A MODEL FOR CALCULATING THE DEGASSING PIPES OF LAKE NYOS

Why do we imperatively need these degassing calculations?

-to make a safe design of the degassing system, through the knowledge of the radial pipe compression and the axial lift force
-to optimize the efficiency of a wholescale degassing campaign, in respect to size and number of the pipes, depth of implementation, and duration of the campaign
-to define the operating and shutdown procedures (location of valves, efficiency...)

What is the scenario of the self sustained gas lift flow?

We focus on steady state operation which will be reached after an initial triggering with the help of a pump.
Liquid water, heavily loaded with dissolved carbon dioxide, enters at the lake bottom into the pipe. As it flows upwards, the pressure decreases due to the smaller gravitational head and the flow induced pressure drop; when the pressure reaches the saturation threshhold the dissolved gas starts to escape. The flow is now two-phase, with a gas fraction increasing continuously till the outlet, as the pressure decreases. The smaller density of the water-gas mixture gives the buoyancy which is the motor that drives the flow upwards. As the mass flow remains constant, the density decrease results in a large increase of the velocity which entails a slender high jet at the pipe's outlet.

What physical phenomena have to be modelled?

-the gravity of the liquid or two phase mixture in the pipe
-the pressure drop of the one or two phase flow, with several components:
    linear friction pressure drop
    flow acceleration due to density change
    local pressure drop due to geometrical discontinuities
-the gas release as a function of the pressure and time
-the specific volume increase due to gas release and pressure decrease

We assume, in a simplifying way, justified approximately by the large velocities, that the two phase flow is a homogeneous mixture where gas and water move at the same speed.

How are calculations done?

The tube is divided into about 200 axial meshes with variable length, large in the liquid flow at the bottom and shorter at the top.
Calculations are done in an iterative way: an inlet flow is assumed, then the pressure evolution and flow characteristics are calculated till the outlet pressure matches exactly the atmospheric pressure.

The following main equations are used:

pressure evolution through the Bernoulli equation:
:

$$\mathbf{Dp = - r\ g\ h - x\ r\ h\ w^2 - 1/2\ r\ D(w^2)}$$

gas release:

$$\mathbf{Crel = Ce\text{-}Cs}$$

$$\mathbf{Cs = 4.363\ 10^{-5}\ p^{0.872}}$$

a time dependant gas release may be calculated through the use of a time constant

gas volume fraction:

$$\mathbf{a = (Crel\ pat / p) / (1+Crel\ pat / p)}$$

mass conservation:

$$\mathbf{w = we / (1\text{-}a)}$$

$$\mathbf{r = re\ (1\text{-}a)}$$

with:

Crel	amount of gas released out of 1 liter of water	m^3 NTP/m^3
Ce	gas content in liquid water at pipe entrance	m^3 NTP/m^3
Cs	gas content in liquid water at saturation	m^3 NTP/m^3
D	diameter of pipe	m
g	gravity	m/s^2
h	height of mesh	m
H	depth of pipe in the lake	m
p	pressure	Pa
pat	atmospheric pressure	Pa
w	linear velocity	m/s
we	linear velocity at pipe entrance	m/s
α	gas volume fraction	l/l
ρ	density	kg/m^3
ρe	density at pipe entrance	kg/m^3
ξ	friction factor	m^{-1}

Calculational results:

The test performed by Dr. Halbwachs in 1995 on lake NYOS was recalculated with the following data: H=193 m; Ce=6.2 m^3 NTP/m^3; D=0.136 m.
Local pressure drops were taken into account as well as an increased rugosity.
Calculational and experimental results match fairly well as seen in the following table:

	Inlet water velocity m/s	Jet height m
Experiment	3.3	20
Calculations	3.4	22.3

The maximum calculated pipe compression is 1.26 bar at a depth of -58m, and the lift force 3300 N. For these parameters no experimental measure is available, but there is some presumption that the initial lift force might have been somewhat higher.

Other results are given on the figure.

Gaston KAYSER
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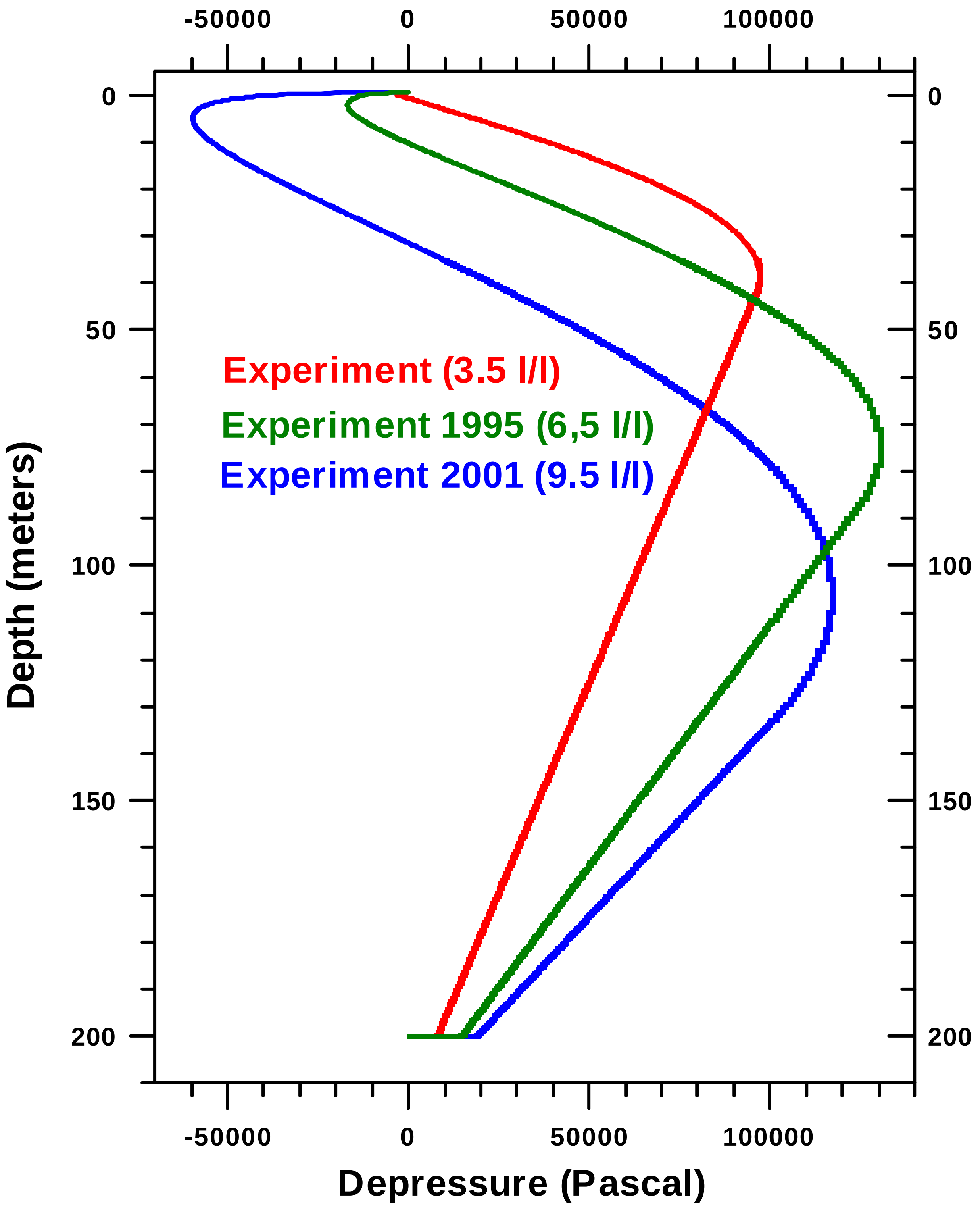

-50000
0
50000
100000
0
50
100
150
200
Experiment (3.5 l/l)
Experiment 1995 (6,5 l/l)
Experiment 2001 (9.5 l/l)
Depth (meters)
Depressure (Pascal)