Air Liquide

2020

Nitrogen Membrane Systems

Air Liquide Advanced Separations

M1000 Series
M1500 Series
M2000 Series
AMSA Series

Up to 2000 NM^3/hr with purity range 95% to 99.9%

1 Contents

Air Liquide Advanced Separations, A Division of Air Liquide Advanced Technologies, U.S. LLC.
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2 Introduction

Air Liquide is the global leader in advanced technology methods to purify and produce gases for a wide range of applications. Located in Newport, Delaware USA, MEDAL now Air Liquide Advanced Separations (ALAS) was created in 1988 as a joint venture between Air Liquide and DuPont. Since 1992, ALAS has been wholly-owned by Air Liquide.
ALAS has developed and commercialized the most advanced gas separation membranes available to industry. ALAS manufactures hollow fiber membrane modules and complete systems for air separation/nitrogen generation, carbon dioxide removal and hydrogen purification.

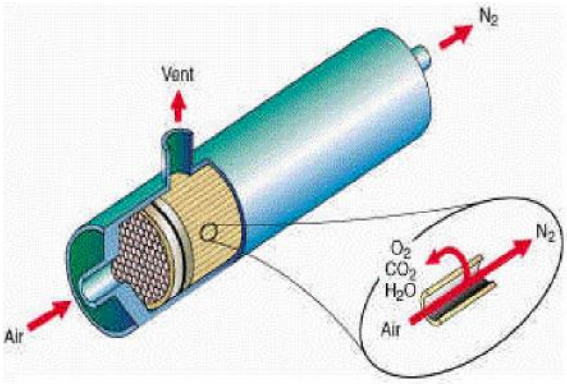
This document provides technical information for selecting the correct nitrogen membrane system for the customer needs. Whilst the document aims to cover all the aspects related to a standard nitrogen membrane system, ALAS would encourage you to contact them once you have chosen the system to validate your design before any purchase orders are made.

3 Nitrogen membranes

All systems incorporate ALAS membrane modules. The membrane module manufacturing process is ISO 9001 certified. Air Liquide uses advanced selective membrane technology through hollow fibers to separate N2 from Air. Due to high selectivity, Air Liquide membranes provide more flow rate than our nearest competitor. This amounts to less membranes required for a given output which in turn means less maintenance and space required. Air Liquide membranes can separate N2 efficiently for purities up to 99.9%.

Ambient air is compressed and rigorously filtered (coalescing filters, carbon tower...) before entering membrane modules, each containing thousands of hollow fibers. Within these fibers, oxygen is quickly separated from the gaseous nitrogen which is finally delivered to the customer's process.

Most of "high permeation speed" molecules are vented to the atmosphere (and are called "permeate") and "low permeation speed" molecules, especially Nitrogen, are collected at membrane outlet.



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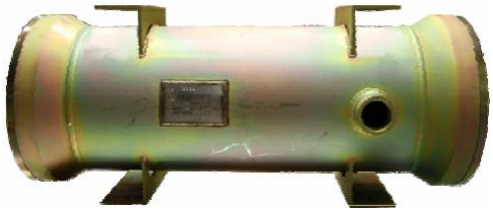
Two types of membranes will be used in ALAS systems. The AMSA series incorporates the MDL04240V membrane. The M1000, 1500 and 2000 series incorporates the MDL04640FRP membrane.



4240V

L 1000 mm D 300mm

- max pressure 24 barg-350psig
- max temperature 65C
- carbon steel shell coated in zinc chromate. SS optional
- ASME U stamp
- stackable when mounted horizontally.
- productivity 58Nm3/hr, Recovery 35.5% at 98% purity, 7 barg and 40C

4640FRP

- L 1125mm D 150mm
- max pressure 15.2 barg-220psig
- max temperature 65C
- fiber Reinforced plastic shell
- ASME X. ASME U stamp not required due to size and vessel material.
- mounted horizontally or vertically
- productivity 16Nm3/hr, Recovery 36% at 98% purity, 7 barg and 40C

4 Nitrogen membrane systems

ALAS offer 4 types of membrane systems to cover the majority of customer requirements from 95% to 99.9% purity and 10Nm^3/hr to 2000Nm^3/hr. ALAS has named the systems M series and AMSA.

The model numbers on the membrane systems indicates the type of system and number of membranes installed.

M1000

M	10	00
Type	Piping diameter inches (10 is 1") (15 is 1.5") (20 is 2.0") (30 is 3")	Number membranes

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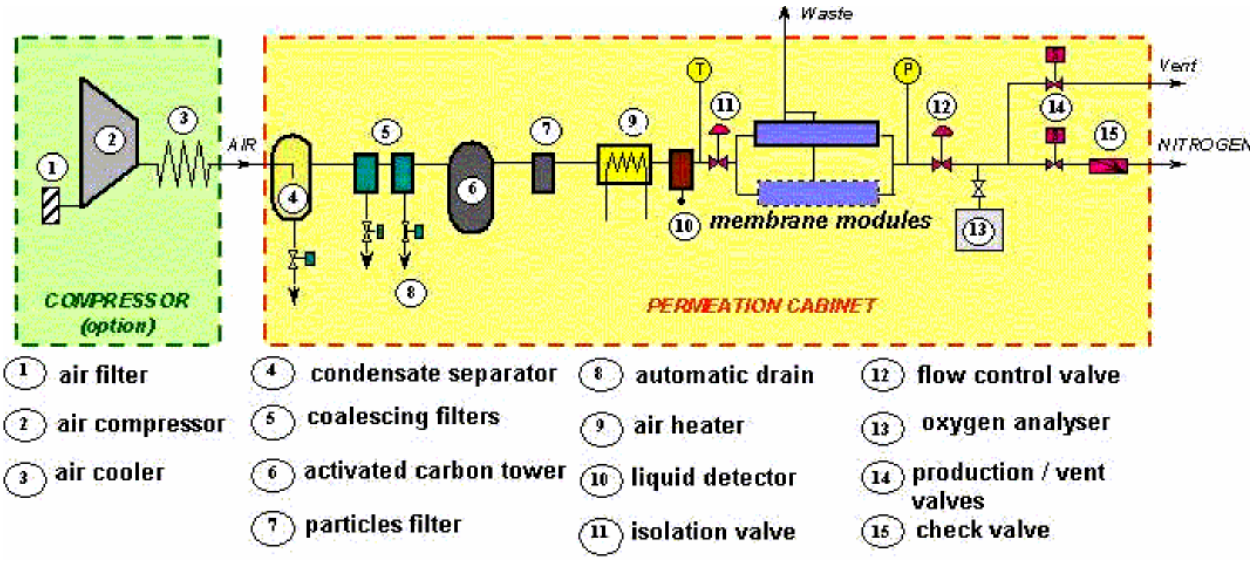
4.1 Membrane standard system



Compressed air from a dedicated air compressor or customer supplied air system enters the membrane unit. The maximum temperature of the compressed is 60C but ideally <40C should be the norm since higher than 45C to membrane increases aging.

Air Pre-Treatment System

A water separator (4) takes out the majority of the water. Then two coalescing filters (5) removes heavy oil and water before passing through a carbon tower (6). The coalescing filters are drained automatically through "smart" drains (8) with failure alarm. The carbon tower is sized to remove oil mist and vapor down to less than 5 microgram/m^3. Finally, a particulate filter (7) after the carbon tower removes any particulates down to 0.01microns.

Air exiting the coalescing filters will normally be fully saturated with water vapor. To ensure no subsequent moisture condensation occurs in the carbon tower, piping, or membrane bundles, a small electric pre-heater (M series only) is installed at the carbon tower inlet. This maintains the carbon tower temp to ensure efficiency is maintained even during start up.

A larger process heater (9) adds a "dew point margin" to the process air of 3 to 5^{o}C. The dew point margin is then maintained through the process all the way to the membrane modules. The effect of raising the dew point margin allows the moisture to vent from the membrane and deliver a N2 product stream with moisture dew point content at -70C atmosphere at purity +95%.

The carbon tower is also heat traced and continuously powered (even in standby) so that it is warmer than inlet air, even at startup. A liquid detector (10) is installed in the final filter, with alarm, for ultimate membrane protection.

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Shut off

An automatic shut off valve (11) is fit before the membranes to isolate the compressed air during shut down and stand bye. This valve also controls the speed of pressure build to protect the membranes on start up.

O2 control

O2 analyzer (13) measures the product O2 content. A manual flow control valve (12) is set to ensure O2 purity is maintained. On the AMSA systems, this valve is automatic (optional on M1500 and M2000) and can provide active purity control for different outlet purities if required. If the purity falls below preset values, the system will alarm and vent to atmosphere. This is achieved by two valves (14) controlled by the plc. With the product on-spec, the on-spec valve is open and the off-spec valve is closed and visa-versa if the product is off-spec.

Process Control PLC

PLC is configured to provide for:
Automatic start/standby based on customer demand.
Automatic venting of off-spec product gas.
Fault detection and response.
MODBUS/TCP for DCS signals and alarms.
HMI display.

4.2 M1000 series

The M1000 is a compact unit that has a maximum flow rate of 215Nm^3/hr @ 95% purity and 10 barg, utilizing a maximum of eight MDL04640FRP membranes. The unit is ideal for small installations and offers purities of up to 99.9%. The unit has a maximum operating pressure of 13 barg.

Operation is fully automated and remote stop start and alarms can be linked to the control room. Remote monitoring is an optional extra. Purity is controlled by a fixed purity control valve.

Enclosure
Rated for Indoor or Outdoor service, providing protection against windblown dust and rain, splashing water, and hose directed water. Containerized or skid mounted option available.

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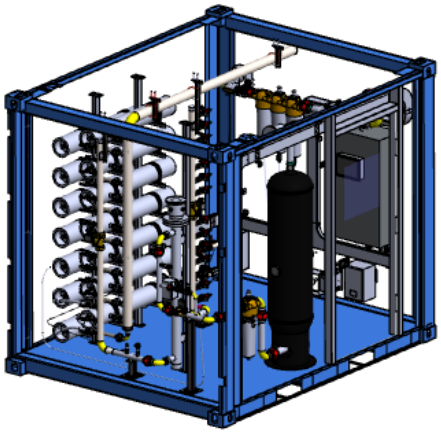
4.3 M1500 series

The M1500 is a medium sized unit that has a maximum flow rate of 517Nm^3/hr @ 95% purity and 10 barg, utilizing a maximum of 14 MDL04640FRP membranes. The unit is ideal for mid-sized installations and offers purities of up to 99.9%. The unit has a maximum operating pressure of 13 barg.

Operation is fully automated and remote stop start and alarms can be linked to the control room. Purity is controlled by a fixed purity control valve.

Enclosure
Rated for Indoor or Outdoor service, providing protection against windblown dust and rain. Inside the containerized system is an O2 sensor for depleted O2 atmosphere which alarms and operates an exhaust fan. Skid mounted option is available.

4.4 M2000 series



The M2000 is a mid to large sized unit that has a maximum flow rate of 991Nm^3/hr @ 95% purity and 10 , utilizing a maximum of 24 MDL04640FRP membranes. The unit is ideal for mid-sized installations and offers purities of up to 99.9%. The unit has a maximum operating pressure of 13 barg. However, 24 barg can achieved as a special build request.

The only difference to the M1500 series is the pipe size ID is 2" as opposed to 1.5" and the filters are larger, allowing more flow rate.

Operation is fully automated and remote stop start and alarms can be linked to the control room. Purity is controlled by a fixed purity control valve.

Enclosure
Rated for Indoor or Outdoor service, providing protection against windblown dust and rain. Inside the containerized system is an O2 sensor for depleted O2 atmosphere which alarms and operates an exhaust fan. Skid mounted option is available.

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4.5 AMSA3000 series

The AMSA3000 is large sized unit that has a maximum flow rate of 2042Nm^3/hr @ 95% purity and 10 barg, utilizing a maximum of 24 MDL04240 membranes. The unit is ideal for larger sized installations particularly where space is important since the flow rate per m^2 ratio is higher than that of other system choices.

Like the M series, purities of up to 99.9% can be achieved but this system offers active purity control meaning that different purities can be selected from the HMI.

The standard unit has a maximum operating pressure of 13 barg. However, 24 barg can achieved as a special build request.

Operation is fully automated and remote stop start and alarms can be linked to the control room.

Enclosure
Rated for Indoor or Outdoor service, providing protection against windblown dust and rain. Inside the containerized system is an O2 sensor for depleted O2 atmosphere which alarms and operates an exhaust fan. Skid mounted option is available.

4.6 System Dimensions

The following dimensions (mm) are accurate but the weights (kg) may vary depending on number of membranes. The weights are listed as approximate weights.

	Length	Width	Height	Weight
M1000	1730	865	2000	600
M1500	3048	2440	2426	4500
M2000	3048	2440	2426	5100
AMSA3000	6058	2440	2895	13000

For plot plans please allow room for access of opening doors. Please refer to general arrangement diagrams available from ALAS for detailed information.

4.7 Codes and standards

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All systems are built to IEC electrical code. Pressure codes are ASME or PED.

Marine standards are also available on request.

All systems are built to safe zone standards but hazardous zone standards are available on request.

4.8 N2 Product specification

Based on using an oil lubricated screw compressor and assuming the air is fully saturated, the following nitrogen specification can be used.

- nitrogen Product Gas at 95% to 99.9% Nitrogen + Inerts.
- 29 psi / 2 bar below inlet compressed air pressure.
- moisture Content < 10 ppm
- oil Content < 0.003 ppm (not measurable)
- particulates < 0.01 micron

4.9 Membrane system exclusions

- air compressors which are available on request.
- electrical wiring between membrane system and air compressor (if compressor is not integrated in ALAS System). Note: proper integration is critical to assure zero air feed pressure in standby.
- interconnecting piping between ALAS membrane system and air compressor (if compressor is not integrated in ALAS System).
- membrane system erection and start-up supervision.
- buffer tank and nitrogen back up (if required).
- electrical power.
- concrete pad
- telephone/data line for external communication.

5 Selecting a nitrogen membrane system

5.1 Customer requirements

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When selecting the right unit to fit the customer requirements the following parameters are required.

a) Site conditions - required for low temperature installations where winterization option may be required. For compressor sizing the following is required
   - Elevation (meters above sea level) for inlet pressure calculation.
   - Minimum and maximum ambient temperatures.
   - Average relative humidity.

b) Nitrogen flow rate - normally measured in Nm^3/hr but sometimes other units such a SCFM, kg/hr, l/s and Sm^3/hr can also be given. This needs to be converted to Nm^3/hr since the systems have been sized for Nm^3/hr. Pay attention to average flow rates and peak flow rates. Unless a buffer vessel is to be fit or liquid back up to smooth out the peak flow rates, then the system must be designed to the peak flow rate. Turndown on the M1500, M2000 and AMSA can be fit to save energy by isolating membranes when peak flow is not required, thus reducing compressed air.

c) Nitrogen pressure - in barg is required to select the compressor and membrane system size. The membrane system will induce a 2 barg pressure drop so the compressor pressure must always be 2 barg higher than N2 pressure. Pressure is critical in terms of system size. The higher the pressure the less number of membranes required. Therefore, if the customer has low pressure requirements, it is often better to select higher pressure system and fit a pressure reducing valve at the outlet or on the buffer vessel. Typical standard compressor pressures are 10 barg and 12 barg.

d) Nitrogen temperature - in degree Celsius is preset by the membrane system heater to the normal operating temp of 45C which is what the systems are sized at in this catalogue. The heater setting will be dependent on the compressed air temperature. The normal setting of 45C will generally accommodate ambient temperatures of up to 33C with standard air cooled compressors. For higher ambient temperatures, please consult ALAS

e) Nitrogen purity - in % generally ranges from 95% to 99.9% (max). For lower purities consult ALAS. Purity is critical to system cost and operating cost. It is often found that the customer specifies too high a purity based on some historic value from previous liquid supply and not actually what their minimum value could be. Lower purities mean lower system size and cost.

5.2 System sizing

Once the customer details are gathered, the next step is to define which system is most suitable for the application.

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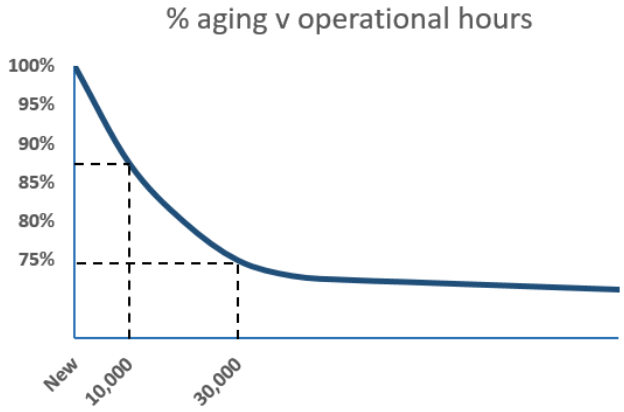
5.2.1 Membrane aging

All systems from ALAS have been sized to fully aged (30,000hrs operation) membrane flow rates. This means that because membranes age over time, their performance reduces. ALAS calculates two aging profiles. Mid aged (10,000 to 15,000hrs) have a performance of 87.5% of that when new. Fully aged membranes have a performance of 75% of that as when new. Beyond 30,000 hours, the performance deterioration is minimal.



Therefore, for a set flow rate in a FLOXAL installation, it is necessary to ensure the system can deliver this flow rate beyond 30,000hrs operation. Otherwise, membrane renewal will be required more frequently.

The effect of fully aged systems requires more membranes in the system. For example, a system with 8 membranes, actually only requires 6 membranes for the same flow rate at new condition. But those 6 membranes will age and flow rates will reduce. In fact, what happens in reality is that when a system is delivered, two of those membranes are isolated and re-introduced over time as the aging effect takes place. This maintenance procedure is described in the operating manual.

5.2.2 Selecting system type

The following tables cover the full range of systems and customer design parameters..

The customer nitrogen pressures often range from 3 barg to 10 barg. If the customer has its own compressed air, then the pressure inlet to the nitrogen generator is fixed by their supply. If the customer does not have compressed air and you are supplying a compressor, then you need to select a 12 barg compressor (10 barg N2) to get optimum efficiency. For higher than 10 barg N2, please consult ALAS.

The temperature is set at 45C but for lower and higher temperatures, please consult ALAS for a new calculation.

The purity range is set from 95% to 99.9% but for lower purities, please consult ALAS.

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Once you have defined the pressure and purity, you can select the type of system required by finding the flow rate in Nm^3/hr in the corresponding pressure/purity axis in the table. You will need to search through the tables until you find the N2 flow rate you require. The flow rates are indicated with the N2 flow rate first and then the feed air flow rate second (N2/Air).

The feed air flow rate is that which is required for your compressor selection in Nm^3/hr. You will also notice the compressor pressure requirements which is listed in the table along the same axis. Again 2 barg higher than customer N2 pressure requirements.

Example

Customer requires 135Nm3/hr of N2 at 7 barg and 97% purity. You can see from the table below that an M1007 unit is required. Although the flow is more than 135Nm3/hr, the M1006 only produces 118Nm3/hr at these conditions so the next size up is required.

You can also see that the feed air is 347 Nm3/hr for this flow rate at these conditions. Additionally, the compressed air pressure is 9 barg for 7 barg N2 pressure.

Finally, these tables show that at a certain N2 flow rate it's not possible to achieve this with the M1000 series even though it can be achieved with 7 membranes. This is due to pipe diameter and filter sizing for the maximum allowable velocity of feed air which is 20m/s. Thus, you can see that the shaded blue area directs you to the next system size up or down, in this case the M1507 system.

M1007

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	73/173	62/161	51/150	40/138	28/122	20/112	11/100
6	4	102/231	86/214	71/197	56/180	39/158	28/144	15/128
7	5	133/290	112/268	93/246	73/224	50/195	36/177	19/156
8	6	165/351	139/323	115/296	90/269	62/232	45/211	24/184
9	7	199/413	167/379	138/347	108/314	74/270	54/244	28/212
10	8	232/476	196/436	161/398	126/359	87/308	63/278	33/241
11	9	267/540	225/494	185/450	145/405	99/347	72/312	38/269
12	10	302/604	254/552	208/502	164/451	112/385	81/346	42/298
		See M1507 tables						

5.2.3 Sizing tables

M1000 series

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M1002

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	21/49	18/46	15/43	11/39	8/35	6/32	3/29
6	4	29/66	25/61	20/56	16/52	11/45	8/41	4/36
7	5	38/83	32/76	26/70	21/64	14/56	10/51	5/44
8	6	47/100	40/92	33/85	26/77	18/66	13/60	7/53
9	7	57/118	48/108	39/99	31/90	21/77	15/70	8/61
10	8	66/136	56/125	46/114	36/103	25/88	18/79	9/69
11	9	76/154	64/141	53/128	41/116	28/99	20/89	11/77
12	10	86/173	73/158	60/143	47/129	32/110	23/99	12/85

M1003

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	31/74	26/69	22/64	17/59	12/52	9/48	5/43
6	4	44/99	37/92	30/84	24/77	17/68	12/62	6/55
7	5	57/124	48/115	40/105	31/96	21/84	16/76	8/67
8	6	71/150	60/138	49/127	39/115	27/100	19/90	10/79
9	7	85/177	72/163	59/149	46/134	32/116	23/105	12/91
10	8	100/204	84/187	69/171	54/154	37/132	27/119	14/103
11	9	114/231	96/212	79/193	62/174	42/149	31/134	16/115
12	10	129/259	109/237	89/215	70/193	48/165	35/148	18/128

M1004

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	42/99	35/92	29/86	23/79	16/70	12/64	6/57
6	4	58/132	49/122	41/113	32/103	22/90	16/82	9/73
7	5	76/166	64/153	53/141	42/128	29/111	21/101	11/89
8	6	95/201	80/185	66/169	52/154	35/133	26/120	14/105
9	7	113/236	96/217	79/198	62/179	42/154	31/140	16/121
10	8	133/272	112/249	92/227	72/205	49/176	36/159	19/137
11	9	152/308	128/282	105/257	83/232	57/198	41/178	21/154
12	10	172/345	145/315	119/287	93/258	64/220	46/198	24/170

M1005

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	52/124	44/115	36/107	29/99	20/87	14/80	8/71
6	4	73/165	62/153	51/141	40/129	28/113	20/103	11/91
7	5	95/207	80/191	66/176	52/160	36/139	26/127	14/111
8	6	118/251	100/231	82/211	64/192	44/166	32/150	17/131
9	7	142/295	120/271	98/248	77/224	53/193	38/174	20/152
10	8	166/340	140/312	115/284	90/257	62/220	45/199	23/172
11	9	191/385	160/353	132/321	103/289	71/248	51/223	27/192
12	10	215/431	181/394	149/358	117/322	80/275	58/247	30/213

M1006

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	63/148	53/138	44/128	34/118	24/104	17/96	9/86
6	4	88/198	74/183	61/169	48/155	33/135	24/124	13/109
7	5	114/249	96/229	79/211	62/192	43/167	31/152	16/133
8	6	142/301	120/277	98/254	77/230	53/199	39/181	20/158
9	7	170/354	143/325	118/297	93/269	64/232	46/209	24/182
10	8	199/408	168/374	138/341	108/308	74/264	54/238	28/206
11	9	229/463	193/423	158/385	124/347	85/297	61/267	32/231
12	10	259/518	218/473	179/430	140/387	96/330	69/297	36/255
		See M1506 tables						

M1007

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	73/173	62/161	51/150	40/138	28/122	20/112	11/100
6	4	102/231	86/214	71/197	56/180	39/158	28/144	15/128
7	5	133/290	112/268	93/246	73/224	50/195	36/177	19/156
8	6	165/351	139/323	115/296	90/269	62/232	45/211	24/184
9	7	199/413	167/379	138/347	108/314	74/270	54/244	28/212
10	8	232/476	196/436	161/398	126/359	87/308	63/278	33/241
11	9	267/540	225/494	185/450	145/405	99/347	72/312	38/269
12	10	302/604	254/552	208/502	164/451	112/385	81/346	42/298
		See M1507 tables						

M1008

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	83/198	70/184	58/171	46/158	32/139	23/128	12/114
6	4	117/264	99/244	81/225	64/206	44/180	32/165	17/146
7	5	152/332	128/306	106/281	83/256	57/223	42/203	22/178
8	6	189/401	159/369	131/338	103/307	71/266	51/241	27/210
9	7	227/472	191/434	157/396	124/359	85/309	61/279	32/242
10	8	266/544	224/499	184/455	144/411	99/352	72/318	38/275
11	9	305/617	257/564	211/514	166/463	113/396	82/357	43/308
12	10	345/690	290/631	238/573	187/516	128/440	92/396	48/340
		See M1508 tables						

M1500 Series

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M1506

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	63/148	53/138	44/128	34/118	24/104	17/96	9/86
6	4	88/198	74/183	61/169	48/155	33/135	24/124	13/109
7	5	114/249	96/229	79/211	62/192	43/167	31/152	16/133
8	6	142/301	120/277	98/254	77/230	53/199	39/181	20/158
9	7	170/354	143/325	118/297	93/269	64/232	46/209	24/182
10	8	199/408	168/374	138/341	108/308	74/264	54/238	28/206
11	9	229/463	193/423	158/385	124/347	85/297	61/267	32/231
12	10	259/518	218/473	179/430	140/387	96/330	69/297	36/255

See M1006 tables

M1507

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	73/173	62/161	51/150	40/138	28/122	20/112	11/100
6	4	102/231	86/214	71/197	56/180	39/158	28/144	15/128
7	5	133/290	112/268	93/246	73/224	50/195	36/177	19/156
8	6	165/351	139/323	115/296	90/269	62/232	45/211	24/184
9	7	199/413	167/379	138/347	108/314	74/270	54/244	28/212
10	8	232/476	196/436	161/398	126/359	87/308	63/278	33/241
11	9	267/540	225/494	185/450	145/405	99/347	72/312	38/269
12	10	302/604	254/552	208/502	164/451	112/385	81/346	42/298

See M1007 tables

M1508

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	83/198	70/184	58/171	46/158	32/139	23/128	12/114
6	4	117/264	99/244	81/225	64/206	44/180	32/165	17/146
7	5	152/332	128/306	106/281	83/256	57/223	42/203	22/178
8	6	189/401	159/369	131/338	103/307	71/266	51/241	27/210
9	7	227/472	191/434	157/396	124/359	85/309	61/279	32/242
10	8	266/544	224/499	184/455	144/411	99/352	72/318	38/275
11	9	305/617	257/564	211/514	166/463	113/396	82/357	43/308
12	10	345/690	290/631	238/573	187/516	128/440	92/396	48/340

See M1008 tables

M1509

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	94/223	79/207	65/192	52/177	36/156	26/144	14/128
6	4	131/296	111/275	91/253	72/232	50/203	36/186	19/164
7	5	171/373	145/344	119/316	94/288	64/251	47/228	25/200
8	6	213/451	179/415	148/381	116/345	80/299	58/271	30/236
9	7	255/531	215/488	177/446	139/403	95/347	69/314	36/273
10	8	299/612	252/561	207/512	162/462	111/397	81/357	42/309
11	9	343/694	289/635	237/578	186/521	127/446	92/401	48/346
12	10	388/776	326/710	268/645	210/580	144/496	104/445	54/383

M1510

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	104/247	88/230	73/214	57/197	40/174	29/160	15/143
6	4	146/329	123/305	102/282	80/258	55/226	40/206	21/182
7	5	190/414	161/382	132/352	104/320	72/278	52/253	27/222
8	6	236/501	199/462	164/423	129/384	89/332	64/301	34/263
9	7	284/590	239/542	197/495	154/448	106/386	77/349	40/303
10	8	332/680	280/623	230/569	181/513	124/441	90/397	47/344
11	9	381/771	321/706	264/642	207/579	142/495	102/446	54/384
12	10	431/863	363/788	298/717	234/645	160/551	116/494	60/425

M1511

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	115/272	97/253	80/235	63/217	44/191	32/176	17/157
6	4	161/362	136/336	112/310	88/284	61/248	44/227	23/201
7	5	209/456	177/421	145/387	115/352	79/306	57/279	30/245
8	6	260/552	219/508	180/465	142/422	97/365	71/331	37/289
9	7	312/649	263/596	216/545	170/493	116/425	84/384	44/333
10	8	365/748	308/686	253/625	199/565	136/485	98/437	52/378
11	9	419/848	353/776	290/707	228/637	156/545	113/490	59/423
12	10	474/949	399/867	328/789	257/709	176/606	127/544	67/468

M1512

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	125/297	106/276	87/257	69/236	48/209	35/192	18/171
6	4	175/395	148/366	122/338	96/309	66/271	48/247	26/219
7	5	228/497	193/459	159/422	125/384	86/334	62/304	33/267
8	6	284/602	239/554	197/507	155/461	106/398	77/361	41/315
9	7	340/708	287/650	236/594	185/538	127/463	92/419	48/364
10	8	398/816	336/748	276/682	217/616	148/529	107/477	56/412
11	9	457/925	385/847	316/771	248/695	170/595	123/535	64/461
12	10	517/1035	435/946	357/860	280/774	192/661	139/593	73/510

M1513

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	135/322	114/299	95/278	75/256	52/226	38/208	20/186
6	4	190/428	160/397	132/366	104/335	72/293	52/268	28/237
7	5	248/539	209/497	172/457	135/416	93/362	68/329	36/289
8	6	307/652	259/600	213/550	168/499	115/432	84/391	44/341
9	7	369/767	311/704	256/644	201/583	138/502	100/454	52/394
10	8	432/884	364/811	299/739	235/667	161/573	116/516	61/447
11	9	495/1002	417/917	343/835	269/753	184/644	133/579	70/500
12	10	560/1121	471/1025	387/932	304/838	208/716	150/643	79/553

See M2013 tables

M1514

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	146/346	123/322	102/299	80/276	56/243	41/224	22/200
6	4	204/461	173/427	142/394	112/361	77/316	56/289	30/255
7	5	267/580	225/535	185/492	146/448	100/390	73/355	38/311
8	6	331/702	279/646	230/592	181/537	124/465	90/421	47/368
9	7	397/826	335/759	275/693	216/627	148/541	107/488	56/424
10	8	465/952	392/873	322/796	253/719	173/617	125/556	66/481
11	9	533/1079	449/988	369/899	290/810	198/694	143/624	75/538
12	10	603/1208	508/1104	417/1004	327/903	224/771	162/692	85/595

See M2014 tables

M2000 Series

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M2013

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	135/322	114/299	95/278	75/256	52/226	38/208	20/186
6	4	190/428	160/397	132/366	104/335	72/293	52/268	28/237
7	5	248/539	209/497	172/457	135/416	93/362	68/329	36/289
8	6	307/652	259/600	213/550	168/499	115/432	84/391	44/341
9	7	369/767	311/704	256/644	201/583	138/502	100/454	52/394
10	8	432/884	364/811	299/739	235/667	161/573	116/516	61/447
11	9	495/1002	417/917	343/835	269/753	184/644	133/579	70/500
12	10	560/1121	471/1025	387/932	304/838	208/716	150/643	79/553

See M1513 tables

M2014

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	146/346	123/322	102/299	80/276	56/243	41/224	22/200
6	4	204/461	173/427	142/394	112/361	77/316	56/289	30/255
7	5	267/580	225/535	185/492	146/448	100/390	73/355	38/311
8	6	331/702	279/646	230/592	181/537	124/465	90/421	47/368
9	7	397/826	335/759	275/693	216/627	148/541	107/488	56/424
10	8	465/952	392/873	322/796	253/719	173/617	125/556	66/481
11	9	533/1079	449/988	369/899	290/810	198/694	143/624	75/538
12	10	603/1208	508/1104	417/1004	327/903	224/771	162/692	85/595

See M1514 tables

M2015

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	156/371	132/346	109/321	86/296	60/261	43/240	23/214
6	4	219/494	185/458	152/422	120/387	83/338	60/309	32/274
7	5	286/622	241/574	198/527	156/480	107/418	78/380	41/334
8	6	354/752	299/692	246/634	193/576	133/498	96/451	51/394
9	7	426/885	359/813	295/743	232/672	159/579	115/523	61/455
10	8	498/1020	420/935	345/853	271/770	185/661	134/596	70/516
11	9	572/1156	481/1058	395/964	310/868	212/743	154/668	81/577
12	10	646/1294	544/1183	447/1075	351/967	239/826	173/742	91/638

M2016

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	167/396	141/369	116/342	92/315	63/278	46/256	25/228
6	4	234/527	197/488	163/451	128/413	88/361	64/330	34/292
7	5	305/663	257/612	212/562	167/512	115/445	83/405	44/356
8	6	378/802	319/738	262/677	206/614	142/531	103/481	54/420
9	7	454/944	382/867	315/793	247/717	169/618	123/558	65/485
10	8	531/1088	448/998	368/910	289/821	198/705	143/635	75/550
11	9	610/1233	513/1129	422/1028	331/926	226/793	164/713	86/615
12	10	689/1380	580/1261	476/1147	374/1032	255/881	185/791	97/681

M2017

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	177/421	150/392	124/363	98/335	67/295	49/272	26/243
6	4	248/560	210/519	173/479	136/438	94/383	68/351	36/310
7	5	324/705	273/650	225/598	177/544	122/473	88/431	47/378
8	6	402/852	339/785	279/719	219/653	151/564	109/511	57/446
9	7	482/1003	406/921	334/842	263/762	180/656	131/593	69/515
10	8	564/1156	476/1060	391/967	307/873	210/749	152/675	80/584
11	9	648/1310	546/1200	448/1092	352/984	241/842	174/758	91/654
12	10	732/1466	616/1340	506/1219	397/1096	271/936	196/841	103/723

M2018

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	188/445	158/415	131/385	103/355	71/313	52/288	28/257
6	4	263/593	222/549	183/507	144/464	99/406	72/371	38/328
7	5	343/746	289/688	238/633	187/576	129/501	94/456	49/400
8	6	425/903	359/831	295/761	232/691	159/598	116/542	61/473
9	7	511/1062	430/975	354/892	278/807	191/695	138/628	73/546
10	8	598/1224	504/1122	414/1023	325/924	222/793	161/715	85/619
11	9	686/1388	578/1270	475/1156	372/1042	255/892	184/802	97/692
12	10	776/1553	653/1419	536/1290	421/1161	287/991	208/890	109/766

M2019

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	198/470	167/438	138/406	109/374	75/330	55/304	29/271
6	4	277/626	234/580	193/535	152/490	105/429	76/392	40/346
7	5	362/788	305/727	251/668	198/608	136/529	99/481	52/422
8	6	449/953	379/877	312/803	245/729	168/631	122/572	64/499
9	7	539/1121	454/1030	374/941	293/852	201/734	146/663	77/576
10	8	631/1292	532/1185	437/1080	343/975	235/837	170/755	89/653
11	9	724/1465	610/1341	501/1221	393/1100	269/941	195/847	102/731
12	10	819/1639	689/1498	566/1362	444/1225	303/1046	220/939	115/808

M2020

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	208/495	176/461	145/428	115/394	79/348	58/320	31/285
6	4	292/659	247/610	203/563	160/516	110/451	80/412	43/365
7	5	381/829	321/765	265/703	208/640	143/557	104/507	55/445
8	6	473/1003	399/923	328/846	258/768	177/664	129/602	68/525
9	7	567/1180	478/1084	393/991	309/896	212/772	154/698	81/606
10	8	664/1360	560/1247	460/1137	361/1027	247/881	179/794	94/687
11	9	762/1542	642/1411	527/1285	414/1158	283/991	205/891	107/769
12	10	862/1725	725/1577	596/1434	467/1290	319/1101	231/989	121/851

M2021

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	219/520	185/484	153/449	121/414	83/365	61/336	32/300
6	4	307/692	259/641	213/591	168/541	116/474	84/433	45/383
7	5	400/870	337/803	278/738	219/673	150/585	109/532	58/467
8	6	496/1053	418/969	344/888	271/806	186/697	135/632	71/551
9	7	596/1239	502/1138	413/1040	324/941	222/811	161/733	85/637
10	8	697/1428	588/1309	483/1194	379/1078	260/925	188/834	99/722
11	9	800/1619	674/1482	554/1349	435/1216	297/1041	215/936	113/807
12	10	905/1811	761/1656	625/1505	491/1354	335/1156	243/1038	127/893

M2022

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	229/544	194/507	160/470	126/433	87/382	64/352	34/314
6	4	321/725	271/671	224/620	176/567	122/496	88/454	47/401
7	5	419/912	353/841	291/773	229/705	157/612	115/557	60/489
8	6	520/1103	438/1015	361/930	284/844	195/730	141/662	74/578
9	7	624/1298	526/1192	433/1090	340/986	233/849	169/767	89/667
10	8	730/1496	616/1372	506/1251	397/1129	272/969	197/874	103/756
11	9	838/1696	706/1552	580/1413	455/1273	311/1090	225/980	118/846
12	10	948/1898	798/1734	655/1577	514/1419	351/1211	254/1088	133/936

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M2023

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	240/569	202/530	167/492	132/453	91/400	67/368	35/328
6	4	336/758	284/702	234/648	184/593	127/519	92/474	49/419
7	5	438/953	369/880	304/809	239/737	165/640	120/583	63/511
8	6	544/1153	458/1061	377/973	297/883	204/764	148/692	78/604
9	7	652/1357	550/1246	452/1139	355/1031	244/888	177/802	93/697
10	8	763/1564	644/1434	529/1308	415/1181	284/1013	206/913	108/791
11	9	876/1773	738/1623	606/1478	476/1331	326/1140	236/1025	124/884
12	10	991/1984	834/1813	685/1649	538/1483	367/1266	266/1137	139/978

M2024

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	250/594	211/553	175/513	138/473	95/417	70/384	37/343
6	4	350/791	296/732	244/676	192/619	133/541	97/495	51/438
7	5	457/995	385/918	317/844	250/769	172/668	125/608	66/534
8	6	567/1203	478/1108	394/1015	310/921	212/797	154/722	81/630
9	7	681/1416	574/1301	472/1189	371/1076	254/927	184/837	97/727
10	8	797/1632	671/1496	552/1365	433/1232	297/1057	215/953	113/825
11	9	915/1850	770/1693	633/1542	497/1389	340/1189	246/1070	129/923
12	10	1034/2070	870/1892	715/1720	561/1548	383/1321	277/1187	145/1021

See AMSA tables

AMSA Series

AMSA 3007

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	269/643	227/598	187/554	147/510	101/449	73/412	38/368
6	4	376/853	316/789	260/728	204/665	140/581	101/530	53/469
7	5	488/1071	410/987	337/906	264/825	180/715	130/650	68/571
8	6	604/1293	508/1188	417/1088	327/987	223/852	161/771	84/673
9	7	724/1519	608/1393	499/1273	391/1151	266/990	192/894	100/777
10	8	846/1747	711/1601	583/1459	456/1317	310/1128	224/1016	116/880
11	9	969/1978	815/1810	667/1647	522/1483	355/1268	256/1140	132/984
12	10	1095/2212	919/2020	753/1836	589/1651	400/1408	288/1264	149/1088

AMSA 3008

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	307/735	259/683	213/633	168/583	115/513	83/471	44/420
6	4	429/975	361/902	297/832	233/760	159/664	115/606	60/536
7	5	557/1223	469/1128	385/1036	302/943	206/818	149/743	78/652
8	6	690/1477	581/1358	477/1244	374/1128	255/973	184/882	96/770
9	7	827/1736	695/1592	570/1454	447/1315	304/1131	219/1021	114/888
10	8	966/1997	813/1830	666/1667	521/1505	355/1289	255/1162	132/1006
11	9	1108/2261	931/2068	763/1882	597/1695	406/1449	292/1303	151/1124
12	10	1252/2528	1051/2308	861/2098	673/1887	457/1609	329/1444	170/1243

AMSA 3009

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	345/827	291/768	240/712	189/655	129/577	94/530	49/473
6	4	483/1097	406/1015	334/935	262/856	179/747	130/682	68/603
7	5	627/1376	528/1269	433/1165	340/1060	232/920	168/836	87/734
8	6	777/1662	653/1528	536/1399	420/1269	287/1095	207/992	108/866
9	7	931/1953	782/1791	642/1636	502/1480	342/1272	247/1149	128/999
10	8	1087/2247	914/2058	749/1876	587/1693	399/1451	287/1307	149/1132
11	9	1246/2544	1047/2327	858/2117	672/1907	456/1630	329/1465	170/1265
12	10	1408/2844	1182/2597	968/2360	758/2123	514/1810	370/1625	192/1399

AMSA 3010

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	384/918	324/854	266/791	210/728	144/641	104/589	55/525
6	4	536/1219	452/1128	371/1039	292/951	199/830	144/758	75/670
7	5	697/1529	586/1410	482/1295	378/1178	258/1022	186/929	97/815
8	6	863/1847	726/1698	596/1554	467/1410	318/1217	230/1102	119/962
9	7	1034/2170	869/1990	713/1818	558/1644	380/1414	274/1277	142/1109
10	8	1208/2496	1016/2287	832/2084	652/1881	443/1612	319/1452	166/1257
11	9	1385/2826	1164/2585	953/2352	746/2119	507/1811	365/1628	189/1406
12	10	1565/3160	1313/2886	1076/2623	842/2358	572/2011	411/1805	213/1554

AMSA 3011

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	422/1010	356/939	293/871	231/801	158/705	115/648	60/578
6	4	590/1341	497/1240	408/1143	321/1046	219/912	159/833	83/737
7	5	766/1682	645/1551	530/1424	415/1296	284/1124	205/1022	107/897
8	6	949/2031	798/1868	655/1710	514/1551	350/1339	253/1212	131/1058
9	7	1137/2387	956/2189	784/2000	614/1808	418/1555	302/1404	157/1220
10	8	1329/2746	1117/2516	916/2293	717/2069	488/1773	351/1597	182/1383
11	9	1523/3109	1280/2844	1049/2588	821/2331	558/1992	402/1791	208/1546
12	10	1721/3476	1445/3174	1184/2885	926/2594	629/2212	453/1986	234/1710

AMSA 3012

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	461/1102	388/1024	320/950	252/874	172/769	125/706	66/630
6	4	644/1463	542/1353	445/1247	350/1141	239/995	173/909	90/803
7	5	836/1835	703/1692	578/1553	453/1414	309/1226	224/1115	116/978
8	6	1036/2216	871/2037	715/1865	560/1692	382/1460	276/1322	143/1154
9	7	1241/2604	1043/2388	856/2182	670/1973	456/1696	329/1532	171/1331
10	8	1450/2996	1219/2744	999/2501	782/2257	532/1934	383/1742	199/1509
11	9	1661/3391	1396/3102	1144/2823	895/2543	609/2173	438/1954	227/1687
12	10	1877/3792	1576/3463	1291/3147	1010/2830	686/2413	494/2166	255/1865

AMSA 3013

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	499/1194	421/1110	346/1029	273/947	187/833	136/765	71/683
6	4	697/1585	587/1466	482/1351	379/1236	259/1078	188/985	98/870
7	5	906/1988	762/1833	626/1683	491/1532	335/1329	242/1208	126/1060
8	6	1122/2401	944/2207	775/2021	607/1833	414/1582	299/1433	155/1251
9	7	1344/2820	1130/2588	927/2363	726/2137	494/1838	356/1659	185/1442
10	8	1570/3245	1320/2973	1082/2709	847/2445	576/2095	415/1888	215/1635
11	9	1800/3674	1513/3361	1240/3058	970/2755	659/2354	475/2117	246/1827
12	10	2034/4108	1707/3751	1399/3409	1094/3066	743/2614	535/2347	277/2020

AMSA 3014

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	537/1286	453/1195	373/1108	294/1020	201/897	146/824	76/735
6	4	751/1707	632/1579	520/1455	408/1331	279/1161	202/1061	106/937
7	5	975/2141	821/1974	674/1812	529/1650	361/1431	261/1301	136/1141
8	6	1208/2585	1016/2377	834/2176	654/1974	446/1704	322/1543	167/1347
9	7	1447/3037	1217/2787	998/2545	782/2302	532/1979	384/1787	199/1553
10	8	1691/3495	1422/3202	1165/2918	912/2633	621/2256	447/2033	232/1760
11	9	1938/3957	1629/3619	1335/3293	1045/2966	710/2535	511/2280	265/1968
12	10	2190/4424	1839/4040	1506/3672	1179/3302	800/2815	576/2527	298/2176

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Air Liquide

AMSA 3015

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	576/1378	485/1281	400/1187	314/1092	216/961	156/883	82/788
6	4	805/1829	677/1691	557/1559	437/1426	299/1244	216/1136	113/1004
7	5	1045/2294	879/2114	722/1942	567/1767	387/1533	280/1393	146/1223
8	6	1295/2770	1089/2547	894/2332	701/2115	478/1825	345/1653	179/1443
9	7	1551/3254	1304/2986	1070/2727	837/2466	570/2120	411/1915	214/1664
10	8		1524/3430	1249/3126	978/2821	665/2418	479/2178	248/1886
11	9		1745/3878	1430/3529	1119/3178	761/2716	548/2442	284/2108
12	10		1970/4328	1614/3934	1263/3538	857/3016	617/2708	319/2331

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AMSA 3016

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	614/1469	518/1366	426/1266	335/1165	230/1025	167/942	87/840
6	4	858/1951	723/1804	594/1663	466/1521	319/1327	231/1212	121/1071
7	5	1115/2447	938/2255	771/2071	604/1885	413/1635	298/1486	155/1305
8	6	1381/2955	1161/2717	953/2487	747/2256	509/1947	368/1763	191/1539
9	7		1391/3185	1141/2909	893/2631	608/2262	439/2042	228/1775
10	8		1625/3659	1332/3335	1043/3009	709/2579	511/2323	265/2012
11	9			1526/3764	1194/3390	811/2898	584/2605	303/2249
12	10			1722/4196	1347/3773	915/3218	658/2888	341/2487

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AMSA 3017

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	652/1561	550/1451	453/1345	356/1238	244/1089	177/1001	93/893
6	4	912/2073	768/1917	631/1767	496/1616	339/1410	245/1288	128/1138
7	5	1184/2600	997/2396	819/2201	642/2003	438/1737	317/1579	165/1386
8	6		1234/2886	1013/2642	794/2397	541/2069	391/1874	203/1636
9	7			1212/3090	949/2795	646/2403	466/2170	242/1886
10	8			1415/3543	1108/3197	754/2740	543/2468	282/2137
11	9			1621/3999	1268/3602	862/3079	621/2768	322/2389
12	10				1431/4009	972/3419	699/3069	362/2642

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AMSA 3018

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	691/1653	582/1537	480/1424	377/1311	259/1153	188/1060	98/945
6	4	966/2195	813/2030	668/1871	525/1711	359/1493	260/1364	136/1205
7	5		1055/2537	867/2330	680/2121	464/1839	335/1672	175/1468
8	6			1072/2798	841/2538	573/2190	414/1984	215/1732
9	7			1283/3272	1005/2959	684/2545	493/2298	256/1997
10	8				1173/3385	798/2901	575/2614	298/2263
11	9				1343/3814	913/3260	657/2931	340/2530
12	10				1515/4245	1029/3620	741/3249	383/2797

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AMSA 3019

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	729/1745	615/1622	506/1504	398/1384	273/1217	198/1119	104/998
6	4	1019/2317	858/2143	705/1975	554/1806	379/1576	274/1439	143/1272
7	5			915/2460	718/2239	490/1942	354/1765	184/1549
8	6			1132/2953	887/2679	605/2312	437/2094	227/1828
9	7				1061/3124	722/2686	521/2425	271/2108
10	8				1238/3573	842/3062	607/2759	315/2389
11	9					963/3441	694/3094	359/2671
12	10					1086/3821	782/3430	405/2953

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AMSA 3020

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	768/1837	647/1707	533/1583	419/1457	287/1282	208/1177	109/1050
6	4		903/2255	742/2079	583/1901	399/1659	289/1515	151/1339
7	5			963/2589	755/2357	516/2044	373/1858	194/1631
8	6				934/2820	637/2434	459/2204	239/1924
9	7				1117/3288	761/2827	548/2553	285/2219
10	8					887/3223	639/2904	331/2515
11	9					1014/3622	730/3256	378/2811
12	10					1143/4022	823/3610	426/3108

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AMSA 3021

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3	806/1929	680/1793	560/1662	440/1529	302/1346	219/1236	115/1103
6	4			779/2183	612/1996	419/1742	303/1591	158/1406
7	5				793/2474	541/2146	391/1951	204/1712
8	6				981/2961	669/2555	482/2314	251/2020
9	7					799/2969	576/2681	299/2330
10	8					931/3385	671/3049	348/2640
11	9					1065/3803	767/3419	397/2952
12	10					1200/4223	864/3791	447/3264

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AMSA 3022

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3		712/1878	586/1741	461/1602	316/1410	229/1295	120/1155
6	4			816/2287	641/2091	439/1825	317/1667	166/1473
7	5				831/2592	567/2248	410/2044	214/1794
8	6					700/2677	505/2425	263/2117
9	7					837/3110	603/2808	313/2441
10	8					975/3546	703/3194	364/2766
11	9					1116/3984	803/3582	416/3092
12	10						905/3971	468/3419

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AMSA 3023

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3		744/1964	613/1820	482/1675	331/1474	240/1354	126/1208
6	4				670/2186	458/1908	332/1742	173/1540
7	5					593/2350	429/2137	223/1875
8	6					732/2799	528/2535	275/2213
9	7					875/3251	631/2936	327/2552
10	8						734/3340	381/2892
11	9						840/3745	435/3233
12	10						946/4152	490/3574

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AMSA 3024

Feed Air Pressure (barg)	N2 Pressure (barg)	Operating temperature = 45 C (113 F) N2 flow rate/feed air (Nm3/hr) @ Purity (%)						
		95	96	97	98	99	99.5	99.9
5	3			639/1899	503/1748	345/1538	250/1413	131/1260
6	4				700/2281	478/1991	346/1818	181/1607
7	5					619/2453	447/2229	233/1957
8	6					764/2920	551/2645	287/2309
9	7						658/3064	342/2663
10	8						766/3485	397/3018
11	9						876/3908	454/3373
12	10							511/3730

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6 Installed power

Installed power is made up of:

• The membrane skid: process and skid heater + instrumentation + PLC + air cooler (when needed) + fans.

Installed power for N2 membrane unit is listed in the following table considering a minimum compressor discharge temperature of 20C (-20C ambient). The table also shows the current rating for the system.

Maximum Installed Power (KW) Without Compressor

Assumes compressed air temp of 20C, worst case winter

	M1000	M1500	M2000	AMSA3010	AMSA3024
Max feed air flow rate Nm3/hr	495	1015	1935	3162	4342
Process Heater	4.7	9.5	18.2	29.7	40.8
Electric preheater	0.4	0.8	1.6		
Heat tracing carbon tower	0.08	0.12	0.2	0.4	0.4
plc/instrumentation	1.4	1.8	1.8	1.8	1.8
Extractor fan		0.6	0.6	1.2	1.2
Winterisation Space Heater and Fan	0.4	1.5	1.5	3	3
Total power (KW)	**7**	**13**	**22**	**33**	**44**
Total power with winterisation (KW)	**7**	**14**	**24**	**36**	**47**
Power fixed (KW)	**1.9**	**3.3**	**4.2**	**3.4**	**3.4**
Current *I*(A) assuming *power factor* of 0.95					
415	**10**	**21**	**35**	**53**	**69**
480	**9**	**18**	**30**	**46**	**60**

7 Maintenance

Membrane systems have evolved since the early 1990's with many different iterations to improve both performance and reliability. In the early stages of development and use, the reliability has been somewhat mixed. This has mainly been attributed to lack of knowledge on the importance of regular maintenance of the filtration which has contaminated the membranes, unreliable component parts and poor design of the pre-filtration system. Today the membrane system uses more reliable pcomponents and the design is optimized to ensure the membranes are better protected. One such improvement in design is a differential pressure transmitter across the filters to alarm when they require changing. Overall, nitrogen membranes are proving to be very reliable with maintenance costs minimized.

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Maintenance of nitrogen systems is required based on running hours. Estimated replacement of filters and O2 analyzer are the main cost items for periodic maintenance;

- every 4000hrs change filters cartridges
- every 8000hrs change activated carbon
- other system inspection and checks required during period maintenance.

Each membrane system will be supplied with a maintenance manual which covers the above list and much more.

Generally, membranes are required to be replaced by the end of the 10-year period. However, not all membranes need replacing at one time since they do not fail simultaneously. It is advisable to plan the change out from year 7 through to 10. Membrane replacement is noticeable when the design flow rate is not being met or the purity falls below set value after the analyzer and control valves have been eliminated as a cause. The maintenance manual will explain how to identify those membranes that are failing.

7.1 Spare parts

The spare parts list for operational and capital/critical spares will have the original equipment supplier product code. ALAS does not carry spare parts so any spares will need to be purchased direct from the supplier. However, a set of operational and critical spares can be provided at the time of system order.

Capital/critical spares are the most difficult to decide what is needed since these are not consumables and are only needed in case of breakdown. Items such as the plc for example would be unlikely to be held on your stock for one system but if you have many systems, then it would make sense. ALAS will advise on which capital/critical spares should be kept at the time of order. You should consider the non-off the shelf items with long lead times. However, there is a balance between cost of spares and risk of breakdown and, it also depends on the customer backup solution.

Operational spares are those which require placement periodically. The cost of operational spares is relatively low which helps the overall operating cost for the nitrogen membrane system.

Full detailed list of spares is available from ALAS.

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8 Optional Extra's

Cabinet Winterization Option
An ambient heater to keep condensate purge lines from freezing during winter conditions while system is not operating. This option is available for the M1000 Series only. The M1500, M2000 and AMSA 3000 is supplied with these heaters as standard.

Turn Down Option
Consists of additional isolating control valves that automatically reduce the number of active membranes that are on-line in order to follow your customer's instantaneous nitrogen demand. Although energy reductions are achieved when using a conventional air compressor capacity control (i.e. modulating inlet butterfly valve), significant savings are obtained using turndown. This is because a set of membranes that are not required to produce N2 will still use compressed air through the permeate. Thus isolating this set of membranes saves that lost compressed air.

One set of turndown valves gives 50% turndown, 2 sets gives 33% turn down and 3 sets gives 25% turndown and so on. Note that turn down % is also dependent on number of membranes in system. Turn Down option requires active purity control option for M1500 and M2000.

Active Purity Control
Consists of a control valve complete with electro-pneumatic (4-20 ma) positioner controlled by a PID controller within the PLC. The active purity control is standard on AMSA-3000. In this method, the self-operating part of the control valve automatically adjusts its position to account for changes in downstream pressure. The electro pneumatic part of the valve adjusts its position according to the current oxygen level versus set point. In a period of low demand, the valve control is frozen to ensure that the valve is well positioned for an increase in demand to avoid venting due to off-spec gas during the transition.

O2 Analyzer
Extra O2 analyzers may be required for client safety reasons. Sometimes only one extra is required but normally 2 extra should be used in this case to build a 2 out 3 voting arrangement.

Moisture Analyzer
Moisture analyzer will continuously monitor the product gas during operation or the buffer tank gas during standby so as to always keep the sensor blanketed with dry gas (connected after the final system check valve).

Flow Measurement
Consists of an orifice plate pressure and temperature compensated flow measurement installed within the skid limits. Flow measurement will be indicated on the PLC.

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9 Warranty

Warranty covers three main areas, system fabrication, components and membranes.

System Fabrication
ALAS warrants for five (5) years the system fabrication and assembly against defects in material and workmanship, including cabinet, piping, wiring, etc. Claims against fabrication must be communicated to ALAS within one year of shipment.

System Components
ALAS warrants system components (excluding membranes) for a period of one (1) year after shipment. ALAS will exchange on ex works component supplier, the defective component. All costs related to removal, installation and shipping will be borne by the customer. If desired, customer may also send warranty claims directly to the component manufacturer.

System component warranty is valid only if (1) the system has been operated according to instructions in ALAS's operating manual, (2) customer provides a complete written description of the problem and (3) customer provides a copy of operation and maintenance documents. System component warranty does not extend to repair or replacements resulting from normal wear and tear or from faulty operation.

Membrane Modules
ALAS's membrane modules are warranted for two (2) years, by a limited warranty, against defects resulting in a mechanical failure or excess performance decline in comparison to initial quality control tests. All shipping costs, for module return and replacements will be borne by the customer.

Excess performance decline is defined as:

1. >20% productivity decline above fully aged conditions, or
2. >10% decline in recovery, both measured at ALAS's Standard Test Conditions (STC).

Membranes are not covered by warranty if they;
1. are found to be contaminated by particulates, oil or water based solutions.
2. have been subject to improper handling, maintenance or storage.
3. operated outside of the pressure and temperature limits.
4. modified in any way from original design.
5. failure to follow operational guidelines.

ALAS reserves the right to request operating data from the claimant and return of membrane at claimants cost for inspection.

10 contact details

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For technical enquiries and order placement contact:
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Air Liquide Advanced Separations, A Division of Air Liquide Advanced Technologies, U.S. LLC.
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Appendix 1. Enquiry form

Project name: **Project location:**

Performance:
Design N2 Flow:_____
Contract N2 Purity: _____ Design N2 Purity:_____

Compressed Air
Compressor discharge pressure:_____ *(Normally 175 psig/ 12 bar g)*
Maximum Inlet Temperature to system:_____ ℃
Minimum Inlet Temperature to system:_____℃

Electrical:
Voltage:_____ Frequency: _____ *(50 or 60 Hz)* Phase: _____ *(Normally 3 Phase)*

Environment:
Indoor or Outdoor:_____ Minimum & Maximum Ambient Temperature:_____/_____

Options:
Flow Metering:_____ Active Purity Control:_____ Turndown (#valves):_____ Extra O2 analyzer (# of): _____

Winterization:_____ Moisture analyzer:_____

If ALAS is providing the compressor:
Compressor Environment

Altitude (m):_____
Indoor or Outdoor:_____
Minimum & Maximum Ambient Temperature (cannot be outside range of -20C to +40C) : _____/_____
Air Cooled or Water Cooled _____
Maximum relative humidity_____

<u>Electrical</u>
Voltage:_____ Frequency: _____ *(50 or 60 Hz)* Phase: _____ *(Normally 3 Phase)*

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