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WHAT ICI'S AMMONIA PROCESS DOES FOR LOW TONNAGE AMMONIA PLANTS

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1 INTRODUCTION

Ever since the first ammonia was produced at the German site at Oppau in the early nineteen hundreds the designers in the developed countries have been striving to produce larger and more economic plants to reduce both capital and operating costs as well as to cope with increasing demands for ammonia.

In the early sixties the first single stream ammonia plants were designed and built but despite this major breakthrough in technology with catalytic purification and reforming the plant capacities were still restricted by the size of reciprocating compressors available and the costs of operating at high synthesis pressures (200-300 atmospheres). Besides oil contamination of the product from the compressors these plants were expensive to operate largely because of the high compression costs. In the middle sixties the first generation of 1000 tonnes/day ammonia plants were commissioned. These large producing units, centrally located, answered many of the fertilizer marketing economic problems as well as offering a very large reduction in the cost of production, since these plants operated at about 150 atmospheres synthesis pressures and now oil free and reliable centrifugal compressors were available. The steam turbine drives for the compressors used steam generated from waste heat recovered from the reforming sections of the process and so considerably reduced compression costs. Progress in the search for lower capital and operating costs in the sixties and seventies was largely achieved by modifications to this basic single stream design but besides raising plant capital costs these changes have also tended to make the processes more complicated and difficult to operate.

Whilst the trend in the developed world still favours large central producing units, it is interesting to note that, in those countries developing new ammonia and fertilizer industries, the fertilizer distribution economics are such that the need for smaller capacity ammonia plants is being seriously examined. This has important implications since a study of world ammonia production between 1970 to 1983 shows that the developing world is producing an increasing share (from 17% to 29%) of world production during this period. There are signs that this trend is likely to continue in the future in response to a gradual drift in favour of producing ammonia in those countries which have large reserves of natural gas. Ammonia plant designers are therefore turning their attention to designing small capacity plants that can compete on economic terms with the large central producing units now commonplace in the Western World.

Imperial Chemical Industries (ICI) has been making ammonia and designing plants since 1923 and, in order to cope with the increasing demand for ammonia and also to reverse the trend for increasing capital and operating costs and complication of process, has designed its new AMV Process. This process overcomes the disadvantages of the conventional process and offers a simple, less complicated plant at reduced capital cost and produces ammonia cheaper than any other design. One of the many advantages of the AMV Process is the wide range of plant capacity (200-2000 tonnes/day) available with only very little change in overall efficiency throughout the range.

2 WHY THE INTEREST IN SMALL CAPACITY PLANTS?

2.1 ECONOMIC

Many of the countries developing new fertilizer industries have relatively poor road and rail transport facilities and so unless the plants are close to useful waterways they cannot economically market their product. This is obviously a situation calling for consideration of smaller units rather than the large central producing unit. There are also many situations where isolated oil-fields are flaring associated gas or where there are isolated gas-fields and the presence of a small local producing unit would be economic.

2.2 COSTS

2.2.1 CAPITAL COSTS

Capital costs, as well as complication in operation, have made large single stream plants less attractive to the developing countries than a smaller more robust and simpler plant, such as can be offered by the AMV process. There are fewer items of equipment and the smaller plants can be modularised at manufacturers' workshops and assembled on site in much faster times and at lower cost. As experience grows, more and more of the items can be manufactured within the developing countries at reduced cost. AMV is the simplest process yet available because of the ability to use centrifugal compressors throughout and it offers approximately 20% reduction in overall capital costs against conventional processes.

2.2.2 OPERATING COSTS

New ammonia processes like AMV now mean that plant capacity can be reduced to as low as 200 tonnes/day capacity with much lower energy consumptions than conventional processes (see Table 1).

TABLE 1

Trend in Typical Energy Consumptions on Ammonia Plants

Period	Plant Capacity Tes/day	Ave Efficiency G Joules/Te	Plant Capacity Tes/day	Ave Efficiency G Joules/Te
	1000-1350		250-450	
1940		-		65
1960		49		55
1970		39		48
1980		36		43
1984		32		35
Modern AMV		29		31

As well as the improved energy consumption the AMV Process operates with a methane and nitrogen rich synthesis gas compressed in a single stage synthesis gas compressor and offers a process much simpler and more robust to upsets in operating conditions than any other yet offered.

2.3 EFFICIENCY

As shown in Table 1 the new small capacity plants can now be designed such that overall efficiency is as low as 35 G Joules/Tonne and AMV is even lower at 31 G Joules/Tonne. The use of a gas turbine generator to drive the air compressor offers a further improvement in reformer efficiency by using turbine exhaust air for combustion air to the primary reformer. AMV is particuarly efficient since the use of a new formulation of ammonia catalyst at low pressure and the nitrogen rich circulating gas composition means that a single case centrifugal compressor can be used even in these small plants.

2.4 RELIABILITY

Modern ammonia producers demand a higher level of reliability in their plants. Designers have therefore been forced to consider improving reliability by simplifying the processes and, where possible, reducing the numbers of items of equipment. Recent world survey figures show the average "on line" time for modern plants is about 85%, and any successful new process must achieve an improvement on this performance. The smaller, simpler, cheaper and more robust processes are particularly attractive to countries developing new industries and which have relatively little operating skill.

2.5 TRAINING

It is important that local operators and managers, with a pride in the achievements in their own areas, are chosen to operate these projects. They should be recruited and trained almost from the time that it is decided to proceed with a project in a particular locality.

Management must ensure that training is given as far as possible on similar plants in similar environments, too often training programmes are organised sending personnel to bigger and more sophisticated complexes than their own. Where possible proper "hands on" training is to be recommended. Similarly, the maintenance personnel must be taught to improvise and use local resources as far as possible, after discussion with recognised experts who may be helpful in supplying superstructures to assist the rate of learning and technology transfer.

3 THE SMALL CAPACITY PLANT - AMV PROCESS

3.1 PROCESS DESCRIPTION (See Figure 1)

Natural gas feed is mixed with recycle hydrogen, heated and desulphurised. It is then cooled by preheating the feed to the desulphuriser before passing to a feed gas saturator where it is contacted with circulating hot process condensate. The feed gas from the saturator is mixed with a further quantity of steam to give a steam carbon ratio of the order of 3:1, preheated in a reformer flue gas duct and reformed at 700-790°C and 400-500 psig. The gas mixture is then fed to a secondary reformer for further reforming with excess process air but with no separate air preheat. The secondary reformer operates at a temperature of 870-950°C. A typical methane slip from the reformer is about 1% although the optimum level will be dependent on individual plants' economic requirements. The reformed gas is then cooled by generating superheated high pressure steam and then shifted in high and low temperature shift converters. The cooling of the reformed gas between HT and LT shift converters is effected by preheating the feed gas saturator circulating water. The heat in the gas leaving the LT shift converter is used to preheat high pressure boiler feed water.

The cooled gas from the LT shift converter is then taken to a low energy CO_2 removal plant. The gas leaving the CO_2 removal plant is compressed to 70-85 Bar and methanated. The methanated gas is cooled, dried and fed to an ammonia synthesis loop operating at 68-83 Bar. The catalysts used in the production of synthesis gas are all conventional.

Circulating gas from the ammonia synthesis loop is mixed with the dried synthesis gas and fed to a circulator. The gas from the circulator is heated and passed over an optimised ICI low pressure ammonia synthesis catalyst to produce ammonia. The hot gas leaving the ammonia converter is cooled by further heating high pressure boiler feed water and the feed gas to the converter. Ammonia is separated from the partially cooled gas using mechanical refrigeration. Inerts and excess nitrogen from the ammonia synthesis loop are removed by taking a purge from the circulator delivery and treating it in a hydrogen recovery unit. The recovered hydrogen is recycled back to the circulator suction.

3.2 STEAM SYSTEM

Involuntary steam raising has been reduced to a minimum and it is not necessary to export steam from the plant to obtain high overall efficiency. This improvement is largely due to the mild reforming conditions in the reforming section.

The steam generated in the plant at just above process gas pressure is let down through a pass out/condensing turbine and is used to drive the air compressor and an alternator. Since all the remaining drives are smaller than the air compressor, they can easily and efficiently be motor driven.

4 ADVANTAGES OF AMV FOR SMALL CAPACITY PLANTS

4.1 ECONOMIC

The new ammonia catalyst formulation means that the AMV process operates as low as 70-85 Bar pressure and this means lower pressure for vessels and piping design with considerable reduction in capital costs. The process employs about 20% fewer items of equipment than conventional plants and so reduces capital costs and complications on transporting equipment over difficult roads. The large reduction in the size of primary reformer, about half of conventional size, also reduces capital costs. The use of dynamic real time simulation means operational problems can be checked and changes can be made before any equipment is purchased.

4.1.1 CAPITAL COSTS

The capital investment for the AMV process is approximately 20% below that required for a conventional plant of small capacity. This has been achieved by the following improvements :-

The size of the primary reformer almost halved.
Total steam generation is halved.
Steam is generated at process pressures.
No separate preheaters are used.
Total power demand is reduced.
There is maximum use of small electric drives.
*The air compressor turbine is the only major steam drive.
There is only one single stage synthesis gas compressor.
It is a centrifugal compressor.
Synthesis is at low pressure 75-80 Bars.

* Where steam turbines are preferred they can be offered with some slight loss in efficiency.

4.1.2 OPERATING COSTS

The use of milder reforming conditions and a high methane slip (16% exit primary reformer) means fuel cost is almost half of conventional cost. The high methane slip from the secondary reformer with as much as 20-30% excess air means that boiler problems are reduced since secondary reformer temperatures are 100°C below conventional. The hydrogen/nitrogen ratio at 2.2 to 2.5:1 in the circulating gas gives a synthesis loop that is much less sensitive to make gas catalyst performance as well as operator system upsets and so plant outages are much reduced.

4.1.3 EFFICIENCY

The AMV process can achieve overall efficiency as low as 31 G Joules/Tonne. The most significant improvements over conventional processes have been achieved by the use of mild reforming conditions, the natural gas saturator, the nitrogen enriched circulating gas, the synthesis at 70-85 Bar pressure, and the raising of steam at process gas pressures. It must be emphasised that all the energy saving steps give maximum return when integrated together into a process, and that individually installed their improvements are not additive.

4.1.4 RELIABILITY

The target for availability on the AMV process has been set above the 94% availability achieved on the last plant ICI built at Billingham. The new process involves about 20% fewer major items, each with its own unreliability factor, than conventional processes and therefore must be an improvement. Real time simulation of the process has meant that the effect of disturbances can be checked and improved before any equipment is bought and this must improve reliability.

The AMV designers have endeavoured, through ICI's experience, to eliminate all known problems that exist in conventional processes. Where elimination has not been possible the process has been designed to minimise the effect of such problems. Emphasis throughout the development of this process has been on simplicity and flexibility of operation.

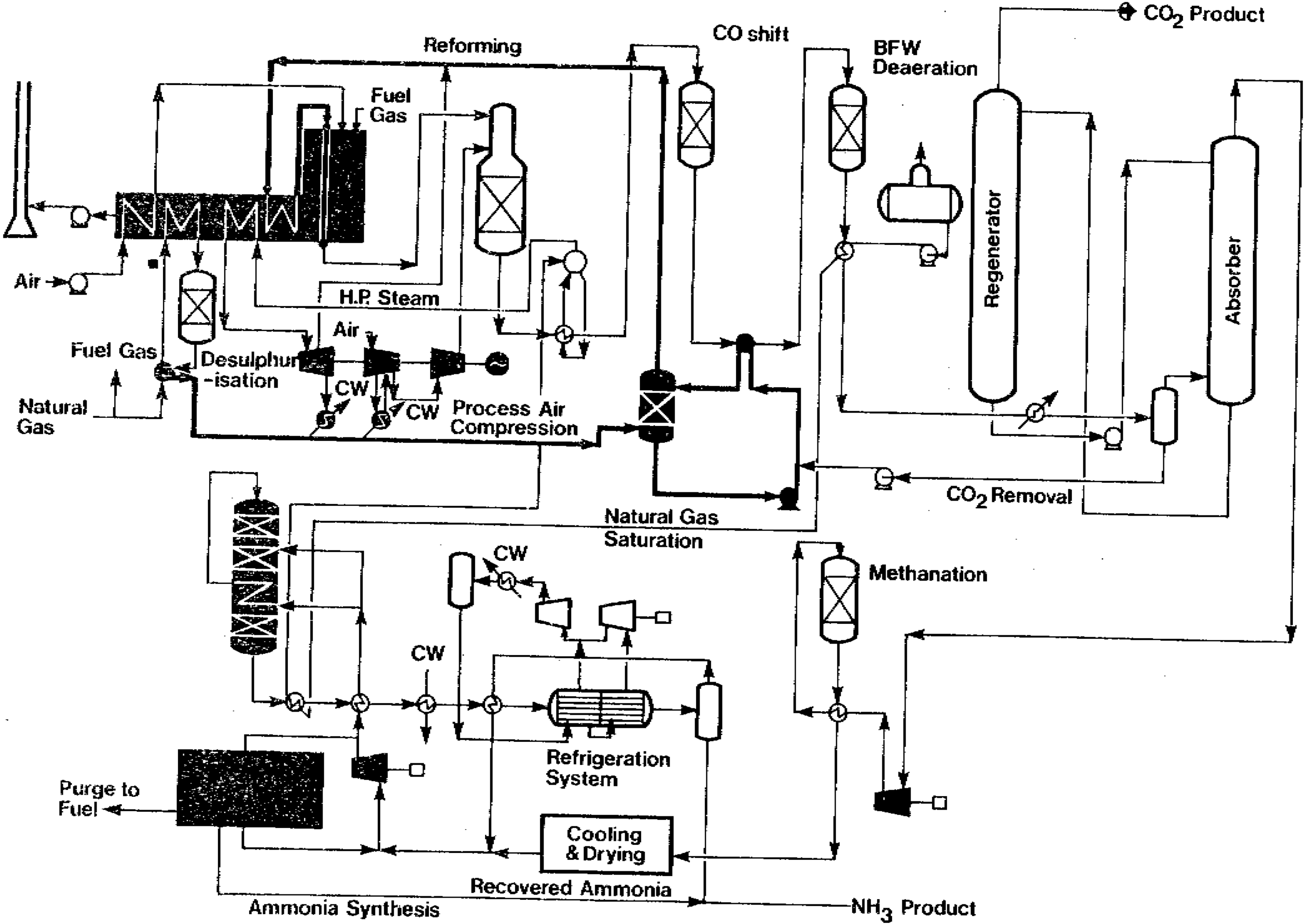
4.1.5 TRAINING

ICI operates 33 ammonia plants around the world and so is an operating company with long experience of most of the major process designs available to modern ammonia producers. The training programmes offered to personnel can easily be matched to meet the individual requirements of the particular customer. The use of process simulators makes the training extremely realistic. Assistance at any stage in the project can be given but it is always with the prime aim that the customer will quickly acquire the skills and technology to become self sufficient.

5 SUMMARY

The new ICI AMV Process offers a unique energy and cost saving design for a very large range of capacity of single stream ammonia plant. The increasing interest in the developing world, at a time when energy, communication, transport and capital costs are continuing to rise, in a simple cheaper and more efficient small capacity plant has been met by this new AMV Process.

All the improvements in this process have been achieved by simplifying the process and removing inefficient and unreliable steps from the design. Real time simulation and modern methods for training complete the programme which means the challenge of the modern world for efficient reliable and cheaper plants acceptable in a clean and healthy environment can now be met by such processes as AMV.


CO2 Product
CO shift
Reforming
BFW
Deaeration
Fuel
Gas
Regenerator
Absorber
Air
H.P. Steam
Air
Fuel Gas
Desulphur
-isation
CW
CW
Process Air
Compression
Natural
Gas
CO2 Removal
Natural Gas
Saturation
CW
Methanation
CW
Refrigeration
System
Purge to
Fuel
Cooling
& Drying
Recovered Ammonia
Ammonia Synthesis
NH3 Product

TA/84/14 What ICI's ammonia process does for low tonnage ammonia plants by J.G. Livingstone, ICI PLC, United Kingdom

DISCUSSION: Rapporteur N.D. WARD, Norsk Hydro Fertilizers Ltd, United Kingdom

Q - Mr. O. HANSEN, Haldor Topsoe, Denmark

In the paper you refer repeatedly to "conventional processes" and claim e.g. a 20% reduction in overall capital against such processes. Please give the main features of the "conventional process" used as a reference.

A - I think the point here is that the conventional process used for comparison was in fact as stated on the slide. I showed the last plant that ICI designed. What we tried to do in this exercise was what ICI, with ICI's standards and ICI's approaches, would pay for this sort of process as opposed to what it paid for its last process. So the basis for a conventional process was the last ICI designed/built. The N° 4 ammonia plant in Billingham was the basis.

Q - Mr. J. SARLABOUS, CdF Chimie AZF, France

At what time will the start-up of the CIL unit with the ICI AMV process be anticipated? Why such a delay?

A - The CIL plant at Courtright in Ontario is in fact the first with this new process to be operated. Unfortunately, that plant was designed to cater for the American fertilizer market, but, as that market suffered badly in 1982/83, the Canadians decided to slow down the project because it was no point in making ammonia they could not sell. The plant is presently in the precommissioning stage. The demineralization units are being precommissioned. The plant will first produce ammonia in July of 1985. Everything seems now to be on program, the American economy is hopefully going in the right direction and the plant will produce ammonia.

Q - Dr. S.K. MUKHERJEE, FAI, India

What has been the longest continuous run in a commercial plant on the low pressure (68-75 atm) ammonia synthesis catalyst?

A - The catalyst is perhaps one thing I did not clarify in the presentation . One constraint put on the designers on this process with ICI was that all the new steps in the process had to be proven. We do not like prototypes in ICI. We have suffered too many times from prototypes. All must be proven in one of our plants somewhere in the world, before it goes into the new process.

The low pressure synthesis catalyst, that is mentioned here as the major step forward in the new process, has now been operating just over 4-1/2 years in the N° 1 ammonia plant in Billingham. I am happy to report that after 4-1/2 years, the activity of the catalyst is still well above initial activity of our conventional catalyst at start of life. So it is quite a dramatic step forward in the performance of ammonia synthesis catalyst.

Q - Mr. T.S. HARIHARAN, FERTIL, Abu Dhabi

Refer to page 14-6, first §. How does H2/N2 ratio of 2.2 to 2.5:1 in the synthesis loop improve operability as a certain ratio still needs to be controlled to avoid operational upsets and compressor performance problems? Could you please elaborate.

A - The simulation of the low pressure synthesis loop has shown that sensitivity to inerts in the H2:N ratio of 2.2.-2.5:1 is much, much less than it is with a conventional plant. What we have simulated and shown on the slides is that a 50% increase in the methane slipping into, the synthesis loop will almost certainly shut down a modern plant, but will hardly affect this process.

The reason for this is that the actual conversion in this process is less than in conventional processes. It is about 77%. What improves the overall situation is the fact that the H2 recovered across the circulator without recompression goes back into the process with 90 odd percent. The plant now is much less sensitive to effects of the upstream catalysts. In a modern process something like 80% of the methane that goes into the synthesis loop is contributed from the make gas catalysts and 20% from the reforming section. What we have done with the AMV process is to completely reverse that, like 80% of the methane going into the synthesis loop is from the reforming section and only 20% from the make gas catalysts.

The sensitivity at low pressure to CH4 and N2 concentration, as can be demonstrated by real time simulation, is much less than in conventional processes.

If you then look at the point that has been made in the extra compression cost for trying to improve the conversion, the overall economics is very much in favour of going for high CH4 slippage, high N2 and low pressure.