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A NEW CONCEPT FOR AMMONIA PRODUCTION
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SUMMARY

The new concept for ammonia production described hereafter consists of utilising
for 400 MT/D ammonia synthesis hydrogen produced by steam-reforming of natural
gas and purified by a pressure-swing-adsorption system and nitrogen produced by
an air-separation unit.

Although the basic applied techniques are well proven, their combination for am-
monia production is made for the first time and will result in a low energy (7.2
Gcal + 22 kwh per ton of ammonia) ammonia production, compared with much larger
plants (above 1000 MT/D).

Besides the energy-efficiency of the basic concept, several energy-efficiency
targeting innovations have contributed to the above mentioned low figures.

1. Introduction

The intensive oil exploration undertaken after 1974 led to the discovery of the
first exploitable hydrocarbon deposits in Greece. These offshore reserves near
Kavala, Northern Greece, consist of 25 mbd oil field and a gasfield with approx.
27×10^9 SCF reserve. The particularity about the exploitation of this gas as
well as of the treated associated gas was that no gas network exists in Greece
and the only possible and economical use was for PFI whose plant is located at
10 km distance from the onshore plant of the oil company, and who already ran
an old ammonia unit of 180 T/D.

PFI was confronted in 1979-1980 to the task of finding an ammonia process which
could have an extremely low energy consumption so that for a unit size of 400 T/D
the gas supply could last for approx. 10 years. After extensive enquiries it was
decided in 1982 that the only economic feasible solution was to apply the new
KTI's concept for ammonia production which is described hereafter with a specific
energy consumption of 7.2 GKcal and 222 kwh per ton ammonia. The contract with
KTI was made effective in December 1982 and the commissioning is expected in the
second half of 1985.

2. Design Features

Although the applied ammonia production concept is new, the various process units
incorporated in this Process are all well established and the process scheme has
been arranged to achieve low ammonia production cost, coupled with a high degree
of plant reliability through simplicity of DESIGN AND OPERATION.

The Process comprises a combination of the following process steps, namely:

- Air separation to produce pure nitrogen.

- Synthesis gas production by hydrocarbon steam reforming, H.T. shift conversion
  and hydrogen purification in a modified Pressure Swing Adsorption (PSA) system.

- Synthesis gas compression and ammonia synthesis to produce liquid semirefrige-
  rated ammonia as final product.

- Energy - Power section to utilize the waste heat produced in the Syn-gas sec-
  tion and the Ammonia Synthesis section.

Reference is made to the enclosed Process Block Flow Diagramms I and II (Fig. 1
and 2).

2.1. Syn-gas production unit

Natural gas from the battery limits is reduced in pressure from 52 - 39 to 37.4 kg/cm^2 ga. Condensates, if any, (hydrocarbons and water' are knocked out and returned to the battery limits. Sulphur components in the gas are removed by adsorption with molecular sieves located in four adsorber vessels. A part of the sulphur free natural gas is used for regeneration of the molecular sieves by desorption at elevated temperature. The sulphur containing regeneration gas is used as fuel in the reformer furnace. Recycle hydrogen was added to the gas conversion of the last traces of sulphur components to hydrogen sulphide, which is removed from the gas by non-regenerative absorption on zinc oxide. Both conversion and absorption take place at 400° C in the same reactor.

High pressure steam is mixed with the sulphur free gas; this mixture is heated in the convection section of the reformer furnace and passed to the reformer tubes at 595° C and 31 kg/cm^2 ga.

These reformer tubes are filled with a nickel catalyst to promote the conversion of the hydrocarbons in the natural gas and the steam to hydrogen carbon monoxide and carbon dioxide. The required heat of reaction is supplied by burners in the furnace using waste gas from the hydrogen purification units (PSA), some flash gas from the ammonia loop and the above mentioned regeneration gas.

The gas mixture leaving the reformer at 843° C and 28.95 kg/cm^2 ga is cooled down to 350° C against boiling water and passed to the HT shift reactor, where the major part of the carbon monoxide is converted to hydrogen and carbon dioxide in presence of an iron-chromium oxide catalyst.

The raw hydrogen from the HT shift reactor is cooled down in a number of heat exchangers to recover the heat followed by final cooling with air and cooling water. Unconverted steam is condensed, separated from the raw hydrogen and sent to the water treatment unit to make it suitable for re-use as boiler feed water.

The raw hydrogen is passed to the PSA unit where the impurities viz. methane, carbon monoxide, carbon dioxide and water vapour are removed from the gas by adsorption on a suitable adsorbent at 26.8 kg/cm^2 ga and 38° C and subsequently desorbed at low pressure (0.5 kg/cm^2 ga).

This process operates in a repeated cycle with essentially no change of temperature. Ten adsorber vessels are in various stages of adsorption and regeneration. For the collection of the waste gas two collecting drums are provided. Nitrogen is used for purging and partial repressurisation. A mixture of hydrogen and nitrogen (90 : 10) leaves the PSA unit as product.

The waste heat from the reforming section is recovered by generating and superheating system. Part of the steam is used as process steam. The remainder is passed to a turbine for power generation (8500 KW per hour produced). Reference is made to the enclosed simplified flow sheets (Fig. 3 and 4.).

Features of the synthesis gas production unit are:

- Compared to conventional ammonia synthesis gas production units fewer processing steps are required. Thus the secondary reformer, the low temperature shift, the carbon dioxide removal and the methanation steps are replaced by one PSA purification unit.

   This process simplification not only increases plant reliability, but also improves the overall plant thermal efficiency.

- The steam reformer can operate at the lowest possible steam to carbon ratio since there is no limitation on the quantity of methane slip in the reformer product gas stream. Further improvements in thermal efficiency are obtained by the application of topfiring in the reformer, use of enriched air for combustion, optimal use of waste heat and other special design features described further in section 4.

- No start up steam boiler is required.

2.2. Production of Ammonia (AMMONIA CASALE REACTOR)

The hydrogen nitrogen ratio of the gas mixture leaving the PSA unit is brought to 3 : 1 by adding compressed nitrogen.

With flash gas from the ammonia loop this syngas is compressed to 238 kg/cm^2 ga. Lubricating oil is removed and the make-up gas is added to a circulating gas flow, which has left the ammonia converter and has been passed through a number of heat exchangers and coolers. The gas contains approximately 19% vol. ammonia which is partially condensed. By further cooling down most of the ammonia is condensed at 4° C against evaporating ammonia from a closed refrigeration system. The gas is separated from the liquid ammonia and recycled with the syngas circulator to the ammonia converter.

At the inlet of the converter the gas mixture (hydrogen, nitrogen and around 4% vol. ammonia) has reached 238° C and is preheated further in a heat exchanger located in the converter. The gas passes in the converter two iron catalyst beds where the hydrogen and nitrogen are partially converted into ammonia in axial-radial flow pattern beds.

Between the two catalyst beds the gas is cooled against entering gas mixture. The gas leaving the ammonia converter at 463° C is cooled against boiling water, the produced HP steam is combined with the steam generated in the hydrogen production unit.

The gas is cooled down against the gas following the converted feed and further by air and cooling water. In the air cooler the condensation of ammonia starts. The cooled converter effluent is mixed with make-up gas and flows as described above.

The liquid ammonia separated in the HP separator is sent to the MP flash vessel. A part of the dissolved gases are released from the liquid and recycled to the section of the multi-service compressor. The remaining inert gases are flashed off in the LP flash vessel and are passed to the reformer furnace for combustion. The liquid ammonia is sent to the battery limits at 4° C and 8 kg/cm^2 ga. Reference is made to the enclosed simplified flowsheet (Fig. 5) with the relevant material balance.

2.3. Production of nitrogen

- Pure gaseous nitrogen is produced by separation of compressed air at low temperatures. To avoid blockage by freezing up of water and carbon dioxide, the air is dried with molecular sieves before entering the cold box. The cold for condensation of air is obtained by expanding a part of the air in a turbine. The unit can produce liquid nitrogen which is stored for use in emergency cases.

- The produced waste gas enriched to about 40% with O2 can be used as combustion air in the reformer and it is used to cool the chilling water in the direct contact compressor after cooler.

- 35800 Nm³/h air are compressed in a three stage bull gear type compressor at 4.59 kg/cm² a pressure to produce 14,900 Nm³/H pure nitrogen (100 ppm Ar-8 ppm 02) delivered at 3.57 kg/cm² a.

Reference is made to the enclosed simplified Block Diagram (Fig. 6).

2.4. Utilities

The unit consists of the following utility stations:

1. Water treatment unit (see simplified flow diagram in Fig. 7).

2. Cooling water tower and related circulation pumps.

3. Power generation unit 12 MVA with air cooled condenser and steam control system (see simplified flow diagram in Fig. 11);

4. Plant air and instrument air facilities (integrated with air separation unit).

5. Fire fighting.

6. Refrigeration unit which consists of three ammonia screw compressors, ammonia condenser and liquid received.

Items 1 - 5 contain no hazardous media. Therefore all those utility stations are concentrated in a non-hazardous area.

2.5. The fully electronic control-system of the plant is FOXBORO's SPECTRUM VIDEO-SPECT IV microprocessor system with redundant processor, the required unit-control moduls, input/output units, multiplexing units, CRT screens, keyboards, diskette drives, alarm printer, videocopier and alarm announciator panels. The system can be easily completed with the FOX 300 computer for process optimisation and graphic and trending capabilities.

Several automatic batch process in the plant are run by dedicated microprocessor based sequencers.

Such are the PSA units, the demin. unit and the molsieve driers of the air separation unit.

3. Manufacturing Costs

Ammonia plants have two significant cost factors. These are the costs of the feedstock and fuel, which usually represent about 90% or more of the variable production costs, and the fixed costs which are linked directly with the investment cost of the plant.

3.1. Variable Costs

A modern ammonia plant has a much lower feedstock and fuel consumption compared with a plant that was built some seven years ago. For example, a modern large capacity plant with a capacity ranging from 1,000 to 1,500 MTPD today is designed to consume about 7,0 Gcal (29,.3 GJ) of feedstock and fuel per metric ton of liquid ammonia.

The natural gas feedstock and fuel consumption for our small capacity 400 MTPD ammonia plant will be 7.2 Gcal plus 220 kwh per metric ton of liquid ammonia. This compares favourably with the modern large capacity unit.

This consumption includes:

- All process units.

- Ammonia refrigeration to deliver liquid ammonia at battery limits at + 4° C.

- All required utilities (cooling water, water treatment, instrument air/plant air) power stations, electrical distribution etc. to make a fully independent plant supplied only with feedstock, 3.9 MW/6 KV cable and 50 m³/h crude water.

3.2. Specific consumptions

The guaranteed specific consumption for 31° C - 70% R.H. ambient air conditions and 29° C cooling water temperature are as follows:

1. Nat. gas (80% CH4 - 7% C2H6)   7.2 Gcal/MT of NH3
2. Imported electricity   220 kwh/MT of NH3
3. Make up water   50 m³/per hour
4. Imported steam   Nil
5. Imported nitrogen   "
6. Imported Demin. Water   "
7. Imported instrument-plant air   "
8. Chemicals   Required for demin. water unit regeneration and cooling/boiler water treatment.

3.3. Fixed Costs

The fixed costs for ammonia production are usually the most important cost factor after the feedstock and fuel costs. This is where the small capacity plant is at a disadvantage. For example, if we consider a modern 1,000 MTPD ammonia plant generating steam at about 100 bar and steam turbine driven centrifugal compressors and depreciate the investment cost at 15% per annum, the fixed cost per metric ton of liquid ammonia would be US$ 38-42.

In this process the investment cost is minimized by process optimization. Further cost reduction is achieved by shop fabricated skid mounted units in specialized workshops which reduced construction time and cost. By depreciating the investment cost at 15% per annum for this 400 MTPD ammonia plant with electric motor driven reciprocating compressors, including the nitrogen generation unit and power recovery unit, and all other utilities the fixed cost per metric ton of liquid ammonia is US$ 40-45, depending on on stream time and other specific conditions.

3.4. Cost Evaluation

The number of operators for the PFI Ammonia Unit is estimated at 5 per shift and operating labour has been taken as costing US$ 20,000 per annum per man.

Maintenance costs are estimated conservatively at 3.5% of the investment cost per annum.

Fixed costs are taken at 15% of the investment cost per annum.

Feedstock	$7.2.10^6$ x 16	=	152.2	US$/MT
Electricity	220 x 0.05	=	11.0	"
Labour		=	8.0	"
Maintenance (3.5% of invest.)		=	10.0	"
Investment cost		=	45.0	"
TOTAL			189.2	US$/MT

4. INNOVATIVE AND ENERGY SAVING FEATURES

The main innovative and energy saving features incorporated in the design of the ammonia plant are the following:

- A low energy desulfurization scheme for direct removal with regenerative mol-sieves of H2S, COS and mercaptans.

- A special design fixed tube sheet waste heat boiler recovering energy from the reformed gas.

- A special design on the purge-gas part of the PSA unit in order to use as reformer fuel even very low calorific value purge gas.

- An innovative patented step introduced in the PSA cycle allowing the recompression of a substantial part of N2 required for the synthesis without external compression work.

- A new low Δp axial-radial ammonia synthesis reactor by ACSA.

- A special design U tube vertical syn-loop waste heat boiler producing 1.35 t of 45 bar saturated steam per ton of produced ammonia.

- The use of O2 rich waste stream from the N2 generator as combustion air in the reformer firing.

- An integrated ion exchange water treatment unit for low energy treatment of cooling water, BFW, process and steam condensates.

- An optimised capacity control of the nitrogen/syn-gas reciprocating compressors.

Below are given more details about some of the above mentioned special features.

4.1. Desulfurisation

The N.G. containing 200 ppm sulphur compounds of which 160-170 ppm methyl/ethyl mercaptans (mostly ethyl-mercaptans), 20-40 ppm COS and 10 ppm H2S is desulfurised to less than 0.4 ppm total sulphur. One of the conventional procedures was initially envisaged:

Heating-up to 400° C, hydrogenation and catalytic conversion to H2S over a comox bed, cooling, removal of H2S in Molsieve and removal of last traces in a ZnO bed and finally reheating of the sulphur-free N.G. feed.

Instead of this energy-consuming process, a new process is applied. The N.G. passes first at ambient temperature over a 4-bed fully automatic molsieve desulfuriser-unit where all the H2S and most of mercaptans and of the COS are adsorbed. The last traces of mercaptans and COS are converted to H2S over a small comox bed at 400° C after hydrogenation. This rest H2S is then adsorbed by a ZnO guard-bed and the S-free N.G. feed is mixed with steam, further heated and sent to the reformer.

The N.G. stream used for regeneration of the molsieve bed is used as fuel in the reformer-furnace.

At any moment two adsorbers are in production, one is cooled after being heated and the fourth is regenerating.

Reference is made to the enclosed simplified flowsheet (Fig. 8).

The energy saving by this innovative design is 0.12×10^6 kcal/T NH3.

4.2. Special design W.H. Boiler for reformed gas

4.2.1. General Description

The flexible tube sheet boiler is today considered an efficient system for heat recovery from reformed gases.

In order to ensure that this type of boiler is both economically and reliably designed, we have adopted a well-proven Haldor/Topsøe/Nuovo Pignone design boiler.

The item we are describing (see Fig. 9) is designed to achieve optimum efficiency, economy, safety and reliability in service. The boiler is one compartment, 45 barg pressure steam boiler designed especially to meet the severe requirements resulting from the high pressure, the high temperature and chemical properties of the process gas.

High resistance to stress corrosion and hydrogenation is achieved by the low temperature level in all steel parts and by application of low-alloy carbon steel, according to Nelson curves.

Outlet gas temperature control is made possible by an external by-pass.

The control valve can be maintained more easily and greater operating reliability may be obtained. Another reason for our preference is that an internal by-pass would increase the boiler size and create unnecessary mechanical stresses in the adjacent tubes.

The system is sized so that the outlet temperature can be controlled within a set range with any gas flow in the specified limits and with clean as well as fouled surfaces.

Finally, repairs are made easy by the design as the tubes can easily be plugged or replaced and steel materials are applied with local stress relief treatment done on site.

For this type of boiler some critical parts must be designed properly: for example a correct stress and fatigue analysis of the tube sheet-to-shell junctions and of the joints between tubes and tube sheets is mandatory.

For this reason a careful study of the whole construction has been carried out with the aid of extensive computing facilities.

Mention only can be made here of the following studies and/or investigations made for this boiler:

- study of thermal distribution
- study of stress distribution
- fatigue tests on tube - tubesheet welded joints
- metallographic examination of possible structural alteration of welded joint
- development of microprocessor governed automatic welding with internal rotating TIG torch
- development of special X-ray techniques to check tube - tubesheet welding

4.3. PSA purge-gas use

Further to the main merits of using a PSA hydrogen purification unit in an ammonia plant, which are mentioned in 2 above, the following energy-saving innovation is applied in our unit: a part of the adsorber purging is done with low pressure nitrogen, which of course is saving equivalent quantities of pure hydrogen.

This N2-purge is up to now applied only in one plant worldwide, where, however, a considerable part of the N2-rich purge-gas coming out of the purged vessel towards the end of the purge-step, with very low calorific value (of the order of 600 kcal/kg) is sent to the flare.

In our case the plant is designed to mix the whole quantity of the N2-rich, low calorific value gas in a mixing drum and send it to be used as the main fuel in the steam-reformer with an average calorific value of 1500 kcal/kg.

Reference is made to the enclosed block-diagram (Fig. 4) with the relevant material balance. The energy-saving by this design feature is 0.22×10^6 kcal/t NH3.

4.4. N2-repressurisation step in the PSA Unit

After the purging at low pressure of the impurities, each adsorber has to be repressurised up to the operating pressure (27 barg) to be put in production. Up to now in all the PSA-units in operation this was achieved by several equalising steps and finally with product hydrogen. A completely new step, the repressurisation with low pressure N2, has been added in our unit with the following result:

The quantity of low pressure nitrogen trapped in the vessels by this step (as well as by the N2-purge step) is brought by the subsequent equalisation steps up to the pressure of 27 barg and is sent directly to the syngas-part of the multi-service compressors after mixing with the nitrogen compressed by the N2-part of the same compressors.

Thus one-third of the total nitrogen required for the ammonia synthesis is compressed by the pressure of the N.G., saving equivalent electric energy in the nitrogen compressors.

Reference is made to the enclosed block-diagram with the relevant material balance (Fig. 4). The energy saving by this patented feature is substantial.

4.5. Low Δp synthesis reactor

The new synthesis reactor designed by ACSA shown schematically on Fig. 10 creates to the loop a Δp as low as 2.3. bar.

This compared with conventional reactors for small ammonia plants brings a saving in Δp of the order of 2 bar which translated in terms of electrical energy of the syn-loop circulator corresponds to an energy-saving of 12 kwh/t NH3.

Reference is made to the enclosed block-diagram with the relevant material balance (Fig. 4). The energy saving by this patented feature is substantial.

4.6. Enhanced synthesis-loop steam production

Up to now the limit for steam production by syn-loop waste-heat boilers was of the order of 1.1 t of steam per ton of ammonia. In our case the loop

was designed to produce 1.35 t steam/t NH3. This has been achieved by a higher temperature of the syngas entering the loop-boiler (470° C) and even higher under certain hot re-start-up conditions. These high temperatures in conjunction with high pressures (275 bar under E.O.R. conditions) could lead to the well-known problems of nitrading and hydrogen embrittlement. On the other hand the high thermal stresses prohibited the use of thick tube-sheet designs.

To overcome these problems we have adopted a special vertical U-tube, thin tube-sheet with stiffeners, loop-boiler design. The tubes and tubesheet are protected by ferrules and an inconel layer. Special stress calculations have been done on computer. New welding technique is applied after extensive testing.

The energy-saving by this boiler is 56 kwh/t NH3.

4.7. Use of 02-rich air

The waste-gas from the nitrogen generator after being used for chilling the water in the chiller tower (see Fig. 6) can be sent to the reformer burners as combustion air. The oxygen contained in this stream is the 35% of total oxygen requirement for combustion. A better combustion can be achieved and less inert gas thrown hot through the flue-stack. The resulting saving is 0.04×10^6 kcal/t NH3.

4.8. Integrated water treatment unit

This unit fed only with 50 m^3/h raw water provides water for the boiler feed water and the cooling water system by treating in an optimised scheme the turbine condensates, the process condensates, and the make-up water.

The unit is microprocessor run fully automatic with a regeneration cycle-time of 48 h. A lot of flexibility is built-in permitting the plant to continue operating under several upset conditions.
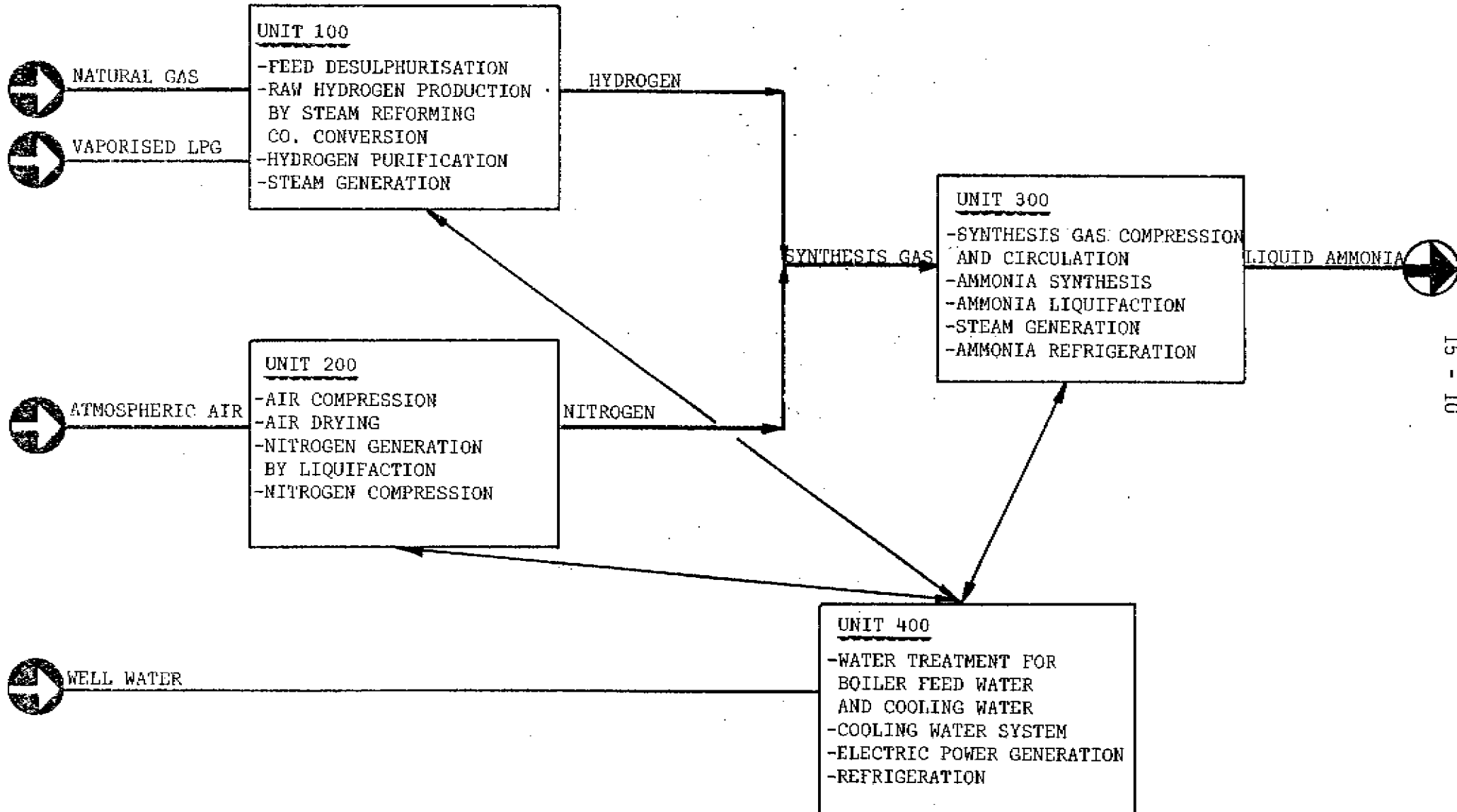
Reference is made to the enclosed simplified flowsheet (Fig. 7).

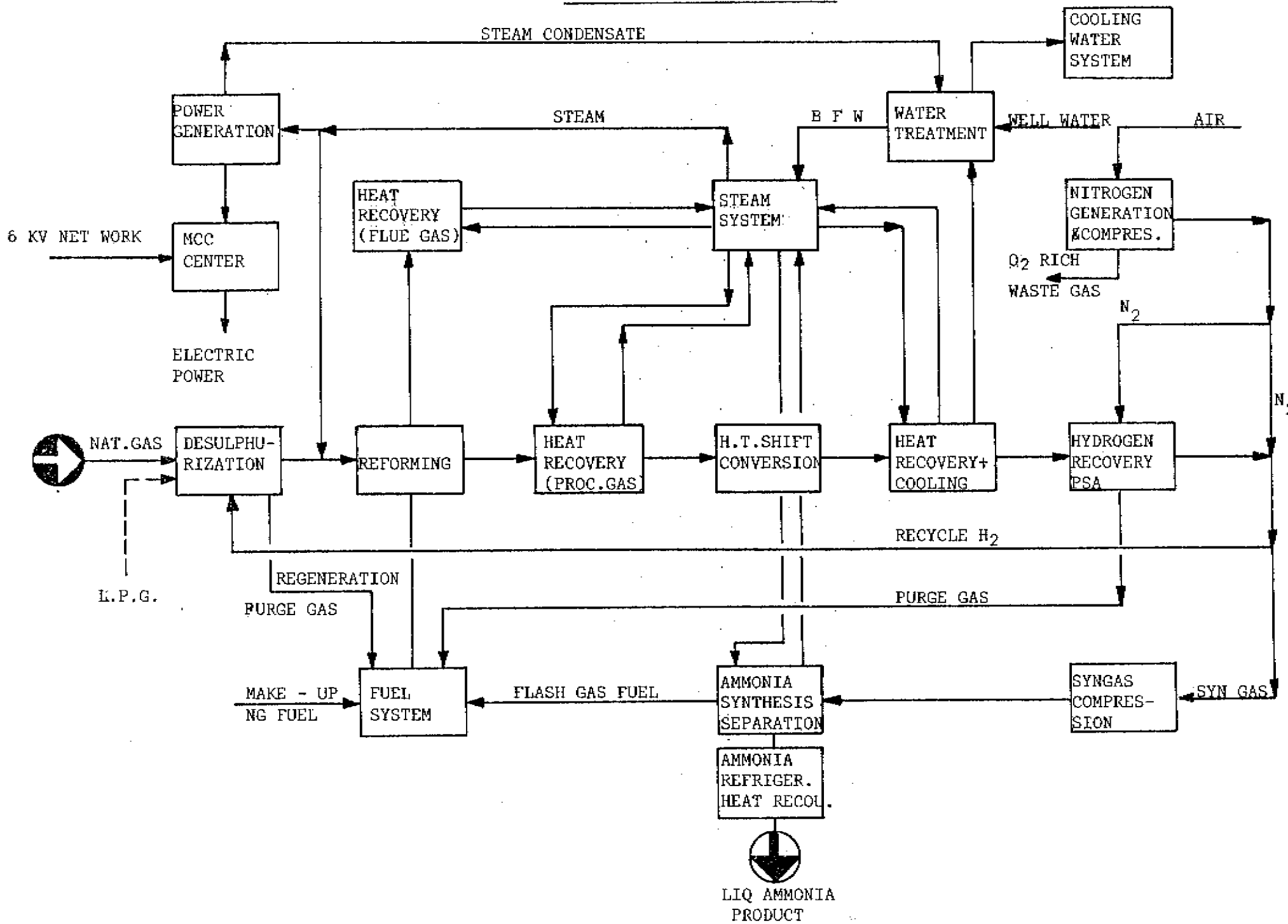The special features of this unit are:

- The make-up to the cooling water system is dealkalized so that it runs with high concentration ratio with reduced use of chemicals made possible.

- The process condensates are at ambient temperature degasified and treated over ion-exchange resins; they are re-used as BFW or as make-up water to the cooling system.

- The turbine steam condensates are polished over mixed bed resins.

- Although the pressure of the produced steam is only 45 bar the requirements set forth for the boiler feed water quality are equivalent to those for high pressure systems (64 bar and above).

NATURAL GAS

VAPORISED LPG

UNIT 100
-FEED DESULPHURISATION
-RAW HYDROGEN PRODUCTION
 BY STEAM REFORMING
 CO. CONVERSION
-HYDROGEN PURIFICATION
-STEAM GENERATION

HYDROGEN

UNIT 300
-SYNTHESIS GAS COMPRESSION
 AND CIRCULATION
-AMMONIA SYNTHESIS
-AMMONIA LIQUIFACTION
-STEAM GENERATION
-AMMONIA REFRIGERATION

SYNTHESIS GAS

LIQUID AMMONIA

ATMOSPHERIC AIR

UNIT 200
-AIR COMPRESSION
-AIR DRYING
-NITROGEN GENERATION
 BY LIQUIFACTION
-NITROGEN COMPRESSION

NITROGEN

WELL WATER

UNIT 400
-WATER TREATMENT FOR
 BOILER FEED WATER
 AND COOLING WATER
-COOLING WATER SYSTEM
-ELECTRIC POWER GENERATION
-REFRIGERATION

15 - 10

BLOCK DIAGRAM II

STEAM CONDENSATE

COOLING WATER SYSTEM

POWER GENERATION

WATER TREATMENT

B F W   WELL WATER   AIR

STEAM

HEAT RECOVERY (FLUE GAS)

STEAM SYSTEM

NITROGEN GENERATION &COMPRES.

6 KV NET WORK

MCC CENTER

O₂ RICH

WASTE GAS

N₂

ELECTRIC POWER

NAT. GAS   DESULPHU-RIZATION   REFORMING   HEAT RECOVERY (PROC.GAS)   H.T.SHIFT CONVERSION   HEAT RECOVERY+ COOLING   HYDROGEN RECOVERY PSA

RECYCLE H₂

REGENERATION

PURGE GAS   PURGE GAS

L.P.G.

MAKE - UP NG FUEL   FUEL SYSTEM   FLASH GAS FUEL   AMMONIA SYNTHESIS SEPARATION   SYNGAS COMPRES-SION   SYN GAS

AMMONIA REFRIGER. HEAT RECOU.

LIQ AMMONIA PRODUCT

15 - 11

P.F.I. AMMONIA UNIT
SYNTHESIS GAS

FIG. 3

O$_2$ ENRICHED AIR

FUEL GAS

SAT STEAM   FROM SYN. LOOP

BFW TO SYN. LOOP

O$_2$ RICH | NITROGEN GENERATOR | AIR
AIR

HYSIV - PSA UNIT   SYN GAS

NAT. GAS

DESULFURIC SEPS

H.T. SHIFT CONVERTOR

PROCESS STEAM
SUPER EXCESS STEAM

POWER GENERATOR

PROCESS CON.

COMOX

ZNO$_2$

NAT. GAS FEED

O$_2$ ENRICHED AIR

AIR

VAP. LPG   DEAGRATOR

WATER TREATMENT UNIT

WELL WATER

15 - 12
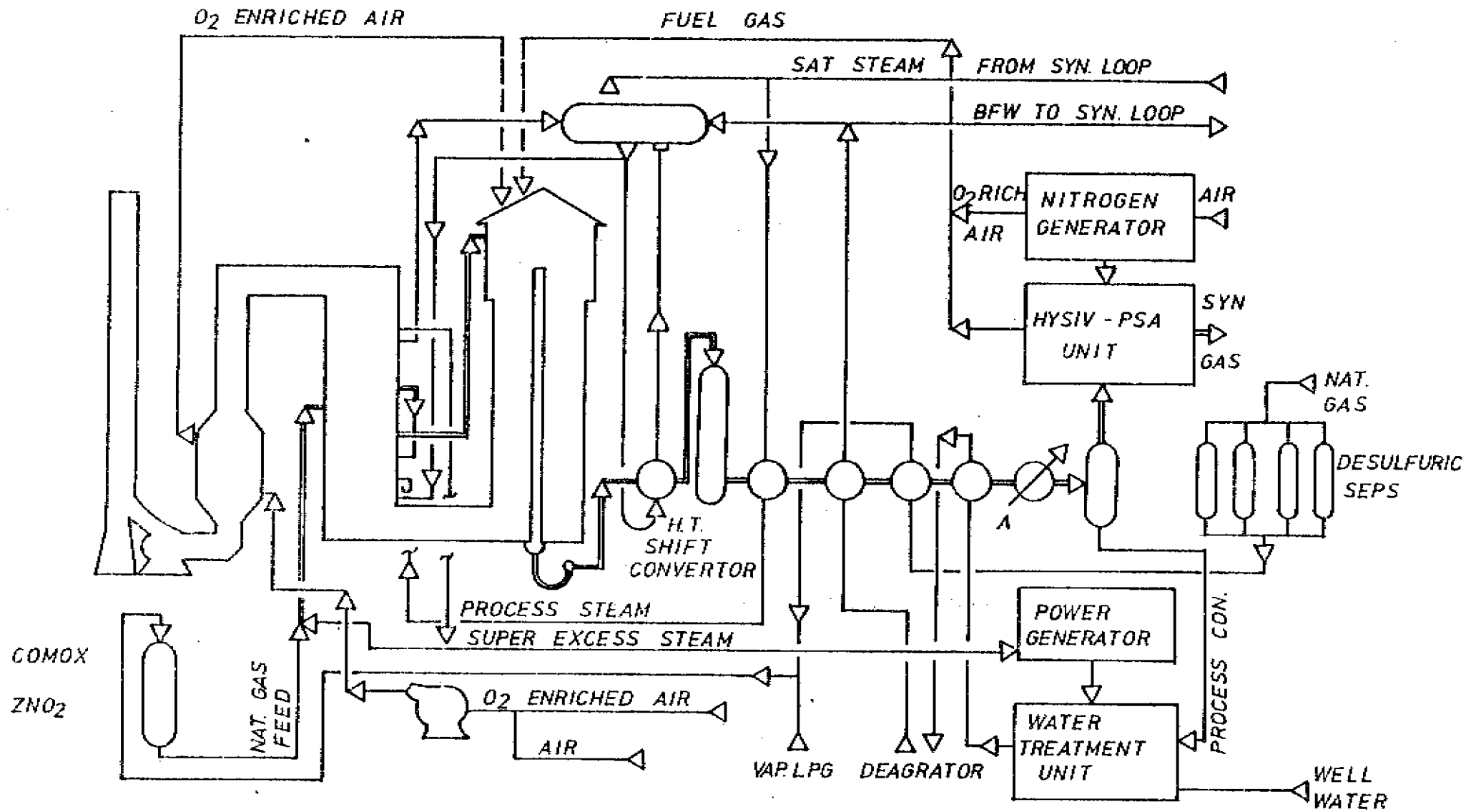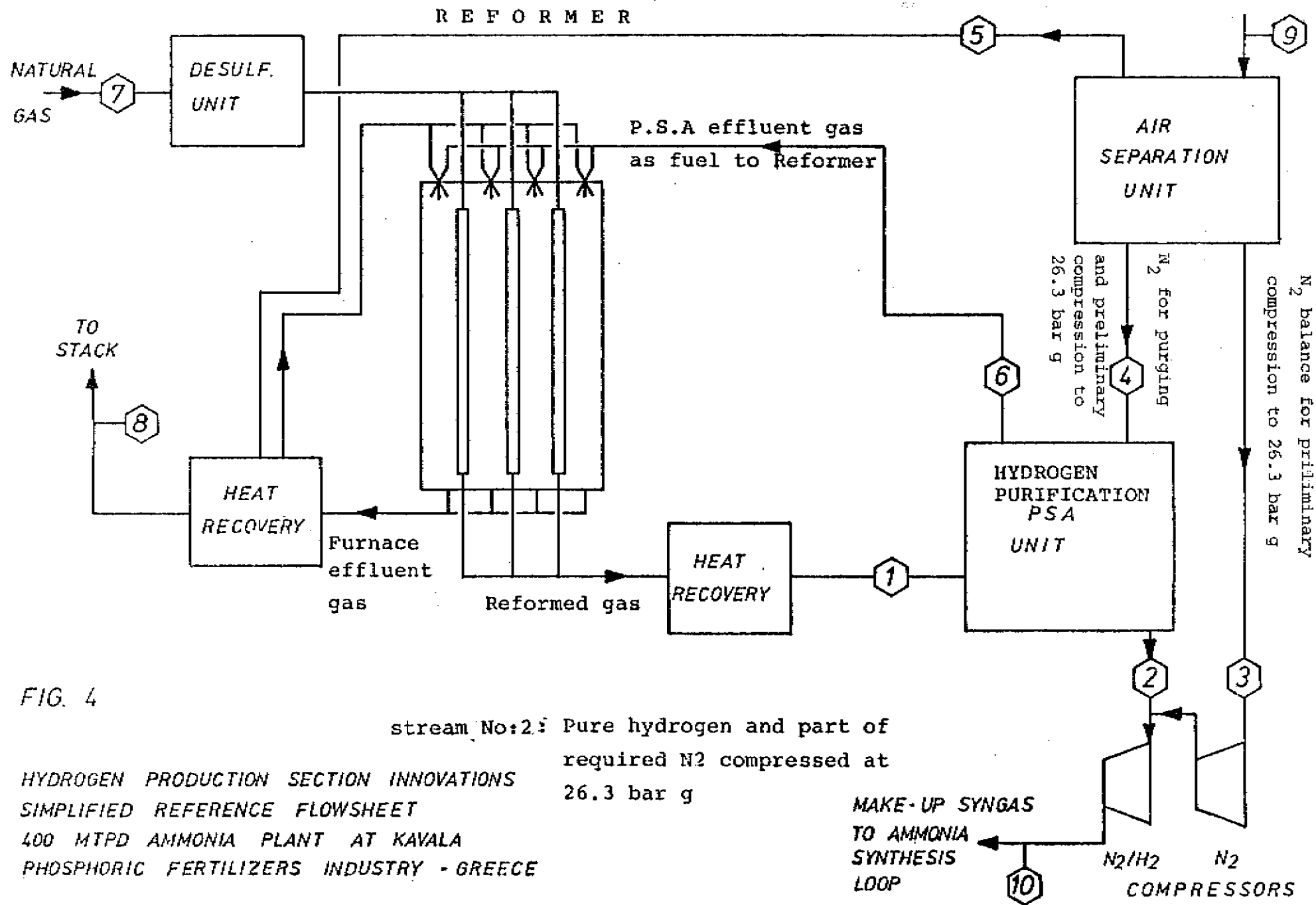
FIG. 4

stream No:2: Pure hydrogen and part of
required N2 compressed at
26.3 bar g

HYDROGEN   PRODUCTION   SECTION   INNOVATIONS
SIMPLIFIED   REFERENCE   FLOWSHEET
400   MTPD   AMMONIA   PLANT   AT   KAVALA
PHOSPHORIC   FERTILIZERS   INDUSTRY - GREECE

Stream No.*	1	3 + 4	5	6	7	8	9	10
Pressure (Barg)	26,8	2.5	0,2	0,3	45.0	0	1	238.0
Temperature(°C)	38	26	24	38	15	144	Ambient	46
Flow (Nm³/h)	50.731	14.850	12.760	20.952	10.640	81.550	35.100	44.285
H_2 (%)	71.8	-	-	14,3	-			74.82
N_2 (%)	0.48	100	62,81	18,6	0.84	63.15	72%	24.98
O_2 (%)	-	-	35,69	-		1.56	28%	
Ar (%)	-	-	1,58	ppm		0.71		0.05
Co (%)	3,47	-	-	8,4				0.001
CO_2 (%)	17,2	-	-	40,4	0.03	18.54		
HC(%)	6,78	-	-	16,4	98.89			0.006

* Please refer stream numbers shown
  in Fig. 4 M
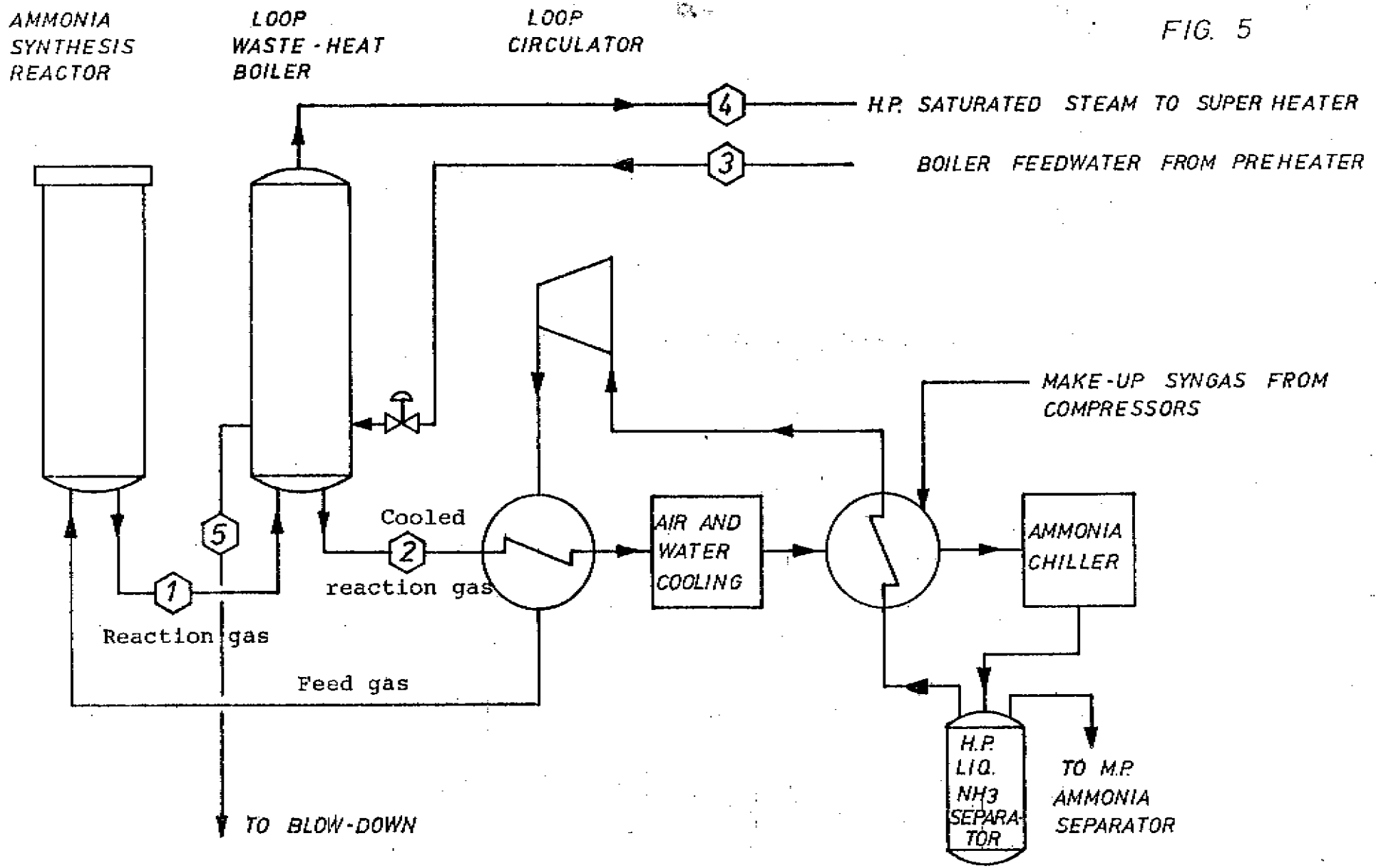
AMMONIA SYNTHESIS SECTION INNOVATION
SIMPLIFIED REFERENCE FLOWSHEET
400 MTPD AMMONIA PLANT AT KAVALA
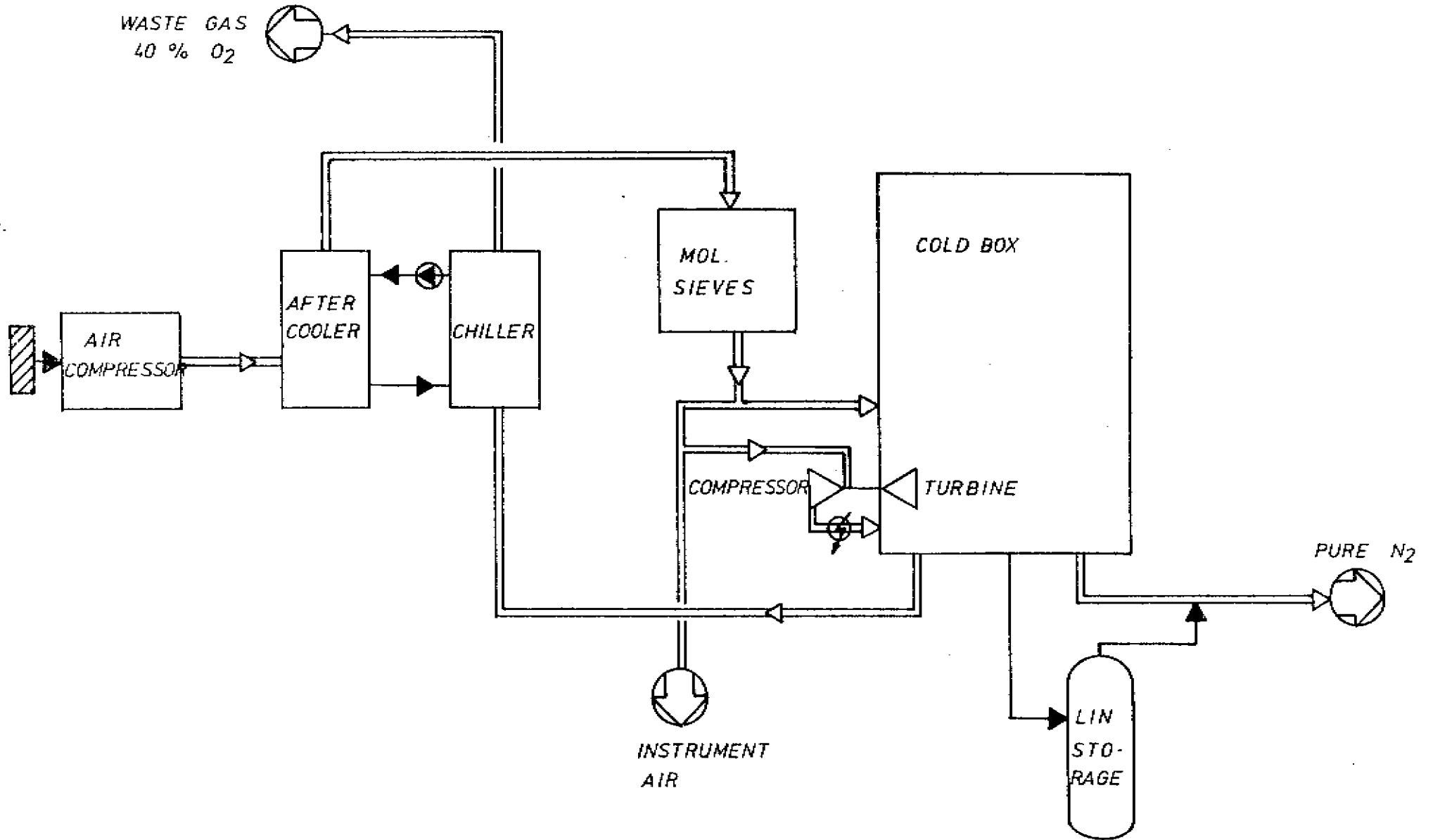PHOSPHORIC FERTILIZERS INDUSTRY - GREECE

FIG. 5

Stream No.:	1	2	3	4	5
p (kg/cm^{2}g)	241,5	240,2	54	47	47
t (oc)	462,7[1]	275	213	260	260
Flow (m^3/h)/(kg/h)	1.911,3/	1.911,3/	/22961	/21961	/1000
N2 (%)	18,2	18,2	-	-	-
H2 (%)	54,6	54,6	-	-	-
Ar (%)	7,9	7,9	-	-	-
NH3(%)	19	19	-	-	-
H20(%)	ppm	ppm	100	100	100
			water	stream	water

(1): Maximum gas temperature at
    inlet to boiler=490° C.
    (start-up conditions).

Fig. 5 M

FIG. 6

P.F.I.   AMMONIA   UNIT

AIR   SEPARATION

SIMPLIFIED   BLOCK   DIAGRAM

WASTE GAS
40 % O_2

AFTER COOLER

CHILLER

AIR COMPRESSOR

MOL. SIEVES

COLD BOX

COMPRESSOR

TURBINE

INSTRUMENT AIR

LIN STO-RAGE

PURE N_2

P.F.T. - AMMONIA UNIT
WATER TREATMENT SYSTEM
SIMPLIFIED FLOW DIAGRAM

FIG. 7

15 - 13

FIG. 8

RAW N.G.

FUEL GAS
TO REFORMER

ARC H

HP STEAM

FEEDGAS TO
REFORMER

COMOX

ZNO

FEED GAS
PREHEATING

N.G.
PREHEATING

VAPORIZED
LPG

STEAM
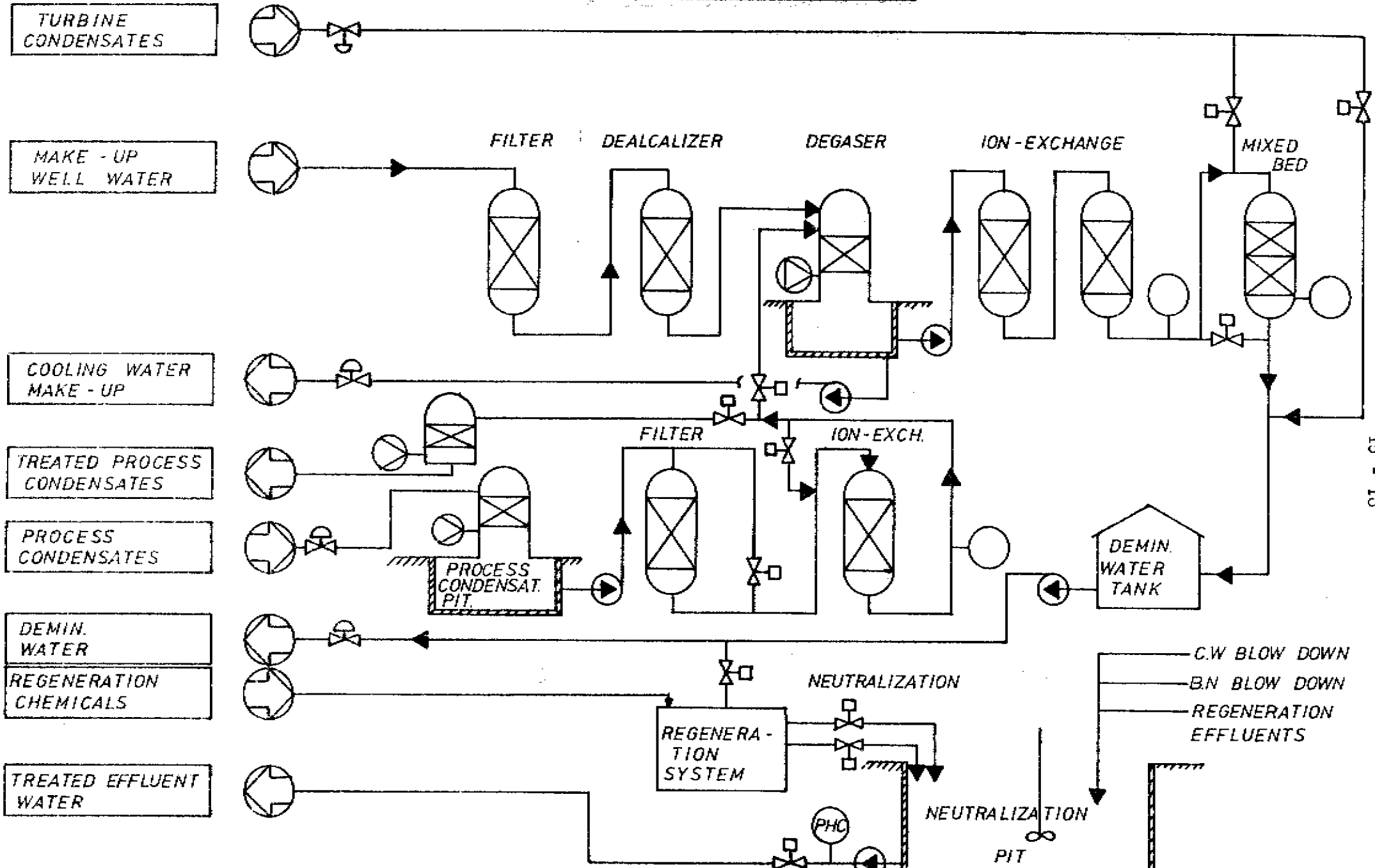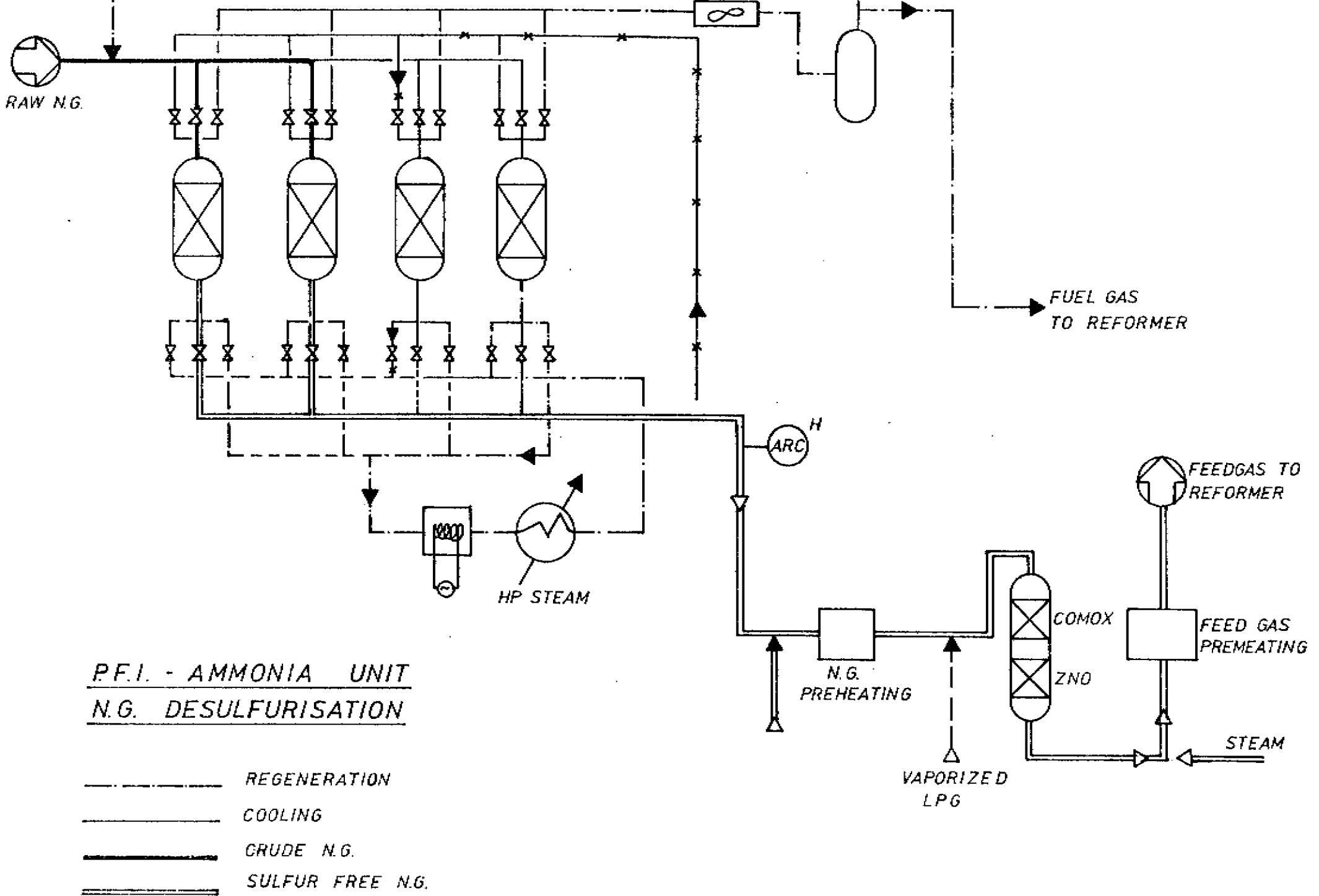
P.F.I. - AMMONIA   UNIT
N.G. DESULFURISATION

REGENERATION
COOLING
CRUDE N.G.
SULFUR FREE N.G.

15 - 19

OUTLET
350°C
28,4 Kg/cm² g

TUBESHEET - TUBE
DETAIL

T.C

INLET

843°C
28,5 Kg/cm² g

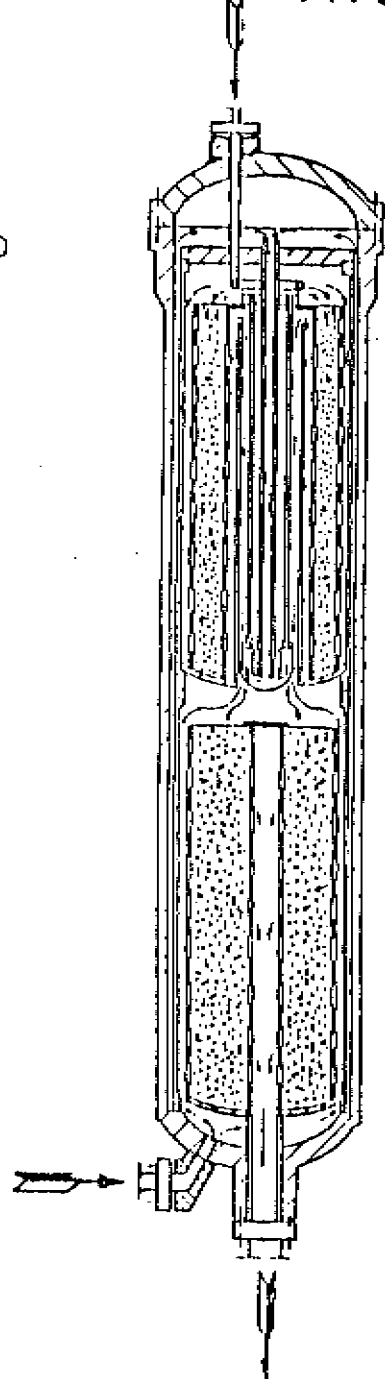Ø 1630 ID

Ø 25,4 × 2,77

15

SCHEMATIC VIEW
OF PROCESS GAS
WASTE HEAT BOILER

4496
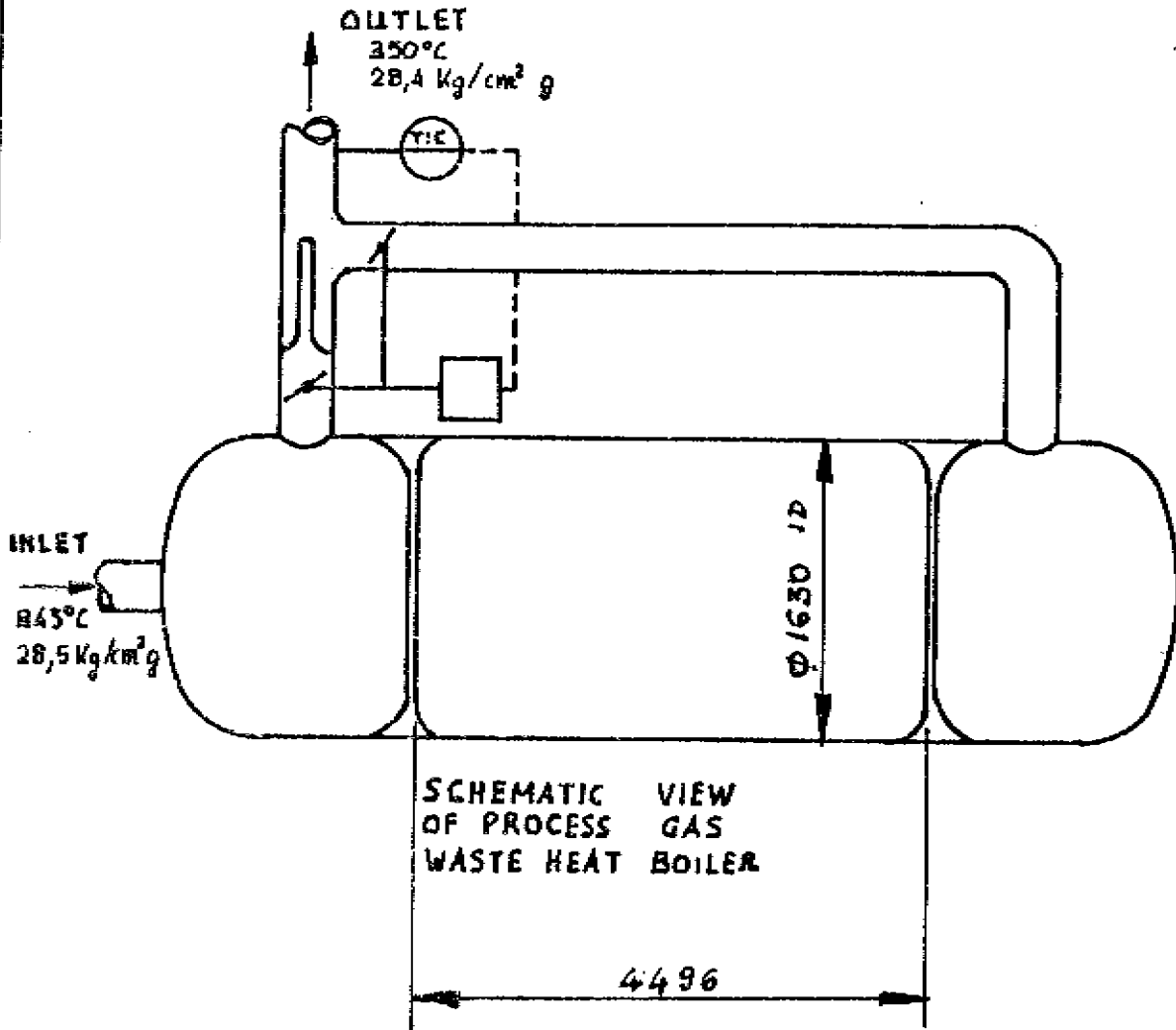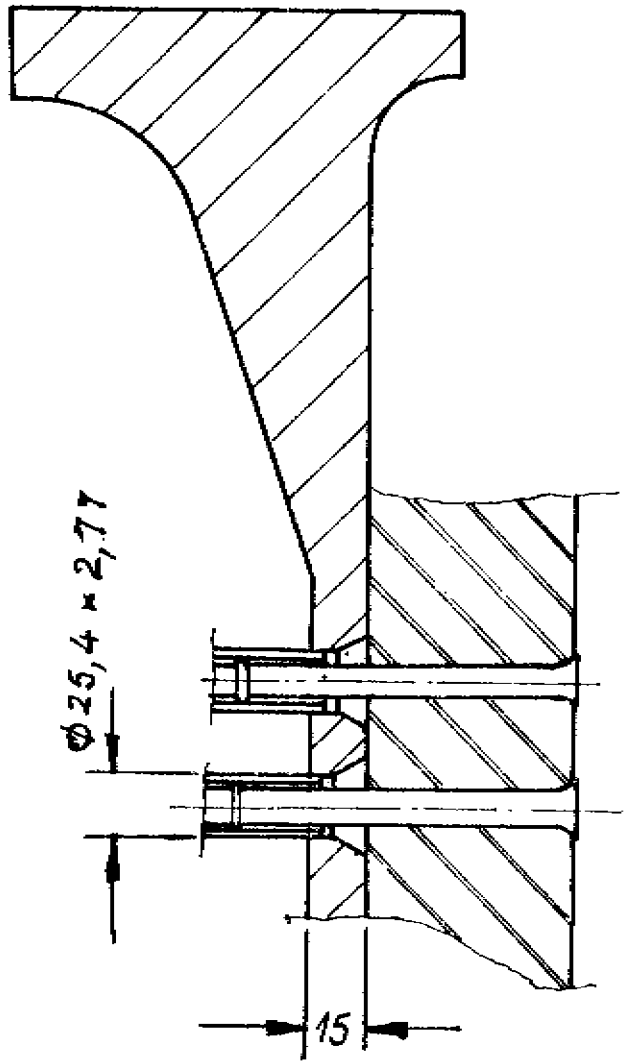
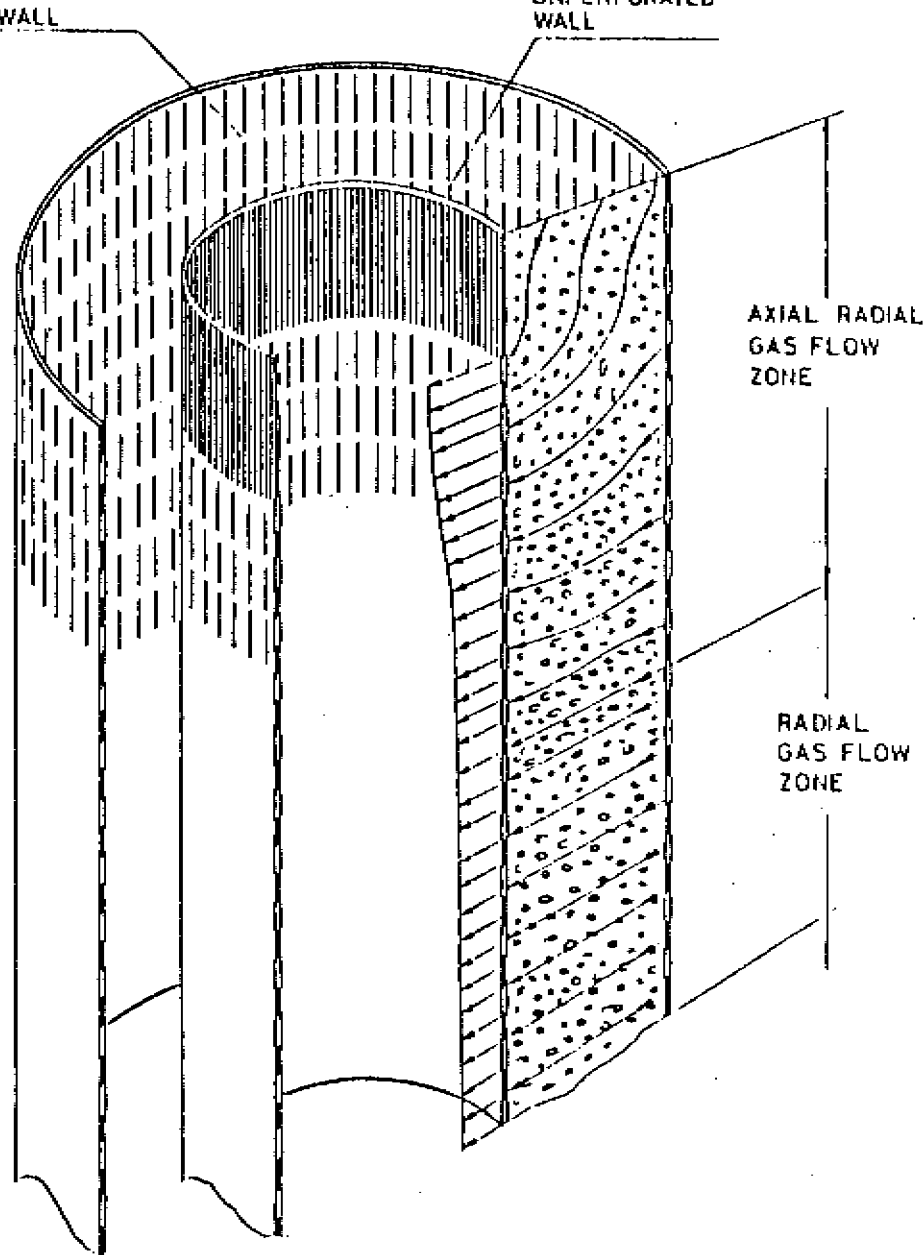FIG 9

PFI'S AMMONIA PLANT
REFORMED GAS
W.H. BOILER.

Fig. 10

GENERAL SCHEMATIC VIEW OF A
PRESSURE ACAR AMMONIA REACTOR

WALL

UNPERFORATED
WALL

AXIAL RADIAL
GAS FLOW
ZONE

RADIAL
GAS FLOW
ZONE

PERSPECTIVE VIEW OF TOP END OF BASKET WALLS
AND CROSS SECTION OF CATALYST BED WITH GAS
FLOW PATTERN

PFI's AMMONIA PLANT/STEAM-POWER SYSTEM.

FIG 11

- EXCESS SUP. STEAM
- SAT. STEAM. 45 KG/cm2
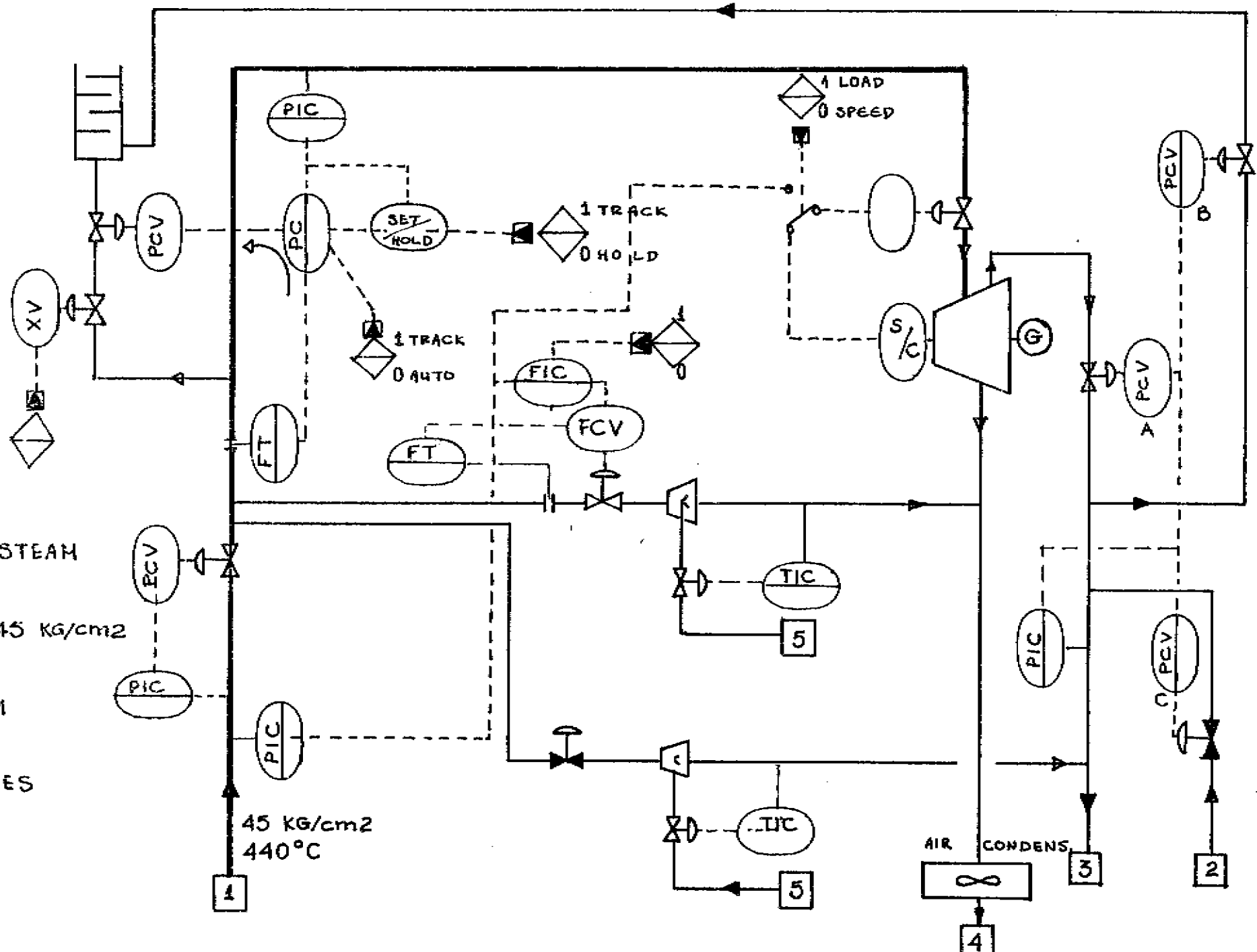- L.P. STEAM
- CONDENSATES
- BFW

45 KG/cm2
440°C

A/84/15   A new concept   for ammonia production by P. Orphanides & Ch.
          Polychronides, PFI, Greece

DISCUSSION: Rapporteur J.E. REYNOLDS, Grace W.R. & Co. USA

Q - Mr. H. ALLYOT, TECHNIP, France

   1. What are the references of the recovery boiler the reformer
      gases of the Haldor Topsoe/Nuove Pignone concept?
   2. Why did you choose a different technology for the boiler in
      the synthesis loop?

A - 1. The reference list can be obtained from the IFA Secretariat.

   2. At the time of selection, BORSIG had the best references for a
      boiler for the gas pressure, temperature and composition
      prevailing in the synloop. However, we believe that
      Topsoe/Pignone could also be a valid solution.

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

   1. Who is responsible for engineering, construction and
      commissioning?

   2. What is the overall completion period of the project?

   3. After introducing feed gas to the plant, within how many days
      you expect ammonia production?

   4. What is the expected on stream capacity of realization for
      first year operation?

   5. Could you please give reference of any other plant using PSA
      process for hydrogen purification?

   6. What type of adsorbent is used for PSA H2 purification, and
      during operation what is the frequency of regeneration cycle
      change?

   7. Waste heat boiler for reformed gas - what precautions have
      been taken to avoid tube fouling problem?

   8. What type of training is foreseen for operating and
      maintenance staff for Foxboro's Spect: IV system?

A - 1. KTI of Holland. Project is on "turn-key" basis.

   2. 33 months.

   3. Approximately 24 hours.

   4. 330 days per year.

   5. The reference list can be obtained from the IFA Secretariat.

   6. For adsorbent type please ask Union Carbide Corporation. Full
      cycle-time of each bed is 2 minutes.

7. He has supplied a very sophisticated water treatment based on VGB 64 (for high pressure boilers) though steam pressure is 45 bar.

8. Two-weeks operators training course for 2 process and 3 instrument engineers and two weeks maintenance course (for 3 instrument engineers) at Foxboro educational centre, Soest, Holland.