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OPERATING INSTRUCTIONS

ASP*light* **A**ccumulator **S**imulation **P**rogram

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1. Program description

ASP*light* enables you to calculate the:
→ pressures,
→ volume,
→ temperature as well as
→ pressure and flow ratios of an accumulator, simply by entering a few accumulator parameters.

The calculation is similar to that done on a pocket calculator.

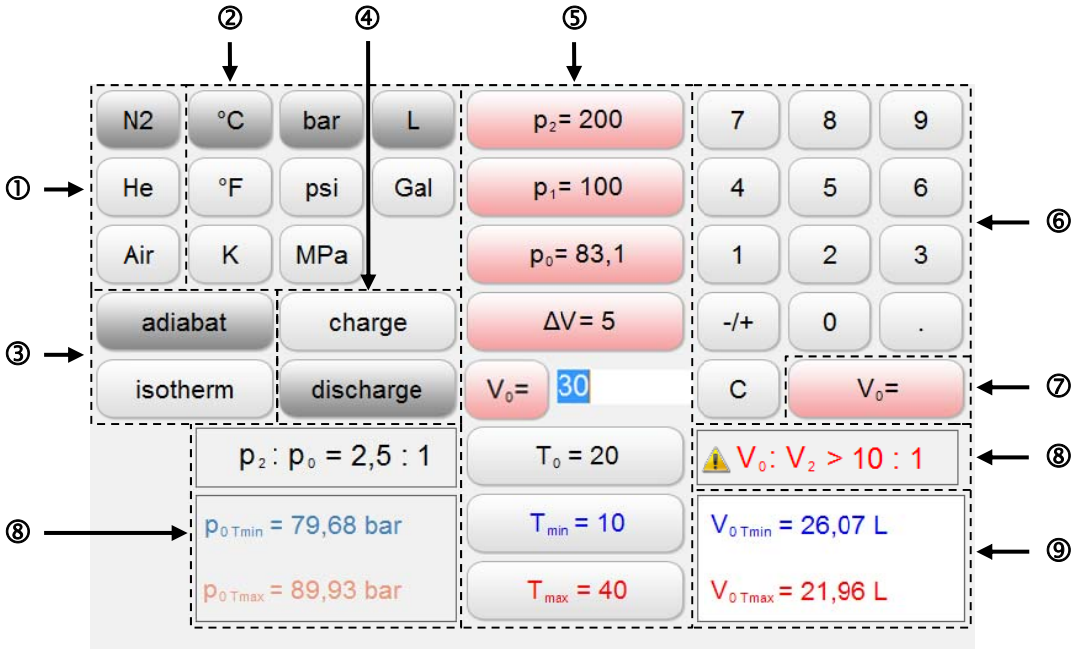
Basic knowledge of the operating characteristics of hydraulic accumulators is required.

The **ASP***light* is optimised to use on the smartphone.

2. User interface

The user interface for **ASP***light* is divided into different fields and includes: selection fields, function and input fields, as well as result and information fields. This section describes these fields in more detail.

2.1. Overview



① = Operating gas: Choice between N2 (nitrogen), He (helium) and air

② = Units: For temperature, pressure and volume

③ = Exchange speed: Choice between adiabatic (fast) and isothermal (slow) process

④ = Exchange direction: Choice between charge and discharge

⑤ = Calculation and input parameters: For accumulator parameters such as pressure, volume, temperature
Calculation parameters are displayed in red

⑥ = Number pad: Can be used for entering values

⑦ = Result button: Example: Calculation V_0
The calculation parameter V_0 is activated

⑧ = Information field: Information about pressure/volume ratio

⑨ = Results field: In this case, "V_0" at T_{min} and T_{max}

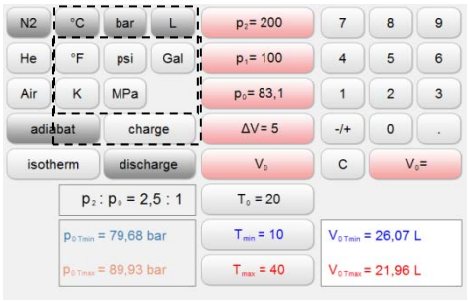
2.2. Selection fields

Operating gas

The "Operating gas" selection field also offers the selection fields Helium (He) and (Air), in addition to the default gas type (N_2) Nitrogen. You can set the desired gas type here.

Hydraulic accumulators must only be charged with nitrogen. Never use oxygen or air - **Risk of explosion!** If there are variations, please enquire.

Units



The physical units for temperature, pressure and volume can be selected as follows:

Temperature: Degrees Celsius (°C), Fahrenheit (°F), Kelvin (K)

Pressure: bar, psi, MPa (Mega Pascal)

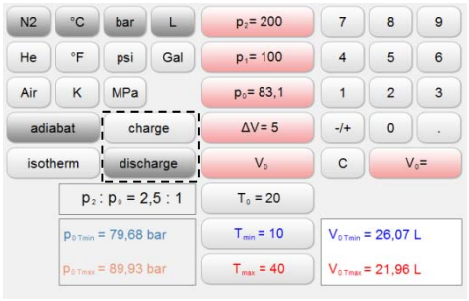
Volume: Litres (L), gallons (Gal (US))

Click the appropriate button to activate the desired unit.
The value that is input or output will then be in this unit.

The following overview shows the relationship between the physical unit and the calculation parameter.

Physical units	**Calculation parameters**			
Temperature [°C, °F, K]	T_{max}	T_{min}	T_0	
Pressure [bar, psi, MPa]	p_2	p_1	p_0	p_{0Tmin} p_{0Tmax}
Volume [L, Gal (US)]	ΔV		V_0	

Exchange direction



Hydropneumatic accumulators are generally used for energy storage.

discharge

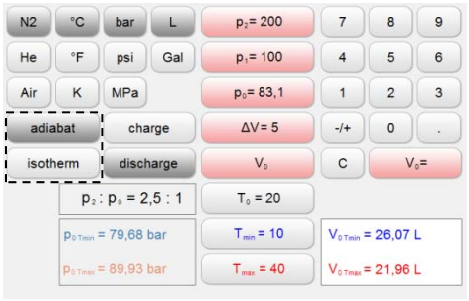
The accumulator must
provide a certain amount of energy/fluid
at a certain time.
This means that it is **discharged**.

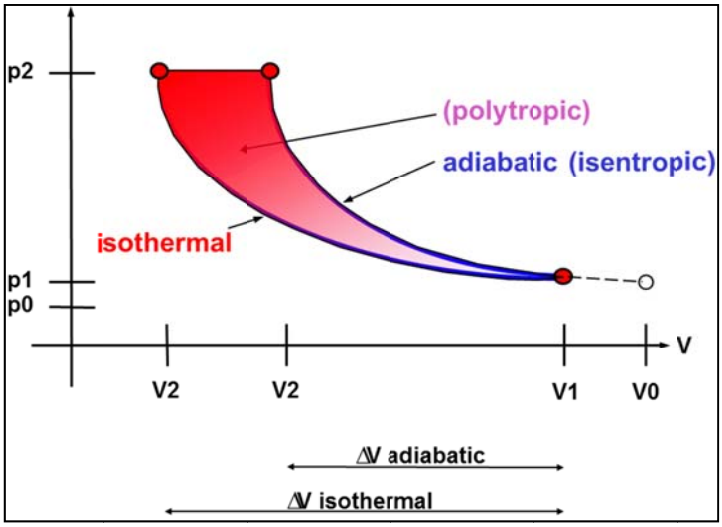
charge

Conversely, select **charge** if the accumulator is to be charged in its application.

Both exchange directions, both charge and discharge, can take place quickly or slowly; see Exchange Speed.

Exchange speed





Exchange speed in p-V graph

In thermodynamics, there are different changes in state for gases. **ASP***light* is limited to the minimum and maximum values for the calculation:

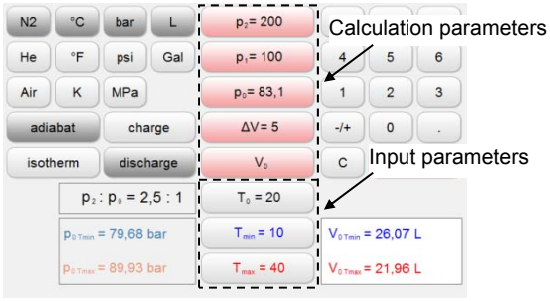
Adiabatic (= isentropic) change of state = no heat exchange with the environment

With this option, the program is based on very rapid accumulator charging or discharging processes. In this case, heat exchange with the environment is not possible. This option results in large accumulator volumes or in small ΔV values.

Isothermal change of state = complete heat exchange with the environment

With this option, the program is based on very slow accumulator charging or discharging processes. In this case, there is complete heat exchange with the environment. This results in smaller accumulator volumes, or large ΔV values, comparatively speaking.

2.3. Calculation and input parameters



The selected area consists of the calculation parameters (p_2, p_1, p_0, ΔV, V_0) as well as the input parameters (T_0, T_{min} and T_{max}).

The calculation parameters, in red displayed, are the input and output values required for calculating a hydraulic accumulator. They can be thought of as a mathematical equation that is manipulated according to the desired size.

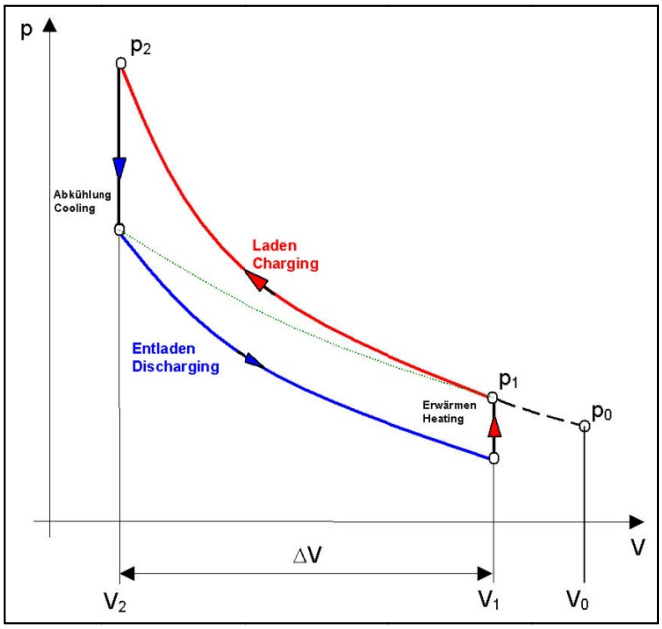
A value cannot be calculated until all other calculation parameters have been entered.

The value p_0 is suggested automatically based on T_0, T_{max} as well as p_1.
If an input value for p_0 must be specified, i.e. forced by the user, it must be changed manually **after** the temperature and also **after** the p_1 have been entered.

The following table shows the input and display options for the parameters:

Input parameter		Input option	
Abbreviation	Description	Input value	Output value (calculation possible)
p_2	Maximum operating pressure	x	x
p_1	Minimum operating pressure	x	x
p_0	Pre-charge pressure	x	⚠
ΔV	Usable volume	x	x
V_0	Effective gas volume	x	x
T_0	Gas pre-charge temperature	x	
T_{min}	Minimum operating pressure	x	
T_{max}	Maximum operating pressure	x	
p_{0Tmin}	Pre-charge pressure at T_{min}		x
p_{0Tmax}	Pre-charge pressure at T_{max}		x
$p_2 : p_0$	Pressure ratio		x
$V_0 : V_2$	Volume ratio		x

⚠ If an input value for p_0 must be specified, i.e. forced by the user, it must be changed manually **after** the temperature and also **after** the p1 have been entered.

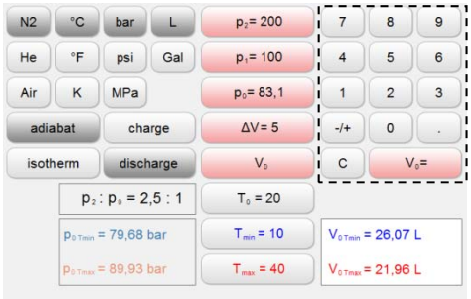


Exchange direction in the PV graph

For a diagram, see
PV graph of an accumulator cycle.

This contains all the parameters of the accumulator calculation.

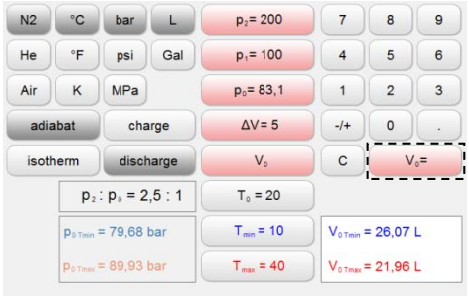
2.4. Number pad & result button



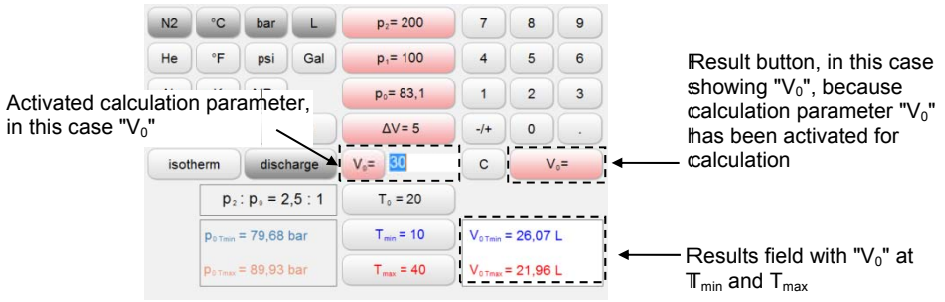
The number pad is arranged like the number pad of a calculator. As an alternative to entering the calculation parameters via the keyboard, they can also be selected using the mouse/touchpad.

The result button is also located on the number pad and will be descrited in the following section.

2.5. Informations and results field



The label on the result button will change depending on the calculation parameter activated (e.g., p_2 =, p_1 =, ΔV =, V_0 =). It is the same as the "equals" button on a pocket calculator.

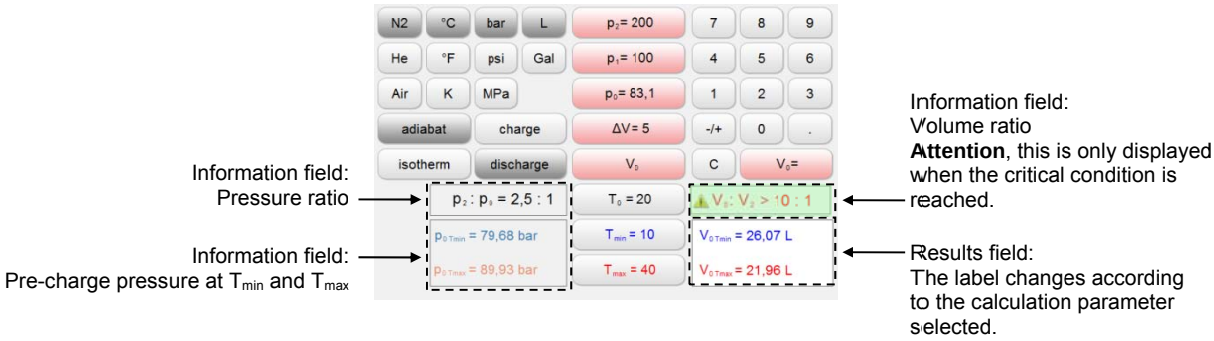


ATTENTION

Correct entry of all necessary parameters is required

Empty parameters are not valid → invalid input

After you press the result button, the following information and results fields are displayed on the left and right side.



Results field

In order to select the calculation parameter to be displayed for T_{min} and T_{max} in the results field (in this case V_{0Tmin} and V_{0Tmax}), click in the calculation parameter area

Information fields

In addition to the actual results field, **ASP***light* provides important information that suggests an accumulator model (bladder, piston or diaphragm accumulator).

$p_2 : p_0$ = Max. pressure ratio, in this case $p_2 : p_0 = 2.5 : 1$

$V_0 : V_2$ = Volume ratio
is only displayed when the critical condition is reached.
The critical state is when $V_0 : V_2 > 4 : 1$ or $V_0 : V_2 > 10 : 1$.
In the example above, the piston accumulator would be recommended, depending on the application, diaphragm accumulators could also be used.
This must be agreed with HYDAC.

p_{0Tmin} and p_{0Tmax} = Hydraulic accumulators must be pressurised with a pre-charge pressure prior to commissioning (p_0 at T_0). These values indicate the pre-charge pressure at minimum or maximum ambient temperature, in this case:

p_{0Tmin} = 79.68 bar, which means the pre-charge pressure of the hydraulic accumulator reaches 79.68 bar at an ambient temperature of 10 °C

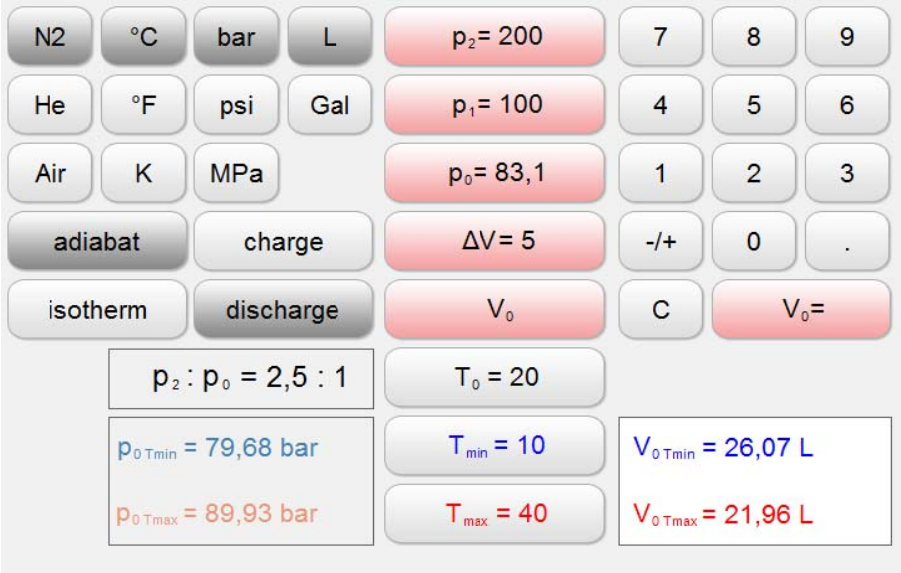
p_{0Tmax} = 89.92 bar, which means the pre-charge pressure of the hydraulic accumulator reaches 89.92 bar at an ambient temperature of 40 °C.
The pre-charge pressure changes as the operating temperature changes.

3. Calculation process

Calculation in **ASP***light* is similar to using a pocket calculator.

This section describes the calculation process:

1.	Select the gas type	N2
2.	Define units	°C bar L (default setting is adopted)
3.	Define exchange speed	adiabat
4.	Define exchange direction	discharge
5.	Enter known calculation parameters	p_2= 200 p_1= 100 p_0= 83,1 ΔV= 5 T_0 = 20 T_{min} = 10 T_{max} = 40 (p_0 is suggested automatcally by the program based on T and p_1)
6.	Activate desired calculation parameter, here: V_0	V_0=
7.	Press result button	V_0= (label can vary according to calculation parameter selected)
8.	Read and evaluate result and information fields	$p_2 : p_0$ = 2,5 : 1 $p_{0\,Tmin}$ = 79,68 $p_{0\,Tmax}$ = 89,92 $V_{0\,Tmin}$ = 26,10 $V_{0\,Tmax}$ = 22,03



4. Example task

4.1. Task to calculate V_0

Situation

A consumer requires 2.5 litres of hydraulic fluid within a very short time.
The minimum pressure must not fall below 180 bar. The pump charges the accumulator to a maximum of 350 bar. The accumulator is pre-charged at 20 °C and works between 0 °C and 60 °C.

Task

- Accumulator nominal volume = V_0

Solution method

- V_0 at T_{min} = 19.33 l
- V_0 at T_{max} = 12.89 l

Additional information:

- $p_2 : p_0$ = 2.8 : 1
- p_0 at T_{min} = 124.71 bar
- p_0 at T_{max} = 161.45 bar

Evaluation

Because the pressure ratio is 2.8 : 1, bladder, piston and diaphragm accumulators can be used. However, because the V_0 result is between 12.89 and 19.33 litres, a bladder or piston accumulator is recommended.

4.2. Task to calculate p_1

Situation

A 10 litres piston accumulator is discharged within 2 seconds. 1 litre of hydraulic fluid is discharged. The initial pressure is 1000 bar. The pre-charge pressure is 100 bar at 10 °C.

Task

- What is the pressure p_1 when the accumulator is discharged at 0 °C and also at 40 °C?

Solution

- p_1 at T_{min} = 187.81 bar
- p_1 at T_{max} = 256.52 bar

Additional information:

- $p_2 : p_0$ = 10.5 : 1
- p_0 at T_{min} = 95.54 bar
- p_0 at T_{max} = 113.34 bar
- $V_0 : V_2$ > 4 : 1

The additional information is used to select the suitable accumulator types.
E.g., if selected a bladder accumulator the pressure ratio of 4 : 1 musst not be exceeded.
The piston accumulator ist the right choice in this example task.