Fachbereich AKTUELL

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Hydraulic test benches

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Hydraulic test benches of various designs, sizes and pressure levels have been used for many years, for example to conduct the relevant pressure-, leak- or function tests for different kinds of hydraulic compo-nents or assemblies, or to examine components for machines and vehicles for their technical properties or durability. They are used both in the development departments of component manufactures to determine and improve component properties and component characteristics as well as within series production in order to permanently ensure the intended component quality.

Figure 1: Burst pressure test bench with guard open

These hydraulic test benches are test machines which are subject to the requirements of the European Machinery Directive [1]. Since most of these test machines are custom-built for specific applications, there are hardly any type C-standards available. This “Fachbereich AKTUELL” (“German Social Accident Insurance”) provides an overview of important safety aspects for the construction and operation of these hydraulic test machines and supports both, the manufacturer of the test bench during the implementation of the general requirements of the Machinery Directive (in the following referred to as “MD”) as well as the users.

Inhalt

1 General

Hydraulic test benches are used in almost every field of the machine and vehicle construction, in a large number and in various ways. It´s common to develop, to build and to operate a test bench for an individual test task.

Hydraulic test benches are mainly applied in the fields of quality assurance, development and research. The scope of the quality assurance comprises the „100%-testing“ of production as well as random samples. Hydraulic development test benches are used for component development before series production starts.

Machinery for research purposes in laboratories (see MD article 1 para. 2, letter h) are temporarily combined for use and are excluded from the scope of the Machinery Directive (MD). Equipment with „changing hydraulic superstructures“ for

various research tasks may possibly be included and excluded from the scope of the MD. More information is given in section 5.2.

The test tasks to be implemented by a test bench as well as all relevant resulting aspects must be precisely specified in the order or in the specifications of a test bench. The manufacturer of the test bench has to determine all necessary protective measures.

All new test benches (including self-made devices of users) are subject to the provisions of the Produktsicherheitsgesetz (“Product Safety Act”), in the following referred to as “ProdSG” [2]) with the relevant current regulations for the implementation of the Europäische Binnenmarktrichtlinien (“European Internal Market Directives”), e. g. Maschinenrichtlinie (“Machinery Directive”), Niederspannungs-Richtlinie (“Low Voltage-Directive” LVD) [3] and Druckgeräte-Richtlinie (“Pressure Equipment-Directive PED”) [4]. The EMV-Richtlinie (“EMC-Directive”) [5] must be complied with as well.

According to the MD, e. g. a technical file has to be prepared by the test bench manufacturer (MD, Annex VII A). Along with the new test bench, the customer receives the operating instructions with the data according to MD Annex I No. 1.7.4 and the required declarations of conformity.

The operation of hydraulic test benches is subject to the Betriebssicherheitsverordnung („Ordinance on Industrial Safety and Health“ in the following referred to as “BetrSichV”) [6]. The user has to carry out a risk assessment according to § 3 for all machines and thus for hydraulic test benches as well, and may conclude that technical retrofitting is necessary, especially for older test benches. The relevant documentation must be filed in writing (see §§ 5, 6 Arbeitsschutzgesetz (“German Occu¬pational Safety and Health Act”, in the following referred to as ArbSchG) [7]) and has to be retained.

According to the BetrSichV [6] it has to be clarified for older test benches if,

- according to section 2, the protective measures against “hazards due to the used energies” (including hydraulic energy) are taken as required under § 8 paragraph 1 No. 1, and
- the piping is carried out in that way, that hazards are avoided according to § 9 para. 1 no. 10 and,
- the “protective devices against splinter and crack danger as well as against dropping or ejecting components” mentioned under § 9, para. 1 no. 4

are available.

This Information considers only those hydraulic test benches which exclusively use pressure fluids of fluid group 2 as operating medium for the testing of hydraulic components or rather in the hydraulic test benches according to article 13, para. 1, letter b of the DGRL.

> For the acceptance of pressure equipment, the Europäische Druckgeräte-Richtlinie (“Pressure Equipment Directive” PED) requires in Annex I section 3.2.2 that normally hydrostatic pressure tests need to be carried out and notes that certain conditions must be fulfilled before other tests than the hydrostatic pressure tests may be carried out.

Figure 2: Pressure- und leak tightness test bench for hydraulic hoses with guard open

Since the control and piping components used in hydraulic test benches do not exceed the relevant limit values of the Pressure Equipment Directive in most cases and thus do not fall within the scope of the PED, the PED is not dealt with in detail in this DGUV-Information. However, for the hydraulic accumulators or pressure intensifiers which may eventually be installed in the hydraulic test bench, the PED may be applied in full. This has to be examined individually on the design of a test bench.

If it is intended to use air or similar inert gases instead of pressure fluids, reference is made to the requirements of section 5 of the DGUV Information 213-062 „Druckprüfungen von Druckbehältern und Rohrleitungen – Flüssigkeitsdruckprüfungen, Gasdruckprüfungen“ [“Pres-sure tests of pressure vessels and piping – hydrostatic tests, gas pressure test”] (until now BGI 619) [8].

> The solutions for hydraulic test benches presented in this Information have been developed in cooperation with the Institute for Occupational Safety and Health IFA. They do, however, not represent mandatory provisions for test bench manufacturers.

Further information as to the limits of application are given in section 8.

2 Designs

This „Fachbereich AKTUELL“ distinguishes between hydraulic pressure test benches and hydraulic movement test benches depending on the test task. The classification of the designs of hydraulically driven test benches can be made on the basis of different criteria due to different purposes of use, see table 1.

Design	Test benches	Examples
1	Pressure test benches	- test benches for strength test (pressure, leakage) - function- and adjusting test benches (e. g. adjustment of parameters on valves) - troubleshooting (repair and service)
2	Movement test benches	- static tests (tensile tests) - dynamic tests (servo hydraulic endurance test benches, crash simulation test benches)
3	Combined Test benches	- impulse pressure test benches with overlain movement - test benches for drive or output units (e. g. motors, pumps and cylinders

Table 1: Designs of test benches

The main hazard on hydraulic pressure test benches is the pressure which can be applied statically or dynamically (pressure pulsation). This includes test benches for strength test of components, test benches to adjust components or for function tests, and test benches for troubleshooting and repair work on components or assemblies.

Test benches for strength test are used to determine the burst pressure (see Figure 1) of pressurized casings or for quality assurance in production at pressure and leakage tests (see Figure 2).

The test benches for the adjustment of components or assemblies (see Figure 3) are intended to adjust the parameters of hydraulic components (such as valves, pumps, motors, cylinders) or assemblies and their function test under pressure. The test benches for troubleshooting and the repair of hydraulic components and assemblies are usually used in the course of customer services to check complaints.

Figure 3: Hydraulic component test bench with guard open

For all the aforementioned test benches, the pressure in the system is the cause for the hazards by ejected parts or escaping pressurized fluid jets. The determination of the burst pressure is always a destructive testing.

Figure 4: Hydraulic test bench for tensile test with closed guard with polycarbonate vision panels

The main hazard on movement test benches is caused by a hydraulically driven movement. This includes test benches with hydraulically driven axes for testing components and assemblies,

such as e. g. test benches for static tests (tensile tests, see Figure 4) or for dynamic tests (damper test or crash tests).

The test benches for static tests are e. g machines which generate high tensile and compressive forces to determine mechanical component properties. They may partially be counted to the material testing machines according to DIN 51233 [9].

Figure 5: Hydraulic cylinder test bench with closed guard

The test benches for dynamic tests include test benches for servo-hydraulically controlled endurance tests for determining the component properties during typical load duty cycles (see Figure 8 and 9 in section 4). The generation of temporary extreme accelerations in test benches for crash simulation can also be done hydraulically.

At the above mentioned test benches, hazards like crushing and shearing can occur due to unexpected start-up or due to non-stop of a movement.

Furthermore, there are combined test benches, in case of which pressure and movement occur simultaneously. This results in various hazards, which can also occur simultaneously and need to be considered as safety-related. Leakage, pressure and function test benches for hydraulic cylinders are counted among the combined test benches (see Figure 5).

Another example are impulse pressure test benches with overlaid alternating bending for testing hydraulic hoses according to DIN EN ISO 6802 [10] and DIN EN ISO 6803 [11], see figure 10.

Test benches for repair and adjustment of pumps, hydro motors and cylinders also belong to the *combined* test benches due to the occurrence of pressure *and* the mechanical movement by the shaft or piston rod.

The test benches of the aforementioned designs, in this information designated as 1 and 3, are used in the research sector of component manufacturers as well as in their series production and maintenance and repair.

The different frequency of intervention at both of the aforementioned applications (research and series) results in deviating requirements to the safety-related parts of the control system. For ease of differentiation, the test bench designs 1 to 3 are designated by **E** for development and **S** for series production.

3 Hazards

There exist various hazards on hydraulic test benches. On one hand, the test specimens can fail mechanically, expected or unexpected (bursting, breaking etc.), during the test series. On the other hand, parts of the test bench equipment can also fail due to aging and abrasion. This kind of failure always needs to be expected during the design of test machines. Annex I of the Machinery Directive specifies the essential safety and health requirements for all machines and thus also for the design of hydraulic test benches.

This Information refers to the following sections of the MD in extracts:

- MD, Annex I, No. 1.1.3. Materials and products

  The materials used to construct machinery or products used or created during its use must not endanger persons' safety or health. In particular, where fluids are used, machinery must be designed and constructed to prevent risks due to filling, use, recovery or draining.

- MD, Annex I, No. 1.3.2. Risk of break-up during operation

  Both rigid and flexible pipes carrying fluids, particularly those under high pressure, must be able to withstand the foreseen internal and external stresses and must be firmly attached and/or protected to ensure that no risk is posed by a rupture

- MD, Annex I, No. 1.3.3. Risks due to falling or ejected objects

  Precautions must be taken to prevent risks from falling or ejected objects.

- MD, Annex I, No. 1.5.4. Errors of fitting

  Where a faulty connection can be the source of risk, incorrect connections must be made impossible by design or, failing this, by information given on the elements to be connected and, where appropriate, on the means of connection.

- MD, Annex I, No. 1.5.3. Energy supply other than electricity [e. g. Hydraulic]

  Where machinery is powered by source of energy other than electricity, it must be so designed, constructed and equipped as to avoid all potential risks associated with such sources of energy.

- MD, Annex I, No. 1.5.13. Emissions of hazardous materials and substances

  Machinery must be designed and constructed in such a way that risks of inhalation, ingestion, contact with the skin, eyes and mucous membranes and penetration through the skin of hazardous materials and substances which it produces can be avoided.

  This also includes the injection of pressure fluid under the skin.

- MD, Annex I, No. 1.6.3. Isolation of energy sources

  After the energy is cut off, it must be possible to dissipate normally any energy remaining or stored in the circuits of the machinery without risk to persons.

Harmonized European standards can be used to meet the requirements of the Machinery Directive. In the absence of Type-C standards for hydraulic test benches, Type-A and Type-B standards can be used. The (Type-A)-standard DIN EN ISO 12100 [12] includes the general principles for design as well as the risk assessment.

In particular it should be considered, that the inherently safe way of construction and technical protective measures always take precedence over personal protective equipment or information for use.

This „Fachbereich AKTUELL“ deals with the additional hazards which have to be considered on hydraulic test benches (see Table 2), which exceed the generally described hazards for machines according to DIN EN ISO 12100 or specify them.

For the safety-related parts of control systems of test benches, it is necessary to execute a risk assessment according to (Type-B) standard DIN EN ISO 13849 part 1 [13] and part 2 [14] and to determine the required Performance Level PL_r.

For the hydraulic equipment, the (Type-B) standard DIN EN ISO 4413 [15] applies. For electrical equipment, the (Type-B) standard DIN EN 60204-1 [16] has to be applied. All the necessary adaptions for the different test specimens within the scope of the intended use are related to the test bench. This includes e. g. fixing elements, adapting manifolds, couplings and shafts as well as their coverings.

Test bench manufacturers have a general responsibility to conduct a risk assessment (for the intended range of applications of the test bench) and to deliver safe adaptions within the scope of the intended use and the scope of delivery agreed to. Subsequent changes and supplements are the responsibility of the user.

No.	Specific hazards at hydraulic test benches	Section FB HM-086
1	Mechanical hazards – Flying fragments during bursting (components of different geometry, mass, energy) – crushing / shearing at movement test benches – (cylinders, component test benches) – lifted loads – medium jet under pressure – danger of slipping due to leaked pressure fluid	4.1 4.4
2	Hazards caused by control mistakes – unintended pressure build-up – no pressure reduction e. g. when opening the protection device – unexpected start-up of movements (movement test benches) – no stop of a movement	4.2
3	Hazards due to inadequate equipment – hoses damage – abrasion of couplings and connections – insufficient covering of aggregates – missing or insufficient guards	4.3
4	Hazards caused by operating errors – compressed air (insufficient venting)	4.4
5	Hazards by pressure fluid – skin hazard – burns – fire and explosion – hazardous emissions from vapors or aerosols from pressure fluids	 4.4 5.3 5.4, 5.5 5.6
6	Thermal hazards – burns (e. g. on hot surfaces)	 4.4, 5.3
7	Hazards by neglecting ergonomic principles	5.6
8	Hazards by noise – sound emission	 4.4, 5.7

Table 2: Specific hazards at hydraulic test benches

Depending on the intended use and scope of supply, the test bench manufacturer must provide detailed information in the operating manual on the design and manufacture of the individually required adaptions to be implemented by the user. This includes e. g. the type of technical components, screws and their strength class, the design of shaft covers, example drawings of adaptions, coverings and fastenings.

The user is obligated to observe the requirements of the test bench manufacturer when retrofitting to other test specimens or for the self-assembly of adaptions, including appropriate coverings.

4 Protective measures

4.1 Guards

The hazards caused by flying fragments and fluid jets under high pressure can only be avoided, if the test bench is equipped with an adequate solid guard (housing, vision panels, protective plates or workshop wall).

Figure 6: Open guard on a hydraulic text bench

The access protection to the hazardous area is carried out by movable guards (working area safety doors), see Figure 6. The requirements of the Machinery Directive, including those of Annex I No. 1.3.2 regarding the “risk of break-up” can be implemented by this protective measure.

The risks for the following cases can be reduced by means of the guard:

- Failure of fittings and hydraulic hoses (pull out of the bonding, bursting, Pinhole)
- Failure of quick disconnect couplings (abrasion)
- Flying plugs (interchanged threads, faulty caulked balls, expanders)
- Failure of sealings (extrusion of O-rings)
- Burst of pressurized housings
- Error in the control system of the test functions

The requirements for the design and construction of fixed and movable guards are defined in DIN EN ISO 14120 [17].

4.1.1 Determination of thickness of the protective vison panel

Due to the variety of influencing parameters of possible ejected components of different shapes, masses and operating pressures etc., the FB HM cannot provide reliable values for the minimum thickness of protective vision panels to the manufacturers .

The required thickness of the protective vision panel has to be determined on the basis of the greatest kinetic energy of the potentially ejected components. The characteristics (e. g. mass, shape, strength) of the components (including test bench and measuring equipment) and the test pressures must be considered.

The kinetic energy depends on the mass of the ejected components and the velocity. The velocity arises from the short-term acceleration of the component. This acceleration depends on the pressure and the involved fluid volume. The distance between the test specimen and the guard is influential as well.

> The energy stored in a pressurized component which causes the acceleration of the fragments of the pressure-retaining cover of the test specimen in the case of bursting, depends in addition to the pressure and volume (of the test specimen and related pipe components) also on the
> - compressibility of the pressure fluid as well as on
> - the elastic/plastic change in volume of the pressure-retaining covers
>
> under the respective test pressure

Due to the varietey of undeterminable influencing para-meters and uncertainties, the calculated results on the kinetic energy should be added a safety margin. The expert committee wood-working and metalworking is not in a position to indicate definite values for safety margins on a general basis.

> Some manufacturers of pressure test benches add a 100% safety margin to the theoretically defined kinetic energy for serial pressure test

benches (i.e. for a single, clearly defined and recurring test task in production). For development test benches, on which different components (newly developed test specimens, connector pipes, adapters etc.) are pressurized for the first time, a safety margin of 200% is defined. This results in the rated energy for the calculation of a guard, for example a polycarbonate vision panel or a sheet metal.

Due to the ageing behaviour of plastic vision panels, the retention capability could decrease over time and the vision panel has to be replaced.

The ageing or rather the decrease in the retention capability also depends on the environmental conditions (oil moistening, surface coating and a lot of other factors). During some test series for the retention capability of polycarbonate panels on lathes, it was determined that after 5 years, unprotected polycarbonate panels only have about 50 % of their original retention capability and after 10 years only 20 % of their original retention capability. For comparison, the literature about test series for vision panels from Mewes, Warlich & Trapp [18] is recommended.

The roughly described process about the decrease of the retention capability depends on a number of further parameters such as the material structure of the polycarbonate, the applied surface-wetting pressure fluids or lubricants as well as the degree of scratching. Due to the amount of possible parameters and uncertainties, it is quite difficult for the FB HM to suggest values for the minimum thickness of polycarbonate vision panels. If thicker vision panels are used, the decrease of the retention capability starts „on a higher retention level“ and enables longer replacement intervals which reduces the maintenance effort for the test bench users. Besides its strength, possible scratching of the vision panel after a certain time of operational use should be considered as well. An initial design of excessive thickness is not reasonable in case of a high degree of scratching and an early replacement for optical reasons.

The *dimensioning thickness* of the polycarbonate pane for its intended operating time is based on the rated energy (kinetic energy plus safety factor) and by adding an allowance (for aging or the decrease of the retention capability).

A similar approach is necessary for the dimensioning of metallic separating walls.

On some test benches, the thickness of polycarbonate vision panels can be specified to e. g 8 mm, depending on the test task or the test pressure. According to previous experiences, the retention capability of an 8 mm polycarbonate is equal to a 3 mm steel plate DC01.

If the design requires a polycarbonate pane of high thickness, this thickness should be implemented by assembling single panes to a pane package (for example 4+8+4 mm = 16 mm). The edges of this package as well as the outer surfaces must be protected (e. g. by an oil resistant coating).

The minimum thickness of vision panels and other guards shall be determined by the manufacturers based on the test task, all relevant conditions and possible impact energy of ejected parts. The responsibility remains exclusively with the manufacturers; the same applies in the case of self-constructions by users.

If it is not possible for the user to calculate the kinetic energies and to determine the required thickness of the guard for the individual test bench and if there is also no experience available from the manufacturer, even the FB HM cannot provide a suitable value for this thickness.

Based on the knowledge from proceedings with test bench manufacturers and observance of the previous accident occurrence during the operation of test benches, the FB HM suggests values for a minimum thickness of polycarbonate vision panels at hydraulic test benches, in case of which no hazards have arisen up to now.

These values have been confirmed by experiments conducted at the Institute for Occupational Safety and Health (IFA) and analogous tests about the retention capability of vision panels at other applications. The data in Table 3 below can be used as a reference during the design or for comparison.

Pressure p (bar)	Suggested pane thickness
≤ 300	6 mm
> 300 ≤ 500	8 mm
> 500 ≤ 1.000	12 mm
> 1.000 ≤ 2.000	16 mm
> 2.000 ≤ 4.000	28 mm

Table 3: Recommended minimum thickness of polycarbonate vision panels for hydraulic test benches

At values exceeding p = 4.000 bar it is not allowed to extrapolate.

The manufacturer must indicate in the operating instructions for the test bench that the tests of the guards and all installations (e. g. measuring ports, hoses) within the test bench need to be carried out for the safe working condition at regular intervals by persons who are qualified for testing.

According to information given by a large number of manufacturers, the replacement intervals should be every five years.

For an extension of the replacement intervals of the polycarbonate vision panels, it must be ensured, that

- appropriate experience is available on the part of the machine manufacturers, the vision panel suppliers or the users of the test bench to ensure a riskless further use beyond the recommended maximum period of use,
- a risk assessment has been carried out and recorded in writing by the employer, which also includes protective measures for the case of failure of hydraulic hoses and pressurized assemblies within a test bench, and
- the testing of the used vision panels and hydraulic hoses and other pressurized assemblies for safe working condition is carried out in adapted, if necessary reduced time intervals, by persons who are qualified for testing.

Due to the extension of the replacement intervals of vision panels, no dangerous situation must occur which could injure employees or other persons.

Criteria for the replacement of polycarbonate vision panels are:

- blinded vision panels
- cracks in the vision panels
- penetrating media in the interspace of glass bonds
- mechanical damage, e. g. by test operation.

In case of observed failure of vision panels (even near-misses) during operation or if frequent damages or deficiencies at the vision panels are determined by recurring tests, the testing and replacement intervals should be reduced or the thickness of the vision panel should be increased. The cause of the damage needs to be investigated.

Based on the knowledge about the test task and the dimensioning of the vision panel package, the test bench manufacturer has to include the following in the operating instructions:

- a recommendation on the replacement interval of the vision panel, and
- information that the thickness of the selected vision panels and guards has been selected for the intended use and that any subsequent change of use of the test bench might be a significant change to the test bench in terms of the interpretation paper [19] to the Product Safety Act for which a new conformity assessment is necessary.

> The above mentioned table should be considered for the determination of the required thickness of subsequent vision panels on older hydraulic test benches for the evaluation of the protective measures.

The mentioned table can also be used to evaluate the protective measures for necessary covers of hydraulic hoses at miscellaneous old machines, in case of which no pressure tests are carried out and no bursting of pressurized parts has to be assumed during the intended normal use. However, due to passenger traffic, hazard potential exists. Due to the pane thickness according to table 3 which is rather too thick for those kind of applications, users can conclude in their individual risk assessment, corresponding to § 3 BetrSichV [6], to extend the replacement intervals of the vision panels, taking into account the individual operational requirements and experience.

> The FB HM of the German Social Accident Insurance DGUV gladly receives operational experiences associated with dimensioning and durability of vision panels at test benches for optimizing purposes and quality assurance (contact, see last page).

> **Manufacturers of guards have to ensure a safe design of the vision panels and other partitions. The minimum thickness and the specification of the replacement interval remain exclusively to the responsibility of the manufacturers; the same applies accordingly to self-made constructions by the users of the test bench.**

4.1.2 Further requirements for the structure

The support pillars and the frame of the guard (housing, cover and fixing of the vision panels, fixing materials and if applicable filling materials) must be selected and mounted in such a way that a stable construction is achieved.

> The Information FBHM-040 „Schutzscheiben an Werkzeugmaschinen der Metallbearbeitung“

[20] (“Protective vision panels for metal working machine tools”) recommends different kinds of overlapping, based on tests with centric bombardment of vision panels on doors of lathes, with a projectile mass of 2,5 kg. For example, an all-side overlapping with at least 40 mm overlap at a pane thickness of 8 mm is recommended or an all-side over¬lapping of 25 mm overlap at a pane thickness of 12 mm. More detailed information can be found in Information FBHM-040.

The adjustment at test specimens may require the intervention of the operator in the working area with tools (e. g. screwdriver). Therefore, the design of the test bench has to consider the clamping of the test specimen to be such that the adjustment screws can be reached by tools through the smallest possible opening in the guard. In case of test benches with different changing test specimen sizes, it may be necessary to retrofit the specific guards suitable for each test specimen with the smallest possible opening. Alternatively, adjustable guards can be used.

For some test tasks, e. g. for set up in large test benches with accessible test room, adjustable protective devices can be used. By use of enabling devices, these adjustable protective devices provide a higher protection to the operator (see figure 7).

Figure 7: Manually adjustable protective device for maximum protection during the adjustment on a pump test bench in a separate test room

If movable guards are used, they have to be interlocked with the control system. For more information, see section 4.2.2.

If the application and the handling of interlocking guards is impossible, the test bench manufacturers have to define organizational measures for those remaining risks in the operation manual, which have proven to be adequate and which have to be implemented by the users.

The organizational measures include the usage of movable guards (like covers or partitions) that are not interlocked with the control system. If this should not be possible, either the manufacturer´s operating manual or the user’s operating instructions should specify that:

- The test specimens should be pre-tested under full load (highest pressure, highest speed etc.) after installation and connection from a safe operator station
- After turning off the power or after unloading, the test specimens should be visually inspected for identifiable damages such as leakages at connection ports or supply lines and only then
- the adjustment under pressure at the specific operating points of the test specimens is conducted by using personal protective equipment.

It is possible to fulfill the requirements for protective measures by means of guards for test benches for large test objects with appropriate structural equipment, such as e. g a separate test room with secured access door (see figure 8).

In particular at the entrances to the hazard zone and outside at the locked access doors, additional signs (prohibition sign P006: „Access prohibited for unauthorized persons “) need to be installed.

Figure 8: Servo hydraulic chassis test bench in a separate test room

4.2 Protective measures by the control system

4.2.1 Control system requirements

Due to the different designs 1 to 3 and the applications E (development) and S (serial production), deviating requirements arise for the safety-related parts of the control systems, according to DIN EN ISO 13849-1, which are explained in the following subsections by relevant tables. The most relevant safety functions on test benches are considered as examples.

> The safety measures described in the following sections, do not replace the required risk assessment to be carried out under the manufacturer's responsibility. The individual risk assessment of the manufacturer may result in different safety functions and corresponding Performance Levels. If the manufacturer intends to use a low "probability of occurrence of a dangerous situation" in his risk assessment of a new test bench based on Annex no. A.2.3.2 of DIN EN ISO 13849-1 of 2016, he has to deliver justifiable proof regarding the accident occurrence on comparable test machines (same risks, same process, same way of actuation by the operator and same technology) in order to justify this assessment. A low number of accidents might consequently confirm the existing PLr assessment, the accident occurrence is based on. However, it is not suitable as argument to assess a required PLr for a safety function of a new test bench lower than it corresponds to the current state of test benches delivered.

4.2.1.1 Pressure test benches

This "Fachbereich AKTUELL" does not distinguish between setting and test operation at the pressure test benches, because generally there is no need to execute the setting operation during pressure and testing is conducted with the guard closed. Table 4 indicates some examples of safety functions (SF) for type 1**E** (pressure test benches in the component development) as well as 1**S** (pressure test benches for serial production) with risk graph and required performance level PLr.

> The control requirements for the safety functions listed in table 4 design 1S are related to a manual loading of the test bench with test objects.
>
> During fully automated loading of a test bench, e. g. in the course of a 100 % quality test regarding the density of components, including the automated connection or the assembling of pressurized connections of the test object, lower requirements may result.

SF	Description	Risk graph Design		PL_r Design		Comment
		1E	1S	1E	1S	
1	Protection against unexpected pressure build-up	S2 F1 P2	S2 F2 P2	d	e	while protective door open
2	Safe unloading	S2 F1 P2	S2 F2 P2	d	e	before opening the protective door

Table 4: Safety functions at pressure test benches of **design 1E** (pressure test bench at component development) as well as **design 1S** (pressure test benches in series production)

For the more rare manual loading of an automated test bench, design 1S, e. g. F1 may be assumed which results in a lower Performance Level PL_r. This can be done by design, in the course of the individual risk assessment, possibly in the risk graph or with the safety function of table 4. Further protective measures need to be considered for those automated test benches according to DIN EN ISO 12100 and other standards which are not mentioned in this "Fachbereich AKTUELL"

Figure 9: Servo cylinder for highly dynamic simulation of movements in a separate test room

If the components to be tested are fixed by means of power-operated clamping devices, a risk assessment for the clamping function needs to be conducted as well. Various measures can be executed to reduce the risk, such as inching mode, limited clamping stroke, reduced speed, and reduced force.

4.2.1.2 Movement test benches

For movement test benches (see figure 9), this information distinguishes between set-up operation and test operation.

Some safety functions (SF) for designs **2E** (movement test benches in the component development) as well as **2S** (movement test benches in the serial production) (random samples, quality assurance) are listed exemplary in table 5 with a risk graph and the required Performance-Level PL_r.

SF	Description	Risk-graph Design		PL_r Design		Comment
		2E	2S	2E	2S	
1	Protection against unexpected pressure build-up	S2 F1 P2	S2 F2 P2	d	e	protective door open
2	Safe positioning of the test axis for inserting the specimen	S2 F1 P2	S2 F2 P2	d	e	protective door open without risk-reducing measures
3	Safe clamping of the specimen	S2 F1 P2	S2 F2 P2	d	e	e. g. gravity-loaded traverse with protective door open
4	Safe stop of movement	S2 F1 P2	S2 F2 P2	d	e	before opening the protective door
5	Choice of operating modes	S2 F1 P2	S2 F2 P2	d	e	identical with highest PLr

Table 5: Safety functions at movement test benches of **design 2E** (movement test benches in the development) as well as **design 2S** (movement test benches in serial production)

If test axes have to be moved for setup, risk reducing measures like e. g. safely limited speed < 10 mm/s and hold-to run operation can be taken. Due to these measures it is possible to suppose P1 for the safety function SF 2 in the risk graph, which may result in a lower Performance-Level PLr. The control specifications for the hold-to-run operation according to DIN EN 60204-1 No. 9.2.4 must be considered.

4.2.1.3 Combined test benches

On combined test benches, pressure and movement can occur simultaneously (see also section 2, design 3). Therefore, the hazards caused by pressure and by movement must be considered safety-related. If, for example, pumps or hydro motors are tested for pressure, the rotating shafts have to be covered by guards. The simultaneous occurrence of pressure and movement is possible with test benches in the field of development (design 3E) as well as in the serial production (design 3S).

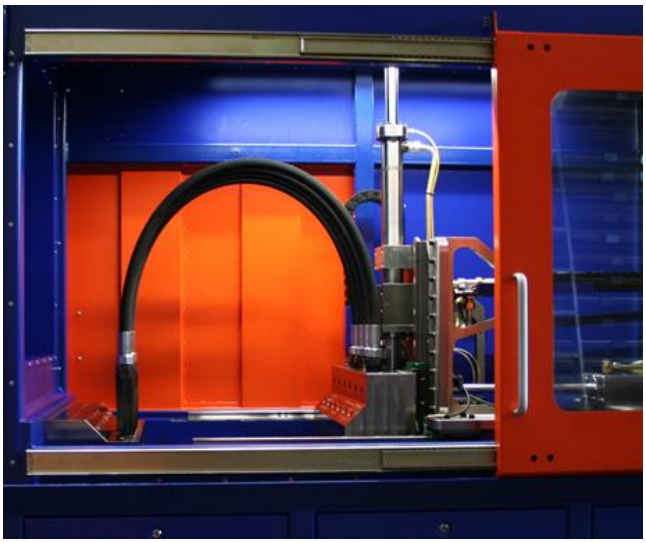

Figure 10: Open combined test bench for pressure and movement

Even service test benches (for repair and maintenance) may be count among the serial test benches, depending on the frequency of the change of the components or aggregates to be tested.

All safety functions need to be defined for the combined test benches as well. Due to overlapping hazards, at least the relevant safety functions of both tables of sections 4.2.1.1 and 4.2.1.2 must be considered.

For combined test benches (design **3**), *at least* the specific safety functions of the relevant columns of both tables 4 and 5 have to be applied. Columns **1E** and **2E** apply to combined test benches in the development area (design **3E**), columns **1S** and **2S** apply to combined test benches of series production including maintenance and repair (design **3S**).

4.2.2 Implementation by control measures

4.2.2.1 Integration of movable guards in the control system

Suitable protective devices must be selected according to the Performance Level listed in the tables of section 4.2.1 and be implemented into the control system.

Movable guards can be equipped with or without guard locking. Guard locking is necessary, if for example, a dangerous overrun or a delayed pressure discharge can occur during the test procedure. The opening of the movable guard must not be carried out before the pressure discharge of the test distance or the standstill of the movement has been identified by the control system. If guard locking is not required, a position monitoring of the movable guard can be provided e. g. by position sensors. Possible bypassing must be prevented.

The standard DIN EN ISO 14119 [21] describes the design and selection of interlocking devices in conjunction with guards. This standard also defines the requirements for escape releases.

4.2.2.2 Mode selection switch

The test benches mentioned in sections 4.2.1.1 and 4.2.1.2 in this “Fachbereich AKTUELL” require different operating modes (setup mode and test mode). For changing the mode of operation, mode selection switches are applied on test machines according to the Machinery Directive.

Since the aforementioned operating modes require different protective measures, a mode selection switch has to be provided which is lockable in each position. Each position of the switch must be clearly recognizable and correspond to one control or operating mode only (see MD Annex I, section 1.2.5). The selected control and operating mode must be superior to all other control and operating modes except emergency stop.

Particular works in the setup mode require the operation with suspended protective effect of the protective devices. Therefore, the following control settings must be assigned simultaneously to the relevant position of the selection switch:

- All other control or operating modes are not possible. This means to stop the functioning and prevent all other operating modes / control types.
- Functions are only possible as long as the corresponding control devices are actuated (control devices with self-acting reset such as hold-to-run control device, enabling device).
- The operation of dangerous functions is only possible during lower risk conditions (e. g. limited speed, reduced pressure, reduced force, step operation, limitation of range of motion) and elimination of hazards resulting from command sequences.
- The operation of dangerous functions by intended or unintended influence on the sensors (e. g. pressure sensors, position sensors) of the test bench is not possible.

Section 4.1 of IFA report 07/2013 [22] contains further information on the selection of the operating mode.

4.2.2.3 Servohydraulic control systems

Servohydraulic control systems and PC-systems in hydraulic test benches cannot meet the requirements of the DIN EN ISO 13849 in general. In such cases a safety-related control must have a higher order. Reaction times and the resulting overrun movements must be considered in particular.

A controlled “operating stop” of a servohydraulic axis is *not* a de-energized condition and thus *not* the safe condition, since servo valves generally do not meet the *basic* and *well-tried* safety principles of DIN EN ISO 13849-2 and therefore can not be used in safety related parts of control systems. These valves do *not* have e.g. a defined safety related switching position and thus do *not* comply with the standby-current principle.

In these controls a safe condition can *only* be assumed *when* all energies are dissipated, i. e. the electrical and electronic controls are switched off at the corresponding performance level, all hydraulic accumulators are safely locked or emptied, all gravity-loaded axes (e. g. vertical axes) are lowered to the lowest position and all other energy accumulators (e. g. springs) are relieved, so that the hydraulic circuit is *depressurized* and remains in this condition.

Protective measures for setting up, maintaining and repairing of servohydraulic test benches must be explained in the operating instructions.

4.3 Measures by equipment

4.3.1 Hydraulic equipment

For the design of hydraulic test benches, the guidelines of DIN EN ISO 4413 need to be considered concerning the hydraulic equipment.

> The Information FBHM-061 “Checklist Hydraulic” includes the most important facts of DIN EN ISO 4413 in the form of a checklist. Due

to copyright reasons, the list cannot and does not represent or replace the entire DIN EN ISO 4413. For the evaluation of older test benches, it could be necessary to consider older requirements and directives, depending on the year of manufacture and/or modifications which have already been made.

Due to the experience of the FB HM with numerous hydraulic test benches of different applications, designs, operating modes and test pressure levels, in particular the following protective measures are of significant importance. They do not only concern new designs but also the retrofitting of existing older hydraulic test benches (see BetrSichV [6] and section 1 of this Information).

The following needs to be considered:

- The use of piping is preferred,
- Pipe connections the failure of which can lead to hazards to persons should be designed as form-locking, e. g. flare fitting,
- Hoses whose failure can expose persons to hazards – in the operating room as well as at the related hydraulic aggregate - need to be installed covered; secondary measures have to be taken if this is not possible. For example:
  – protection against pull-out (e. g. pull-out safe fittings, arrestor cables, protective sleeves)
  – hoses have to be equipped or covered with burst proofed hoses.

  The manufacturer´s assembly manual must be strictly observed.

  It could be necessary to take additional measures, like:

  - Oversizing of hoses
  - Reduction of the inspection intervals
  – Reduction of the replacement intervals
- The use of hoses whose functional reliability is proofed by appropriate test procedures (hydrostatic testing according to DIN EN ISO 1402 [23], impulse pressure test according to DIN EN ISO 6803),
- The use of hoses with complete and enduring labeling, see DGUV-Rule 113-020 [24],
- The hose lines must be installed in such a way that:
  – The bending radius is not below the minimum,
  – Twisting of the hose is reduced to a minimum,
  – The abrasion of the hose is minimized,
  – Hoses are not installed over sharp edges,
  – Sharp edges in the test area are safeguarded by e. g. edge protections.

Permanent test benches which are supplied with pressure fluid by e. g. a central hydraulic system and operated over a long period of time without an operator, should be equipped with an automatic shut-down device in order to prevent an uncontrolled oil leakage in case of a leakage incident at night.

4.3.2 Electrical equipment

For the design of the electrical equipment of hydraulic test benches, the determinations of DIN EN 60204-1, must be considered.

The electrical equipment has to be suitable for the physical environmental conditions and for the operating conditions of its intended use; i. e. the conditions that occur during the operation of the test benches for set-up mode as well as during the test mode. Figure 11 shows an open control cabinet of a pressure test bench.

The requirements mentioned in DIN EN 60204-1 cover the physical environmental conditions and operating conditions for most of the hydraulic test benches. If the parameters of the operational conditions of the test bench exceed the parameter limits (limit values) from DIN EN 60204-1, it is recommended to define an agreement between the user and the supplier, for example in the specification.

Figure 11: Open control cabinet of a test bench

4.3.2.1 Electromagnetic compatibility

The equipment must not generate electromagnetic disturbances above the permissible limit for the intended operating environment.

Additionally, the equipment needs an adequate interference resistance against external electromagnetic interferences, so that it operates flawless in its intended environment.

The generic standards for the industrial sector define general limits for emitted interference in DIN EN 61000-6-4 [25] and for the interference resistance in DIN EN 61000-6-2 [26].

4.3.2.2 Environmental temperature and humidity

A flawless operation of the hydraulic test bench including the availability of the safety functions within the ambient temperature range from +5 °C to +40 °C has to be ensured. The functional capability of the test bench and the safety functions must be ensured even at a relative humidity of 50 % and a maximum temperature of +40 °C. A higher relative humidity is permissible at lower temperatures. If the environmental conditions deviate from the values specified in DIN EN 60204-1, the relevant components should be selected in accordance with the increased requirements.

No dangerous effects should occur due to an occasional condensation, which influences the safety and function.

4.3.2.3 Pollution

An adequate protection against ingress of liquids and solids has to be provided. In general, protection category IP 54 according to DIN EN 60529 (VDE 0470-1) [28] is required for electrical installations. Where pressure fluid can come into contact with electrical equipment (e. g. cables) measures must be taken, such as e. g. protected installation or use of oil-resistant cables, cable runs and sealings.

4.3.2.4 Ionizing and non-ionizing radiation

If the equipment is exposed to radiation, for example during test tasks, additional measures have to be taken to avoid a malfunction of the equipment and an accelerated damage of the isolation. A specific agreement between the supplier and the user is recommended.

4.3.2.5 Vibration, shock and impact

Undesired influences due to vibration, shock or impact as well as the effects generated by the test bench itself, must be avoided by the selection of components, by separated arrangement or by use of vibration-reducing mountings

4.4 Protective measures during operation

Test benches must only be used in accordance with the intended use and within the limits of application specified by the manufacturers. The only pressure medium of the hydraulic test bench is a hydraulic *pressure fluid*.

For the use of hydraulic *test benches*, the ArbSchG [7] as well as the BetrSichV [6] have to be considered.

In general, the employer has to consider and implement all safety regulations laid down in the operation manual. This also applies to the provision of protective devices on site or determined organizational measures.

For works at test benches (even at older ones) the hazards have to be determined, the risks evaluated and the protective measures defined by the employer or by the relevant responsible person; this has to be carried out in writing.

Based on the above mentioned hazard identification, written operating instructions need to be prepared (blue framed). The skills and/or a training concept for the operators must be specified. The operators of the test bench need to be instructed regularly regarding the safe handling of the test bench. In order to increase consciousness for potential hazards, it is recommended to communicate e. g. accident reports and information – even on near-accidents - on a current and regular basis.

The user's protective measures include tests before "initial operation" as well as "periodical" tests, according to BetrSichV.

The effectivity of the protective measures taken including the instructions need to be controlled according to §§ 3 and 6 ArbSchG [7]. This can be done by random checks by the relevant responsible persons.

> The installation and the first test run of a test bench is usually carried out by employees (such as fitters, engineers, service personnel) of the test bench manufacturer. Their supervisors are responsible for the protection of their employees.

The manufacturer´s requirements, listed in the operation manual, need to be observed during *operation* of the test bench. Furthermore, the following protective measures are recommended:

Prior to the testing, the test objects have to be clamped safely on the test machine table by means of suitable fixing elements or similar in the test bench or in the test room.

The hoses in the operation area of the test bench (test area) need to be checked regularly by the operator (visual inspection) for every new installation (changing test assembly). The remaining hoses (e. g. at the aggregate) must be checked at least annually by maintenance personnel (see DGUV regulation 113-020). Damaged hoses must be replaced immediately, otherwise after a fixed replacement interval.

> Test criteria for hoses can be found in Table 4 of Information sheet FBHM-015 [29] and the DGUV Rule 113-020; this table 4 should be handed over to the employees in a laminated manner or attached to the test bench. The operators shall be appointed as “qualified person” for the execution of the test of the hoses in the immediate test area for each new installation in accordance with TRBS 1203 or to BetrSichV [30]. Also the maintenance personnel, who are responsible for the testing of the remaining hoses, are appointed as „qualified persons“.

Quick disconnect couplings are also subject to abrasion and therefore need to be tested regularly. Worn or damaged quick disconnect couplings must be replaced immediately.

In many cases, different types of threads are required to test components. Mix-ups can occur due to geometric analogy, which can result in hazards, see Information sheet FBHM-025 „Hydraulic fittings“ [31].

If accumulators are installed in the hydraulic circuit, they must be checked according to the specifications; for further information, see Information sheet FBHM-046 „Hydraulic accumulators“ [32].

Adequate personal protective equipment, including ear protection and suitable skin protection must be provided to the operators of the hydraulic test bench, (see DGUV Information 209-070 – Safety in hydraulic maintenance (previously: BGI/GUV-I 5100)) [33], section 2). If the pressure fluid used in the specific application should be classified as hazardous substance according to the safety data sheet, operating instructions for hazardous substances for the pressure fluid must be prepared. DGUV Information 209-070, section 2 includes an example.

Slipping hazards in front of the test benches need to be reduced by suitable floor covering or step grids. These may also be subject to wear and need to be renewed if needed.

Due to the danger of slipping, spilled liquids or escaped pressure fluids need to be removed by suitable media, see DGUV Information 209-070, section 2.2.

If movable guards are used, if necessary as retrofitting on older test benches, they have to be interlocked with the relevant safety- related parts of the control system, e. g. for pressure and movements.

Due to the aging and possible damage, the vision panels of the guard at test benches need to be replaced in regular intervals according to the manufacturer´s instructions.

The visual inspection of leakage spots at pressurized cylinders/piping/components is only permitted with the guard closed. If this inspection can only be carried out with the guard open, the references of section 2.3 and 3 in the above mentioned DGUV Information 209-070 must be considered.

The specifications of the test bench manufacturer must be considered if the hydraulic energy must be maintained during setup mode or for other reasons.

Especially for pressure tests, it is mandatory to vent the whole test line since compressed air has a significant higher stored energy than comparable incompressible pressure fluids. Venting should be carried out according to the test bench manufacturer´s specifications listed in the operating manual.

> There is no scientific knowledge available on the minimum operating and test pressure value, below which a risk due to escaping pressure fluid can be excluded.

At test tasks with very high pressure, pressure fluids can no longer be considered as incompressible. The compressibility for a standard oil is about 0,7 % / 100 bar. At tests for bursting pressure with oils, the pressure value is about 800 bar (approx. 5,6 % volume change only by the oil!) and above. This high pressure in combination with a large volume of the test specimen (e. g. large component diameter) results in a high risk. Water has a lower compressibility than oil.

The electrical power supply of test objects (e. g. control voltage of valves) as well as measuring

equipment (sensors) needs to be provided as safety extra-low voltage (PELV) or as galvanically isolated from the supply voltage.

The check of the electrical equipment of the hydraulic test bench has to be done according to DGUV regulation 3 [34].

5 Further aspects

The test bench manufacturer has to consider further aspects during the design, which may result from the particular test task of the user.

5.1 Use of hand operated pumps

A hydraulic test bench the hydraulic energy of which is solely generated by a hand-operated pump, for pressuri-zation or the movement of axes, falls within the scope of the Product Safety Act when being considered as a product and, if used as work equipment, it falls within the scope of the BetrSichV. According to § 5, para. 1 of BetrSichV, work equipment shall be safe when being used. According to § 5, para. 3 of BetrSichV, this includes the use of all applicable EU common directives.

It has to be examined first whether the test bench or its parts fall within the scope of the DGRL. Besides the obligation for preparing operating instructions, for the most part of hydraulic test benches or their assemblies dealt with in this "Fachbereich AKTUELL", it applies the principle of "good engineering practice" according to article 4, para. 3 of the DGRL, but no CE marking according to DGRL. For hydraulic accumulators or pressure intensifiers which may be installed within the hydraulic test bench, the DGRL has to be possibly applied in full.

If, e. g. a lifting process of components or loads or other movements are initiated by the stored pressure, the test bench falls within the scope of the Machinery Directive. The Machinery Directive also applies if pressure energy stored within the system can power movable parts or axes. In this case, an EC Declaration of conformity and a CE marking are required. The exceptions of the DGRL with regard to machines have to be taken into account. (DGRL article 1, para. 2, letter f, j). If, however, only pressure is built up and stored and no movement is generated, it is no machine according to the Machinery Directive.

Work equipment that is not subject to specific requirements stated in EU common directives or which was not subject due to e. g. the year of construction have to fulfill at least the safety requirements according to §§ 6, 8 and 9 of the BetrSichV in order to use the work equipment safely in accordance with the State of the Art. Prior to use, the employer has to carry out a risk assessment according to § 3 BetrSichV and specify protective measures.

The protective measures mentioned in this "Fachbereich AKTUELL" help to implement the safety requirements on hydraulic test benches as machines according to the Machinery Directive and as work equipment according to the BetrSichV in a safe way.

5.2 Temporary laboratory test facilities

Excluded from the scope of the MD are *„Machinery specially designed and constructed for research purposes for temporary use in labo-ratories"* [see MD article 1 paragraph 2 letter h)].

The "Guide to application of the Machinery Directive 2006/42/EC [35] of the European Commission, Executive Board Enterprise and Industry" of June 2010 includes the following explanation:

The exclusion set out in Article 1 (2) (h) was introduced since it was not considered reasonable to submit to the requirements of the Machinery Directive laboratory equipment specially designed and constructed for the needs of particular research projects. Consequently, the exclusion does not apply to machinery permanently installed in laboratories that may be used for general research purposes or to machinery installed in laboratories for purposes other than research such as, for example, for testing purposes. The exclusion only applies to equipment designed and constructed for temporary research use, that is to say, equipment that will cease to be used when the research projects for which it was designed and constructed have been completed.

But, however, for the operation of the afore mentioned machines which have been excluded from the MD (MD article 1 paragraph 2, letter h), the requirements of the BetrSichV [6] have to be complied with. According to § 5 paragraph 3 sentence 3, BetrSichV, these test benches as work equipment have to correspond with the general safety requirements of the relevant EU Directives as well. The present "Fachbereich AKTUELL" provides guidance for this case as well.

5.3 Heated pressure fluids

For the construction of test benches with heated pressure fluids or test chambers, manufacturers must consider the following:

- Temperature monitoring and safety related reactions (e. g. shut-off when exceeding the temperature) have to relate to the risk (Performance Level).
- All components (e. g. hoses, sealings) have to be selected by taking into account the pressure fluids used (hot test oils) and the temperatures to be expected.
- If the limit values for hot surfaces according to DIN EN ISO 13732-1 [36] are exceeded, measures such as shielding or warnings have to be taken.
- Hoses which transport hot pressure fluids must be installed concealed so that nobody can be exposed to a hazard if this pressure fluid escapes.

If the escape of oils or the discharge of oil mist (steam or finely divided aerosols) have to be expected due to:

- leakage,
- during pressure and bursting tests and
- due to bursting components,

further protective measures may be required (see section 5.4 of this Information).
If the risk of burns exist due to hot components of the test bench as well as heated pressure fluids during works at the test bench (e. g. installation of test specimens or during troubleshooting), protective measures have to be taken. This includes operating instructions and personal protective equipment. Further information is included in DGUV Information 209-070 – Safety at hydraulic maintenance (previously: BGI/GUV-I 5100).

5.4 Fire and explosion protection

Due to the diversity of test procedures and the pressure fluids being used, it is not possible to provide detailed requirements for minimization of the risks caused by fire and explosion in this “Fachbereich AKTUELL”. Instructions as to this topic are defined in DIN EN ISO 19353 [37] and in DIN EN 1127-1 [38]. The test bench manufacturers have to take these risks into account.

The *users* of test benches or the employers have to evaluate all risks and define suitable protective measures according to BetrSichV [6] section 2 §§ 3, 4 and 9.

The responsibility of the manufacturers and the users, to identify specific risks (e. g. fire and explosion) and to minimize the resulting risks is crucial for further protective measures (e. g. to decide whether a central extraction system (see figure 12) is needed, how this system has to be designed to encounter the risks and how this system operates correctly).

> Hazards caused by fire and explosion depend on the actual operating conditions of the test bench and/or the use of inflammable pressure fluids and should be considered separately, see DIN EN ISO 19353.

5.4.1 Fire protection

If there is a risk of fire, the following applies:

- The test bench including the control system must be designed in that way that the connection of the fire-detecting equipment (fire alarm), of fire-suppression systems, pressure relief valves etc. is possible in accordance with the installation recommendations of the specific manufacturers.
- If a fire is detected, the extraction system has to be stopped in an adequate way. The time delay until the airstream stops, increases the amount of the fire extinguishing media by use of an automatic suppression system.

5.4.2 Explosion protection

The MD specifies in Annex I section 1.5.7, the requirements for protection of health risks due to explosion:

„Machinery must be designed and constructed in such a way as to avoid any risk of explosion posed by the machinery itself or by gases, liquids, dust, vapors or other substances produced or used by the machinery.

Machinery must comply as far as the risk of explosion due to its use in a potentially explosive atmosphere is concerned with the provisions of the specific Community Directives. “

Therefore, it has to be checked whether the Explosion Protection Directive RL 2014/34/EU [39] has to be applied.

An explosive atmosphere in the work environment of very hot components (ignition source) must always be avoided.

The employer must carry out a risk assessment according to Gefahrstoffverordnung (“Ordinance on Hazardous Substances” in the following referred to as GefStoffV) [40] and BetrSichV [6] and in consideration of the safety data sheet of the pressure fluid used, see also BetrSichV section 2 § 9 paragraph 4.

> Depending on the pressure fluid used, for example water-based test fluid, the test bench manufacturer in consideration of the test task or the user or rather the employer may determine

during the individual internal risk assessment that the occurrence of a dangerous explosive atmosphere need not be expected.

Depending on the test method, e. g. function tests or setup works at components, the test bench manufacturer in consideration of the test task or the user as well as the employer when using mineral oils may determine during the individual internal risk assessment, that the occurrence of a dangerous explosive atmosphere need not be expected.

If, due to the test task, the test mode and the pressure fluid used in the test bench, the formation of flammable, finely divided aerosols has to be expected, the user or employer must create an explosive protection document in accord¬ance with the GefStoffV [40] and define the zone division.

In case of rarely and short-term occurrence of a dangerous explosive atmosphere, zone 2 shall be selected. In this case, devices of category 3 according to Directive 2014/34/EU shall be used inside the test area.

In case of occasional occurrence of a hazardous explosive atmosphere, zone 1 should be selected. In this case, devices of category 2 according to Directive 2014/34/EU shall be used inside the test area.

Figure 12: Extraction at test benches

Depending on the test method, e. g. rare test tasks with hot test oil or rare bursting tests with pressure fluids with a high amount of oil, the test bench manufacturer in consideration of the test task or the user or employer may determine during the individual internal risk assessment that the occurrence of a dangerous explosive atmosphere need not be expected.

Depending on the test method, e. g. frequent bursting tests with hot pressure fluids with a high amount of oil, the test bench manufacturer in consideration of the test task or the user or employer may determine during the individual internal risk assessment, that e. g. a rare or short-term occurrence of a dangerous explosive atmosphere has to be expected and the test bench need to be designed adequately. (This variant of the test task of a test bench is rarely relevant to what happens in practice, but is performed exemplary for demonstration purposes.)

5.5 Emission of dangerous substances due to vapors or aerosols from pressure fluids

If burst pressure tests are conducted at serial test benches and the frequent occurrence of atomized spray in the test area has to be expected, the test bench needs to be designed in that way that splashing, spraying and the formation of vapors (that means vapors or finely divided aerosols) will be avoided outside the guard or the closed test bench (see figure 12).

Depending on the pressure fluid used, an odor emission can occur during the operation of a hydraulic test bench. If there are no correlated references listed in the safety document of the pressure fluid, this odor emission is not associated with a health hazard due to vapors or aerosols.

The hydraulic pressure fluids used are complex hydrocarbon mixtures with additives, which can generate vapors or aerosols caused by heating during normal operating conditions or discharge during the intended bursting of components.

If the applied pressure fluid needs to be classified as a hazardous substance according to the safety data sheet and dangerous substances (vapors or aerosols) are floating in the air due to the serial bursting of components, the user or employer must evaluate the hazards and take suitable protective measures according to BetrSichV [6] § 3 and § 4. Therefore, it could be necessary to install suitable technical extraction systems.

Further information is provided in the DGUV Information 213-726 [41] „Tätigkeiten mit sonstigen komplexen kohlenwasserstoffhaltigen Gemischen (KKG) “Activities with other complex hydrocarbon containing mixtures“. Therefore the pressure fluids being used in hydraulics belong to emission group D, when used as intended, e. g. in a hydraulic circuit of a machine. It is

recommended to use preventively the lowest evaluation value of 10 mg/m³ (sum of vapor and aerosol) for this KKG, for non intended use of the pressure fluid (e. g. bursting of components on purpose). This correlates to emission group C.

5.6 Ergonomic aspects

Hydraulic test benches must be designed like all machines in accordance with ergonomic principles, to avoid excessive exertion, unhealthy posture and tiring during the operation (see also DIN EN 13861 [42]); Particular attention should be paid to the following:

Hydraulic components that should be tested, the tools and accessories must be easily movable. Lifting equipment could be necessary for components exceeding a weight of 10 kg (see DIN EN 1005-1 [43], DIN EN 1005-2 [44] and DIN EN 1005-3 [45]).

If handling equipment, lifting devices or lifting equipment are required, precautions must be arranged for their installation and operation (e. g. by providing access to the working area through the top of the test bench with guards open).

If components are installed manually into the test bench, the clamping devices or holding devices must be installed in such a way that excessive reaching-into the test bench is avoided.

The controls for the actuation of clamping devices for the components to be tested, must be installed in that way, that excessive stretching is avoided during stress (e. g. by use of foot-operated switches).

The positioning, labeling and lighting of control devices as well as monitoring and service spots, for example to charge and discharge reservoirs, must be selected taking into account ergonomic principles according to DIN EN 614-1 [46], DIN EN 614-2 [47], DIN EN 894-1[48], DIN EN 894-2 [49], DIN EN 894-3 [50], DIN EN 1005-1, DIN EN 1005-2, DIN EN 1005-3, DIN EN ISO 13855 [51]. The actuation forces for movable guards must not exceed certain force values, depending on the frequency of actuation (see DIN EN 1005-3).

Inside the operation area, the lighting must be in accordance with DIN EN 1837 [52]; There must be at least 500 lux, measured at the front edge of the component to be tested, while the movable protective device is open.

The labeling of pressure, tank and drain lines in the hydraulic test bench must be clear and unambiguous.

The equipment and accessories for setting up and maintaining the test bench, which are listed in the operating instructions and are not readily available, must be provided.

Input devices (e. g. keyboards, buttons, push-button switches) must comply with DIN EN 894-1 and DIN EN 894-3.

Information displayed on the screen must be clear and unambiguous. Reflections and blindings must be reduced to a minimum (see DIN EN 894-1, DIN EN 894-2).

5.7 Special requirements due to hazards caused by ‘noise’

The Machinery Directive states the requirements for the protection against health hazards due to noise in Annex I section 1.5.8:

„Machinery must be designed and constructed in such a way that risks resulting from the emission of airborne noise are reduced to the lowest level, taking account of technical progress and the availability of means of reducing noise, in particular at source.

The level of noise emission may be assessed with reference to comparative emission data for similar machinery. “

Concerning the data about the level of noise emission in the machine operation manual, the MD (Annex I section 1.7.4.2 letter u) states the following requirements:

„Each instruction manual must contain, where applicable, at least the following information:

u) The following information on airborne noise emissions:

- *The A-weighted emission sound pressure level at workstations, where this exceeds 70 dB(A); where this level does not exceed 70 dB(A), this fact must be indicated;*
- *The peak C-weighted instantaneous sound pressure value at workstations, where this exceeds 63 Pa (130 dB in relation to 20 µPa);*
- *The A-weighted sound power level emitted by the machinery, where the A-weighted emission sound pressure level at workstations exceeds 80 dB(A).*

These values must be either those actually measured for the machinery in question or those established on the basis of measurements taken for technically comparable machinery which is representative of the machinery to be produced.

In the case of very large machinery, instead of the A-weighted sound power level, the A-weighted

emission sound pressure levels at specified positions around the machinery may be indicated.

Where the harmonized standards are not applied, sound levels must be measured using the most appropriate method for the machinery. Whenever sound emission values are indicated the uncertainties surrounding these values must be specified. The operating conditions of the machinery during measurement and the measuring methods used must be described.

Where the workstation(s) are undefined or cannot be defined, A-weighted sound pressure levels must be measured at a distance of 1 meter from the surface of the machinery and at a height of 1,6 meters from the floor or access platform. The position and value of the maximum sound pressure must be indicated.

Where specific Community Directives lay down other requirements for the measurement of sound pressure levels or sound power levels, those Directives must be applied and the corresponding provisions of this section shall not apply;“

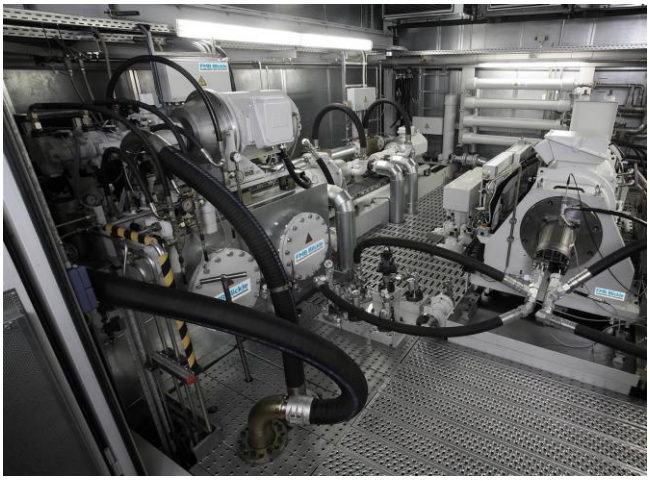

Figure 13: Interior view of an open, all-side covered and accessible test bench for axial piston pumps

When designing the hydraulic test bench, the available information and technical measures for *influencing the noise at its source* can be used (see exemplary DIN EN ISO 11688-1 [53]). Figure 13 shows an open, all-side covered and accessible test bench, on which noise-intensive tests for pumps can be conducted.

The main noise sources at the hydraulic test benches are:

- The hydraulic aggregate
- The pulsating pressure load during endurance tests
- The pulse shaped crack at burst tests.

Due to the absence of a specific standard for noise measurements at hydraulic test benches, it is recommended to align with relevant and comparable standards regarding this procedure.

> For machine tools it is specified to conduct the noise measurement according to DIN ISO 8525 [54]. The noise emission must be determined according to DIN ISO 230-5 [55].

The determined noise emission values of the hydraulic test bench must be specified in the operation manual.

The following information, regarding the airborne noise emissions of the test bench, must be provided:

- The A-weighted emission sound pressure level at workstations, where this exceeds 70 dB(A); where this level does not exceed 70 dB(A), this condition must be described;
- The peak C-weighted instantaneous sound pressure value at workstations, where this exceeds 63 Pa (130 dB in relation to 20 µPa);
- In addition, the A-weighted sound power level L_{WAd} emitted by the test bench, if the A-weighted emission sound pressure level L_{pAd} at workstations exceeds 80 dB(A).

These values must be either the values actually measured at the test bench or values which are determined by measurements at technically comparable test benches that are representative for the test bench to be built.

In case of huge test benches, the emission-noise pressure levels can be indicated at certain spots around the test bench instead of the noise power level.

Wherever noise emission values are specified, the uncertainties of these values must also be indicated. The operating conditions of the test bench during the measurement as well as the measuring method have to be described.

> It is recommended to conduct the noise measurements during adequate operation conditions.

The spot and height of the maximum emission-noise pressure value have to be described.

A statement about the applied measuring method has to be enclosed to this description and the valid operation conditions during the testing as well as the values for the uncertainty K, using the dual-number specification according to DIN EN ISO 47871 [56]:

- *K = 4 dB on application of DIN EN ISO 3746 [57] or DIN EN ISO 11202 [58] (accuracy class 3);*

- *K = 2,5 dB on application of DIN EN ISO 3744 [59] or DIN EN ISO 11204 [60] (accuracy class 2).*

Example

For an acoustic noise power level of LWAd = 83 dB(A) (as measured value) the uncertainty is K = 4 dB(A) for measurements which are conducted according to DIN EN ISO 3746.

> Another exemplary case study for noise emission of a machine tool is shown in DIN ISO 230-5. The listed operation modes of this case study of DIN ISO 230-5 are general and do not refer to the defined control operation modes of a hydraulic test bench of section 4.2.2.2 in this "Fachbereich AKTUELL".

To verify the accuracy of the identified emission values, the measurements have to be conducted by applying th e same measuring method or a method with a higher accuracy class with the described operating conditions.

The noise specifications must be supplemented with the following declaration:

„The mentioned numerical values are emission levels and do not necessarily represent safe working values. Even though there is a correlation between noise emission and noise disturbance, this cannot be used reliably to determine if further protective measures are necessary or not. The parameters affecting the employees are the properties of the working area, other noise sources which mean the amount of machines as well as other closely running processes and the duration during which an employee is exposed to noise. Furthermore the permissible stress level varies from country to country. This information should allow users or employers, to fulfill a better evaluation of the hazards and risks."

6 User information

The test bench manufacturer has to provide detailed user information according to the MD. This user information includes the complete labeling of the test bench (MD Annex I section 1.7.3) as well as the operation manual according to MD annex I section 1.7.4. (include declaration of conformity).

The operation manual must clearly mention the intended use of the hydraulic test bench and all warnings concerning the misuse (exclusions of use) of the machine.

It needs to be announced clearly, that a modification of the test bench or an unintended use may be a significant change according to the ProdSG [2] which results in additional safety requirements and further measures which need to be considered. Therefore, the test bench manufacturer should always be contacted before modifications are made.

7 Documentation of maintenance

The safe operation of test benches also includes maintenance and its continuous documentation (e. g. a maintenance book).

It is recommended to record all test benches in an operative documentation, including the components that are subject to testing and replacement. As a result of this, an operative agreement can be defined, to determine who (operator or maintenance staff) has to test which component in which interval, and if necessary, who replaces the component. During the determination of company-internal specifications, relevant operational experiences can be used.

The safety information of the test bench manufacturer needs to be considered during troubleshooting at the test bench. General information on troubleshooting at hydraulic machines can be extracted from DGUV Information 209-070 „Safe maintenance of hydraulic systems" (previously: BGI-GUV-I 5100), section 3 or annex 1 A.

8 Summary and limits of application

This "Fachbereich AKTUELL" is based on expert knowledge gathered by the expert committee woodworking and metalworking, subcommittee machinery, systems and automation in the field of hydraulic equipment of machines and systems.

The present "Fachbereich AKTUELL" has been developed by the statutory accident insurance' expert committee on hydraulics and pneumatics in cooperation with the „Institut für Arbeitsschutz (IFA) of Deutsche Gesetzliche Unfallversicherung (DGUV). It is particularly intended as information to manufacturers and users of hydraulic test benches, which belong to the scope of the European Machinery Directive [1] and which are operated with a pressure fluid as operating supplies. An overview of important safety aspects is provided with regard to the construction and operation of these hydraulic test machines. Due to the variety of possible test situations for test objects and different test conditions, not all

protective measures mentioned in this “Fachbereich AKTUELL” might be applied in full on each individual test bench. The responsibility for a safe design remains with the test bench manufacturer.

Even for test benches constructed before the entry into force of the Machinery Directive, the information provides comprehensive advice to the users with respect to the subsequent improvement of safety.

The particular specifications for other applications (in mining or similar) and for the use of other pressurized mediums (e. g. gas pressure tests) have to be taken into account.

Test benches for other test tasks – such as for internal combustion engines, gears or their components, assemblies, vehicles with flammable liquids or hot internal combustion engines etc. – are not taken into account in this information sheet. For this kind of test benches, various other legal regulations have to be considered. This would go beyond the scope of an information sheet for “Hydraulic test benches”.

The provisions according to individual laws and regulations remain unaffected by this “Fachbereich AKTUELL”. The requirements of the legal regulations apply in full.

In order to get complete information, it is necessary to read the relevant regulation texts and the current standards.

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The expert committee woodworking and metalworking is composed of representatives of the German Social Accident Insurance Institutions, federal authorities, social partners, manufacturers and users.

Further information sheets of the expert committee woodworking and metalworking (Fachbereich Holz und Metall) or “Fachbereich AKTUELL” can be downloaded from the internet [61].

As to the aims of the “Fachbereich AKTUELL” or DGUV-Information, refer to DGUV-Information FBHM-001 „Aims of the DGUV-Information published by the expert committee woodworking and metalworking“.

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Table credits:

Table 1: Designs of test benches

Table 2: Specific hazards at hydraulic test benches

Table 3: Recommended minimum thickness of polycarbonate vision panels for hydraulic test benches

Table 4: Safety functions at pressure test benches of design 1E (pressure test bench at component development) as well as design 1S (pressure test benches in series production)

Table 5: Safety functions at movement test benches of design 2E (movement test benches in the development) as well as design 2S (movement test benches in serial production)

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