Leak Test of Seruci-I

Aria Internal Review

Carbosulcis August 7th, 2018

M. Razeti

INFN - Sezione di Cagliari

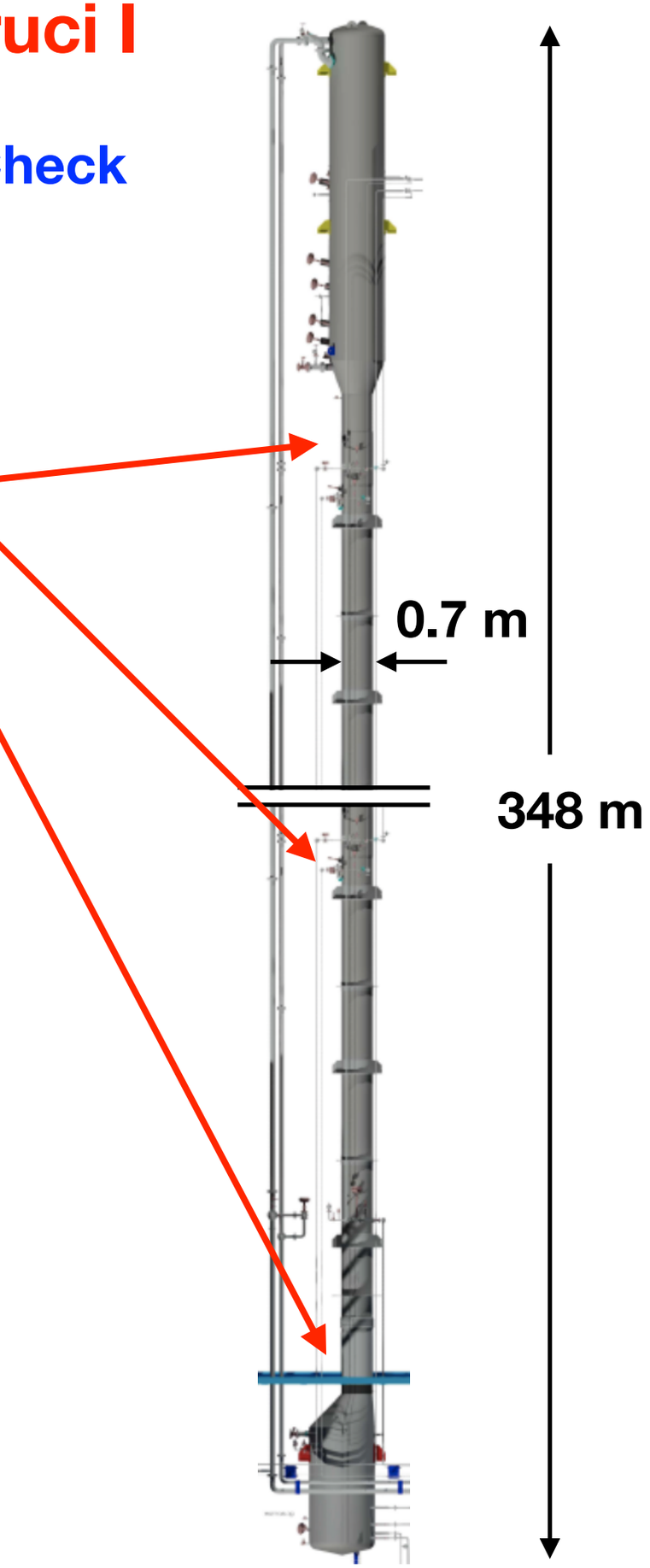
Presentation not in time order, to present at the end the different options for the Internal Lines Leak Check

- **Cold Box Leak check**
- **Global Leak Check**
- **Internal Lines Leak Check (more than one procedure is possible)**

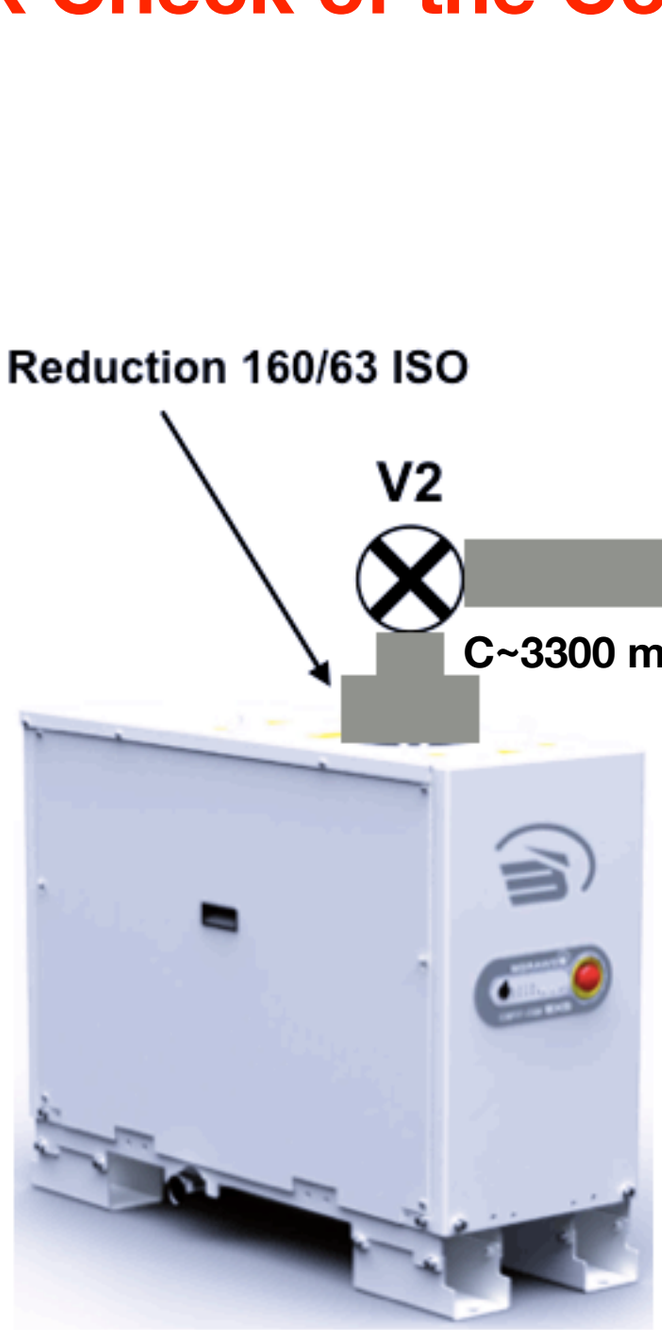
Leak Check of the Cold Box of Seruci I

Assuming done the Internal Lines Leak Check the cold box will be closed and welded…

…and those welds need to be leak checked (~60 welds).



Leak Check of the Cold Box of Seruci I

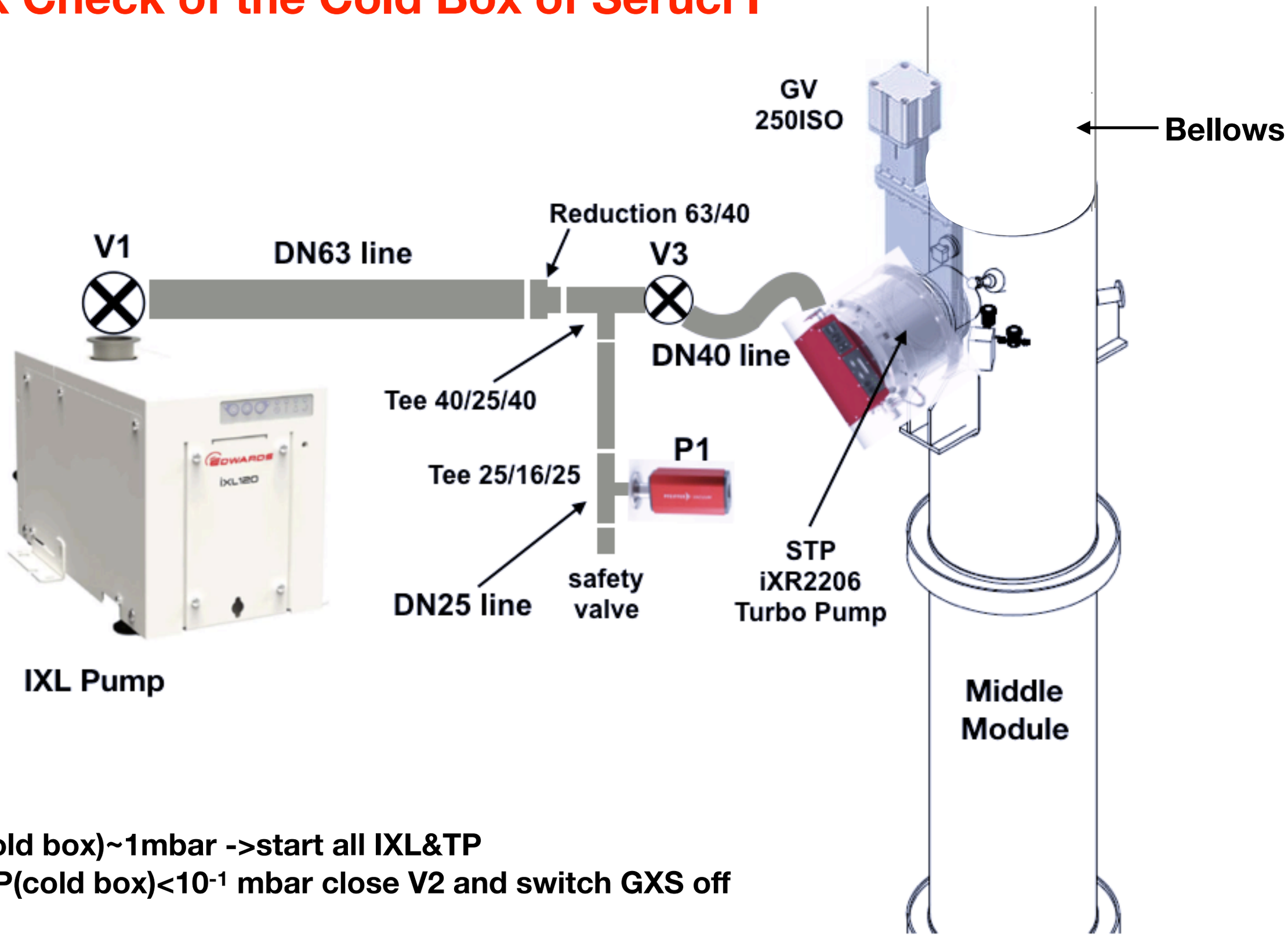


GXS/EH4200 Pump

Pump down time - with no restriction (1000-1 mbar) < 70 min

Pump down time (100-1 mbar) < 50 min

Leak Check of the Cold Box of Seruci I

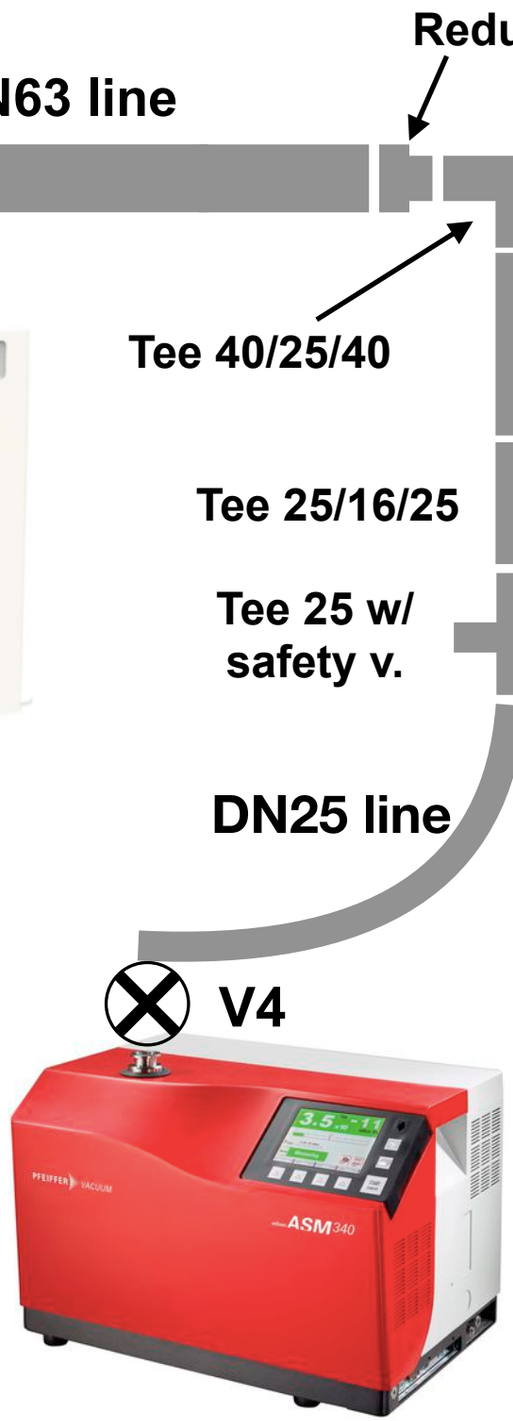


At P(cold box)~1mbar ->start all IXL&TP
When P(cold box)<10^{-1} mbar close V2 and switch GXS off

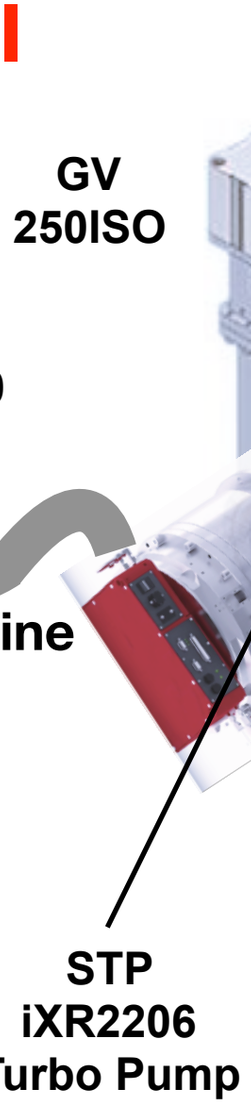
Leak Check of the Cold Box of Seruci I

IXL Pump

When P1<0.1 mbar with other four GV shut and V1 closed start leak check



Leak Detector



STP
iXR2206
Turbo Pump

Global Leak Check of the Internal Lines

Assuming cold box not vented.
If vented, restart with GXS as before.

IXL Pump

V1

DN63 line

Reduction 63/40

V3

DN40 line

Tee 40/25/40

P1

Tee 25/16/25

Tee 25 w/
safety v.

DN25 line

V4

Leak Detector

GV
250ISO

STP
iXR2206
Turbo Pump

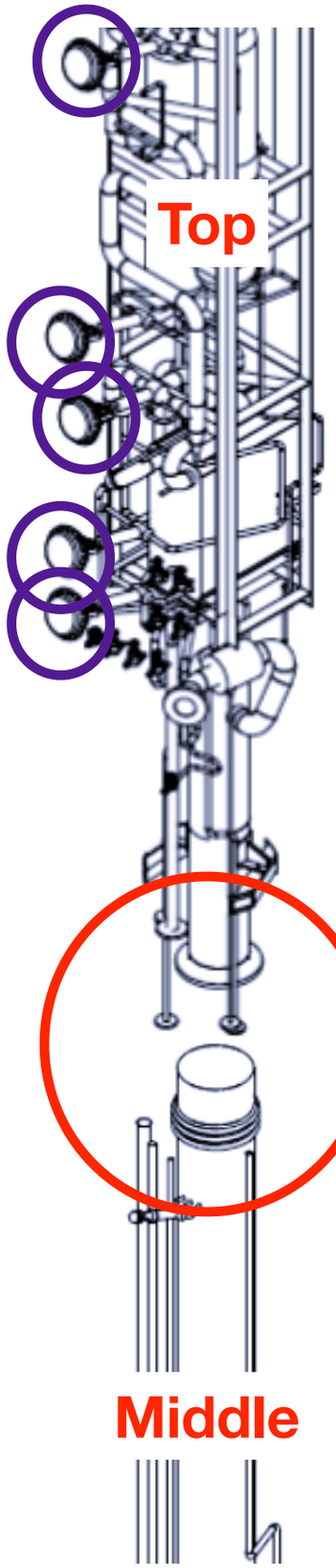
Middle
Module

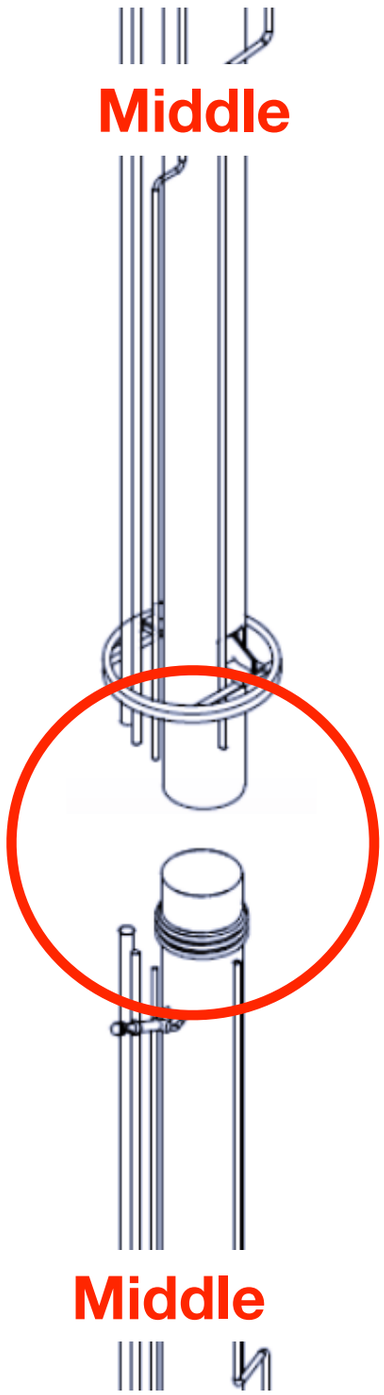
Global Leak Check of the Internal Lines

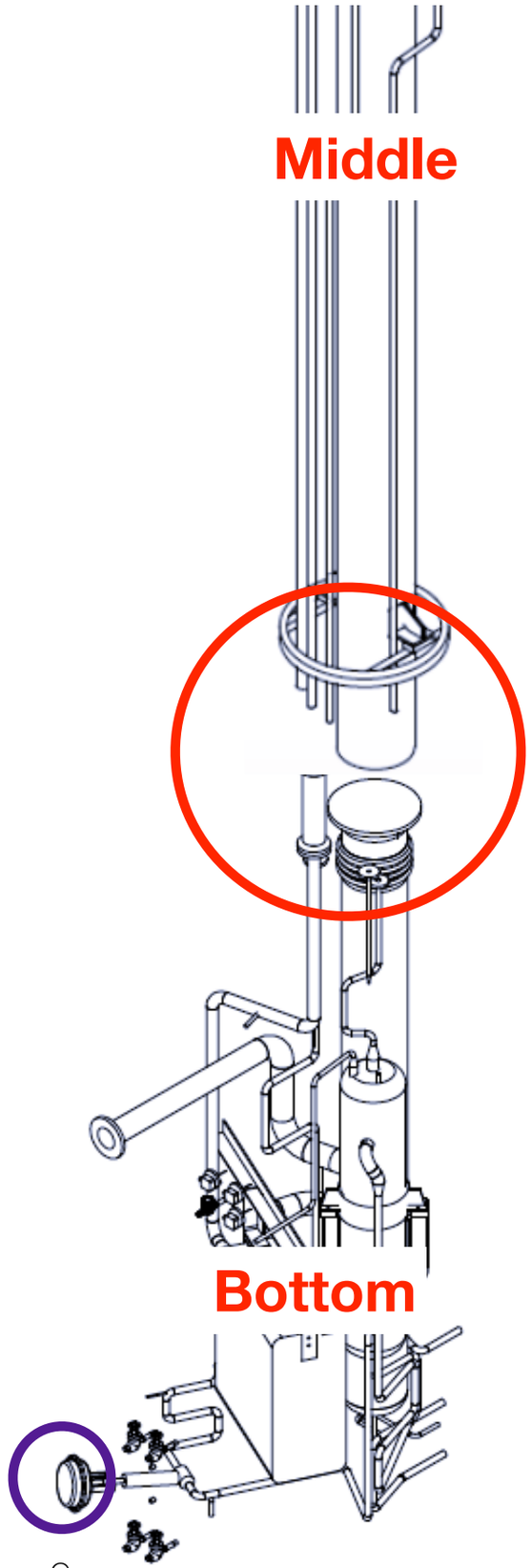
1. Cold Box and Internal Lines need to be ~evacuated
2. First fill with helium C-101 and L107 up to 1 bar and leak check the cold box (as before)
3. Then fill with helium the N2 Internal Lines and leak check again the cold box

The Global Check doesn’t allow to pinpoint a possible leak in the system but provides the overall leak (or the background achieved).

Leak Check of the Internal Lines of Seruci I - 1st configuration



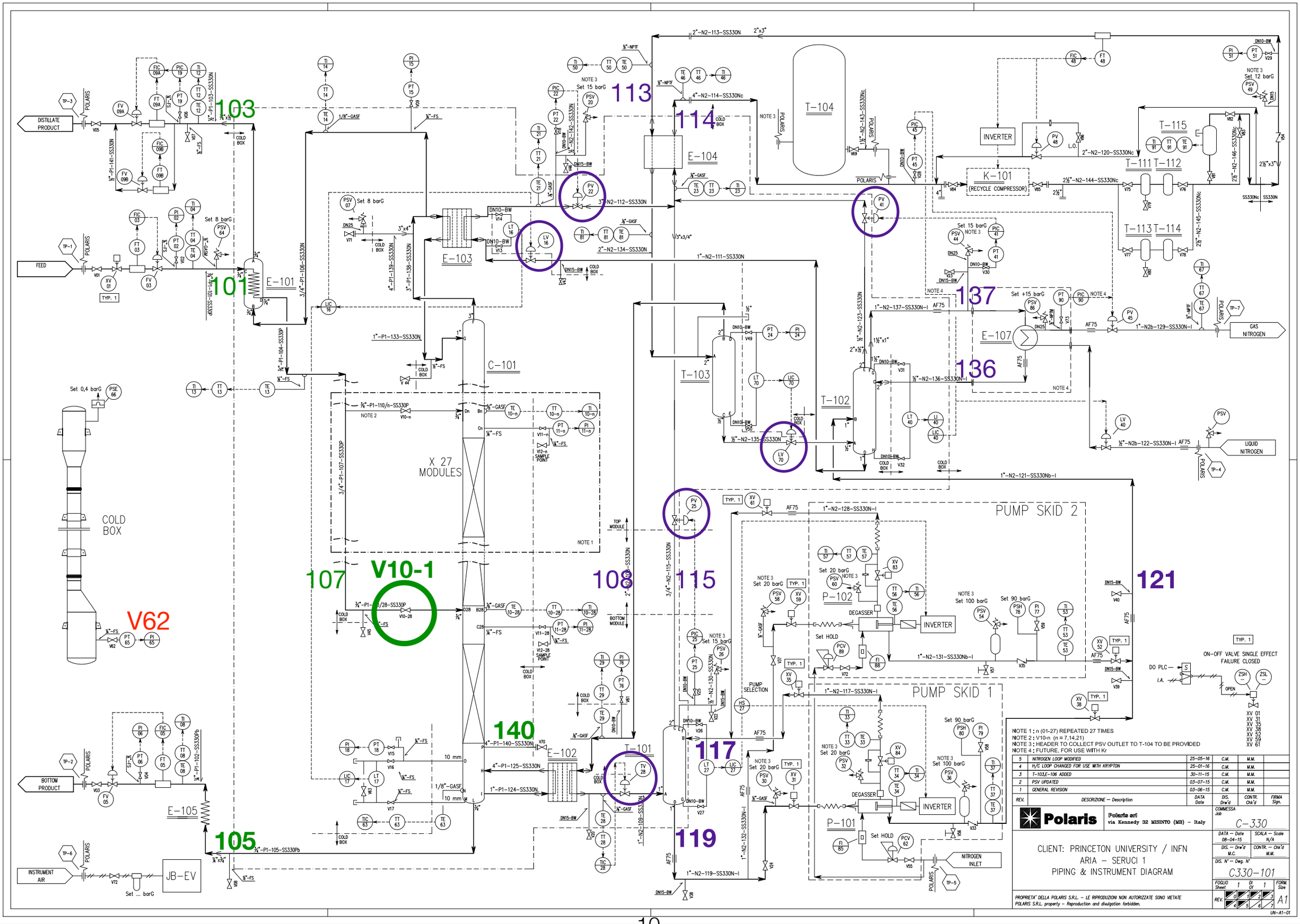




Strategy:
Weld first all the 30 modules and leak check all the welds (column and pipes).

Pneumatic Valves all open to connect all N2 lines

Also V10-x are open to have all the process lines connected


103
101
113
114
137
136
107
V10-1
108
115
121
140
117
119
105
V62
X 27 MODULES
DISTILLATE PRODUCT
FEED
BOTTOM PRODUCT
INSTRUMENT AIR
COLD BOX
E-101
E-103
E-104
E-105
E-107
E-102
C-101
T-101
T-102
T-103
T-104
T-111 T-112
T-113 T-114
T-115
K-101
(RECYCLE COMPRESSOR)
INVERTER
PUMP SKID 2
PUMP SKID 1
P-102
P-101
DEGASSER
PUMP SELECTION
JB-EV
GAS NITROGEN
LIQUID NITROGEN
NITROGEN INLET
ON-OFF VALVE SINGLE EFFECT FAILURE CLOSED
NOTE 1 : n (01-27) REPEATED 27 TIMES
NOTE 2 : V10-n (n = 7,14,21)
NOTE 3 : HEADER TO COLLECT PSV OUTLET TO T-104 TO BE PROVIDED
NOTE 4 : FUTURE, FOR USE WITH Kr
5 NITROGEN LOOP MODIFIED 25-05-16 C.M. M.M.
4 H/C LOOP CHANGED FOR USE WITH KRYPTON 25-01-16 C.M. M.M.
3 T-103,E-106 ADDED 30-11-15 C.M. M.M.
2 PSV UPDATED 03-07-15 C.M. M.M.
1 GENERAL REVISION 03-06-15 C.M. M.M.
Polaris
Polaris srl
via Kennedy 32 MISINTO (MB) - Italy
COMMESSA Job C-330
CLIENT: PRINCETON UNIVERSITY / INFN
ARIA - SERUCI 1
PIPING & INSTRUMENT DIAGRAM
C330-101
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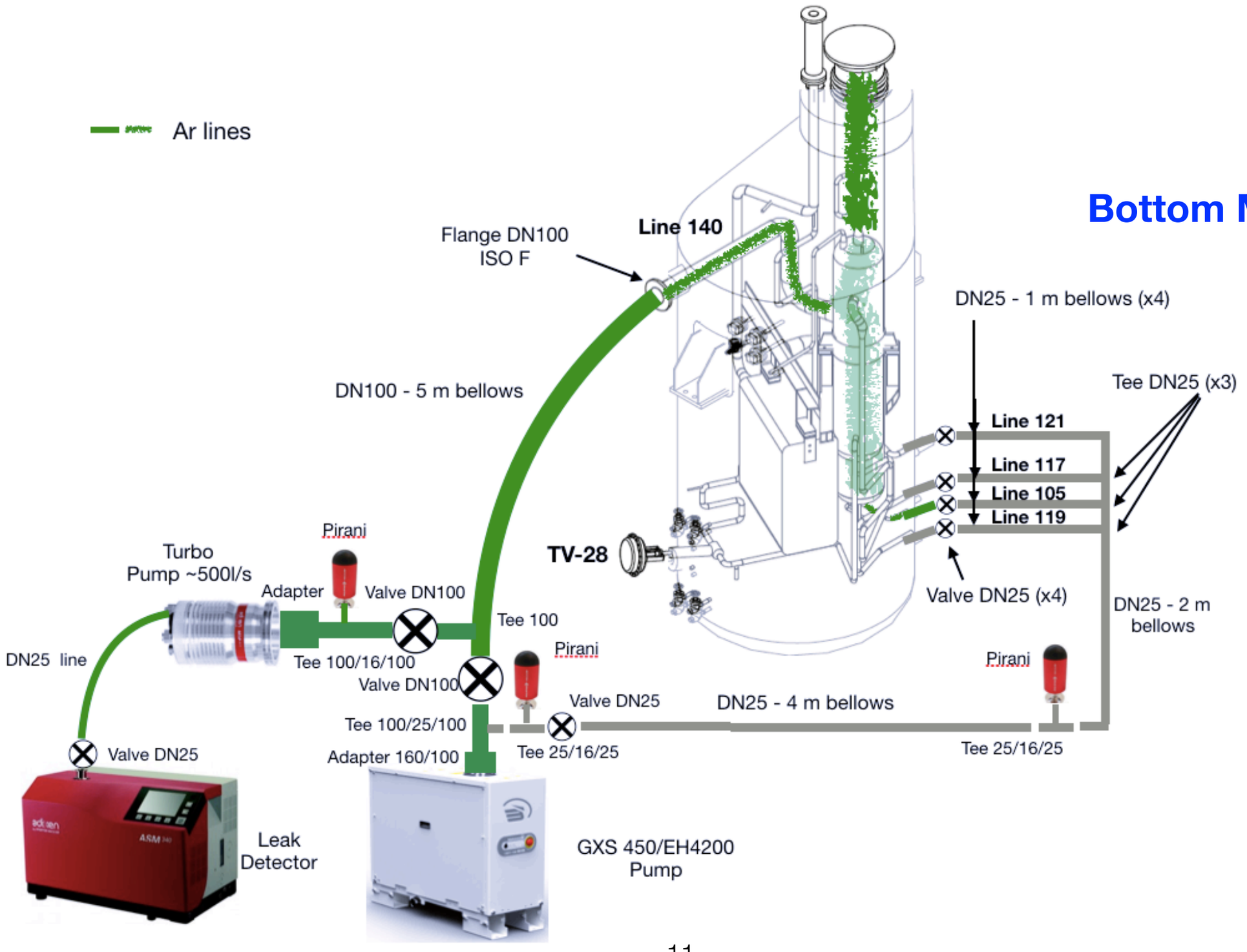
UN-A1-01

Leak Check of the Internal Lines of Seruci I - 1st configuration

All the PROCESS and NITROGEN lines (105, 140, 117, 119, 121) are reachable from the Bottom Module



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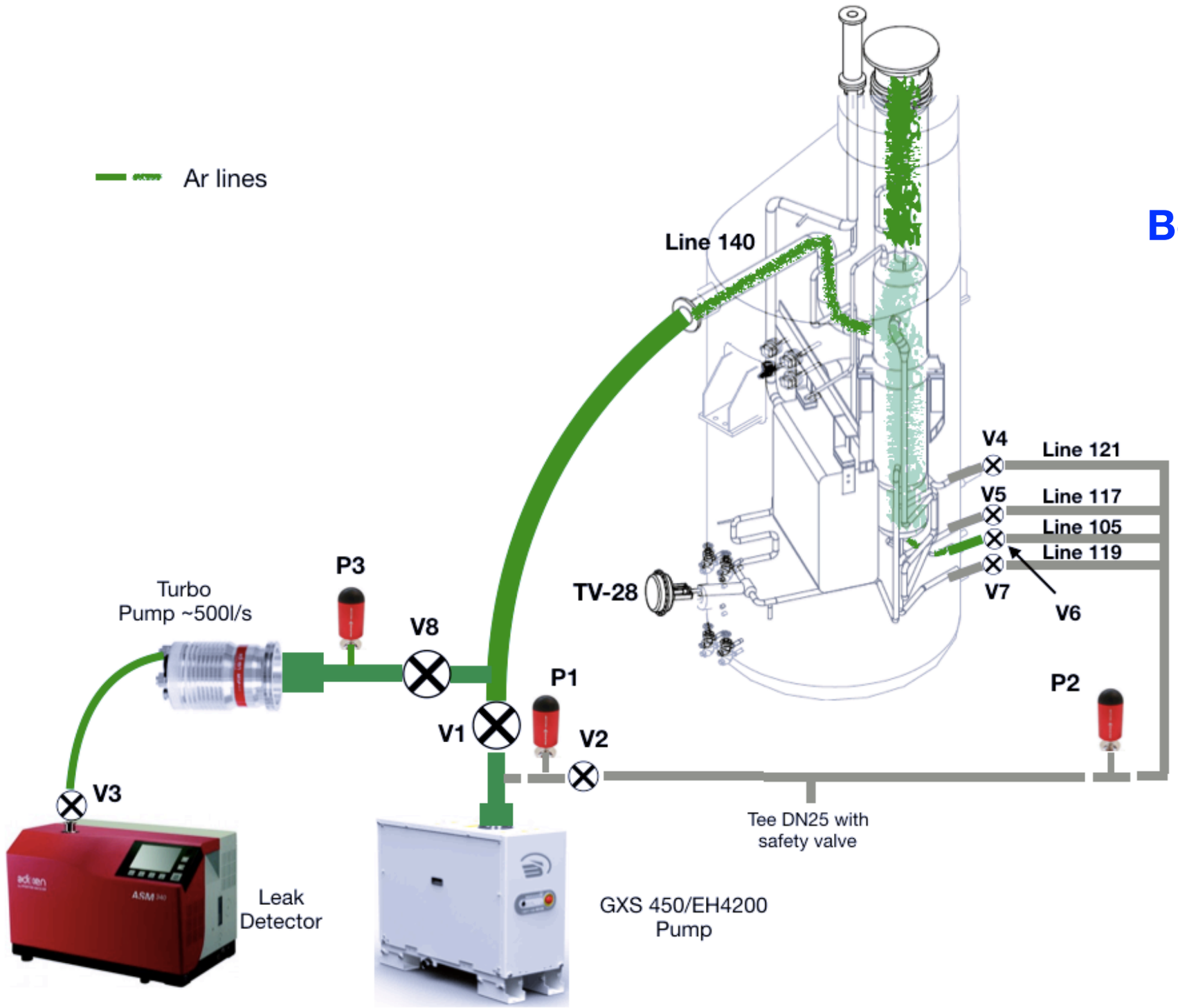


Bottom Module

Leak Check of the Internal Lines of Seruci I - 1st configuration

Signal time constant estimation

Column C-101

We measured the diffusion time T in the column:

T = 4 s in 12 m -> ~2 min in 350 m (max T along C-101).

That is the maximum time needed for the helium to reach the leak detector and the signal to start increasing.

Time constant τ = V/Seff -> 63% of total signal

Response time = 3τ -> 95% of total signal

Let's consider "optimistically" P during leak test ~10^{-1} mbar (likely to be less).

To increase Seff -> Turbo Pump with S~500 l/s on the leak detector (S~1 l/s).
V(C-101) ~ 28 m3, C(DN100, L = 6.5 m) ~ 730 m3/h @ 0.1 mbar (~1/3*C(101))

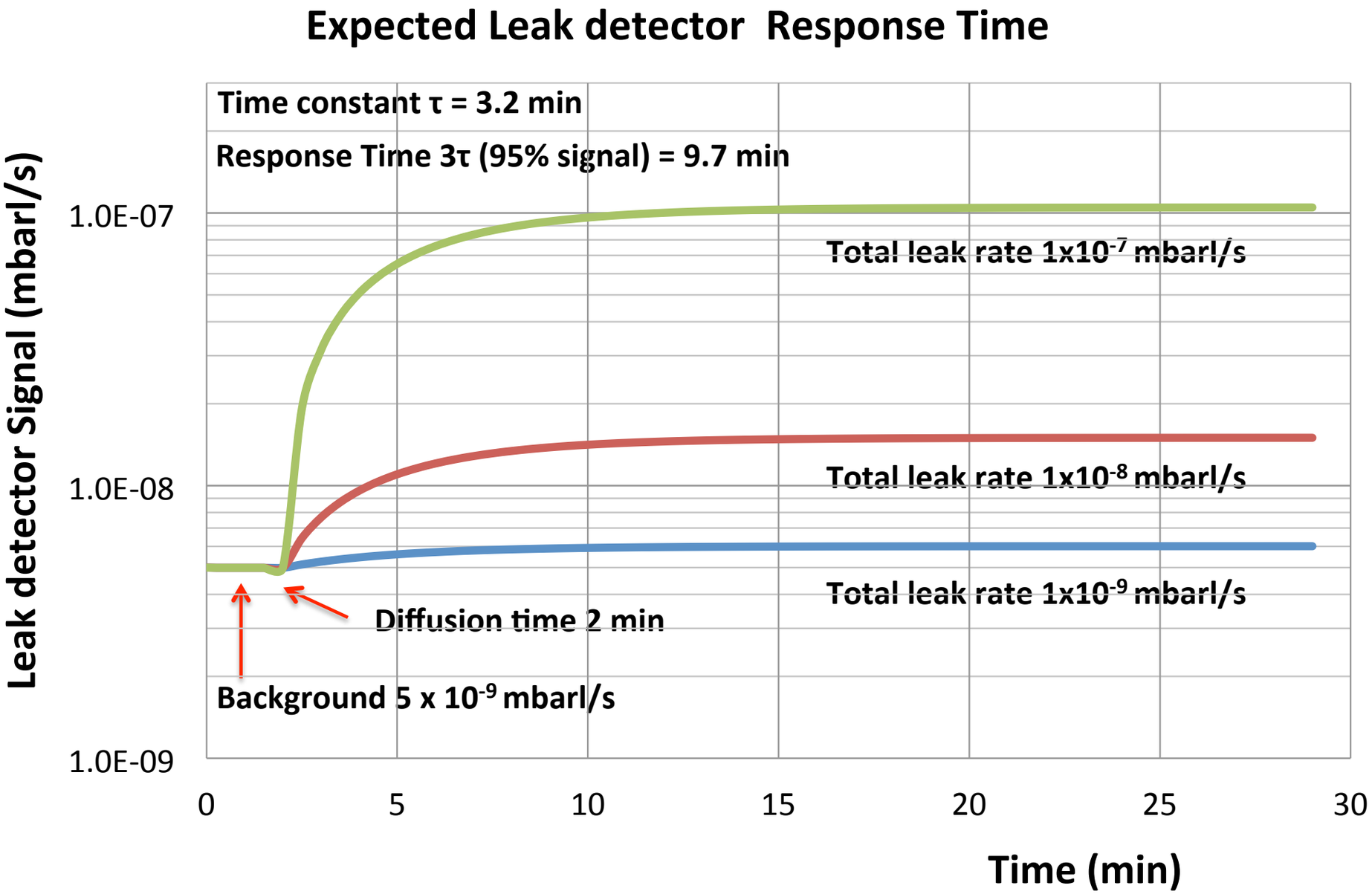
This should provide a τ ~ 3.2 min, i.e. response time ~ 10 min

If the pressure is 10^{-2} mbar -> τ ~ 32 min, response time ~100 min

Being τ ~30 min, no big issues for the Column C-101

Leak Check of the Internal Lines of Seruci I - 1st configuration

Expected leak detector τ(max) in C-101 with a P~10^{-1} mbar. In case the pressure during the leak check is better by some factor, i.e. a factor 10 (P~10^{-2}), *the response time increases by the same factor (until is in viscous mode).*



Leak Check of the Internal Lines of Seruci I - 1st configuration

Service Lines

Time constant τ = V/2C, C conductance of the pipe @ 0.1 mbar

Feed Line - L107 (3/4”)

τ ~ 30 min, response time ~ 90 min (95% of signal)

N2 - L115 (1/2”)

τ ~ 180 min, response time ~ 540 min (95% of signal)

N2 - L108 (2”)

τ ~ 23 min, response time ~ 73 min (95% of signal)

N2 - L121 (1”)

τ ~ 45 min, response time ~ 135 min (95% of signal)

DIFF TIME ~2-5 MIN. IF WE DON’T SEE A CHANGE WITHIN ~10 MIN WE MAY PROCEED. IF WE DO SEE A SIGNAL WE NEED TO WAIT 1τ AND QUANTIFY THE LEAK (IF ACCEPTABLE OR NOT)

Note: all values are approximated and corrections have been applied considering the various connections in the lines. *Values likely to be larger than showed as P will be less than 10^{-1} mbar during the leak tests* -> explore also alternative ways…

Leak Check of the Internal Lines of Seruci I - 2nd configuration

An alternative and very effective method to perform leak checks on the small pipes (as the 1/2” N2 line) is the use of *clamshells* developed and used at CERN.
The pipes need to be filled with helium up to ~1 atm.

- **Pros:**
- **The response time will be reduced to ~second**
- **Easy to use and full control of the system: all in the same place.**
- **…….**
- **…….**

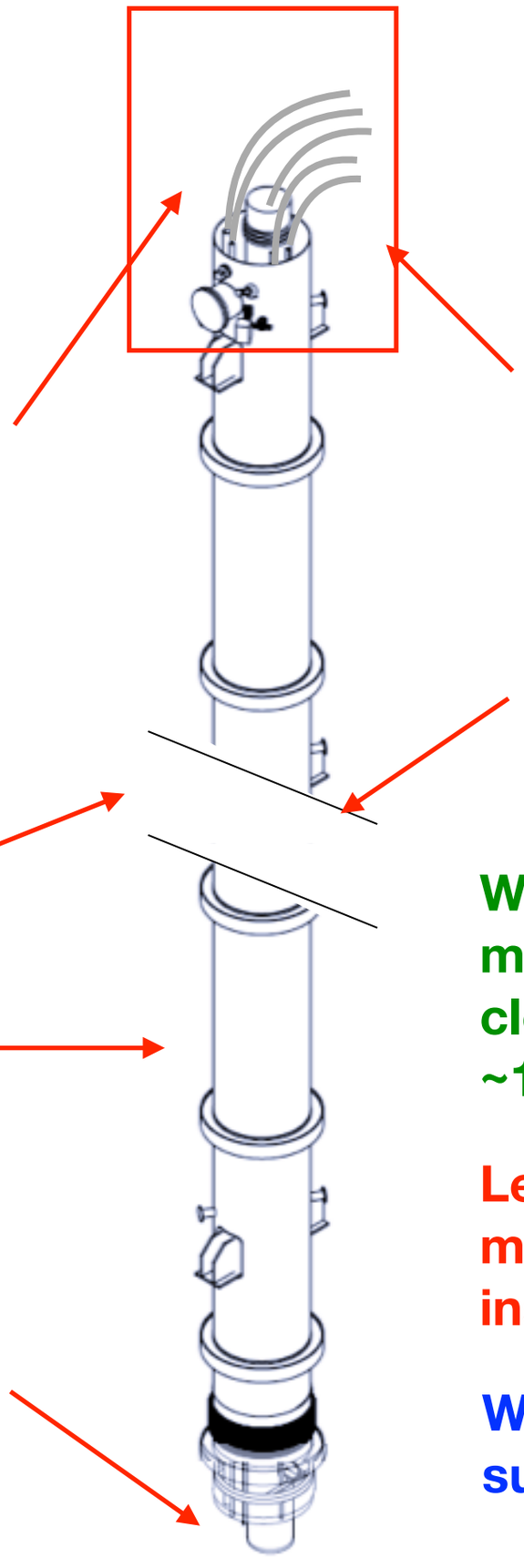
- **Cons:**
- **Should be manufactured on purpose for the different diameters of the pipes.**
- **Surface may need to be polished to allow a good adherence of the seals.**
- **Pay attention to the procedure if we want to use them only for 1 line in the N2 circuit (first internal leak check and then use of clamshells)**
- **…….**
- **…….**

If doable it looks a very attractive solution…

Leak Check of the Internal Lines of Seruci I - 3rd configuration

Methodology:
install and leak check one module at the time

All the lines and the column are connected to DN25 lines through the seals made by Polaris and used for the tests at CERN



2nd, 3rd,...n-th module installed in the shaft

1st module installed in the shaft

All the lines and the column are sealed with the 3 o-ring seals made by Polaris and used for the tests at CERN

Leak check every single line with very short Diffusion Time (~4 s)

Spray helium on the welds between the last two modules installed

We gain in Diffusion Time with this method as the tested welds are always close to the leak detector inlet (always ~12 m)....

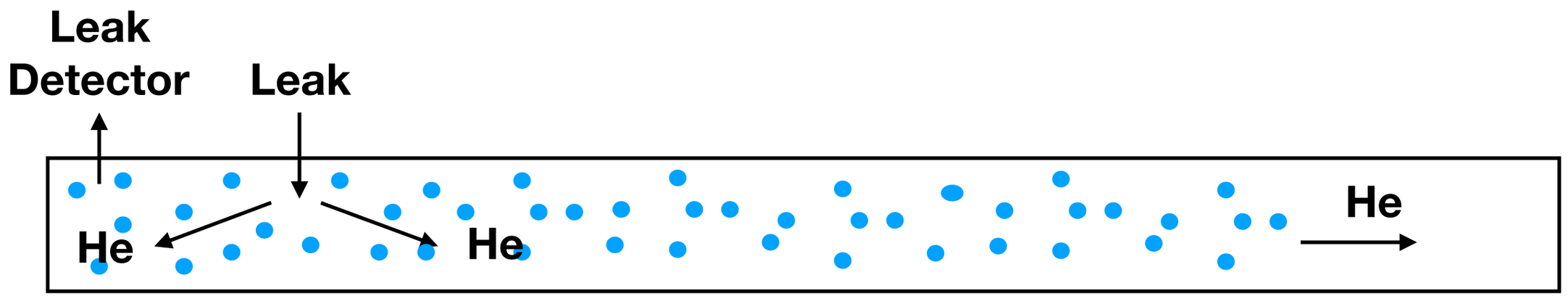
Leak check after installation of each module: does it clash with the installation procedure?

What do we gain in response time for such configuration?

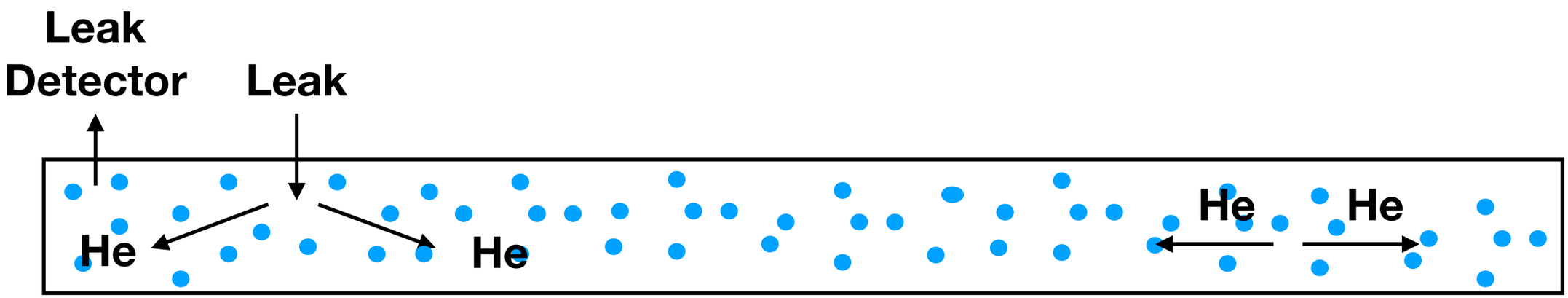
Leak Check of the Internal Lines of Seruci I - 3rd configuration

What do we gain in response time?

What we want is to *gain in response time.*
Helium diffuse rapidly along the column and only a partial amount entering through the leak enters in the leak detector.
The remaining part will flow towards the opposite side of the column.

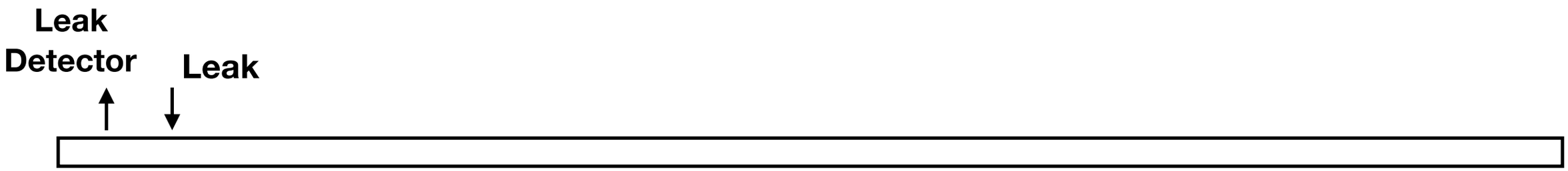


Only at the *dynamic equilibrium* this flow will be counterbalanced by the same flow coming from the opposite side of the column. When we reach such a steady state, *the same amount of helium that enters the column through the leak goes out towards the leak detector.*



Leak Check of the Internal Lines of Seruci I - 3rd configuration

In such dynamic equilibrium the location of the leak doesn't seem to play any role, it can be very close or far off the leak detector.
Therefore the response time doesn't seem to depend on the leak position, ***unless the conductance of the line towards the leak detector is much larger than the conductance along the column in the opposite direction.***



This happens to be the case for all our long pipes.

Being the weld always 12 m away from the leak detector, (even without considering the additional external pumping line) the first ~10 modules will be always involved. This would imply anyway a decrease by a factor ~9 in the max response time, a factor 3 for the volume reduction and a factor 3 for the conductance increase: For the column from ~30 to ~3 min @ P~10^{-2} mbar).

Leak Check of the Internal Lines of Seruci I - 3rd configuration

The other Lines in detail:

2”: C(12m)~0.7 l/s + C(DN25, L=1m @ 10-2 mbar)~0.5 -> C~0.3 l/s. We need to consider ~10 modules and τ can be shortened by a factor ~9.

1”: C(12m)~0.04 l/s + C(DN25, L=1m @ 10-2 mbar)~0.04 -> 0.04 l/s. We need to consider ~10 modules and tau can be shortened by a factor of ~9. A factor of 2 is gained in the 1st config. because in // with the 2” line. Therefore overall a factor ~5 is gained in τ wrt the 1st configuration.

1/2”: We gain again a factor ~5 in τ wrt the 1st configuration.

Feed 19mm: we do not gain much here because of the connections towards the column.

RESULT: with the 3rd configuration we gain in τ a factor ~5-10 depending on the line wrt the 1st configuration.

The End

Back-up slides

Viscous Flow (λ/D<100, P~1000-0.1 mbar):

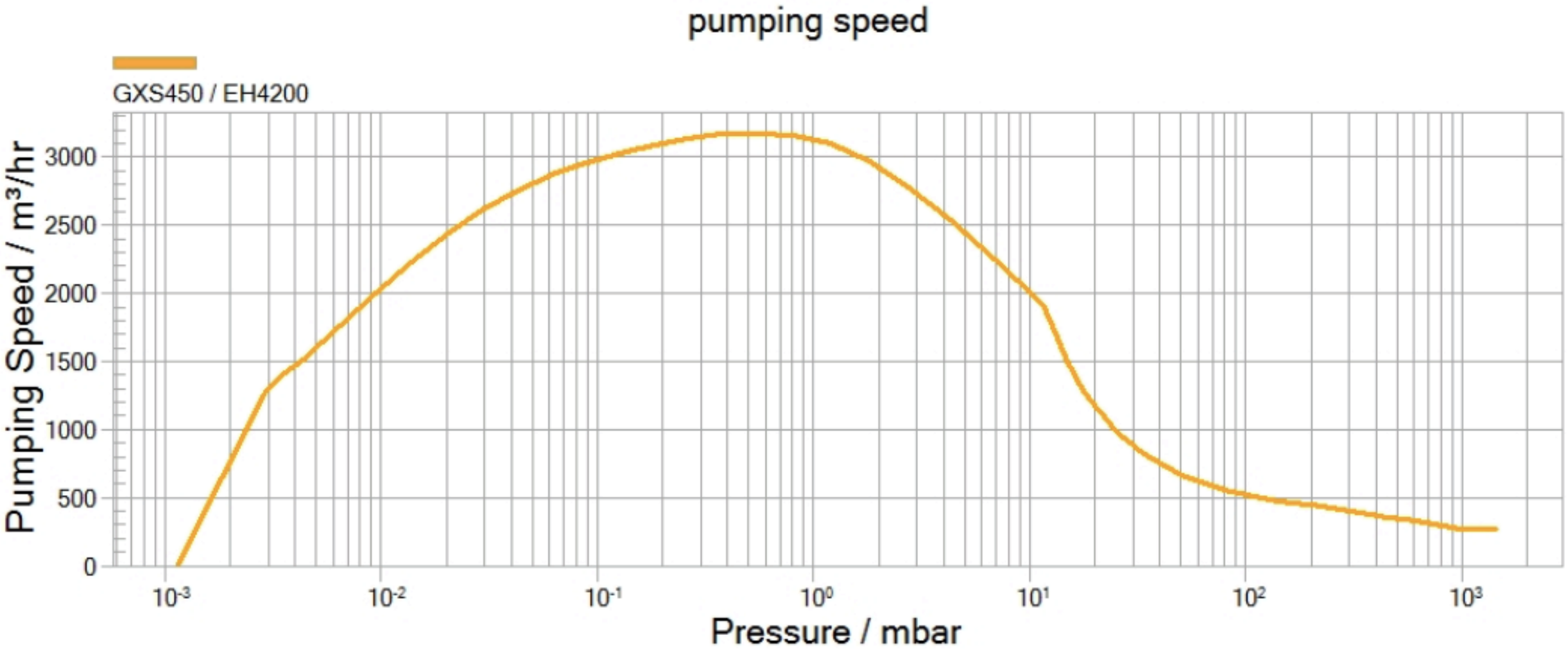
C (straight pipe) = πD^4 P(ave) / 128 η L

L=1 m
D= 0.063 m
P=1 mbar
C~7500 m3/h

L=1 m
D=0.1 m
P=1 mbar
C~48000 m3/h

C(elbow, 90 degrees)= πKD^3 P(ave) / 128 η (angle valve)

D=0.063 m
P=0.1 mbar
K(r/D=1)=0.05
C~6000 m3/h


pumping speed
GXS450 / EH4200
Pumping Speed / m³/hr
3000
2500
2000
1500
1000
500
0
10⁻³
10⁻²
10⁻¹
10⁰
10¹
10²
10³
Pressure / mbar

Leak Check of the Internal Lines of Seruci I - 3rd configuration

The Column C-101 in detail:

Leak detectors have Seff~1 l/s and this is due to the C of the leak detector until its turbo pump, as it has higher S (in the range ~5-50 l/s depending also on the vacuum level).
A flexible line DN25 1 m long has a C~0.5 l/s @ P~10^{-2} mbar. Using a DN40 we have C~3 l/s.

Therefore the lower C is ~1 l/s due to the leak detector conductance. What is the conductance of the Column (12 m)? Neglecting the packing, we have C~ 40 l/s. For 10 modules -> C~4 l/s. Considering the packing we may reduce by a factor ~2/3 the conductance but seems hard to reach the condition were C(column) << C(leak detector).

One solution could be to place a turbo pump on the DN250 flange itself and its outlet towards the leak detector. In this case we may have S~500 l/s and this will be enough to have a fast response time. The bottle neck would the 12 m module connected to the turbo pump and we may consider that after 8-10 modules below the weld the conductance start being small. So we may gain a factor ~9 (3 in volume and 3 in conductance) in response time (from 30 min to ~3 min).