AIR LIQUIDE
GLOBAL E&C SOLUTIONS

Helium Operators Familiarization Program

Unit 325 – Helium Loading Scenario

Dec 2012 l Vincent HELOIN

Course Agenda

- **Loading - Scenario presentation**

- Operation Tasks and Scheduling

- Bays Repartition

- Remark on Plant Capacity – Sizing Scenario

Remark on Plant Capacity – Sizing Scenario

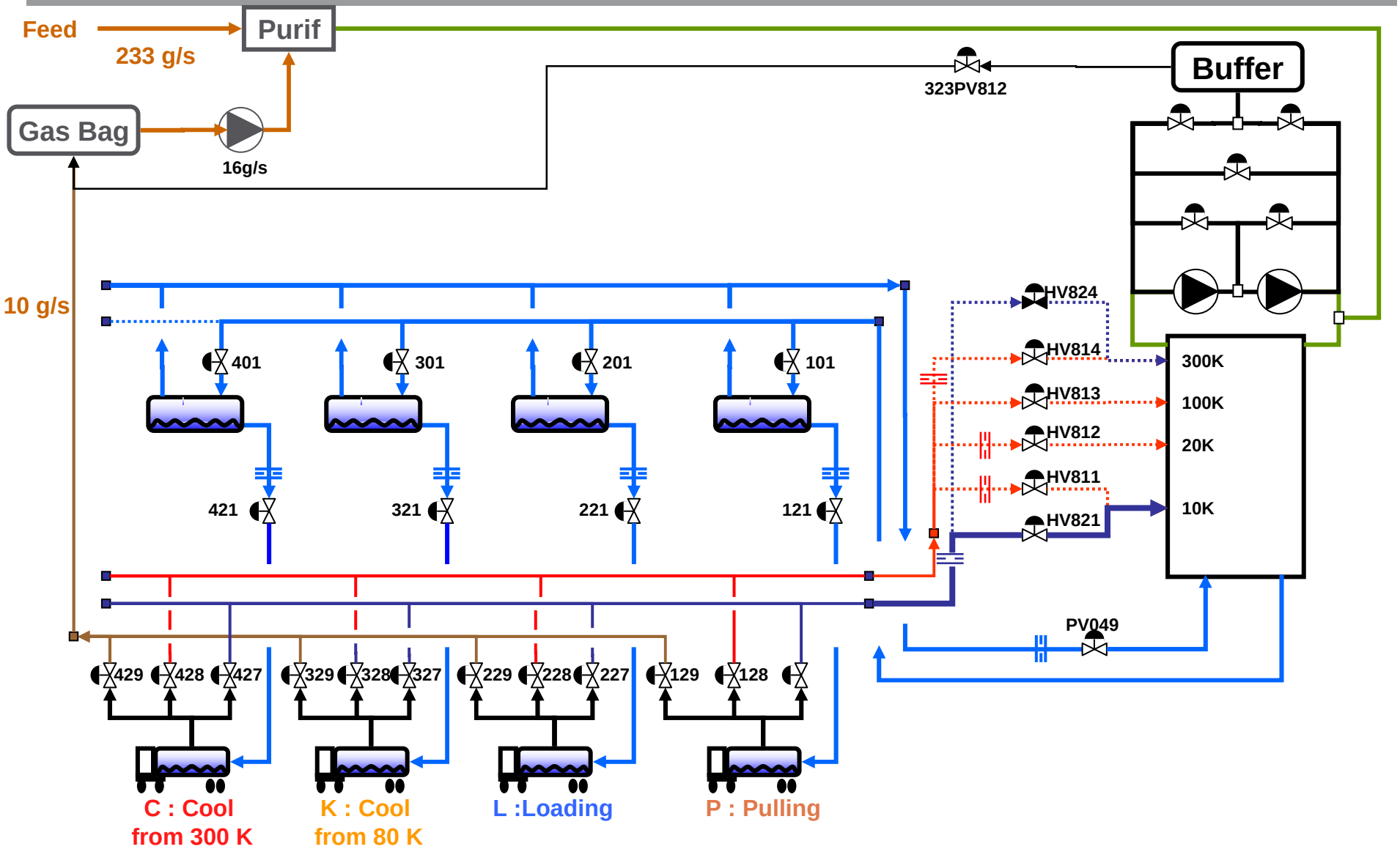
The Liquefier has been sized according to a loading scenario proposed by Ras Gas.

Over a Week Test, the HeRU shall be able to load 31 Trucks distributed as follows:

	Cold Clean	Warm Clean (<200ppm)	Warm Dirty (>200ppm)	Warm Load (Cold Clean)
INDEX	**CC**	**WC**	**WD**	**WL**
Number	x **24** / Week	x **6** / Week	x **1** / Week	x **7** / Week

Note:
-4600 kg is loaded in mobile container (Tare is performed after pulling)
-Warm Trucks [WC&WD] are first Cool-Down and then sent to the parking lot for Soaking (Temp. Homogenization).
-WL Trucks are Warm Trucks returning from Soaking for Loading.
-The number of WL Trucks is equal to the total number of incoming Warm Trucks [WC+WD].

Remark on Plant Capacity – Sizing Scenario



Course Agenda

- Loading - Scenario presentation
- **Operation Tasks and Scheduling**
- Loading Sequences & Main Steps
- Remark on Plant Capacity – Sizing Scenario

Operation Tasks and Scheduling - Tasks

For each task an estimation of required time has been made as following :

	Cold Clean	Warm Clean	Warm Dirty	Cold Clean (From Warm)
INDEX	**CC**	**WC**	**WD**	**WL**
IP: Initial Prep	1 h	1 h	1 h	
F: Flush (Purge)	0 h	0 h	12 h	
C: Cool-Down (300K-80K)	**0 h**	**10 h**	**10 h**	
K: Cool-Down (80K-4K)	**2 h**	**2 h**	**2 h**	
LN: LIN Filling	0 h	4 h	4 h	
S: Soaking	0 h	72 h	72 h	
LN: LIN Filling	2 h			1 h
P: Pressure Pulling	**3 h**			**3 h**
L: LOADING	**6 h**			**6 h**
X: No Activities	**0 h**			**2 h**
FP: Final Preparation	1 h	1 h	1 h	1 h
Time in Bay	15 h	18 h	30 h	13 h

Operation Tasks and Scheduling - Schedule for Week Test

CC=15h
WC=18h
WD=30h
WL=13h

		BAY 1	BAY 2	BAY 3	BAY 4
1	0:00	IP2	IP1		
2	1:00	C	LN		
3	2:00	C	LN		
4	3:00	C	P		
5	4:00	C	P	IP0	
6	5:00	C	P	LN	
7	6:00	C	K	P	
8	7:00	C	K	P	
9	8:00	C	LD	P	
10	9:00	C	LD	LD	IP1
11	10:00	C	LD	LD	LN
12	11:00	K	LD	LD	LN
13	12:00	K	LD	LD	P
14	13:00	LN	LD	LD	P
15	14:00	LN	FP	LD	P
16	15:00	LN	IP2	X	K
17	16:00	LN	C	X	K
18	17:00	FP	C	FP	LD
19	18:00	IP0	C		LD
20	19:00	LN	C		LD
21	20:00	P	C		LD
22	21:00	P	C		LD
23	22:00	P	C		LD
24	23:00	LD	C	IP1	FP
25	00:00	LD	C	LN	
26	1:00	LD	C	LN	
27	2:00	LD	K	P	IP1
28	3:00	LD	K	P	LN
29	4:00	LD	LN	P	LN
30	5:00	X	LN	K	P
31	6:00	X	LN	K	P
32	7:00	FP	LN	LD	P
33	8:00		FP	LD	K
34	9:00	IP2	IP0	LD	K
35	10:00	C	LN	LD	LD
36	11:00	C	P	LD	LD
37	12:00	C	P	LD	LD
38	13:00	C	P	FP	LD
39	14:00	C	LD		LD
40	15:00	C	LD		LD
41	16:00	C	LD	IP1	FP
42	17:00	C	LD	LN	

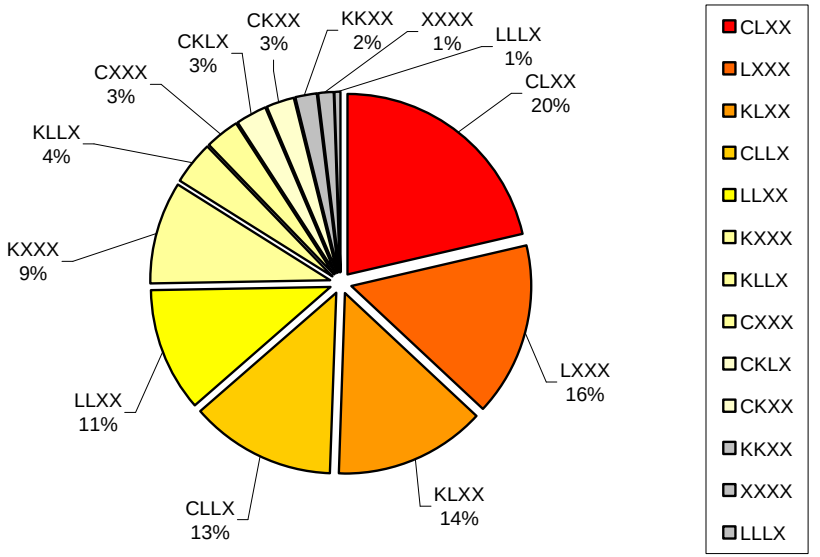
		BAY 1	BAY 2	BAY 3	BAY 4
43	18:00	C	LD	LN	
44	19:00	C	LD	P	
45	20:00	K	X	P	IP1
46	21:00	K	X	P	LN
47	22:00	LN	FP	K	LN
48	23:00	LN		K	P
49	00:00	LN	IP1	LD	P
50	1:00	LN	LN	LD	P
51	2:00	FP	LN	LD	K
52	3:00	IP1	P	LD	K
53	4:00	LN	P	LD	LD
54	5:00	LN	P	LD	LD
55	6:00	P	K	FP	LD
56	7:00	P	K		LD
57	8:00	P	LD	IP1	LD
58	9:00	K	LD	LN	LD
59	10:00	K	LD	LN	FP
60	11:00	LD	LD	P	
61	12:00	LD	LD	P	
62	13:00	LD	LD	P	
63	14:00	LD	FP	K	
64	15:00	LD	IP1	K	
65	16:00	LD	LN	LD	
66	17:00	FP	LN	LD	
67	18:00	IP2	P	LD	
68	19:00	C	P	LD	
69	20:00	C	P	LD	
70	21:00	C	K	LD	IP3
71	22:00	C	K	FP	P
72	23:00	C	LD	IP1	P
73	00:00	C	LD	LN	P
74	1:00	C	LD	LN	P
75	2:00	C	LD	P	P
76	3:00	C	LD	P	P
77	4:00	C	LD	P	P
78	5:00	K	FP	K	P
79	6:00	K	IP1	K	P
80	7:00	LN	LN	LD	P
81	8:00	LN	LN	LD	P
82	9:00	LN	P	LD	P
83	10:00	LN	P	LD	C
84	11:00	FP	P	LD	C

		BAY 1	BAY 2	BAY 3	BAY 4
85	12:00	IP0	K	LD	C
86	13:00	LN	K	FP	C
87	14:00	P	LD		C
88	15:00	P	LD		C
89	16:00	P	LD		C
90	17:00	LD	LD	IP1	C
91	18:00	LD	LD	LN	C
92	19:00	LD	LD	LN	C
93	20:00	LD	FP	P	K
94	21:00	LD	IP1	P	K
95	22:00	LD	LN	P	LN
96	23:00	X	LN	K	LN
97	00:00	X	P	K	LN
98	1:00	FP	P	LD	LN
99	2:00		P	LD	FP
100	3:00	IP2	K	LD	IP0
101	4:00	C	K	LD	LN
102	5:00	C	LD	LD	P
103	6:00	C	LD	LD	P
104	7:00	C	LD	FP	P
105	8:00	C	LD		LD
106	9:00	C	LD		LD
107	10:00	C	LD		LD
108	11:00	C	FP		LD
109	12:00	C	IP1		LD
110	13:00	C	LN		LD
111	14:00	K	LN		X
112	15:00	K	P		X
113	16:00	LN	P		FP
114	17:00	LN	P		IP0
115	18:00	LN	K		LN
116	19:00	LN	K	IP1	P
117	20:00	FP	LD	LN	P
118	21:00		LD	LN	P
119	22:00	IP1	LD	P	LD
120	23:00	LN	LD	P	LD
121	00:00	LN	LD	P	LD
122	1:00	P	LD	K	LD
123	2:00	P	FP	K	LD
124	3:00	P	IP1	LD	LD
125	4:00	K	LN	LD	X
126	5:00	K	LN	LD	X

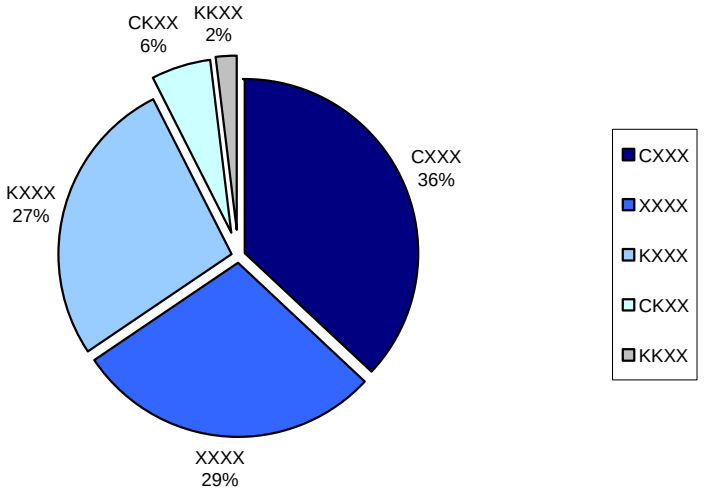
		BAY 1	BAY 2	BAY 3	BAY 4
127	6:00	LD	P	LD	FP
128	7:00	LD	P	LD	IP1
129	8:00	LD	P	LD	LN
130	9:00	LD	K	FP	LN
131	10:00	LD	K		P
132	11:00	LD	LD		P
133	12:00	FP	LD	IP0	P
134	13:00	IP2	LD	LN	K
135	14:00	C	LD	P	K
136	15:00	C	LD	P	LD
137	16:00	C	LD	P	LD
138	17:00	C	FP	LD	LD
139	18:00	C	IP1	LD	LD
140	19:00	C	LN	LD	LD
141	20:00	C	LN	LD	LD
142	21:00	C	P	LD	FP
143	22:00	C	P	LD	
144	23:00	C	P	X	IP1
145	00:00	K	K	X	LN
146	1:00	K	K	FP	LN
147	2:00	LN	LD	IP1	P
148	3:00	LN	LD	LN	P
149	4:00	LN	LD	LN	P
150	5:00	LN	LD	P	K
151	6:00	FP	LD	P	K
152	7:00	IP1	LD	P	LD
153	8:00	LN	FP	K	LD
154	9:00	LN	IP1	K	LD
155	10:00	P	LN	LD	LD
156	11:00	P	LN	LD	LD
157	12:00	P	P	LD	LD
158	13:00	K	P	LD	FP
159	14:00	K	P	LD	
160	15:00	LD	K	LD	
161	16:00	LD	K	FP	
162	17:00	LD	LD		
163	18:00	LD	LD		
164	19:00	LD	LD		
165	20:00	LD	LD		
166	21:00	FP	LD		
167	22:00		LD		
168	23:00		FP		

Repartition of bays

- Bays activities repartitions
  - Loading [**L**]
  - Cooling (300 to 80K) [**C**]
  - Cooling (80 to 4.5K) [**K**]
  - Other activities (LN Filling, Preparations,..) [**X]**



- As loading in Dewar or mobile Dewar has a similar impact on the liquefier, the repartition could be simplified as following :
  - Cooling (300 to 80K) [**C**]
  - Cooling (80 to 4.5K) [**K**]
  - Other activities (**Loading**, LN Filling, Preparations,..) [**X]**



Estimated Average Flow over a Week

	24	6	1	7
	Cold Clean	Warm Clean	Warm Dirty	Cold Clean (From Warm)
INDEX	CC	WC	WD	WL
IP: Initial Prep	1 h	1 h	1 h	
F: Flush (Purge)	0 h	0 h	12 h	
C: Cool-Down (300K-80K)	**0 h**	**10 h**	**10 h**	
K: Cool-Down (80K-4K)	**2 h**	**2 h**	**2 h**	
LN: LIN Filling	0 h	4 h	4 h	
S: Soaking	0 h	72 h	72 h	
LN: LIN Filling	2 h			1 h
P: Pressure Pulling	**3 h**			**3 h**
L: LOADING	**6 h**			**6 h**
X: No Activities	**0 h**			**2 h**
FP: Final Preparation	1 h	1 h	1 h	1 h
Time in Bay	15 h	18 h	30 h	13 h

mass		Average Flow		Average on a Week	
To Truck	From Truck	To Truck	From Truck	To Truck	From Truck
mass					
298 kg		6,9 g/s		0,5 g/s	
1320 kg	1300 kg	36,7 g/s	36,1 g/s	15,3 g/s	15,0 g/s
931 kg	180 kg	129,4 g/s	25,0 g/s	47,7 g/s	9,2 g/s
	200 kg		18,5 g/s		10,3 g/s
4800 kg	750 kg	222,2 g/s	34,7 g/s	246,0 g/s	38,4 g/s

Estimated Flow

Phase	Time	Mass	Flow
Flushing	12 hrs	300 kg	7 g/s
Pulling	3 hrs	200 kg	19 g/s
C: Cool Down (300K -> 80K) To Truck	10 hrs	1320 kg	37 g/s
C: Cool Down (300K -> 80K) From Truck	10 hrs	1300 kg	36 g/s
K: Cool Down (80K-> 4K) To Truck	2 hrs	930 kg	129 g/s
K: Cool Down (80K-> 4K) From Truck	2 hrs	180 kg	25 g/s
Soaking	1 week		
Loading To truck	6 hrs	4800 kg	222 g/s
Loading From truck	6 hrs	750 kg	35 g/s
LIN filling	2 hrs		1000 l/h

Plant Sizing

- The plant has been designed on an **<u>average</u> capacity**, thus the load can be higher than the plant capacity

	CXXX	XXXX	KXXX	CKXX	KKXX	
Load vs Capacity	106%	**93%**	97%	**113%**	103%	
Time repartition	37%	29%	27%	6%	1%	
Load x Time	39%	29%	26%	7%	1%	100%

- The above table shows that overload occurs during cooldown and mainly for warm mobile container.

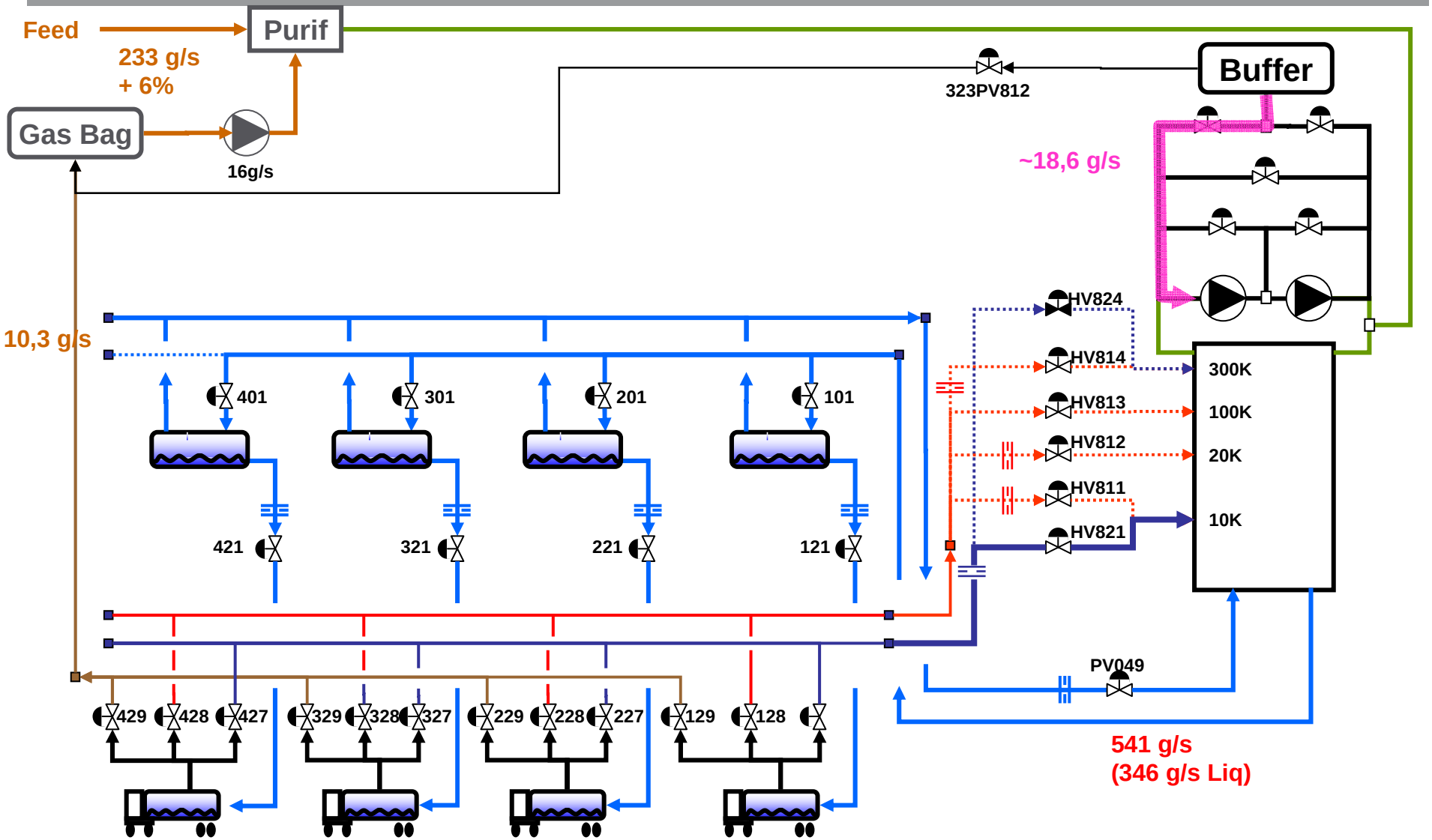
  The warmer the vapors, the higher the plant load.

- Main consequences are :
  - Consumption of LHe (Decrease of Dewar Level)
  - HP increases -> Excess of gas is sent to the Drum

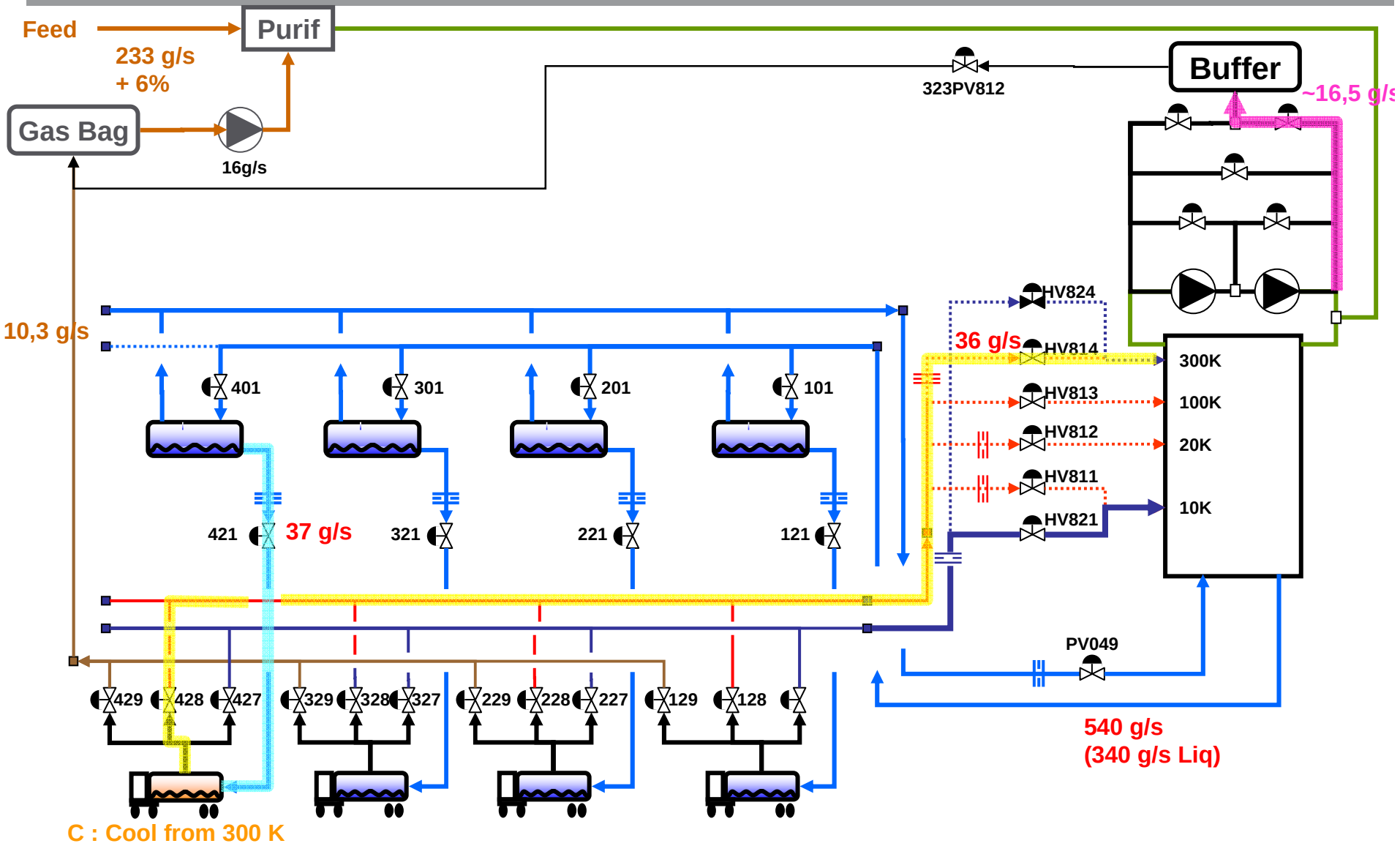
  -> Planification of Loading sequences is a key element to avoid venting gas !

  -> Cooling down of mobile container has to be limited to 1 / week

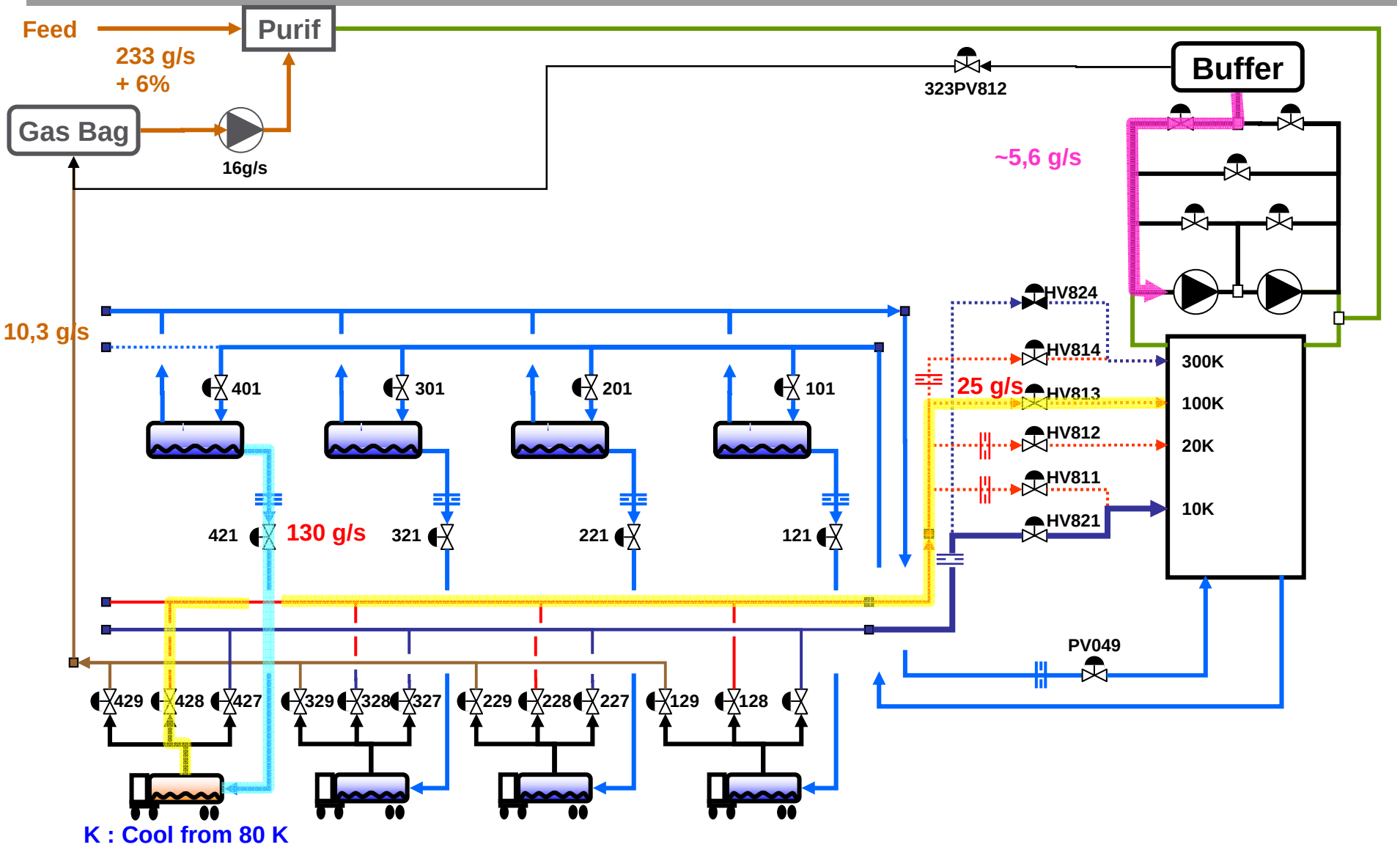
CASE XXXX


Feed
233 g/s
+ 6%
Purif
Gas Bag
16g/s
323PV812
Buffer
~18,6 g/s
10,3 g/s
401
301
201
101
421
321
221
121
HV824
HV814
HV813
HV812
HV811
HV821
300K
100K
20K
10K
PV049
429
428
427
329
328
327
229
228
227
129
128
541 g/s
(346 g/s Liq)

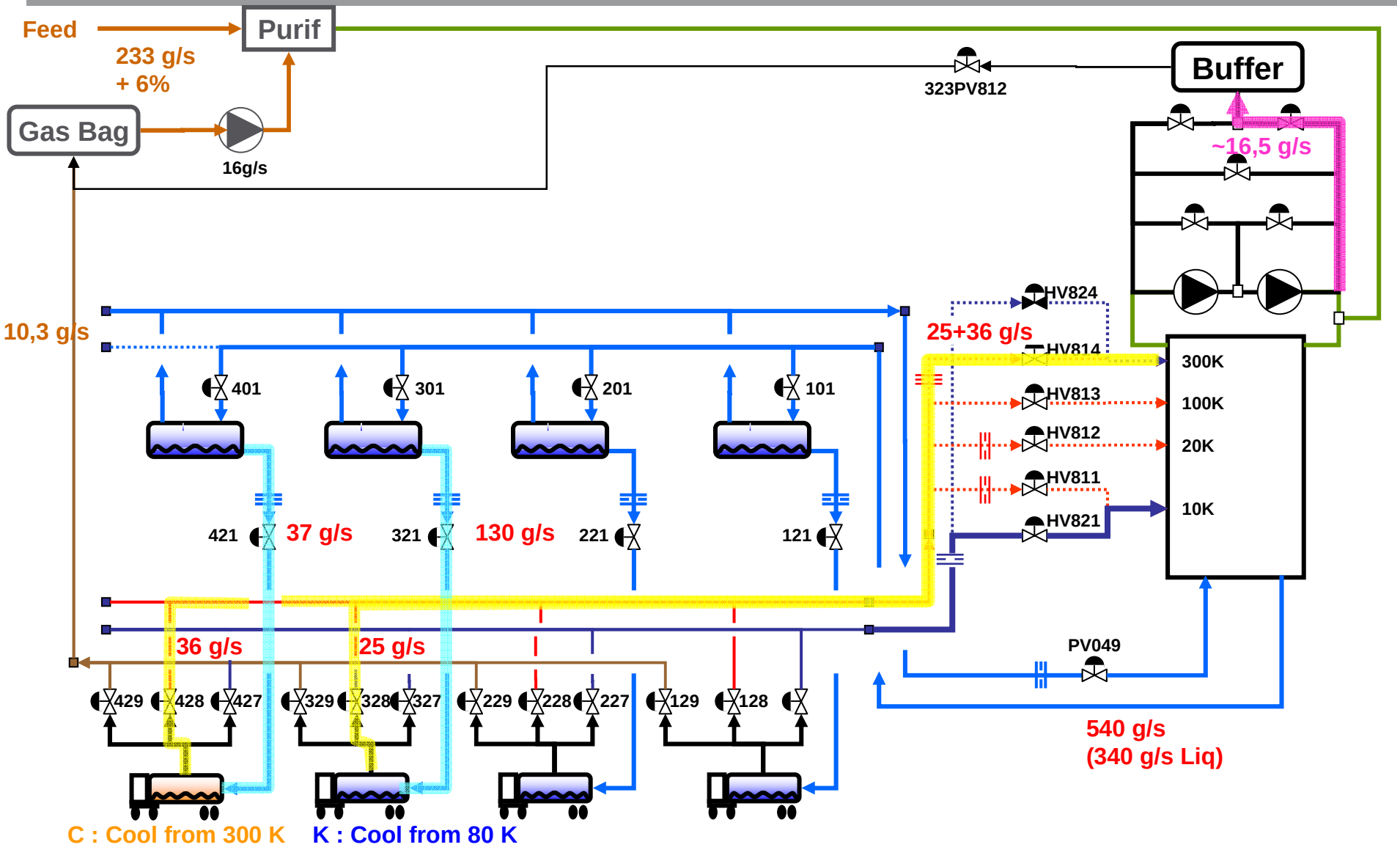
CASE CXXX


Feed
233 g/s
+ 6%
Purif
Gas Bag
16g/s
323PV812
Buffer
~16,5 g/s
10,3 g/s
HV824
36 g/s
HV814
HV813
HV812
HV811
HV821
300K
100K
20K
10K
401
301
201
101
421
37 g/s
321
221
121
429
428
427
329
328
327
229
228
227
129
128
PV049
540 g/s
(340 g/s Liq)
C : Cool from 300 K

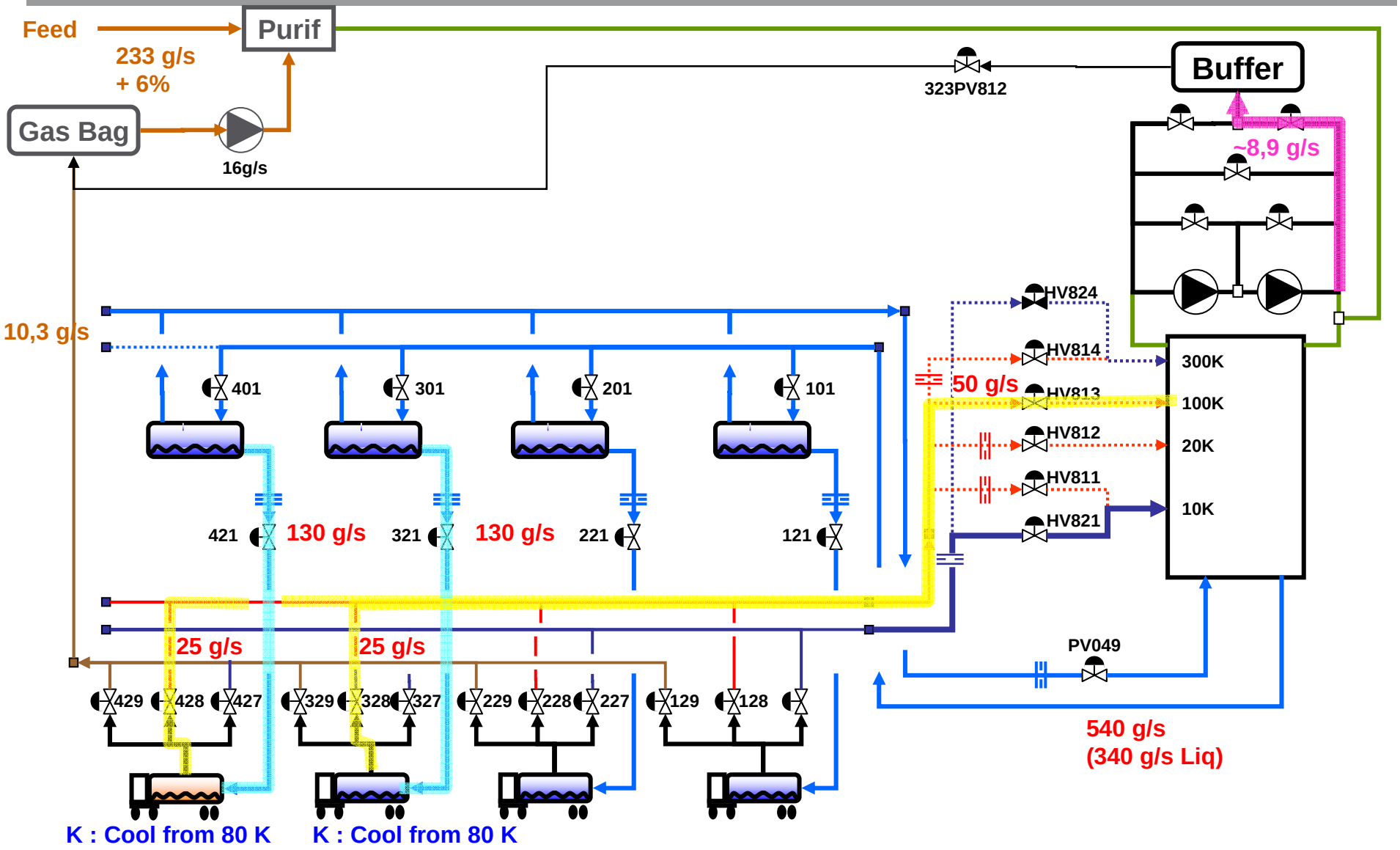
CASE KXXX


Feed
233 g/s
+ 6%
Purif
Gas Bag
16g/s
323PV812
Buffer
~5,6 g/s
10,3 g/s
HV824
HV814
HV813
HV812
HV811
HV821
25 g/s
300K
100K
20K
10K
401
301
201
101
421
130 g/s
321
221
121
PV049
429
428
427
329
328
327
229
228
227
129
128
K : Cool from 80 K

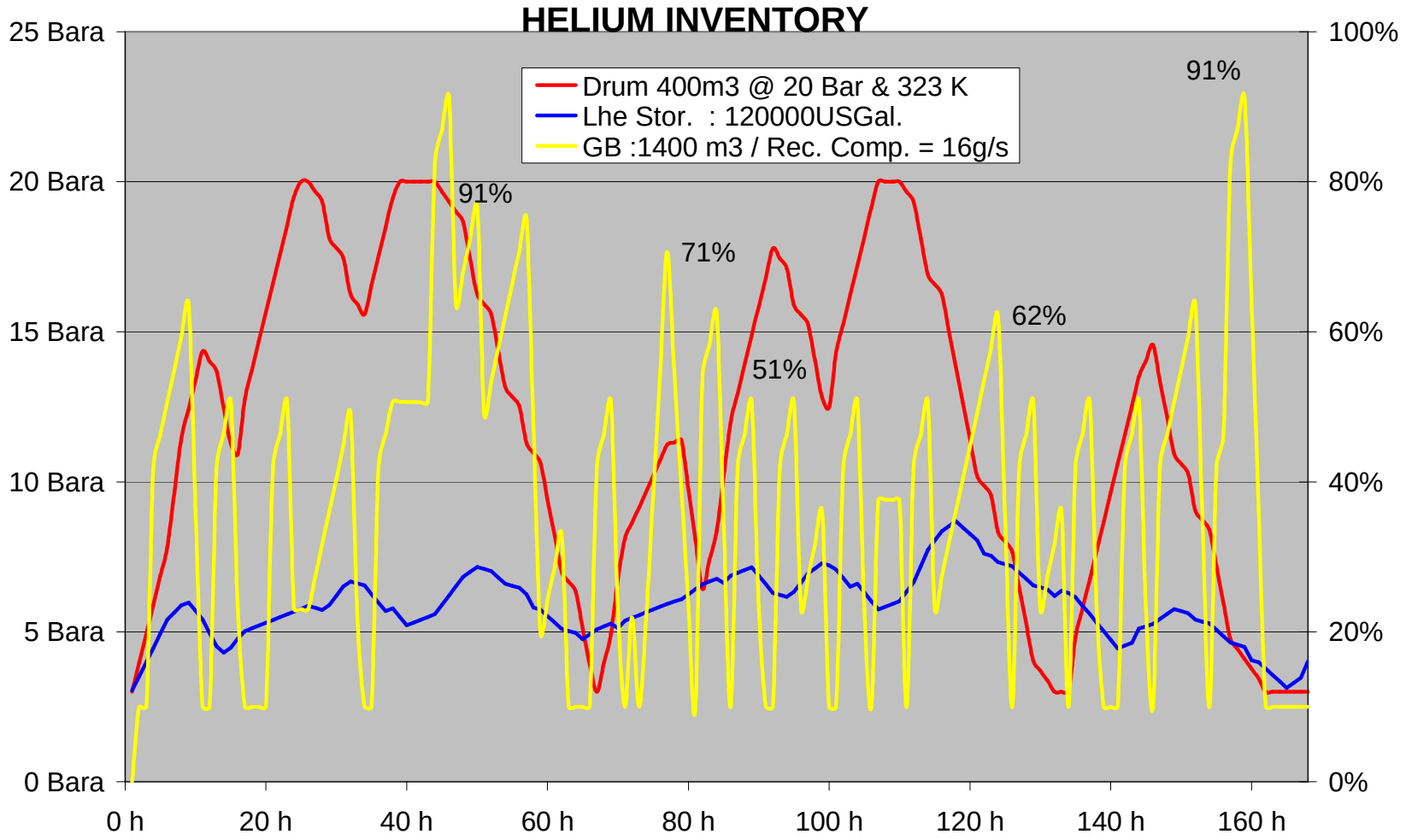
CASE CKXX


Feed
233 g/s
+ 6%
Purif
Gas Bag
16g/s
323PV812
Buffer
~16,5 g/s
10,3 g/s
HV824
25+36 g/s
HV814
HV813
HV812
HV811
HV821
300K
100K
20K
10K
401
301
201
101
421
37 g/s
321
130 g/s
221
121
36 g/s
25 g/s
PV049
429
428
427
329
328
327
229
228
227
129
128
540 g/s
(340 g/s Liq)
C : Cool from 300 K
K : Cool from 80 K

CASE KKXX

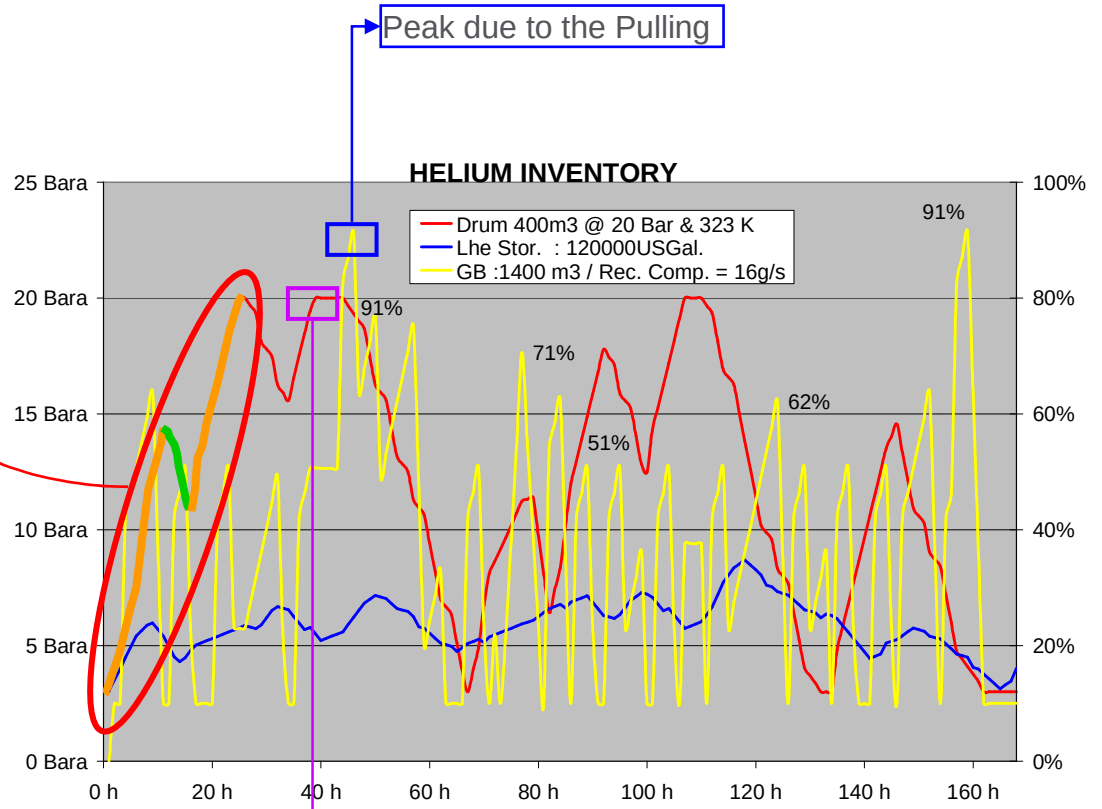

Feed
233 g/s
+ 6%
Purif
Gas Bag
16g/s
323PV812
Buffer
~8,9 g/s
10,3 g/s
HV824
HV814
HV813
HV812
HV811
HV821
50 g/s
300K
100K
20K
10K
401
301
201
101
421
130 g/s
321
130 g/s
221
121
25 g/s
25 g/s
PV049
429
428
427
329
328
327
229
228
227
129
128
540 g/s
(340 g/s Liq)
K : Cool from 80 K
K : Cool from 80 K

Helium Inventory



Helium Inventory

		BAY 1	BAY 2	BAY 3	BAY 4	Gas Bag	Drum	Storage
1	00:00	IP2	IP1			0%	3 Bara	12%
2	1:00	C	LN			10%	4 Bara	14%
3	2:00	C	LN			10%	5 Bara	16%
4	3:00	C	P			42%	6 Bara	18%
5	4:00	C	P	IP0		46%	7 Bara	20%
6	5:00	C	P	LN		51%	8 Bara	22%
7	6:00	C	K	P		55%	10 Bara	23%
8	7:00	C	K	P		59%	11 Bara	24%
9	8:00	C	LD	P		64%	12 Bara	24%
10	9:00	C	LD	LD	IP1	36%	13 Bara	23%
11	10:00	C	LD	LD	LN	10%	14 Bara	22%
12	11:00	K	LD	LD	LN	10%	14 Bara	20%
13	12:00	K	LD	LD	P	42%	14 Bara	18%
14	13:00	LN	LD	LD	P	46%	12 Bara	17%
15	14:00	LN	FP	LD	P	51%	11 Bara	18%
16	15:00	LN	IP2	X	K	23%	11 Bara	19%
17	16:00	LN	C	X	K	10%	13 Bara	20%
18	17:00	FP	C	FP	LD	10%	14 Bara	20%
19	18:00	IP0	C		LD	10%	15 Bara	21%
20	19:00	LN	C		LD	10%	16 Bara	21%
21	20:00	P	C		LD	42%	17 Bara	22%
22	21:00	P	C		LD	46%	18 Bara	22%
23	22:00	P	C		LD	51%	19 Bara	22%
24	23:00	LD	C	IP1	FP	23%	20 Bara	23%
25	00:00	LD	C	LN		23%	20 Bara	23%
26	1:00	LD	C	LN		23%	20 Bara	23%
27	2:00	LD	K	P	IP1	27%	20 Bara	23%
28	3:00	LD	K	P	LN	32%	19 Bara	23%
29	4:00	LD	LN	P	LN	36%	18 Bara	24%
30	5:00	X	LN	K	P	40%	18 Bara	25%
31	6:00	X	LN	K	P	45%	17 Bara	26%
32	7:00	FP	LN	LD	P	49%	16 Bara	27%
33	8:00		FP	LD	K	21%	16 Bara	26%
34	9:00	IP2	IP0	LD	K	10%	16 Bara	26%
35	10:00	C	LN	LD	LD	10%	17 Bara	25%
36	11:00	C	P	LD	LD	42%	18 Bara	24%
37	12:00	C	P	LD	LD	46%	18 Bara	23%
38	13:00	C	P	FP	LD	51%	19 Bara	23%
39	14:00	C	LD		LD	51%	20 Bara	22%
40	15:00	C	LD		LD	51%	20 Bara	21%
41	16:00	C	LD	IP1	FP	51%	20 Bara	21%
42	17:00	C	LD	LN		51%	20 Bara	22%
43	18:00	C	LD	LN		51%	20 Bara	22%
44	19:00	C	LD	P		83%	20 Bara	22%
45	20:00	K	X	P	IP1	87%	20 Bara	24%
46	21:00	K	X	P	LN	91%	19 Bara	25%
47	22:00	LN	FP	K	LN	64%	19 Bara	26%



Loading Cases Summary

	XXXX	CXXX	KXXX	CKXX	KKXX	Design
From Buffer	18,6 g/s	0,0 g/s	5,6 g/s	0,0 g/s	0,0 g/s	0,0 g/s
To Buffer	0,0 g/s	16,5 g/s	0,0 g/s	29,5 g/s	8,9 g/s	0,0 g/s
Return @ 300K	0 g/s	36 g/s	0 g/s	36 g/s	0 g/s	16 g/s
Return @ 80K	0 g/s	0 g/s	25 g/s	25 g/s	50 g/s	50 g/s
xvap	36%	37%	38%	39%	40%	37%
T6	541 g/s	541 g/s	540 g/s	538 g/s	534 g/s	540 g/s
Liq	346 g/s	340 g/s	334 g/s	328 g/s	320 g/s	340 g/s
Heat Loads	15 g/s	15 g/s	15 g/s	15 g/s	15 g/s	15 g/s
Used for Cooling (C&K)	0 g/s	37 g/s	129 g/s	166 g/s	259 g/s	62 g/s
Return from Cooling (C&K)	0 g/s	36 g/s	25 g/s	61 g/s	50 g/s	24 g/s
Liquid Filling	331 g/s	288 g/s	189 g/s	146 g/s	46 g/s	263 g/s
Rising Level	56 g/s	49 g/s	32 g/s	25 g/s	8 g/s	44,7 g/s
Dewar Return @4,5K	210 g/s	216 g/s	221 g/s	226 g/s	229 g/s	215 g/s
Loading Capacity (Net)	274 g/s	239 g/s	157 g/s	121 g/s	38 g/s	218 g/s
Mass sent L +C + K (Net)	274 g/s	240 g/s	261 g/s	226 g/s	247 g/s	256 g/s

→ The Buffer pressure evolution is a good indicator of the Liquefier Load.

Helium Losses

Design has been done to minimize Helium Loss.

The One week design scenario is based on “No Venting” Operation.

The following streams are returned to the gas bag:

- Truck Pressure Pulling
- Truck Flush (Purge)
- Excess of Gas returned to Drum:

To minimize He Losses during operation:

- Do not attempt to process 2 Warm Trucks simultaneously (Drum Pressure)
- Do not attempt to Pull 2 Trucks Simultaneously. (Gas Bag Volume)
- Do not combine 1 Dirty Truck Flush with more than 1 pulling. (Gas Bag Volume)