Safety regulations for accumulators in hydraulic systems

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1. Introduction

1.1 General

The new pressure vessel specifications (Druckbeh.V) (valid for the Federal Republic of Germany), together with the associated technical regulations for pressure vessels (TRB) have been in force since 27.02.1980 and have been applicable to hydraulic accumulators in hydraulic systems and power units.

The pressure vessel specifications were produced by the specialist chemical industry panel at the central office for accident prevention and industrial health (ZefU) within the industrial associations. To all intent, they are laws of the land. This also applies to the technical regulations. Although the pressure vessel specifications were originally conceived for the chemical industry, e. g. for autoclaves etc., they must also be applied to hydraulic systems.

The authors of the pressure vessel specifications and the technical regulations have naturally used the terms normally found in the chemical industry. The requirements of fluid power technology have only partially been covered.

This area is covered by the term "Hydraulic accumulators in hydraulic systems", in the proposed standard for machine building (NAM) for the fluid power industry in the DIN standard.This should cover the application of pressure vessel specifications and technical regulations within the fluid power industry. The requirements of the standard confine themselves to hydraulic power units and hydraulic systems in machines and installations in which hydraulic accumulators are used to store energy.

1.2 The division into groups

The pressure vessel regulations always apply to hydraulic accumulators in hydraulic systems if, during the operation of the accumulator, a pressure of more than 0.1 bar or less than -0.2 bar can occur.

The product of pressure x volume *(p • l, p in bar and l in Litres)* is the factor which is applied in setting the test groups into which accumulators are divided. There are, in fact, seven groups. In general, only groups II, III, and IV are applicable to hydraulic accumulators in hydraulic systems.

Group II:

This group covers all hydraulic accumulators with a permissible operating pressure of more than 1 bar, and in which the product of pressure x volume *(p • l)* is not more than 200.

Group III:

This group covers all hydraulic accumulators with a permissible operating pressure of more than 1 bar, and in which the product of pressure x volume *(p • l)* is more than 200 and not more than 1000.

Group IV:

This group covers all hydraulic accumulators with a permissible operating pressure of more than 1 bar, and in which the product of pressure x volume *(p • l)* exceeds 1000.

Group I applies to all pressure vessels subject to negative pressures.

Groups V, VI, and VII apply to all pressure vessels subject to pressures above 500 bar.

The acceptance details and the associated tests are laid down in the individual group specifications. They apply to both the manufacturer and to the operator of hydraulic accumulators.

2 Terms

Within the pressure vessel specifications and the technical regulations, terms are used which are practically never found or are totally unusable in the fluid power industry. It is therefore necessary to define the terms laid down in the pressure vessel specifications and the technical regulations to make them acceptable to the fluid power industry.

An explanation of these terms related to fluid power technology, and as far as is required, is laid out in the following sections. This does not strictly comply with the standards, but is of more practical use.

2.1 Hydraulic systems/ hydraulic power units

Hydraulic systems consist of an electric motor driven pump delivering fluid, a fluid reservoir, control valves and hydraulic motors together with the necessary pipes and hoses for the operation of the system.

Hydraulic power units consist basically of a pump delivering fluid, driven by an electric motor, the control valves and the fluid reservoir.

(Similar to the official document of the European Community, 19.04.85).

2.2 Hydraulic Accumulators

2.2.1 Hydraulic accumulators as energy storage devices in hydraulic systems

Gas loaded hydraulic accumulators used in hydraulic systems, with of without a separating wall between the liquid and the gas, are pressure vessels in the terms of the pressure vessel specifications and the technical regulations. In general, accumulators employed in hydraulic systems are of piston, bladder, or membrane design. Only occasionally are so-called air loaded accumulators to be found. The first three types all have a separating wall or membrane between the liquid and the gas, while the latter does not.

Pipes, pumps, valves, cylinders, filters, and isolating valves do not , at the moment, come within the scope of the pressure vessel specifications and the technical regulations (of 27. 02. 1980)

2.2.2 The labeiling of hydraulic accumulators

Hydraulic accumulators must at all times have durable and easily readable labels showing:

- Manufacturer or supplier
- Manufacturer's number
- Year of manufacture
- Permissible operating pressure
- Internal volume
- Permissible operating temperature if more than 50 °C or less than 10 °C
- Official test approval number (for officially tested accumulators)

2.3 Operational pressure (above atmospheric zero)

For the operation of pressure vessels in fluid technology and under the pressure vessel specifications and the technical regulations, certain important pressure ratings must be observed.

- Working pressure
- Permissible operational pressure of the hydraulic accumulator
- Permissible operational pressure of the hydraulic system.

2.3.1 Working pressure

This is designated as the pressure at any moment in time during the operational process at a predetermined point in the hydraulic system.

2.3.2 Permissible operational pressure of the hydraulic accumulator

Permissible operational pressure of the hydraulic accumulator is that pressure at which the accumulator is permitted to operate. It is also known as the nominal pressure. This is the pressure at which the hydraulic accumulator must be labelled for continuous operation. Under certain circumstances, the permissible operating pressure of the accumulator may be different dependent upon acceptance society *(see section 5)*.

2.3.3 Permissible pressure of the hydraulic system

The permissible pressure of the hydraulic system is the pressure to which the hydraulic system is limited. This pressure is dependent upon the duty of the system and is determined by the project engineer or the operating company.

2.4 Pressure measuring devices

In hydraulic systems, pressure measuring devices are normally pressure gauges. It is important that this pressure gauge is installed on the fluid side of the accumulator. A pressure gauge may be fitted on the gas side, but is not obligatory.

The range of indication of the pressure gauge must be at least 1.5 times the operating over pressure of the hydraulic system.

It must be possible to test the indication of the pressure gauge e.g. by means of a test connection in the vicinity of the accumulator or an isolating cock to DIN 16 262 or DIN 16271, or by removing it and testing on a separate test stand.

The permissible over-pressure of the system is to be displayed in the vicinity of the pressure gauge. The indication must be durable.

The pressure gauge employed must be compatible with the system fluid and may not be made unworkable by the system fluid.

Damage to the pressure gauge must not cause any kind of danger.

2.5 Safety devices to prevent excessive pressures occurring

Corresponding to the difference between the definitions of operating pressure of the hydraulic accumulator and the hydraulic system, the safety devices must differentiate between limiting the system pressure and preventing the operating pressure of the accumulator from being exceeded.

2.5.1 Safety devices to prevent excessive pressure in the hydraulic system

This can either take the form of a pressure regulated pump or a pressure relief valve.

2.5.2 Safety devices to prevent excessive pressure at the hydraulic accumulator

Safety devices to prevent excessive pressure in an accumulator are defined as safety valves to AD guidance sheet A2. These are officially design tested valves. The valves are subject to an acceptance test in the manufacturer's factory by an official inspector. At this time, they are correctly tested and the setting and their compatibility with the fluid to be used is checked. The setting is then sealed (normally by a lead seal) so that they cannot be set to higher pressures.

These safety valves are described as TÜV valves, as the setting is normally carried out in the manufacturer's factory by an inspector from the TÜV.

The pressure safety valves fitted to hydraulic accumulators must be self operating and must limit the pressure in the accumulator to a maximum excess pressure of 10%.

The accumulator safety valves should not be called upon to operate during the normal operation of the machine. The pressure should therefore be set sufficiently far above the permissible excess pressure of the hydraulic system.

Regardless of the setting of the permissible excess pressure within the hydraulic system, it is recommended that the accumulator safety valve is set so that the operational pressure of the accumulator cannot be exceeded by more than 10%. It must be noted that at this time the whole of the pump flow may be passing through the accumulator safety valve.

And now an example

In a hydraulic system with a system pressure of 100 bar, a hydraulic accumulator with a permissible pressure of 210 bar is to be installed.

With a pressure drop of 31 bar across the relief valve due to the pump volume, the accumulator safety valve may only be set at:

$p_{max.}$ = 210 bar + 10% – 31 bar = 200 bar.

If one pressure relief valve is not sufficient to pass all the pump flow, a number of pressure relief valves may be installed in parallel.

The accumulator safety valve must be connected to the pressure source, on the hydraulic accumulator or the pressure line by its own connector. The valve must not be able to be made unworkable by the system fluid.

It must be ensured that the pressure in the accumulator cannot flow back to the pressure source. Generally a non return valve is fitted between the pump and the accumulator safety valve. This non return valve can only be omitted if the pump design contains its own integral non return valves.

The tank line from the accumulator safety valve must pass the fluid which may pass along it safely to the tank. As this pipe may be subject to sudden shock loading, it must be held firmly in place. In addition, it must be noted that the pipework must not lead to a further rise in pressure at the accumulator safety valve.

Accumulator safety valves must not be designed as fire safety valves.

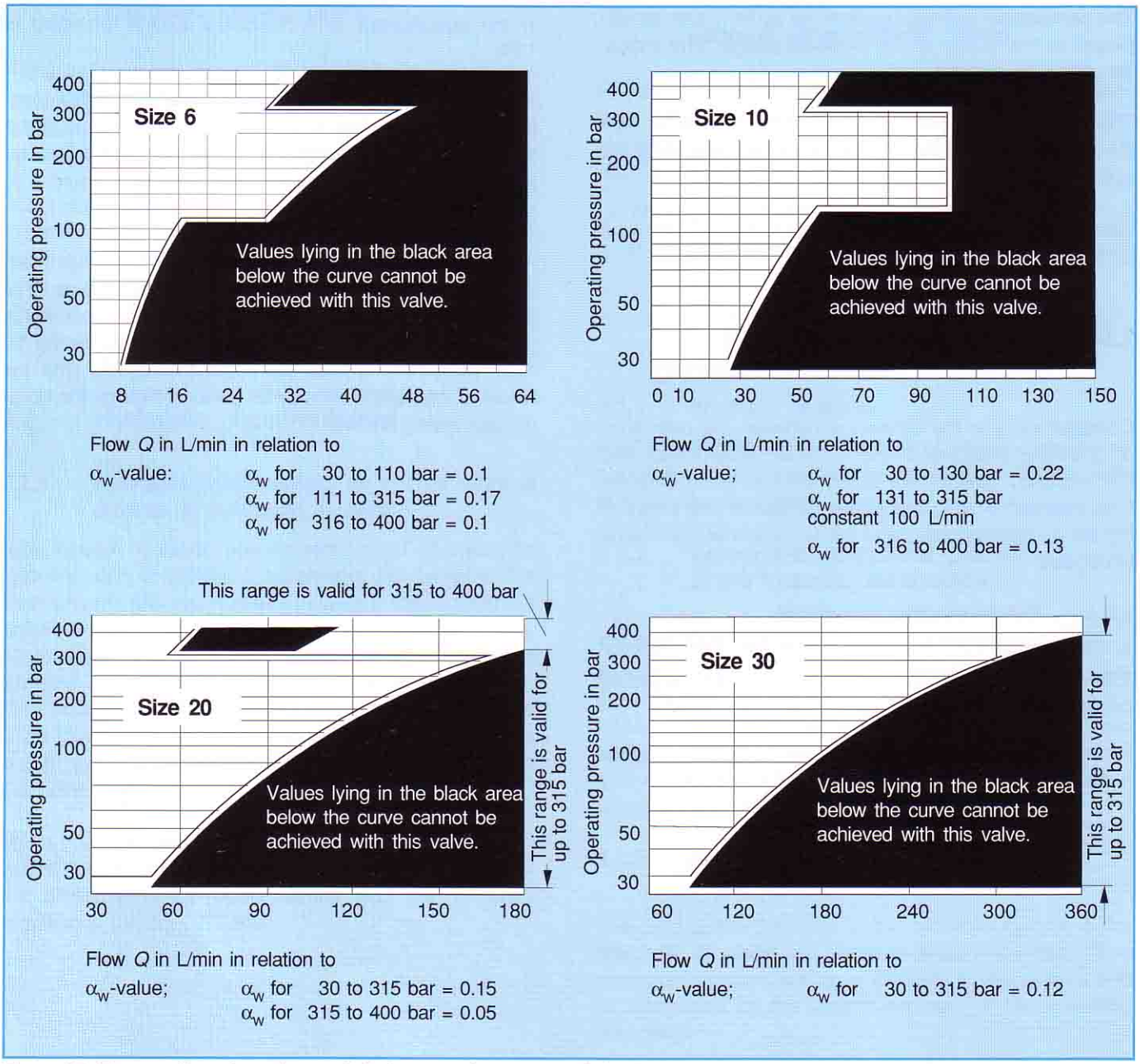

Figure 77: *Pressure/flow dependence of design tested pressure relief valves*

2.6 Isolating devices

Isolating devices are poppet valves, spool valves and cocks.

It should be possible to isolate the accumulator from the pressure line so that maintenance and possible replacement is possible during operation of the system.

All isolating devices must be easily accessible. It must be possible to open and close them under operating conditions and an indication of "open - closed" must be made. It must be impossible to accidently remove spindles by screwing them out.

2.7 Pressure unloading valves

Pressure unloading valves are hand operated devices with which it is possible to unload the fluid side of accumulators in which the gas is physically separated from the fluid. In this process the fluid must be throttled so that it passes safely to the tank. The lever position of these valves must again carry an indication "open-closed".

Pressure unloading valves are "pressure warning devices" in the sense of the pressure vessel regulations.

3 Typical circuits

There follows a few illustrations of hydraulic accumulators as energy storage devices in hydraulic systems. No claim is made that this selection of circuits is complete. Other circuits are certainly possible. They are valid for all accumulators with a separating wall between the gas and the fluid.

3.1 Typical circuit of a hydraulic accumulator without a self operating unloading device.

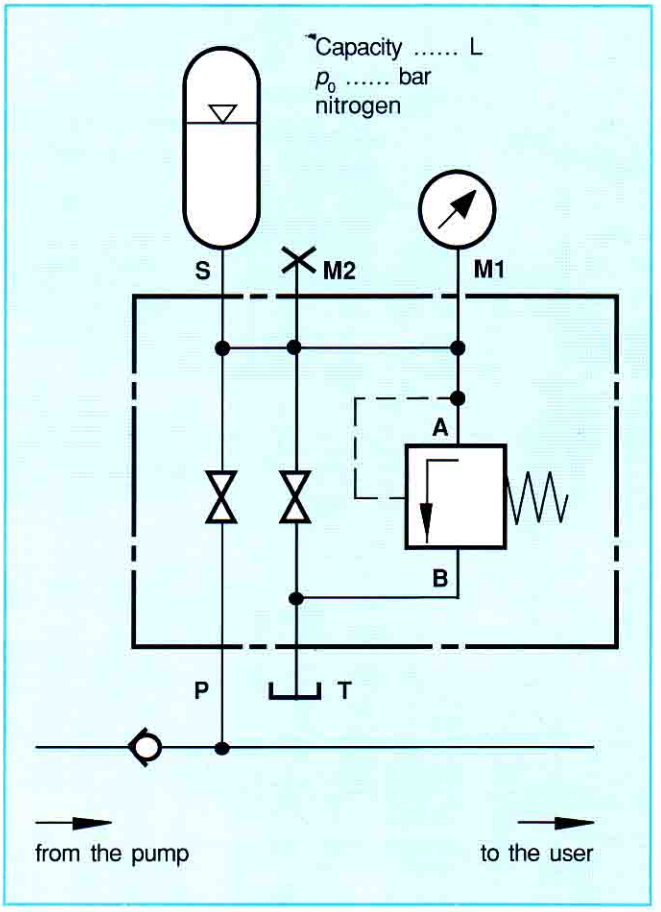

Figure 78

The pressure relief valve shown here can be unloaded by means of a directional poppet valve so that the accumulator is not under pressure when electrical power is not present.

3.2 Typical circuit with a number of accumulators each with its own safety and isolating block

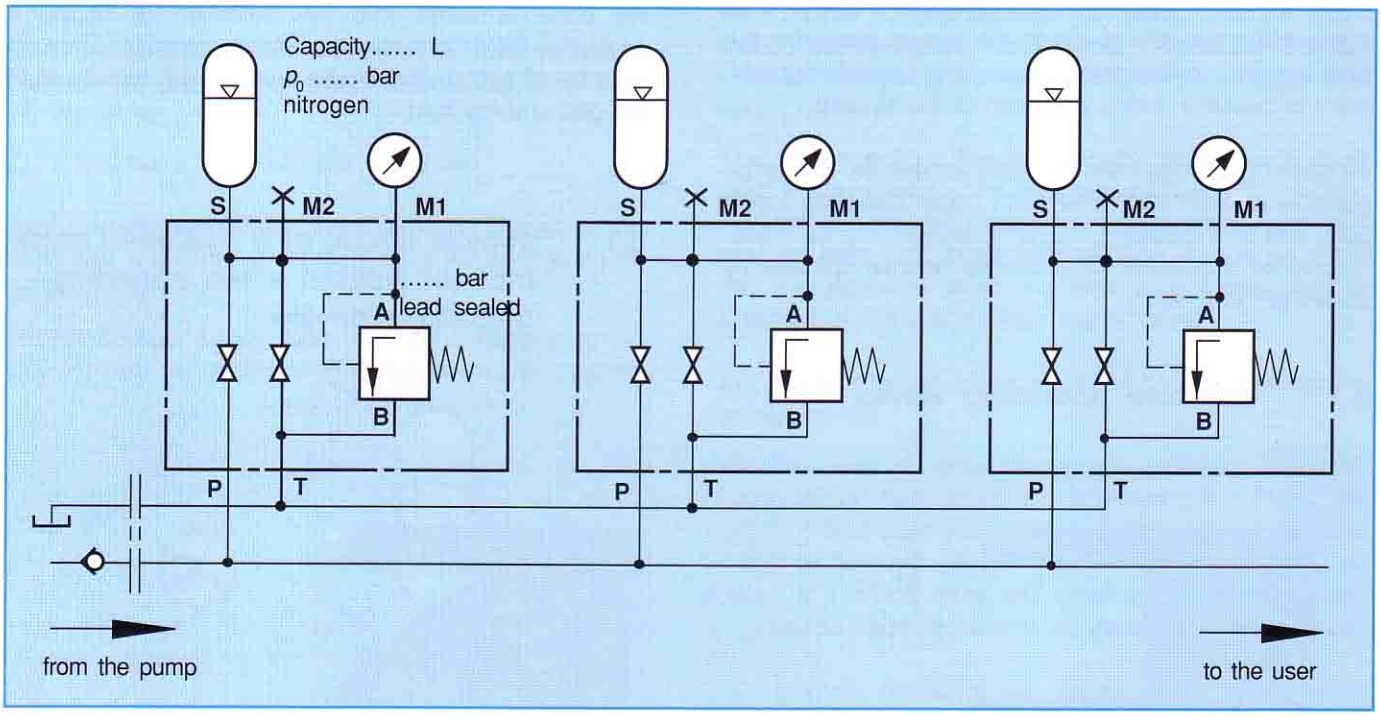

Figure 79

The example in *figure 79* shows that in a circuit with a number of accumulators, each can be equipped with its own isolating and safety block.

3.3 Typical circuit with hydraulic accumulators with a common safety system

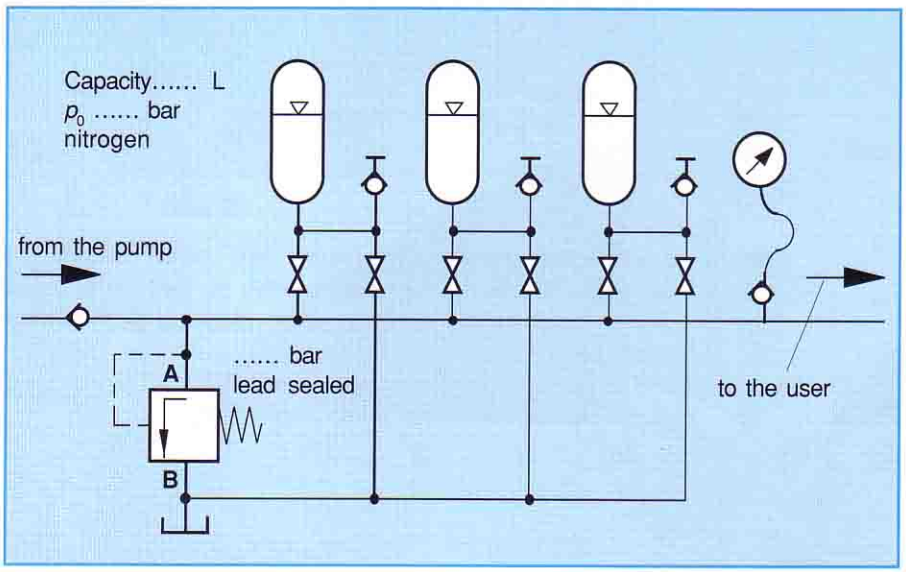

Figure 80

The example in *figure 80* shows that a number of hydraulic accumulators can be safeguarded with a single safety valve. It is recommended, but not the law, that it should be possible to isolate each individual accumulator from the system. If this isolation is included, it must be possible to unload each accumulator individually. It is again to be recommended, but again not the law, that it should be possible to check the pressure in each accumulator separately.

3.4 Typical circuit of one or more accumulators backed up by gas bottles.

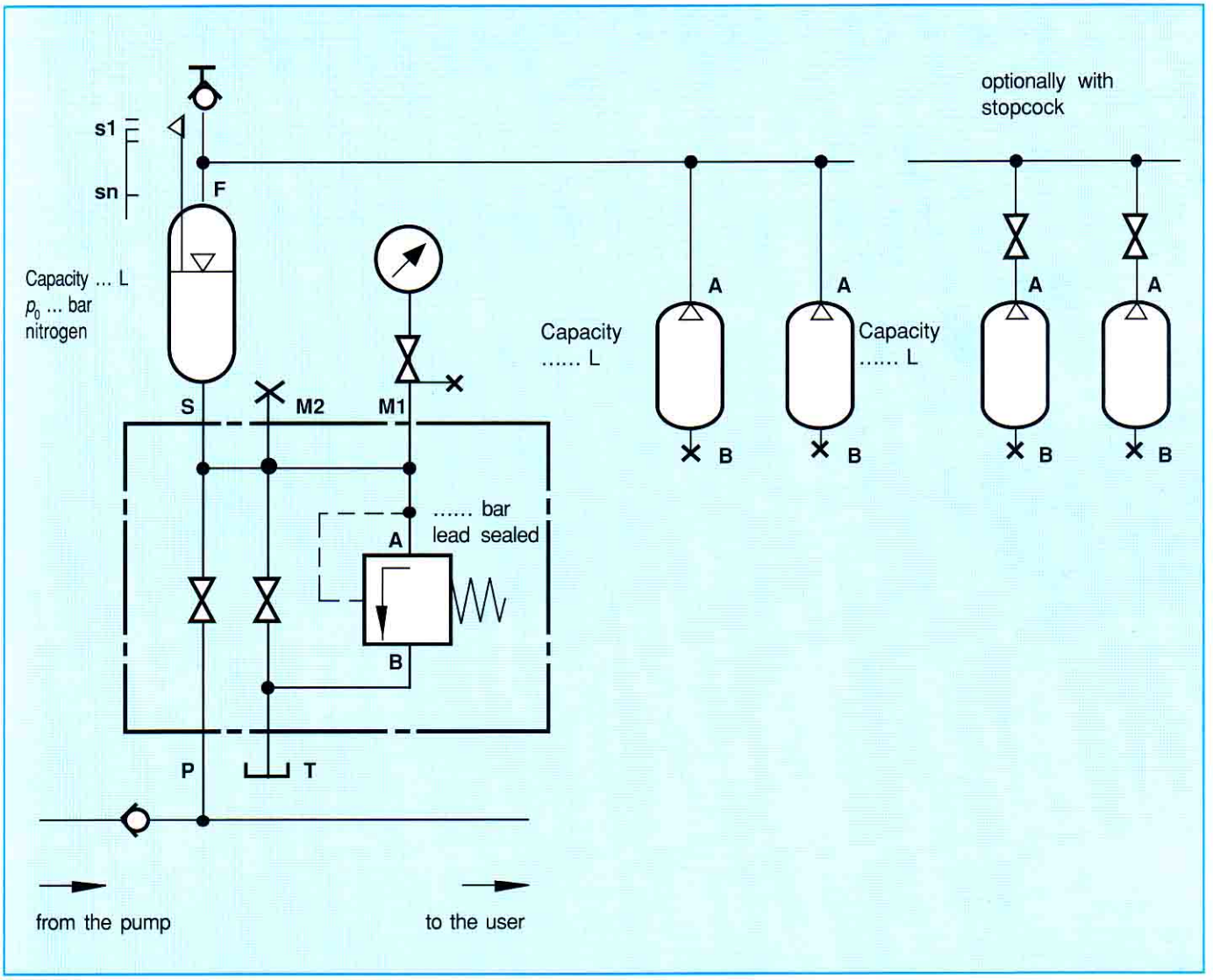

Figure 81

It is a sensible arrangement to fit a connection "B" on the gas bottles to allow condensation to be drained off.

3.5 Typical circuit of a hydraulic accumulator with automatic isolation should electrical power fail

In the previous examples, the accumulator safety valves were all shown between the non return valves and the branch to the accumulator. This is not definitely specified. The accumulator safety valve can be be connected between the pump and the non return valve as shown in *figure 82.*

The set pressure of the safety valve can be reduced by the installation of an additional valve. It must be self operated and ensure that a pressure higher than a 10% excess above the permissible pressure of the accumulator cannot occur.

The unloading valve shown in figure 82 must isolate the accumulator from the system and return the stored fluid

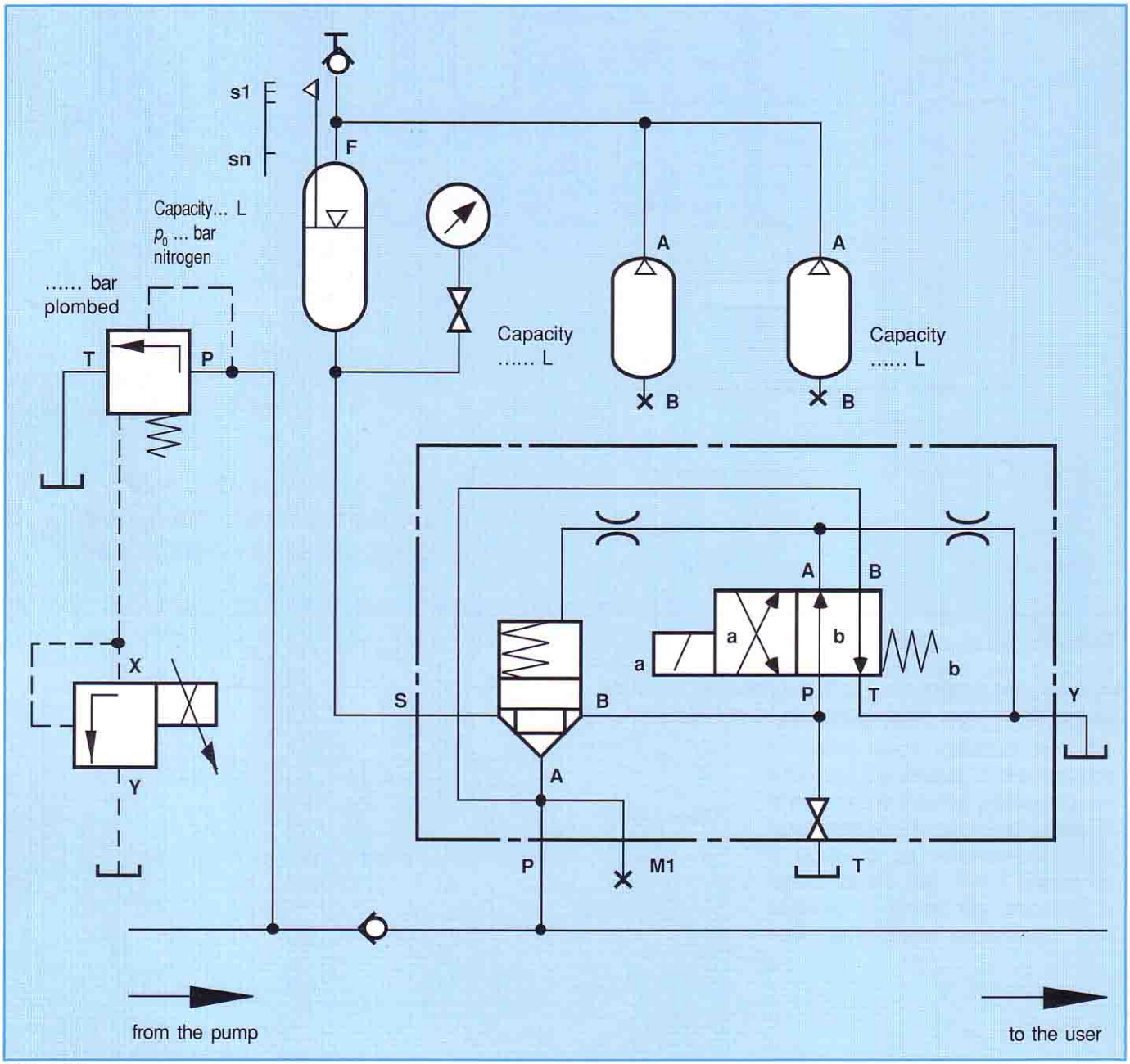

Figure 82

4 The relationship between the sections of this chapter and the relevant official regulations

Section	Title	Guidelines	Issue/ Proclamation	Reference section	Remarks
2.2.1	Hydraulic accumulators	Druckbeh.V. Anhang II § 12 TRB 002 TRB 801	27.02.80 2.84/5.86 2.84/5.86	§ 3, Abs. 1, 2 Abs. 4 1.1 4 Abs. 5	Bladder, piston and membrane accumulators come under pressure vessels (Druckbehälter V).
2.2.2	Labelling hydraulic accumulators	TRB 401	11.83/9.85	2.1	
2.3.2	Permissible operational overpressure of the hydraulic accumulator.	TRB 002	2.84/5.86	1.4.1	The pressure is according to the label on the accumulator.
2.3.3	Maximal operational over-pressure of the hydraulic system in which the hydraulic accumulator is employed.	TRB 002	2.84/5.86	1.4.2	Maximum permissible system pressure.
2.4	Pressure measuring devices	TRB 403	1.84/9.85	2.1 2.1.2 2.1.3 2.1.4 2.1.5 2.2 a, b	Pressure gauge with red warning line. Pressure range 1.5 times the system pressure.
2.5	Safety devices to prevent excessive pressures occuring.	TRB 403	1.84/9.85	3.1 3.1.1 a 3.1.2 3.1.4 3.1.5 3.1.7 3.1.8 3.2 3.5	Safety valve to the AD sheet A2 (TÜV valves). The pump flow must be able to flow via these valves. In doing this the permissible pressure of the accumulator may not be exceeded by more than 10%.
2.6	Isolating devices	TRB 404	1.84/9.85	3.1 3.2 3.3 3.5	Poppet valves, spool valves and cocks.
2.7	Pressure unloading valves	TRB 404	1.84/9.85	4.1	Unloading the accumulator to tank.

Table 17

5 Acceptance specifications for hydraulic accumulators in various countries

Country	Tested by/to	Approved by	Remarks
Africa (other)	TÜV	TÜV	See German Federal Republic, but with documentation in English
Africa (South)	LRIS/ASME code	LRIS or TÜV	In general, the final customer specifies the approval required. If this is not given, to LRIS.
Algeria	Service des Mines Algeria	Service des Mines Algeria	The Service des Mines France is not generally recognised by the Service des Mines Algeria. In exceptional cases the Service des Mines France is accepted. In case of doubt, the customer must decide. Approval by the Service des Mines Algeria is very expensive to obtain. The permissible operating pressures are lower than the Service des Mines France.
America (South)	LRIS/ASME code	LRIS	
Australia	Department of Labour and Industry to Australian standards	LRIS or TÜV	The permissible operating pressures are lower than for TÜV
Austria	TÜV Vienna, to their own standards	TÜV	
Belgium	Apragaz Brussels	Apragaz	
Bulgaria	TÜV	TÜV	Some technical details must be cleared by the final customer.
Canada	National Board (with U stamp) Hydac-ASME code	Lloyd's Register Insurance Inc. (Authorised Inspector)	U stamp (as for the USA) is generally accepted. However, in some provinces the additional testing conditions are expensive both in time and money.
Czechoslovakia	TÜV	TÜV	Some technical details must be cleared by the final customer. An accumulator passport must be obtained for each pressure vessel.
Denmark	Derekoratet for Arbajdsog Fabriktil-synet (available for standard production series accumulators)	TÜV	Name plate in Danish
Finland	TTIC (pretesting to be paid for)	TÜV	

Country	Tested by/to	Approved by	Remarks
France	Service des Mines	Service des Mines	The approval of welded accumulators is very troublesome. Standard are easier.
German Democratic Republic	Staatl. Amt für Technische Überwachung (TÜ), Technical (TÜ) inspection of the type presented	TÜ approved inspector	Some technical details must be cleared by the final customer. Safety valves must have the approval of the TÜ.
German Federal Republic	TÜV	TÜV	
Great Britain	LRIS, British standards	LRIS	
Holland	Stoomwezen Büro of the relevant district	Stoomwezen Büro of the relevant district	
India	LRIS, Indian standard	LRIS	Pre-testing and approval by LRIS. Operational overpressures less than for TÜV.
Italy	ISPESL - Rome	TÜV to Italian standards, partly through ISPESL themselves	TÜV approval accepted up to a nominal volume of 25 L. Above this approval by ISPESL is required. The operational overpressure is reduced by around 20%. Special safety valves must be fitted on the gas side.
Luxembourg	TÜV	TÜV	If required, approval can also be obtained from the Inspection du Travail et Mines (a private organisation). Up to now this approval has not been required.
New Zealand	LRIS in Croydon (GB) to New Zealand standards	LRIS	For approval by LRIS, an "as built drawing" is required for approval by LRIS in Croydon. Only then will the unit be approved.
Poland	UDT	TÜV, Hydac has the right to use the UDT official stamp of approval	Documentation in Polish
Portugal	LRIS	LRIS	Pre-testing and approval lies between Portugal and LRIS. In part, a lower operational over pressure is permitted than for the TÜV.
Rumania	TÜV	TÜV	Some technical details must be cleared by the final customer.
Spain	TÜV	TÜV	TÜV documentation will be validated by the Spanish Consulate.

Country	Tested by/to	Approved by	Remarks
Sweden	AB Statens Anläggningsprovning (SA) und Arbetars-kyddsstyrelesen	TÜV (under contract from SA)	The oil valve and the split ring must be made of a different material to standard
Switzerland	Schweizerischer Verein für Druckbehälter (SVDB)	TÜV	Entry test by SVDB which must be paid for.
USA	National Board (U stamp) Hydac-ASME code	Lloyd's Register Insurance Inc. (Authorised Inspector)	The U stamp is not strictly required in some states. It is most strongly recommended for importation purposes.
USSR	Gost-Norm (covered by TÜV approval)	TÜV	Accumulator pass port
Yugoslavia	TÜV	TÜV	Some technical details must be cleared by the final customer.

LRIS = Lloyd's Register Industrial Services (Hamburg)
TÜV = Technischer Überwachungsverein (Federal Republic of Germany) (Technical monitoring association)
ASME = The American Society of Mechanical Engineers (USA)
AD = Arbeitsgemeinschaft Druckbehälter (Federal Republic of Germany)
TÜ = Staatl. Amt für Technische Überwachung (State office for monitoring technical standards) German Democratic Republic
UDT = Urzqd Dozoru Technicznego (Poland)
TTIC = Teknillinen Tarkastuslaitos (Finland)
SdM = Service des Mines (France)