# The Effect of Virtual Leaks on the Purity in LAPD and MicroBooNE

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## *Abstract*

We calculate the contribution of a virtual leak to the oxygen concentration in a Liquid argon tank.

A live spreadsheet will be posted to allow running other scenarios than presented here.

As an example, we find that a 1 liter virtual leak, filled with air, leaking out with a time constant of 5 days into a 20 ton tank with a filtration time of 1 day peaks at 2.3 e-9 after 1.6 days, and falls to 3 e-11 (30 ppt) after 24 days. More detailed results will be shown.

## Motivation

Virtual leaks, i.e. volumes that are almost, but not completely, sealed from the liquid argon volume, can dispense impurities over short or long times, and will eventually exhaust their oxygen supply. Those leaks may be as small as unvented screw holes, and as large as the space inside structural tubes.

The elimination of virtual leaks may be simple or may be expensive or impossible. The latter category includes porous materials and cables, which are best studied in the Materials Test Station.

We try to quantify the effect of leaks of various time constants with different assumptions about the time required to filter one tank volume. It turns out that such a generic calculation is both possible and applicable. We do not attempt to solve the more specific and tougher problem of calculating time constants for specific leaks; the method we use can yield the worst case contamination rate and the time dependence of the contamination for the worst case.

## Assumptions

We assume a single virtual leak ( or a sum over several such leaks) that is characterized by a volume and a time constant (expressed in “days” here) for dissipation. We assume the leak is filled with standard air at room temperature initially, and that the dissipation time constant is that for the cold state, surrounded by liquid argon.

The tank filtration system assumes perfect filtration in each pass, and perfect mixing, and filters the tank volume in a time that can be entered in “days” as well.

Starting from and initial oxygen concentration (we use 1e-13 because zero would not plot right) , a stepwise integration calculates the oxygen contribution by the leak, and subtracts the oxygen removed by the filter in each step, to arrive at a new concentration for the next step.

The results are shown on semi-log plots for various filtration rates (days per tank volume). The leak size and time constant is common within each plot.

## Equilibrium Concentration

We can calculate the concentration resulting from a constant input of contaminants in a tank of a Mass M that is passing through a filter every f days:

Use the leak volume to calculate the total oxygen mass in the leak.

Calculate the oxygen release rate as the derivative

Rate = (total oxygen) / (time constant) * exp( time/ time constant)

The filter removes oxygen mass at a rate

Removal rate = (concentration) * Mass / (filtration time per tank volume)

By setting the two mass rates equal (steady state ) , we find that the concentration is

Concentration = (Total stored oxygen in leak) * (time to filter one tank volume) / (leak decay time constant * Total tank mass)

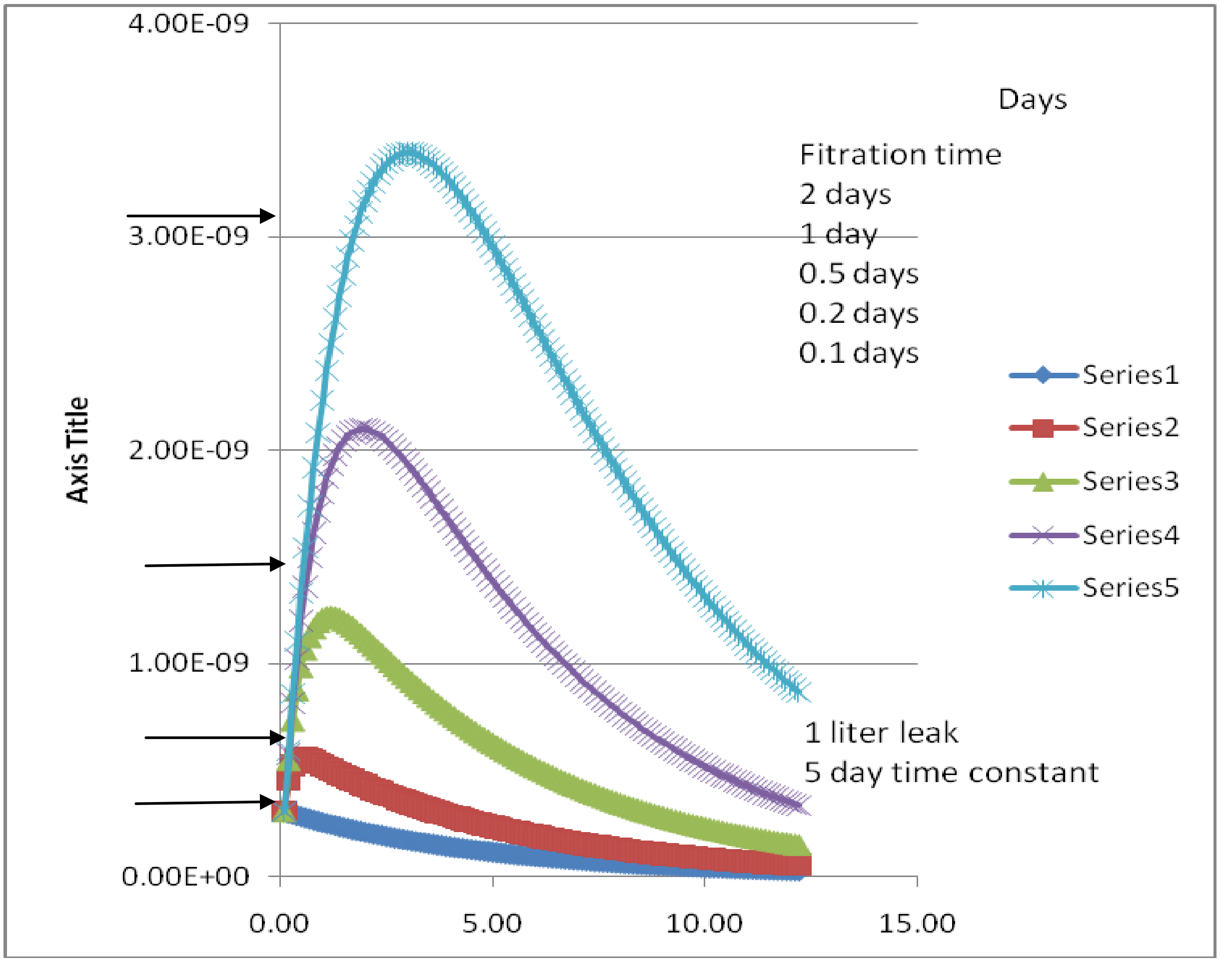
These values are indicated on the first graph as arrows to the left of the vertical axis. They agree with the curves when extrapolated to zero time.

## Results

The next graph shows the concentration of oxygen in the 20 ton tank, resulting from a 1 liter virtual air leak with a decay time constant of 5 days, for various filtration times (time per volume change) as listed on the graph.

The arrows on the left show the equilibrium concentration that would result if the leak rate was time-constant at the time=0 value. The concentration for the 2-day filtration rate is 6.1 e-9, not shown in the graph.

The time dependent concentration rises at first, until the concentration has built up to a value where the filter removal rate matches (or slightly exceeds) the contamination rate:


4.00E-09
3.00E-09
2.00E-09
1.00E-09
0.00E+00
Axis Title
0.00
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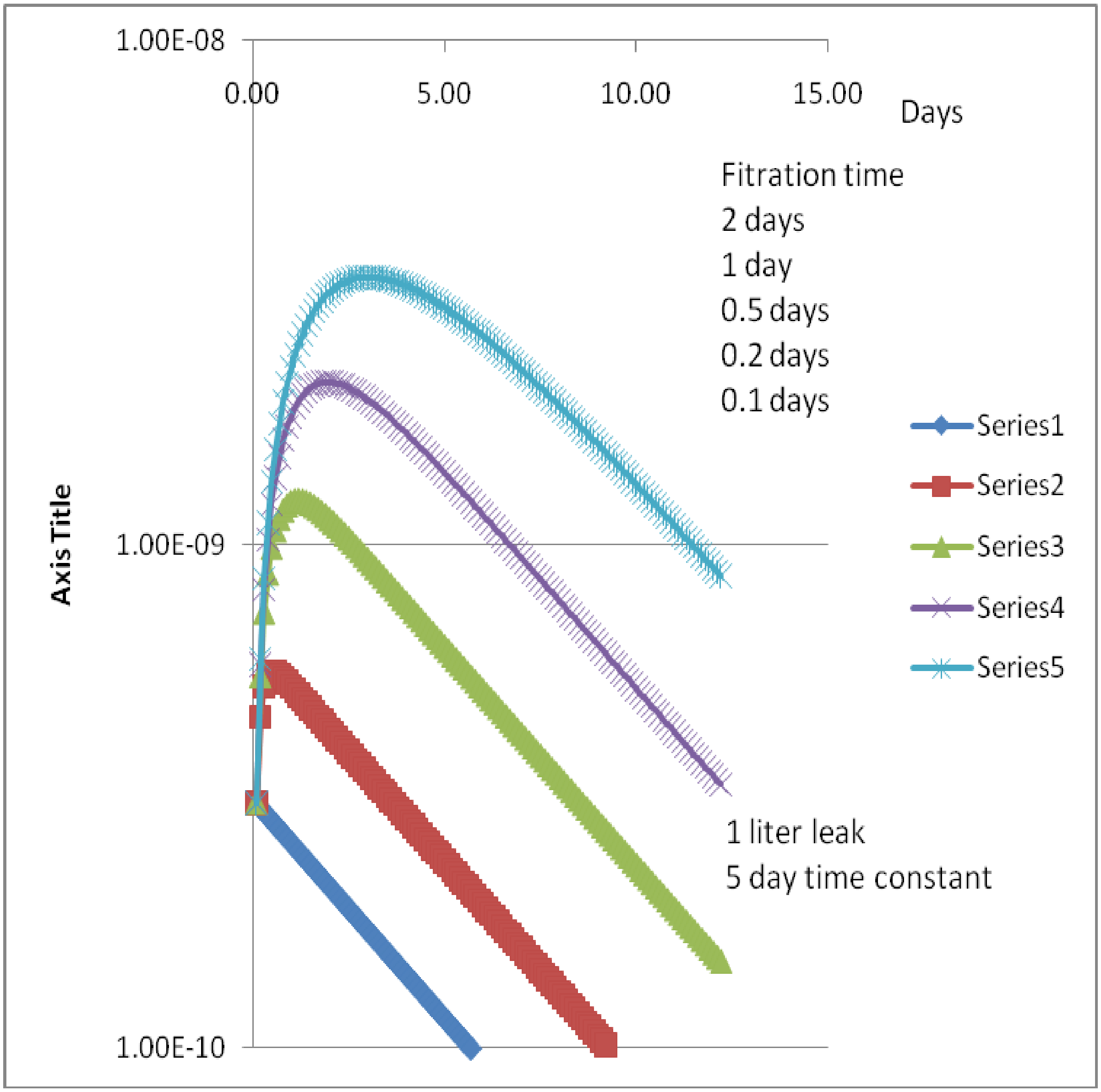
10.00
15.00
Days
Fitration time
2 days
1 day
0.5 days
0.2 days
0.1 days
Series1
Series2
Series3
Series4
Series5
1 liter leak
5 day time constant

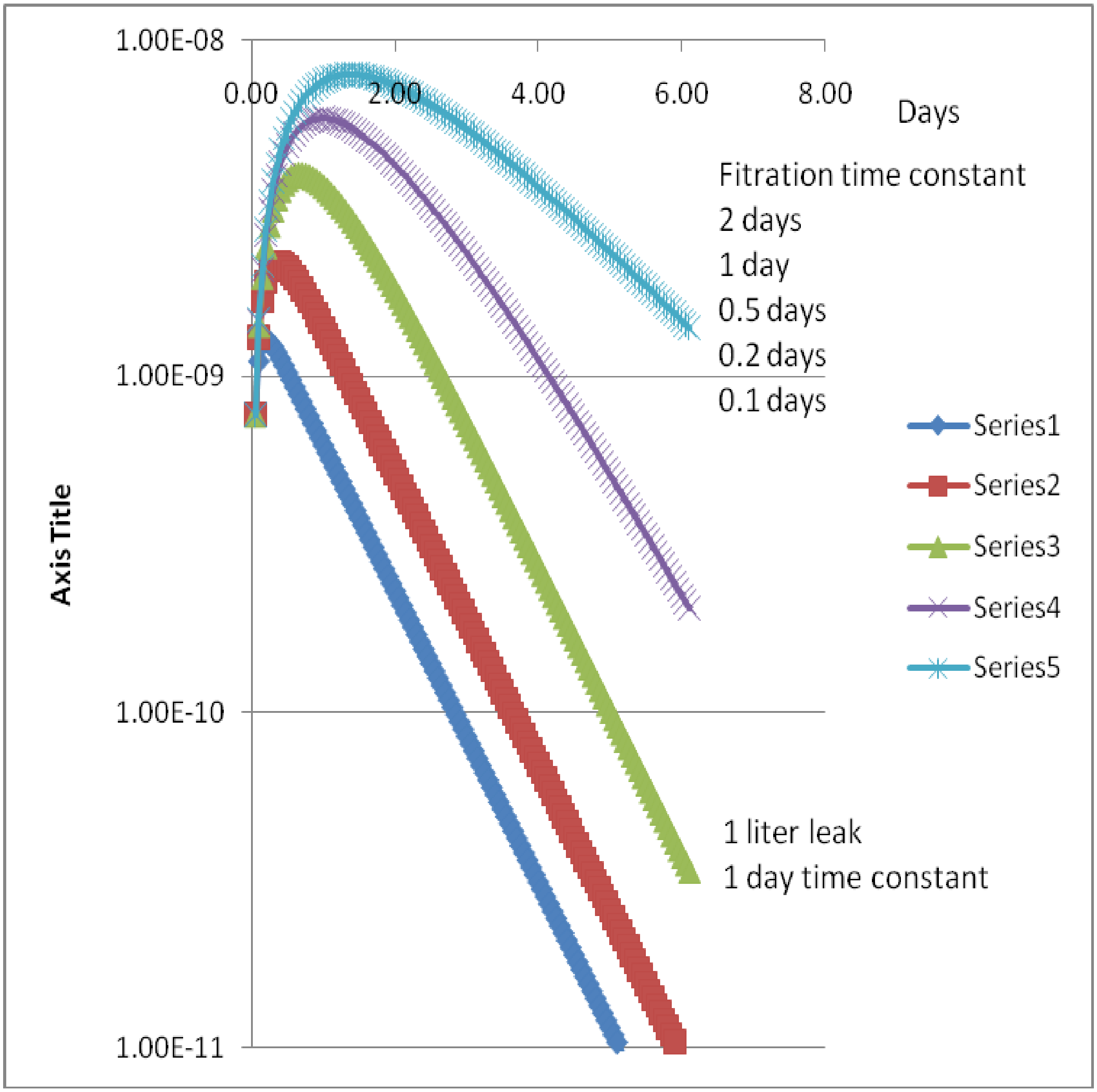
Same data on semi-log scale :



Fast leak:

1 liter leak with a 1-day decay time constant.

Fast leaks like this one clean up very quickly:

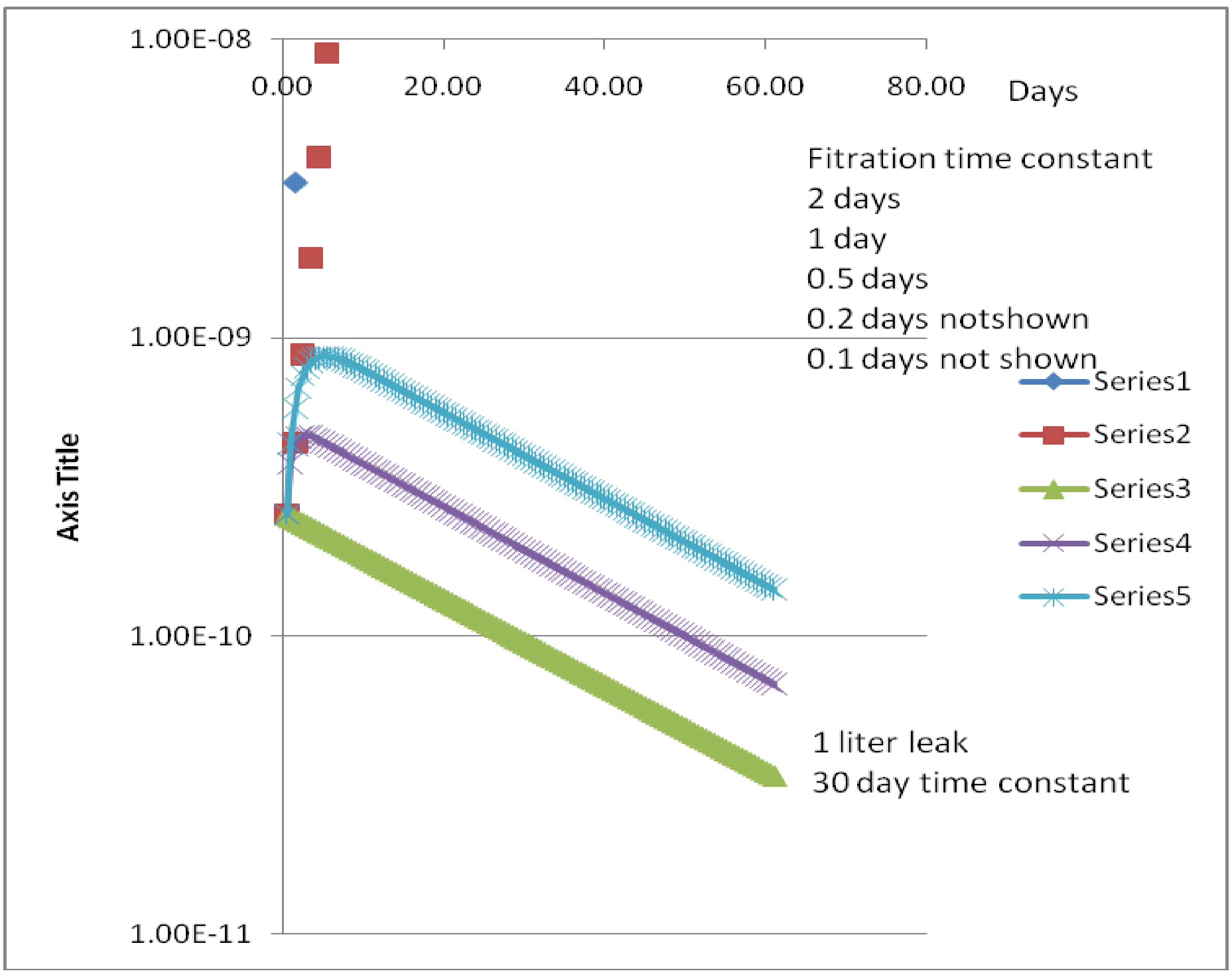


Slow leak,

with a 30-day decay time constant:

Note that the fastes filtrtaion times (0.1 day and 0.2 days) are not calculated correctly because the computational steps are too large when we display the graphs out to very late times.

The concentrations start lower because of the slower contamination rate, but take longer to reach acceptable levels:



## Conclusions

We show the time dependent contamination resulting from virtual leaks with time constant s of 1 day, 5 days, and 30 days , in a 20 ton tank a with filtration systems processing the volume in 0.1, 0.2, 0.5, 1, and 2 days.

We find that virtual leaks of longer decay time constants (e.g. 30 days and above) can require longer clean-up times to acceptable levels;

e.g with a filtration system processing 1 tank volume a day, we find that:

1 day leak decay time needs 5 days to reach 30 ppt purity;

A 5-day leak needs 20 days to reach 30 ppt purity;

A 30-day leak needs 60 days to reach 30 ppt purity.

Clearly, very small virtual leaks (e.g. air trapped in screw holes; less that 1 cc total) will not be a concern.
Large volumes leaks (such as the 1 liter volume used here) are easy to identify and to ventilate.

If we exercise a reasonable amount of care, virtual leaks will not be an important factor in reaching the design purity in LAPD or in MicroBooNE.