended for testing the functionality of the hydraulic system:

1. checking all valve functions for correct sense of direction and shut-down function (neutral position),
2. executing larger travels of cylinders or swiveling areas of motors.

While testing the functionality of the hydraulic system, the machine operator has to ensure that no persons stay in the danger area.

For further notices, see section 5.1.2.

6.1.10 Spare parts

Specifications or approvals of the manufacturer have to be complied with, e. g. regarding spare parts for hydraulic systems, hose assemblies, material specifications, hydraulic fluids, and the like.

Note

The operating instructions (including maintenance and repair instructions), as well as the spare parts list have to be carried along or kept at hand on site in order to implement maintenance work on mobile hydraulic systems!

6.2 Working on industrial trucks

6.2.1 General

Depending on the type and extent of repair works on mobile hydraulic systems of industrial trucks, this work is conducted by internal operating departments, mobile maintenance services, or at service locations of the manufacturers or dealers.

In industrial trucks mobile hydraulic systems are used for
- the traction drive,
- the lifting frame with tilting device,
- the adjustment device for fork-lift forks or the pivoting device,
- the power-assisted steering system.

If maintenance work on industrial trucks poses hazards caused by possibly bumping against the fork-lift forks, e. g. in the area of traffic paths, the forks have to be removed before starting any works. This also applies to the lifting of the industrial truck using a hoisting platform.



Fig. 35
Lifting forks removed for working on the hydraulic system of a fork-lift truck

6.2.2 Traction drive

If replacing the traction drive hydraulic motor requires the lifting frame to be lifted, the frame has to be secured against lowering in accordance with the manufacturer's specification.

6.2.3 Lifting cylinder

The safe condition of the lifting frame is essential for the operational safety of the industrial truck. Repairs should only be conducted by especially trained personnel, e. g. with the manufacturer, or by the customer service. The manufacturer's specifications have to be observed during all works on the lifting frame.

Before starting any works on lifting cylinders, the lifting frame has to be lowered, supported, driven into a frame, or blocked mechanically. Working on telescopable lifting frames, e. g. in duplex or triplex design, should be left to the customer service.

When installing a new lifting cylinder, it has to be observed that the hydraulic hose assemblies are inserted properly into the designed guiding/deflection pulleys.

On older industrial trucks with hose rollers at the side of the lifting frame it has to be observed that the hose assembly is subject to spring force on the roller side. When loosening the connection, the hose assembly has to be secured against whipping, e. g. by means of a second person. In doing so, the hazard of being pulled in or pinched has to be observed at the hose roller.

6.2.4 Tilting cylinder

Before starting to work on the tilting cylinders, the lifting frame has to be secured against moving due to its dead load in accordance with the manufacturer's specifications. This is done for example by lashing the lifting gear in the rearmost position using the designed attachment points or on the driver protection roof (see figure 36).

The tilting cylinders have to be filled with hydraulic fluid before being installed (see section 4.4).



Fig. 36 Lashed lifting frame when working on tilting cylinders

6.2.5 Power-assisted steering

As the installation space of the steering axis unit below the industrial trucks is very narrow, it seems to be advisable to disassemble the complete steering axis unit when working on the steering hydraulic system. The disassembly has to be carried out in accordance with the manufacturer's instructions.

If there are accumulators in the hydraulic circuit of the steering system, they have to be depressurized before starting any works.

6.3 Working on hydraulically driven vehicle attachments and superstructures and vehicle cranes

6.3.1 General

As vehicle attachments or superstructures are often characterized by high weights, e. g. derrick booms, cranes, swivel towers, and due to the influence of gusts of winds during maintenance works in open territory, these attachments and superstructures pose a huge hazard when lifted.

Furthermore, it has to be observed that trapped pressures could exist due to hydraulically elevated loads. Basically, elevated loads have to be lowered or supported in a safe manner (see figures 37 and 38). The system must be depressurized and the depressurized condition must be checked. Further notes on maintenance work on vehicles can also be found in section 5.9.3 of the DGUV Regel 109-009 "Fahrzeuginstandhaltung" (Vehicle maintenance).

Attachments, swivel towers, derrick booms, or the like that are not affected by the repair works, should be moved out of the work area before starting any works.



Fig. 37
Safety support on an hydraulically elevated vehicle superstructure



Fig. 38
Boom of a concrete pump lowered to the ground

6.3.2 Vehicle main pumps

Vehicle main pumps are characterized by high masses and can be removed more easily using lifting gear.

Pumps installed below the vehicle can be positioned on the workshop floor, hand forklift truck or cavity cover below the vehicle with the help of lifting gear (see figure 39). The cavity cover has to have the corresponding load-carrying capacity.

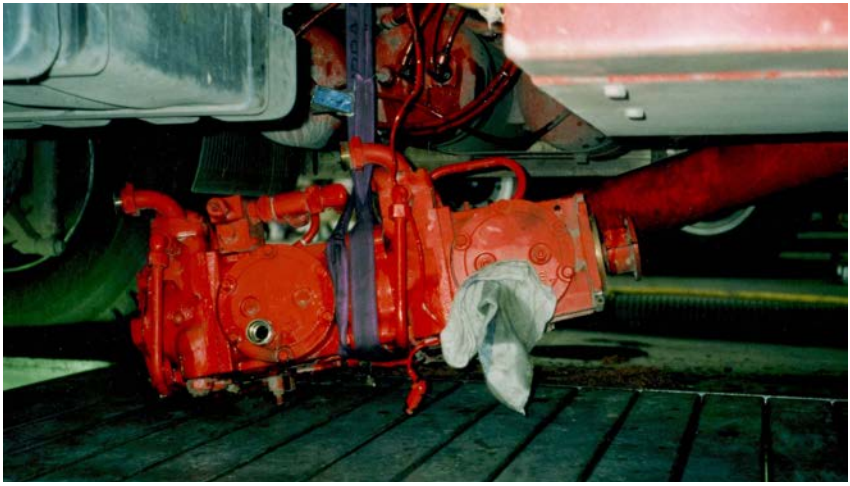


Fig. 39 Vehicle main pump on a load lifting device

6.3.3 Protecting accumulator and hose assemblies

If there is the danger of mechanical damage to installed accumulators or hydraulic hose assemblies during the maintenance work, they have to be removed or screened for the time of the maintenance work.

6.3.4 Replacing cylinders

When disassembling hydraulic cylinders, there must be no external forces on the support points (piston rod and cylinder bottom side). Thus, the booms have to be supported completely or positioned on the floor.

Hydraulic cylinders may be pressurized – even if the load has been lowered. This pressure has to be reduced via the corresponding check valves (piloted check valve) on bottom and rod side or by loosening the fittings carefully before disassembly.

It is reasonable to fill the new cylinders to be installed with hydraulic fluid beforehand and to vent them (see section 4.4).

6.3.5 Checking the hose assemblies

When conducting annual vehicle checks (according to § 57 of the DGUV Regulation 70 and 71 "Fahrzeuge" [Vehicles]) or when checking the attachments or superstructures, the hydraulic hose assemblies have to be checked as well (see section 4.3.5).

6.4 Working on earth-moving equipment and other automotive machines

6.4.1 General

The individual parts of the work equipment and the chassis of earth-moving machines, as well as other automobile machines may be characterized by high dead loads. Along with present oil pressure, accumulators are used frequently posing a particular risk potential (see section 4.7).

Earth moving machines frequently are repaired, serviced and maintained in rough terrain or on construction sites.

Sudden position changes of the machine or its parts, as well as the risk of falling down when being on higher parts of machines while implementing maintenance work cause particular hazards (see section 6.4.3).

6.4.2 Securing machines and machine parts against movement

Before starting any maintenance work, the machine has to be driven onto level territory with firm ground and has to be secured against rolling. The work equipment is to be lowered.

If the maintenance work cannot be carried out on level territory, if work has to be done on the braking system, or if the machine has to be jacked up on one side, an additional safeguarding measure by means of stop-blocks is required.

If machines are lifted for maintenance work, the machines have to be supported by means of bearing frames or with cross stacks consisting of boards or square timbers before starting any work. Work on lifted machines or devices that are only held by the hydraulic pressure of the machine or the vehicle are inadmissible.

By lifting a machine with articulated steering on one side or due to a loss of pressure in the hydraulic system, the steering system could be activated suddenly. In this, the machine may loose its stability and persons standing near the machine could be wedged. If works have to be implemented in the area of the articulated steering system or if machines having an articulated steering system have to be jacked up, the mechanical articulated steering lock (positive locking fixing device) has to be engaged first.

When working on hydraulic excavators, the superstructure has to be secured against swiveling before starting any maintenance work (see figure 40).

Furthermore, it has to be observed that hydraulic excavators and loaders are equipped with counterweights. If heavy parts have to be disassembled, the machine could tilt on the basis of the changed center of gravity.



Fig. 40 Swivel lock on a hydraulic excavator in locked position

Work equipment has to be secured against moving by placing it on the ground, supporting it, or equivalent measures before starting any work. If work has to be conducted below the lifted work equipment, the latter has to be secured against lowering by means of the designed positive fitting supporting devices (see figure 41).

If there are no such safeguarding measures, the corresponding part has to be supported by means of bearing frames having sufficient load-carrying



Fig. 41
Supporting device in place on an earth-moving machine

capacity. Stacking construction materials is not suitable to this end as these materials could lose their stability in case of impulsive stress when mounting the part.

6.4.3 High-level places of work

It has to be possible to reach platforms for maintenance and repair work in a safe manner. If there is the risk of falling down, appropriate safeguarding equipment has to be used. Hydraulic components must not be used as climbing aids or attachment point for safeguarding equipment against falling.

Parts of the machine must only be used as place of work or access if the manufacturer has designed them to this end and if they are stable and skid-proof.

If mounting work on site is conducted with the help of other work machines or industrial trucks, they have to be approved for these purposes and have to be equipped with an admissible device for accommodating persons, e. g. work platform; see DGUV Information 201-029 „Handlungsanleitung für Auswahl und Betrieb von Arbeitsplattformen an Hydraulikbaggern und Ladern“ (Handling instructions for selecting and operating work platforms on hydraulic excavators and loaders). Works must not be carried out from lifted work equipment, e. g. shovel or fork/pallet.

6.4.4 Depressurizing

Before starting to work, the pressure in the hydraulic system has to be reduced. This has to be done in accordance with the manufacturer’s specifications.

Normally, accumulators are used in the steering, braking or hydraulic pilot control systems of machines, as well as in the work hydraulic circuits of loaders/loading machines as vibration dampening system. They have to be depressurized on the fluid side before starting any work.

Note:
If the accumulator of the hydraulic pilot control system has been depressurized already, the work equipment may only be lowered by means of a manual emergency lowering device by hand, e. g. via load holding valve on the boom of an hydraulic excavator.

Note

Before re-commissioning, load holding valves have to be re-adjusted in accordance with the manufacturer's specifications!

The hydraulic tank on work machines can be under overpressure due to operating conditions. Before starting any work on the hydraulic system the tank has to be depressurized.

6.4.5 Disassembling parts

It may be required to use lifting gear in order to carry out mounting work on hydraulic components. On construction sites this work is often conducted with the help of other earth-moving machines. It has to be observed that the manufacturers designed and equipped these machines for lifting gear operation. The notices in the operating instructions have to be observed.

During the mounting work, chain hoists may be of help allowing for positioning the parts precisely.

Hydraulic cylinders have to be lifted by means of suitable lifting accessories, e. g. attached with lifting straps or round slings in two-stringed design. Extending of the piston rod during the lifting procedure can be prevented by closing the connections using blind plugs after having disconnected the lines.

6.5 Working on water vehicles

6.5.1 General

Diverse hydraulic equipment is operated on water vehicles. There is a distinction between hydraulic systems required for traction drive of a vessel, e. g.

- rudder system,
- wheel house lift,
- maneuvering aids such as bow thrusters, articulation devices or the like,

as well as

- winches

and the machines installed on vessels and swimming devices (pontoon) for the most different applications, e. g.

- dredgers,
- rams,
- cranes (see figure 42),
- pump drives especially on tank vessels,
- mobile hydraulic systems, as well as ramps, flaps, and bulkhead closing devices.

Due to the high forces required for the driving operation parts and superstructures to be moved on the vessels, the hydraulic equipment often is characterized by high dead loads. However, further particularities as described in sections 6.5.2 to 6.5.5 have to be observed additionally.



Fig. 42 Shipboard crane on a pusher vessel

6.5.2 Position change of the vessel

Floating vessels never stop moving. Due to pull and wave effects of passing vessels, wind and swell (even in coastal waters), even vessels positioned in ports are subject to slight lateral tilting movements by several angular degrees. Loading and unloading freight vessels result in a constantly changing floating position around the longitudinal and transverse axes.

The vessel movements can lead to unintended movements of unsecured vessel and machine parts. Thus, anticipatory planning of maintenance works on vessels is required.

Note

All works have to be coordinated with the shipmaster.

6.5.3 Unsecured hydraulic drives on vessels

For hydraulic systems for driving operation, e. g. rudder systems, high requirements are posed regarding the availability and the operational safety of the systems. Within the sphere of action of these systems driving operation, safeguarding measures resulting in the rudder system being deactivated automatically are inadmissible from the point of view of traffic law (see figure 43). Technical protective measures such as guards cannot

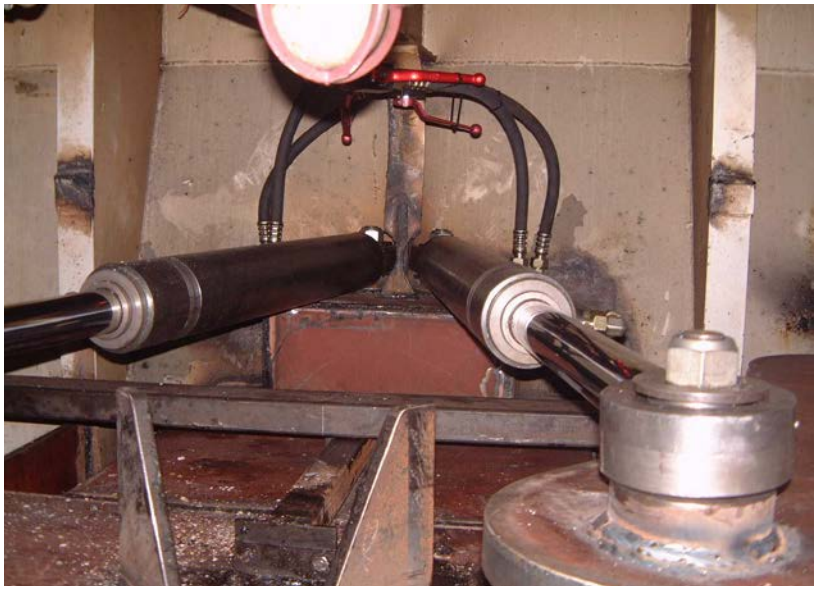


Fig. 43 Risks of pinching on a rudder system

be implemented in all positions. This poses the risk of accessing work and traffic areas, in which hydraulic parts are installed in an unprotected manner and stripping protections and pipe and hose rupture protections are frequently missing. Due to the confined installation situation and possible stumble positions, there is a high risk of pinching and thus direct danger to life due to moving system parts.

6.5.4 Limited installation conditions

On the basis of the narrow installation situation in the hull and the metallic parts, interior walls, bulkheads, and doors on all sides, most of the maintenance work is “work in confined spaces”, which is subject to special requirements regarding the electric equipment.

6.5.5 Redundancy of important drive operation systems

On the basis of vessel safety provisions, rudder systems are designed redundantly, i.e. in double design, in order to provide for high reliability and availability. This is to maintain the maneuverability even if the system has failed.

In doing so, different principles are applied:
- two parallel identical systems supplied by different energy sources with automatic switch-over,
- separately engaged emergency systems with limited continuous operation of the rudder system (emergency manual rudder, electric auxiliary pump),
- accumulators allowing for a limited number of rudder movements.

Work on these systems must only be carried out after consultation with the shipmaster! Before starting any work on the hydraulic system, all relevant energy sources have to be turned off (see section 1.5). Even manual hydraulic rudder systems on small vessels and emergency manual pumps have to be secured against being used before starting any maintenance work.

7 Required tests

7.1 General

Work equipment (machines) has to be checked for a multitude of reasons. The regulations for the test are based on the Ordinance on Industrial Safety and Health.

Proper and safe mounting and functionality of the work equipment are ensured by checks before initial commissioning and after every installation at a new location. The test has to be arranged by the operator of the work equipment (see also section 7.2).

Furthermore, work equipment is subject to damaging influences or wear and tear. In order to detect and remedy damages in a timely manner and to allow for safe operation, the work equipment has to be checked at regular intervals. These tests have to be arranged by the operator as well (see also section 7.3).

7.2 Checking for proper installation and safe function

When checking “for proper installation and safe function”, criteria are assessed that relate to the installation or which can only be assessed on the completely installed machine.

Some of these test criteria can already be assessed during a “visual inspection” in deactivated state, others require “functional testing” with activated energy supply.

An overview over the recommended scope of a “visual inspection” (in connection with the hydraulic equipment) can be found in Annex 1 letter C.

An overview of the recommended scope of testing for a “functional test” (in connection with the hydraulic equipment) can be found in Annex 1 letter D.

7.3 Checking for safe provision and use

Testing for safe provision and use assesses criteria which are subject to damaging influences. However, this test has to be conducted after accidents, modifications (conversions) to the machine, longer terms of non-use, as well as after repair measures as a result of damage (collision, natural phenomenon).

A detailed overview over the recommended scope of testing for “safe provision and use” (in connection with the hydraulic equipment) can be found in Annex E.

7.4 Legal bases for the tests

The legal provisions for testing work equipment, (machines, systems and the like) can be found in the Ordinance on Industrial Safety and Health.

The operator of the work equipment has to specify test lists, as well as type and scope of the tests for individual application conditions within the framework of a risk assessment and has to implement the tests accordingly. Legal provisions and recommendations of the manufacturer have to be observed.

Explanations in this context are contained in the technical rule on operational safety TRBS 1201. The test provisions of previous DGUV Regulations and safety rules still can be used to support the specification of the scope of testing and test intervals.

The tests must only be implemented by authorized persons instructed by the employer. An authorized person in the meaning of the Ordinance on Industrial Safety and Health is a person who, on the basis of the vocational training, the professional experience, and the contemporary professional

activity, has the expertise for testing work equipment, see technical rules for operational safety TRBS 1203 “Befähigte Person” (Authorized person)“.

The test results have to be documented and maintained in accordance with TRBS 1201.

8 First Aid

The first aid measures at the accident site are often decisive for the following course of the healing procedure of an injury or even for saving the employee. In accordance with the DGUV Regulation 1, the required number of trained first aiders have to be present in any case. The training is conducted by authorities approved by the German Social Accident Insurance Institutions. Furthermore, the employees have to be trained regarding the behavior in case of accidents at least once a year.

In order to provide first aid as quickly and immediately as possible, the “reporting chain” has to be specified in a clear manner.

- Who calls for help?
- Where can help be called from (location telephone, reporting authority)?
- Which help is called (first aider, corporate reporting authority, public rescue service)?

This is particularly problematic and thus important for maintenance works situated at a larger distance to other work places.

In case of an accident, an emergency call to the corporate emergency authority or the rescue coordination center (for accidents in Germany -> call 112) has to be implemented as follows:

Where did it happen?
What happened?
How many injured persons/victims?
Which type of injuries/illnesses?
Wait for queries!

Working alone should be avoided in any case.

In areas where implementing first aid measures is not possible or only possible to limited extent, provisions for rescuing possibly injured persons have to be ensured.

Places equipped with first aid kits or flushing devices have to be known and marked.

The hazards occurring especially when handling hydraulic fluids, as well as the corresponding first aid measures are:

Table Measures in case of accidents with hydraulic fluid

Hazard	Measure
Subcutaneous intrusion (injection) of hydraulic fluids under high pressure	**Consult doctor immediately**; very important: inform doctor about course of accident (oil injection), otherwise small wounds could be overlooked or treated improperly!
Hydraulic fluid in the eyes	Flush eyes at least 15 minutes with mild water (eye flushing device or clean water), contact doctor.
Swallowed hydraulic fluids	Do not provoke vomiting, **consult doctor immediately**.
Burns due to hot hydraulic fluid	Cover wound in sterile manner (i.e. with aseptic, non-adhesive dressing or material for burns); minor burns (hand and/or forearm can be cooled before with mild water at least for 10 minutes; contact doctor.

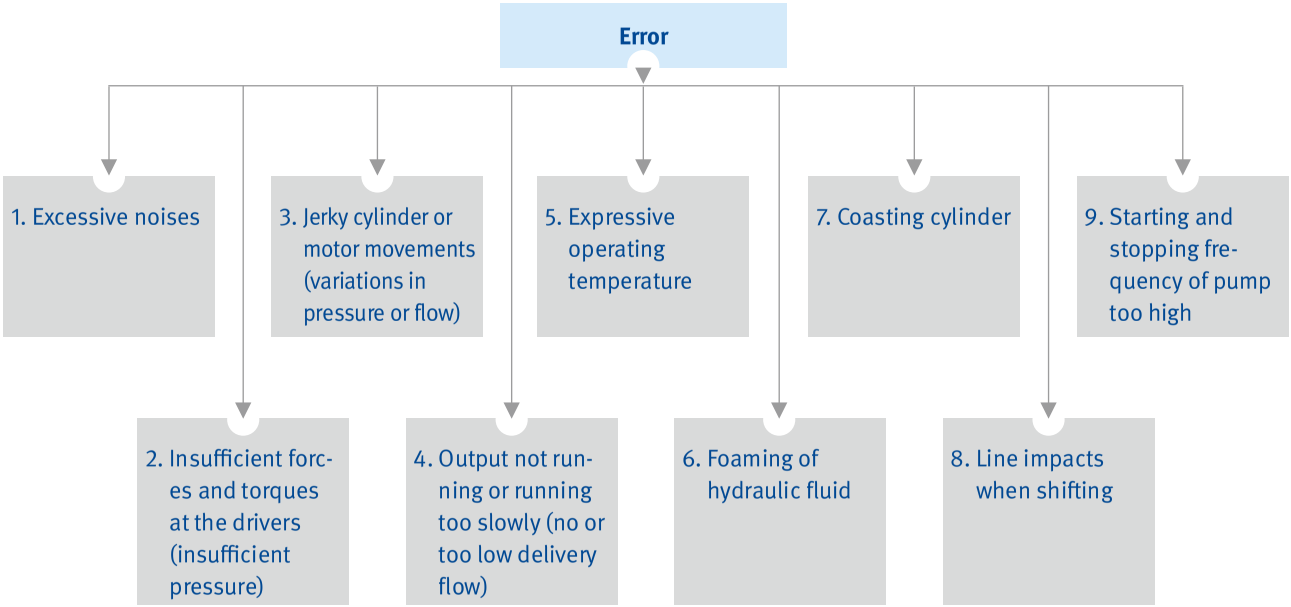
The rescue service/emergency doctor has to be informed immediately on the type of hydraulic fluid.

The current safety data sheet or the operating instructions have to be held ready.

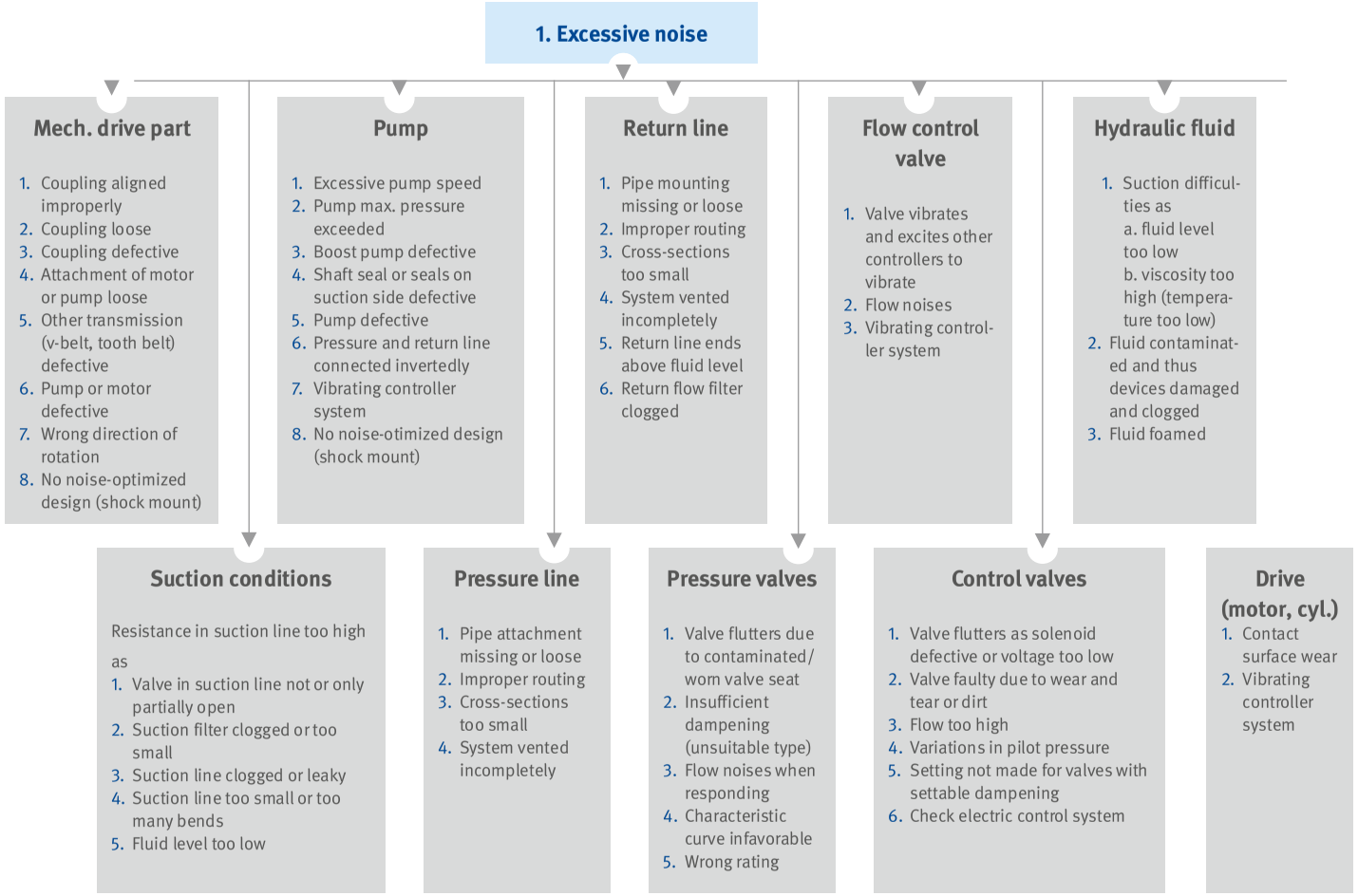
Annex 1

A Troubleshooting

In hydraulic systems, a multitude of different errors can occur. The first step is to describe the error more precisely.
(Trouble-shooting tree by using “General operating instructions 0/1” according to Bosch, version 1.0)



When the nature of the fault has been determined, the individual components are subject to a closer examination.


1. Excessive noise
Mech. drive part
1. Coupling aligned improperly
2. Coupling loose
3. Coupling defective
4. Attachment of motor or pump loose
5. Other transmission (v-belt, tooth belt) defective
6. Pump or motor defective
7. Wrong direction of rotation
8. No noise-optimized design (shock mount)
Pump
1. Excessive pump speed
2. Pump max. pressure exceeded
3. Boost pump defective
4. Shaft seal or seals on suction side defective
5. Pump defective
6. Pressure and return line connected invertedly
7. Vibrating controller system
8. No noise-otimized design (shock mount)
Return line
1. Pipe mounting missing or loose
2. Improper routing
3. Cross-sections too small
4. System vented incompletely
5. Return line ends above fluid level
6. Return flow filter clogged
Flow control valve
1. Valve vibrates and excites other controllers to vibrate
2. Flow noises
3. Vibrating controller system
Hydraulic fluid
1. Suction difficulties as a. fluid level too low b. viscosity too high (temperature too low)
2. Fluid contaminated and thus devices damaged and clogged
3. Fluid foamed
Suction conditions
Resistance in suction line too high as
1. Valve in suction line not or only partially open
2. Suction filter clogged or too small
3. Suction line clogged or leaky
4. Suction line too small or too many bends
5. Fluid level too low
Pressure line
1. Pipe attachment missing or loose
2. Improper routing
3. Cross-sections too small
4. System vented incompletely
Pressure valves
1. Valve flutters due to contaminated/ worn valve seat
2. Insufficient dampening (unsuitable type)
3. Flow noises when responding
4. Characteristic curve infavorable
5. Wrong rating
Control valves
1. Valve flutters as solenoid defective or voltage too low
2. Valve faulty due to wear and tear or dirt
3. Flow too high
4. Variations in pilot pressure
5. Setting not made for valves with settable dampening
6. Check electric control system
Drive (motor, cyl.)
1. Contact surface wear
2. Vibrating controller system

2. Insufficient forces and moments on the outputs (insufficient pressure)

Mech. drive part

1. Power transmission faulty
2. V-belt or toothed belt slipping
3. Wrong direction of rotation
4. Motor faulty
5. Key on pump or motor sheared

Pump

1. Internal leakage due to wear and tear
2. Unsuitable type
3. Pump defective
4. Reduction pressure set too low or controller faulty

Return line

1. Line resistance too high
2. Filter clogged

Flow control valves

1. Pressure losses too high
2. Wrong setting
3. Valve defective
4. Unsuitable type

Hydraulic fluid

1. Viscosity too low and thus leakage too high
2. Viscosity too high: flow resistances too high
3. Fluid foamed

Others

1. Error in open or closed control loop in the case of pressure controls
2. Indicator instrument faulty

Suction conditions

Resistance in suction line too high as

1. Valve in suction line not or only partially open
2. Suction filter clogged or too small
3. Suction line clogged or leaky
4. Suction line too small or too many bends
5. Fluid level too low

Pressure line

1. Leakages
2. Line resistance too high
3. Pressure filter clogged

Pressure valves

1. Operating pressure set too low
2. Internal leakage due to wear and tear
3. Valve seat contaminated or damaged
4. Spring broken
5. Unsuitable type (Setting range too low)

Control valves

1. Wrong spool position (e. g. pressurless circulation does not switch off)
2. Solenoid faulty
3. Internal leakage due to wear and tear
4. Flow resistance too high
5. Spool stuck

Drive (motor, cyl.)

1. Internal leakage (e. g. worn cylinder sleeve)
2. Running surface wear and tear
3. Internal friction too high (inefficient)

3. Jerky cylinder and motor movements (variations in pressure and flow)

Mech. drive part

1. Improperly adjusted clutch
2. Coupling loose
3. Coupling defective
4. Mounting of pump or motor loose
5. Other transmission (v-belt, toothed belt) defective
6. Pump or motor defective
7. Wrong direction of rotation

Pump

1. For control pumps, controller faulty
2. Pump defective
3. System-related repercussions to pump controllers (DMV, SRV)
4. Pilot control valves unsuitable

Return line

1. Leakages
2. Line resistance too high
3. Pressure filter clogged

Flow-control valve

1. Valve contaminated
2. Wrong direction of rotation

Hydraulic fluid

1. Hydraulic fluid contaminated
2. Hydraulic fluid foamed

Others

1. Insufficient load counterbalance at the rear of the output (e. g. load lowering valve, differential pressure regulator)

Suction conditions

Resistance in suction line too high as

1. Valve in suction line not or only partially open
2. Suction filter clogged or too small
3. Suction line clogged or leaky
4. Suction line too small or too many bends
5. Fluid level too low

Pressure line

1. System vented incompletely

Pressure valves

1. Valve flutters due to contaminated/ worn valve seat
2. Insufficient dampening (unsuitable type)
3. Undampened pilot line too long
4. Unsuitable control valve

Control valves

1. Valve flutters as solenoid faulty or voltage too low
2. Valve faulty due to wear and tear or dirt
3. Flow too high
4. Variations in pilot pressure
5. Setting not made for valves with settable dampening
6. Check electric control system

Drive (motor, cyl.)

1. Stick slip effect as friction of cylinder sleeves too high
2. Fallen below the limit speed of hydraulic motor

4. Output not running or running too slowly (no or insufficient flow)

Mech. drive part

1. Coupling aligned improperly
2. Coupling loose
3. Coupling defective
4. Mounting of motor or pump loose
5. Other transmission (v-belt, tooth belt) defective
6. Pump or motor defective
7. Wrong direction of rotation

Pump

1. Internal leakages due to wear and tear
2. Pump defective
3. Supply and return line connected inverted

Return line

1. Line resistance too high
2. Filter clogged

Flow control valves

1. Flow set too low
2. Unsuitable type (setting range too low)
3. Valve clogged or contaminated

Hydraulic fluid

1. Viscosity too low and thus leakage too high
2. Viscosity too high: flow resistances too high
3. Fluid foamed

Others

1. Start preconditions not given (control faulty). Electric cotnrol line (plug-and-socket connection) interrupted. Signal parts (e. g. pressure switch set improperly or faulty: limit switch not approached)

Suction conditions

Resistance in suction line too high as

1. Valve in suction line not or only partially open
2. Suction filter clogged or too small
3. Suction line clogged or leaky
4. Suction line too small or too many bends
5. Fluid level too low

Pressure line

1. Leakages
2. Line resistance too high
3. Pressure filter clogged

Pressure valves

1. Operating pressure set too low
2. Internal leak due to wear and tear
3. Valve seat contaminated or damaged
4. Spring broken
5. Unsuitable type (Setting range too low) for follow-up control
6. Sequence valve set too high or faulty

Control valves

1. Wrong spool position (e. g. pressureless circulation does not switch off)
2. Solenoid faulty
3. Internal leakage due to wear and tear
4. Flow resistance too high
5. Spool stuck
6. Manual valves not in open position

Drive (motor, cyl.)

1. Internal leakage (e. g. worn cylinder sleeve)
2. Running surface wear and tear
3. Internal friction too high (inefficient)
4. Output blocked (e. g. piston seizure)

5. Excessive operating temperature

Pump

1. Losses of efficiency due to wear
2. Faulty controller on control pumps
3. Speed or flow too high

Return line

1. Line cross-sections too low and thus frictional resistances
2. Pressure filters clogged

Flow control valves

1. Flow set too low (pump delivers too much via pressure relief valve)
2. Valve defective

Pressure fluid

1. Viscosity too low and thus leakage too high
2. Viscosity too high: flow resistances too high
3. Fluid foamed

Others

1. Cooling power of the power unit (the system) dimensioned too low in relation to installed output or duty cycle
2. Missing pressureless circulation for too long work breaks (and running pump)
3. Amount of hydraulic fluid in system too low
4. Cooling water valve does not switch
5. Thermostat set too high
6. No cooling water or fan failure
7. Cooling water temperature too high
8. Ambient temperature too high
9. Deposits in the cooler
10. Insufficient heat dissipation due to encapsulation

Pressure line

1. Line cross-sections too small and thus frictional resistances
2. Pressure filters clogged

Pressure valves

1. Permanent flow too high
2. Unsuitable valve type (cross-section too small)

Control valves

1. Leakage losses too high
2. Pressureless circulation does not switch on
3. Spool stuck

Drive (motor, cyl.)

1. Losses of efficiency due to wear
2. Internal friction too high (inefficient)
3. Internal leakage losses

6. Foaming hydraulic fluid

Suction conditions

1. Suction line leaky
2. Fluid level too low
3. Wrong resrevoir design

Pump

1. Shaft seals or seals on suction side faulty
2. Leakage oil line not below oil level

Return line

1. Return ends above fluid level
2. Swirl effect due to improper routing

Hydraulic fluid

1. Unsuitable make

7. Coasting cylinder

Pressure line

1. Hose lines too elastic
2. Lines not vented

Control valves

1. Switching adjustment too slow
2. Solenoid faulty, leakage quantities
3. Valve contaminated

Drive (motor cyl.)

1. Internal leakage quantities
2. Insufficient venting

Hydraulic fluid

1. Pilot operated check valve does not close immediately as
   a. seat contaminated or faulty
   b. switching error
2. Limit switch passed

8. Line shocks when switching

Pressure line

1. Pipe mounting missing or loose
2. Improper routing
3. Cross-sections too small
4. System vented incompletely
5. Storage volume of line system too high

Pressure valves

1. Switching too quick
2. Throttles or orifices damaged

Hydraulic fluid

1. Hydraulic fluid foamed

Others

1. For accumulators: missing throttles upstream of switching valves

Return line

1. Lines loose

Control valves

1. Switching time setting too fast
2. Unsuitable type (opening cross-section changed too fast)

Drive (motor, cyl.)

1. Masses and forces too high
2. No dampening

9. Starting and stopping frequency of pump too high

Pump

1. Pump defective
2. For accumulators: pump too small

Pressure valves

1. Starting or stopping valve set improperly or faulty

Others

For systems with accumulators: gas charging pressure too low.
Bladder (membrane) defective:
Pressure switch set improperly

B Notices on maintenance

(on the basis of the “General operating instructions 0/1” according to BOSCH, version 1.0, pages 63ff.)

The safety notices listed in the following have to be observed at all times and carefully.

- Conduct all maintenance works in due time, properly, and completely.
- All employees have to be informed before starting any maintenance works.
- The maintenance area has to be secured in a wide-ranging manner before starting any works.
- Corresponding signs have to inform about maintenance works.
- Signposts have to be attached to the control cabinet, the circuit breaker, actuators, and access in particular.
- If the hydraulic assembly has to be switched off, it has to be secured against unintended re-closing by the following measures:
  - All drives have to be switched off and the hydraulic system has to be disconnected from the mains using the circuit breaker.
  - The pressure of the hydraulic assembly or component has to be reduced.
  - Possibly existing accumulators have to be depressurized.
  - The circuit breaker has to be secured against unscheduled re-closing.

Prior to every manual intervention on the hydraulic component:
All required details on depressurization and on the hydraulic components that are not depressurized automatically can be found in the corresponding operating instructions.

- Cylinders have to be moved to the safe stop position.
- All loads have to be lowered.
- All pumps have to be turned off.
- All vertical cylinders have to be supported mechanically against lowering. Maintenance works on lifted units must not be conducted without securing the units externally.
- Existing accumulators have to be depressurized properly.
- The pressure supply has to be switched off and the hydraulic assembly has to be secured against unscheduled re-closing.
- It has to be ensured that only authorized personnel stay in the work area.
- The required personal protection equipment has to be used.

- The sections of the system and pressure lines to be opened have to cool down before starting any maintenance works.
- Pressurized segments have to be opened slowly.
- Due to check valves in the pressure lines above the pumps, the hydraulic system may still be under pressure after disconnecting it from the proper pressure supply. Some segments, e. g. servo cylinders, still remain pressurized due to the locked position of the proportional valves (the hydraulic scheme contains all valves in basic position).
- Only new and tested components and spare parts identical in construction and lubricants in OEM quality are admissible for replacement/use. Installing used and untested components is strictly forbidden due to safety reasons.
- During maintenance works which possibly require the removal of certain safeguarding equipment, machine movements must only be carried out with the utmost care. The safeguarding equipment has to be re-installed and tested for functionality before every commissioning procedure.
- Welding, burning, or grinding works on the hydraulic aggregate or its superstructures must only be conducted upon approval of the local safety official and using appropriate protective covers against contaminations.
- When conducting installation works above body height of the operator, dedicated climbing aids and work platforms have to be used. System parts must not be used as climbing aid.
- Tools and devices required for the maintenance works have to be removed from the machine/system.
- Leakages have to be remedied immediately at all times.
- The personnel have to be informed about restarting the machine/system beforehand at all times.

C Scope of visual inspection

(before initial and re-commissioning)

The following scope of testing is recommended:	complied with?
• Does the hydraulic control system, including all connections of the individual parts, correspond to the hydraulic scheme and the system description?	☐
• Do the data given on the nameplate and in the operating instructions correspond to the data of the energies provided?	☐
• Are there main control units for all energies supplied?	☐
• Are there devices for reducing the energy (depressurization units)?	☐
• Have all measurement, venting, and bleeding points, as well as all parts been marked in accordance with the hydraulic circuit diagram?	☐
• Have the hydraulic valves used as “device for rescuing persons” been marked in accordance with the operating instructions?	☐
• Are monitoring devices for all safety-relevant system parameters (e. g. pressure, flow, temperature, oil level) installed and visible?	☐
• Have all actuators been marked practicably and can they be operated quickly, safely, and clearly (especially for manually controlled systems)?	☐
• Have the setting values on all adjustable hydraulic parts (e. g. pressure relief valves, throttle valves, pressure switches) been marked in accordance with the hydraulic circuit diagram?	☐
• Do all warning signs (especially for hydraulic accumulators and energy saved otherwise) exist?	☐
• Have all pipelines been selected and installed in accordance with the hydraulic circuit diagram and parts list and installed according to section 4.2?	☐
• Have all hose assemblies been selected, marked and installed in accordance with the hydraulic circuit diagram and parts list and installed according to section 4.3.4?	☐
• Are hose assemblies, if required, equipped with an efficient protection against lashing and/or leakages of hydraulic fluids?	☐
• Are hose assemblies, if required, equipped with an efficient protection against lashing and/or leakages of hydraulic fluids?	☐

The following scope of testing is recommended:	complied with?
• Have all safety devices been installed and do they comply with the system description?	☐
• Are planned emergency stop devices available?	☐
• Have the hydraulic accumulators used been subjected to an equipment and installation test (and further pressure equipment if required).	☐

D Scope of testing of functional test

The following scope of testing is recommended:	complied with?
• Have the setting values of all settable hydraulic parts been set in accordance with the labeling and have the settings been saved?	☐
• Does the hydraulic control system comply with the intended function and does this function correspond to the system description?	☐
• Do all safety circuits work in accordance with the system description?	☐
• Do all emergency stop devices work and do they work in accordance with the system description?	☐
• Is re-closing only possible after safety conditions are fulfilled?	☐
• Does the operation of the emergency stop devices not result in additional hazards and does their deactivation not result in automatic start?	☐
• Are there no hazards due to interaction with linked systems (locks)?	☐
• Do the control devices for starting and shutting down work in accordance with the system description?	☐
• Are all monitoring devices of the safety-relevant system parameters functional?	☐
• Are the devices for reducing still existing energy efficient and can they be used without any risks after disconnection from the energy supply?	☐
• Do switching the energy supply on and off, energy reductions, as well as failure and return of the energy not lead to hazards?	☐
• Does using the system as intended not result in extraordinarily high pressure surges or pressure boosts?	☐
• For testing any part of the hydraulic system with the maximum operating pressure that can be achieved under all intended applications: – Have no measurable leakages occurred? – Did all hydraulic parts withstand the pressure?	☐
• Does the system temperature not exceed the thresholds specified in the system description?	☐

The following scope of testing is recommended:	complied with?
• Does all user information relevant for operating the hydraulic system in a safe manner exist (e. g. hydraulic circuit diagram, parts list, system description, drawings, operating/maintenance instructions, documents on hydraulic accumulators, safety data sheets on the hydraulic fluids used, etc.)?	☐

E Scope of testing of safe provision and use

The following scope of testing is recommended:	complied with?
• Do the operating and ambient conditions of the machine still comply with the intended use? For this, the following has to be observed for example: – product type, cycle times, number of units – pressures, flows, and temperatures in the hydraulic system – hydraulic fluid(s) used – velocities/stopping times of the dangerous movements – moved/elevated masses – type of feeding and removal – installation location – external influences (e. g. vibrations, moisture, contaminations, mechanical influences, ambient temperature, etc.) – position of the transport paths and type of means of transportation – space and access for operation and maintenance – arrangement and attachment of accessories – interaction with other machines	☐
• Is the user information of the manufacturer still complete and existing?	☐
• Are all safeguarding devices mentioned in the user information still existing and installed?	☐
• Do all safety devices work in accordance with the system description, e. g. – safety distances (especially after changing the application conditions), – secondary protective measures (especially after changing the application and ambient conditions)?	☐
• Are the provided emergency stop devices existing and efficient and does the effect correspond to the system description?	☐
• Is restarting only possible after restoring the safe condition?	☐
• Does the operation of the emergency stop devices not result in additional hazards and does their deactivation not result in automatic start?	☐

The following scope of testing is recommended:	complied with?
• Are there no hazards due to interaction with linked systems (locks)?	☐
• Do the control devices for starting and shutting down work in accordance with the system description?	☐
• Have the setting values of all settable hydraulic parts (e. g. pressure relief valves, throttle valves, pressure switches) been set in accordance with the specifications and have the settings been saved?	☐
• Are all monitoring devices of the safety-relevant system parameters functional (e. g. pressure, flow, temperature, oil level)?	☐
• Are all signposts and warning signs, as well as labels on parts, lines, measurement points, connection openings, depressurization devices, or the like still existing and can these be read?	☐
• Do all depressurization and shut-off devices, including their devices against unauthorized re-closing, work as intended?	☐
• Do the hose assemblies used show none of the deficiencies mentioned in section 4.3.5? In case of detected deficiencies section 4.3.6 has to be followed	☐
• Are the protective measures against lashing and/or leakages of hydraulic fluids on the relevant hose assemblies still existing or are they installed?	☐
• Have the periods for recurring tests on the pressure devices used (hydraulic accumulators) been adhered to? If required, these have to be conducted or arranged by the operator.	☐
• Have the maintenance intervals been adhered to and has the lifetime of wearing parts been considered as recommended by the manufacturer?	☐
• Have the recommended replacement intervals for the hydraulic fluid, as well as the measures for maintaining the purity class been observed?	☐

The following scope of testing is recommended:	complied with?
• In case of modifications to the machine and in the hydraulic system (control system and equipment), as well as after more complex maintenance works, especially if pipes had to be re-routed, the test extent has to be expanded reasonably as for new systems in accordance with section 7.2, e. g.: – design and function of the hydraulic control system – pressure surge, pressure boosts – pressure test – maximum system temperature and noise level – energy supply (switching on and off, reduction, failure and return) – selection and installation of additional and newly installed pipelines and hose assemblies	☐
• Have all changes been identified and incorporated into the documentation of the machine?	☐

F Involvement of staff members

From the German DGUV Regulation 1 “Principles of prevention”

Sec. 15 General support duties and conduct

(1) The insured persons shall, as far as possible and as instructed by the employer, protect their own safety and health at work and the safety and health of those affected by their actions or failure to take action. The insured persons shall support the measures taken to prevent occupational accidents, occupational disease and work-related health risks as well as the measures taken to ensure effective first aid. They shall obey the instructions given by the employer in relation to such matters. They must not obey instructions that are clearly contrary to safety and health requirements.

(2) Insured persons must not, by consuming alcohol, drugs or other intoxicating substances, put themselves in a state in which they might pose a hazard to themselves or others.

(3) (2) shall also apply to use of medicines.

Sec. 16 Special support duties

(1) The insured persons shall report every direct, significant safety and/or health hazard they detect and every defect they detect in protective devices and safety systems immediately to the employer or the relevant manager. Without prejudice to this duty, insured persons shall also report any safety and health hazards or defects in protective devices and safety systems to the OSH professional, occupational physician or the safety delegate.

(2) If an insured person establishes that

- there is a defect in a piece of work equipment or any other installation,
- materials have not been packaged or labelled properly or are not of the correct quality or

- that there are defects in a work process or workflow, and that these factors are relevant in terms of prevention of occupational accidents, occupational disease and work-related health risks, he or she shall remedy the defect immediately, provided that such action is within their area of responsibility and that they have the necessary skills. In all other cases, the insured person shall report the defect immediately to their manager.

Sec. 17 Use of installations, work equipment and materials

Insured persons shall use installations, work equipment, materials and protective devices in the intended manner and to the extent necessary for the tasks assigned to them.

Sec. 18 Unauthorised access

Insured persons may only access hazardous areas in order to perform the tasks assigned to them.

Annex 2

Provisions, Rules and References

In the following, the provisions and rules are compiled that have to be observed particularly for maintenance work on hydraulic systems.

1. Laws, provisions and technical rules*

Reference:
Book trade and Internet: e. g. www.gesetze-im-internet.de

- German Occupational Safety Law (ArbSchG)
- German Ordinance on Occupational Safety and Health (BetrSichV)
- German Hazardous Substances Ordinance (GefStoffV)
- German Noise and Vibration Work Safety Regulation (Lärm-Vibrations-ArbSchV)
- German Product Safety Act (ProdSG)
- TRBS 1112 Technical rule for operating safety “Maintenance”
- TRBS 1201 Technical rule for operating safety “Tests of work equipment and systems requiring monitoring”
- TRBS 1203 Technical rule for operating safety “Authorized persons”
- TRGS 150 “Skin resorbing hazardous substances”
- TRGS 555 “Operating instructions and Instructions according to § 20 GefStoffV”

2. DGUV provisions, rules, and information for safety and health at work*

Reference:
Your relevant accident insurer
or at www.dguv.de/publikationen

Accident prevention regulations

- DGUV Vorschrift 1 “Principles of prevention”
- DGUV Vorschrift 3 and 4 “Electric systems and utilities”
- DGUV Vorschrift 52 and 53 “Cranes”
- DGUV Vorschrift 54 and 55 “Winches, lifting and pulling units”
- DGUV Vorschrift 68 and 69 “Industrial trucks”
- DGUV Vorschrift 70 and 71 “Vehicles”

Rules

- DGUV Regel 100-500 and 100-501 “Operating work equipment”
- DGUV Regel 101-003 “Handling moving road construction machines”
- DGUV Regel 101-005 “Hoistable person-accommodating devices”
- DGUV Regel 109-008 and 109-009 “Vehicle maintenance”
- DGUV Regel 112-189 and 112-989 “Use of protective clothing”
- DGUV Regel 112-198 “Use of personal protection equipment against falling down”
- DGUV Regel 113-004 “Work in containers, silos and confined spaces Part 1 Containers, silos and confined spaces”
- DGUV Regel 113-020 “Hydraulic hose assemblies and hydraulic fluids – Rules for safe use”
- DGUV Regel 114-007 “Rules for safety and health in aircraft maintenance”

Information

- DGUV Information 201-029 “Handling instructions for selecting and operating work platforms on hydraulic excavators and loaders”
- DGUV Information 208-016 “Handling of ladders and treads”
- DGUV Information 209-015 “Maintenance work – safe and practice-oriented execution”
- DGUV Information 212-017 “General preventive guideline for skin protection – Choice, equipment and use”

3. Standards

Reference:
Beuth-Verlag GmbH, Burggrafenstraße 6, 10787 Berlin, Germany

- **DIN EN ISO 4413:2011-04** Hydraulic fluid power – General rules and safety requirements for systems and their components.

4. Other specifications*

Reference:
Fachbereich Holz und Metall, Postfach 3780, 55027 Mainz, Germany

- DGUV-Information-Sheet FB HM-015 “Hydraulic hose assemblies - Testing and changing” (03/2018)

Reference:
Bosch Rexroth AG, Postfach 300240, 70442 Stuttgart, Germany

- General operating instructions 0/1 by Bosch, edition 1.0.

5. References*

Reference:
Fachbereich Holz und Metall, Postfach 3780, 55027 Mainz, Germany

- DGUV-Information FB HM-042 “Hydropneumatic pressure accumulators” (06/2017)

Photographs and graphics in this information by courtesy of the members of the committee of experts „Hydraulics and pneumatics“ of the accident insurers, expert committee Wood Working and Metal Working (FBHM), specialist area Machinery, Robotics and Automation (SG MRF), specialist field of Hydraulics and Pneumatics, Isaac-Fulda-Allee 18, 55124 Mainz, Germany. * Only available in German.

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