Transient flow in pipes and surge chambers

Transient flow

Flows in which flow conditions vary over time at an 'observation point' are known as transient. An exception is changes caused by turbulence. For flows with a free surface a transient flow can be recognised by the variation in the water level over time.

Transient flows occur during all startup and shutdown processes of turbomachines, in equipment and pipelines as well as during discharge processes from containers with variable liquid level; similarly in fluid vibrations (surge chamber), with water hammer processes in pipes and in open channels (positive and negative surges/hydropeaking).

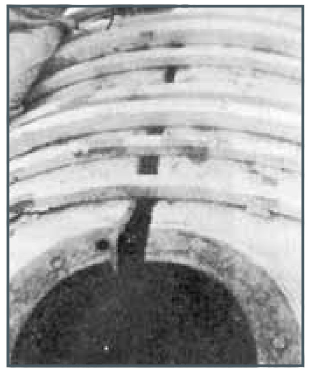
In practice, the understanding of transient flow conditions is useful for commercial designs of pipelines (reserve in water hammer) in water distribution systems, process plants and hydroelectric power stations.

GUNT provides you with illustrative experimental units for studying transient flows in pipelines, representing water hammer, and showing how surge chambers work as safety elements in hydroelectric power stations.

We demonstrate the useful effect of water hammer for pumping water by the operating principle of a hydraulic ram.

Collapsed tank as a result of water hammer

Damaged pipe and pipe brackets caused by a water hammer



Pipe breakage, caused by water hammer

Water hammer in pipes

A common phenomenon of transient flow is the occurrence of water hammer in pipes. Fluctuations of pressure and flow rate can significantly exceed or fall below the designed pressure for a pipeline.

Water hammer is caused by:

- closing or opening shut-off elements in the pipeline
- startup and shutdown pumps and turbines
- re-commissioning systems
- change in the feed water level

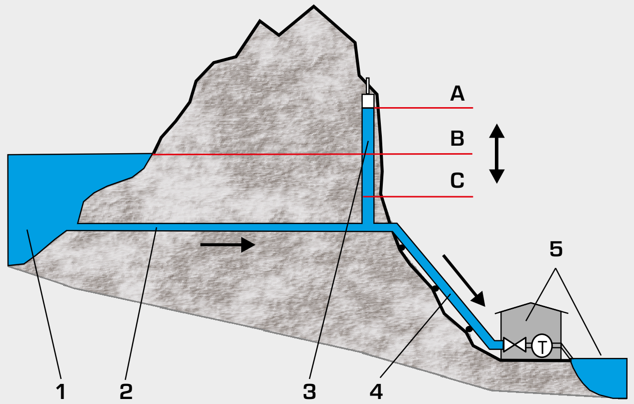
Effects of water hammer

Water hammer causes damage to the affected system. Pipes can burst, pipe brackets may be damaged. Additionally valves, pumps, mounts and other components of the pipe system (e.g. heat exchangers) are at risk. In drinking water pipelines a water hammer can lead to dirty water being drawn in from outside. Since damage to pipelines is not necessarily immediately visible (e.g. a damaged flange), it is necessary to deal with the potential occurrence of water hammer when planning a pipeline.

Reducing water hammer

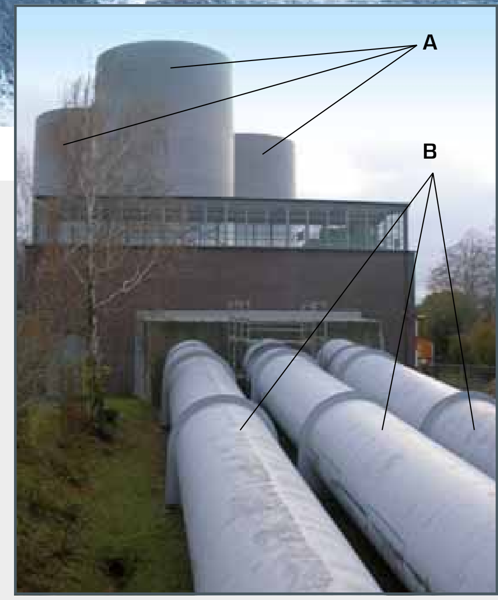
At smaller nominal diameters, installing an expansion tank or the choice of valves affects the emergence of water hammer. Valves and gate valves are less affected than shut-off valves and butterfly valves due to longer closing times. Safety valves can protect pipelines from damage caused by water hammer.

Water hammer in pipes with large nominal diameters and large head are mitigated or avoided by slowly operating the slide gate and using surge chambers at the entrance of the pressure pipes (similar to equalisation basins).



Hydroelectric power station with surge chamber, using the natural geological conditions

1 reservoir, **2** head race tunnel, **3** surge chamber with variable water level, **4** pressure pipe, **5** turbine house with water discharge; **A** turbine shutdown, **B** rest position, **C** turbine start up



Niederwartha pumped storage power station in Dresden. At the entrance of the three pressure pipes there are three surge chambers, which are designed as open containers.
A surge chamber, **B** pressure pipes

Principle of a surge chamber

Hydroelectric power stations use surge chambers to reduce pressure fluctuations. The water moving through the pressure pipe is deflected when valves in the surge chamber are closed. The water level can then oscillate up and down until it returns to rest. The kinetic energy of the flowing water in the pressure tube is therefore converted into potential energy of the increased water level in the surge chamber and not into destructive pressure energy.

The table shows an abstract from a common university curriculum. GUNT devices cover this content to the greatest extent.

Curriculum for the field of transient flow	GUNT products
Flow from tanks with variable water level: discharge velocity	HM 150.09, HM 150.12
Water hammer: investigation of water hammer and pressure waves in pipes, displaying vibrations in the water hammer, determining the speed of sound in water, determining reflection time, measuring water hammer (Joukowsky shock), how flow rate/closing velocity of valves affect water hammer	HM 155, HM 156, HM 143
Hydraulic ram: use of water hammer to pump water	HM 150.15
Surge chamber oscillation: how a surge chamber works, natural frequency of the vibrations	HM 143, HM 156
Positive and negative surges/hydropeaking: transient flow behaviour, e.g. in open channels	HM 160 to HM 163
Transient drainage processes: drainage, delayed drainage processes (retention)	HM 143
Flood wave	
Transient flow processes in hydraulic turbomachines: cavitation	HM 380, ST 250