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AMMONIA : PRODUCTION & STORAGE

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The important role of fertilizers in agriculture needs no elaboration. Chemical fertilizers have revolutionized the basic concepts of farming and have ushered in the era of green revolution in India. Ammonia is the most important form in which nitrogen is fixed in the soil and also an important intermediate for the production of any chemical fertilizer. Thus, manufacturing ammonia is central to any effort to make nitrogen-bearing chemical fertilizer.

Development and growth in ammonia production technology has been spectacular in the last 15 years and particular emphasis has been laid on two significant aspects, i.e. to lower the energy consumption and increase the on-stream days. The type of feedstocks today include naphtha, furnace oil, coal and natural gas, depending on availability. The basic difference in the various technologies accessible today lies in the process chosen to obtain the required proportions of hydrogen and nitrogen and synthesizing them efficiently to produce ammonia.

The fertilizer industry in Indian is almost 50 years old today. From a small plant of 1 MT/day in 1939, based on wood gasification, we have stepped up to large ammonia plants of 1350 MT/day (gas based) capacity today.

Between 1965-75 a number of fertilizer plants with steam reforming of naphtha were set up in India based on total energy concept using centrifugal compressors. A similar modern ammonium/urea complex of Zuari Agro Chemicals located in Goa, on the western coast of India, went on stream in 1973. Its complex phosphatic fertilizer plant was commissioned in March 1975 and a new train of DAP plant was added in December 1984.

The original complex was designed and constructed on a turn-key basis by Toyo Engineering Corp. (TEC), Japan. TEC employed the ICI process for steam reforming of naphtha and MTC (Mitsui Toatsu Corp.) process for ammonia synthesis loop in designing the ammonia plant. The main steps involved in the production of ammonia include two-stage naphtha desulfurization, two-stage reforming of naphtha, two-stage shift conversion, modified Benfield for CO_2 removal (changed over from the Vetrocoke process in 1975), methanation and an ammonia synthesis loop with twin parallel ammonia converters. The technology selected for the ammonia plant was among the best available at the time the contract was awarded.

Some of the salient design features of the ammonia plant at ZACL are as follows :

- the captive power station has ensured uninterrupted power supply;
- most of the major drives being steam-turbines, the overall efficiency as concerns energy consumption is improved;
- oxygen stripper in naphtha treatment section keeps gum formation during sweet naphtha storage to the bare minimum;
- high pressure steam generation in 2 waste heat boilers at secondary reformer outlet improves waste heat recovery;
- quenching of process gas at the inlet of high temperature shift converter by addition of process condensate reduces quantity of process condensate to be treated before disposal as effluent;
- maximum heat recovery from first reformer flue gases is utilized to heat process air, high pressure process steam and combustion air;
- the auxiliary boiler is located in the ammonia plant, which facilitates matching steam supply/demand;
- twin, parallel ammonia converters in ammonia synthesis loop result in a low pressure drop (compared to a single converter in most of the other plants) and provide flexibility during start-up, catalyst loading, unloading and reductions.

Despite a good and efficient plant design, the actual experience of plant operations revealed areas where scope for improvement existed. Continuous efforts to improve on-stream days, reduce energy consumption and remove bottlenecks have culminated in achieving a capacity utilization of 107% in 1986. Some of the constraints faced over the years are discribed below :

- Vibration and oil leakage problems in syn gas compressor and turbines;
- Leaks in waste heat boilers;
- Fouling and corrosion of condensers and heat exchangers;
- High-steam consumption in steam turbines due to fouling.

SYNTHESIS COMPRESSOR PROBLEM

The low pressure barrel of the synthesis gas compressor developed high vibrations at high load in 1979 and the problem continued until 1982 despite various modifications/checks carried out as per the recommendation of Cooper Bessemer. As a result of high vibrations frequent replacements of seals and other parts were required. During the 1983 annual revision the machine was completely overhauled under the supervision of the manufacturer's engineers. However, the problem of high vibration above 6 mills at 10,400 rpm continued and the plant load had to be reduced to 95 %. The problem was referred to the manufacturer and was diagnosed as a self-excited fractional frequency rotor whirl (3800 rpm).

The frequency of the whirl was the lowest natural bending frequency near 3800 rpm, while the normal speed of the machine is 10,400 rpm, giving a frequency ratio of 0.37. During the last ten years the tendency has been to design compressor shafts for higher whirl frequency ratio close to 0.50, but this was not incorporated in the Zuari machine since it was built earlier. The manufacturer proposed increasing the running clearance of the main bearings, increasing the seal diameter, increasing the pressure fits of the impellers of the shaft and demagnetizing the entire rotor. The high vibration problem still continued even after carrying out most of the above modifications.

Normally the seal clearance is much less than the bearing clearance of the machine. Our machine is of an older design with longer unsupported rotor length and, under certain operating conditions when the vibration level increases, the shaft rides on the seals as bearing and undergoes a very high fractional frequency whirl vibration. The "floating" bushing seals can act as bearings if they lock on their faces. The rotor which is quite light can either go into subharmonic whirl or it can use the seals as bearings and reach the critical speed as shown in Fig. 1. While investigating the problem it was felt at one stage that wet synthesis gas that developed static electricity in the rotor and discharged through the outer seal into the seal housing could be causing the binding of the free floating seals. To overcome this problem special bristle type brush was provided to ground the shaft and the shaft current was also measured by connecting microvoltameters. It was expected that after this modification the vibration problem would be solved but, unfortunately, it persisted.

In consultation with the vibration expert engaged by us, it was decided to use old journal bearings with reduced clearances and a small stainless steel strip was connected from the outer seal to the seal housing to discharge static electricity, if any. With this modification made in Sepember 1985, the machine's performance became normal and we were able to operate the compressor at higher speed/loads without any vibration problem.

- The problem of frequent leaks of waste heat boilers was resolved by changing the construction material of the tubes. The present tubes are 1-1/4 Cr and 1/2 Mo contrary to the original material of carbon steel with 1/2 Mo and the hydrogen attack temperature is now raised to 610°C. The gas inlet section has also been refractory lined and it is expected that abnormal waste heat boiler failures will not recur.

- Regarding the corrosion and fouling problem in the condensers and exchangers, we have started organophosphate cooling water treatment with a more effective biocide based on our studies. We have also replaced some carbon steel heat exchangers by stainless steel heat exchangers to minimize the effect of cooling water quality. Some spare condensers have been added to facilitate cleaning without adversely affecting production rate.

- To improve the performance of steam turbines, ZAC has adopted a twofold approach. On one hand, we have devoted our efforts to improving the boiler feed water quality to reduce carryover from the boilers and, on the other, we have started in-situ washing of the turbines with wet steam. These measures have reduced the turbine fouling and have contributed to turbine operation at high efficiency level.

The constant endeavour to improve performance of our ammonia plant is also reflected in various other additions/changes carried out since the plant was commissioned in 1973. These changes have been made to improve capacity utilization, increase operation ease, reduce start-up period and improve energy consumption. Some of the major changes are :

1. Additional refrigeration ammonia condenser

One condenser was added to the existing two. This helped in cleaning the condensers at regular intervals without affecting production, especially during the summer months. It also contributed toward higher capacity utilisation.

2. Purge gas recovery unit

A purge gas recovery unit, supplied by Nippon Sanso (Japan), was installed in 1981. This unit has the capacity to recover almost 85-90% of the hydrogen from 12000 NM^3/h purge gases from the ammonia synthesis loop. The PGRU unit is a cryogenic recovery system and has helped reduce energy consumption.

3. Replacement of ammonia separator

The ammonia separator in the synthesis loop was replaced by a larger separator to reduce pressure drop in the loop as well as to avoid liquid carry over.

4. IN-519 catalyst tubes

Original catalyst tubes in the primary reformer were made of HK-40 material. In 1983 these tubes were replaced by a new set of IN-519 material tubes.

5. Additional final gas cooler

An additional final gas cooler has been installed in parallel with the existing cooler. This has been done to reduce the suction temperature of the syn gas compressor. During the humid summer months in the past, the higher suction temperature adversly affected compressor capacity.

6. Ammonia cracking unit

The facilities were added to produce cracked gas or hydrogen for catalyst reduction during the plant start-ups. The plant was designed to crack ammonia in primary reformer for the catalyst reduction. The LTS catalyst used for reduction by the process gas entailed delays in ammonia production. This unit was set up to avoid these delays and reduce start-up time.

7. Optimization of ammonia synthesis loop

Major optimization in the ammonia plant was carried out in the ammonia synthesis loop. It was observed that the synthesis compressor consumed a high level of energy and the ammonia outlet synthesis converter was of low efficiency compared to similar converters and operating conditions. On further investigation it was found that the temperature profile of the converter was far from ideal. The major problem in optimizing the temperature profile of the converter was the difference in the catalyst bed temperature readings between the indicator and the recorder (Table 1). The temperature indicator readings were assumed to be correct and optimization of the loop was carried out by adjusting the different quench flows. After each adjustment the total temperature rise across the converter and the loop pressure was carefully monitored. A decrease in the loop pressure and an increase in the make up gas flow indicated the adjustment of the quench flow was accurate. This method was adopted in the absence of a reliable temperature indication and quench flow measurement and all the four beds of the converter were optimized accordingly. The results were very encouraging and ammonia conversion per pass increased from 9.7 to 10.2 vol. per cent and the total ammonia production by about 5 per cent. The loop pressure came down by 6 to 7 kg/cm^2 and there was considerable energy savings.

This optimization was carried out in a synthesis converter with the catalyst which was 13 years old. The temperature profiles of the converter before and after optimization are shown in the attached drawings (Figures 1 & 2).

We have now developed a Computer Programme for the optimization of the synthesis converter operation. The parameters like hydrogen/nitrogen ratios, inerts in the loop and temperature profile are varied in an off-line model in a PC and results are noted. This has considerably helped in optimizing the performance of the synthesis converter and the overall production.

We feel that plant performance can be improved by a critical evaluation of all operating parameters. Our efforts and the results achieved are a testimony to this belief and we shall continue to look for further improvements in our ammonia plant in the future.

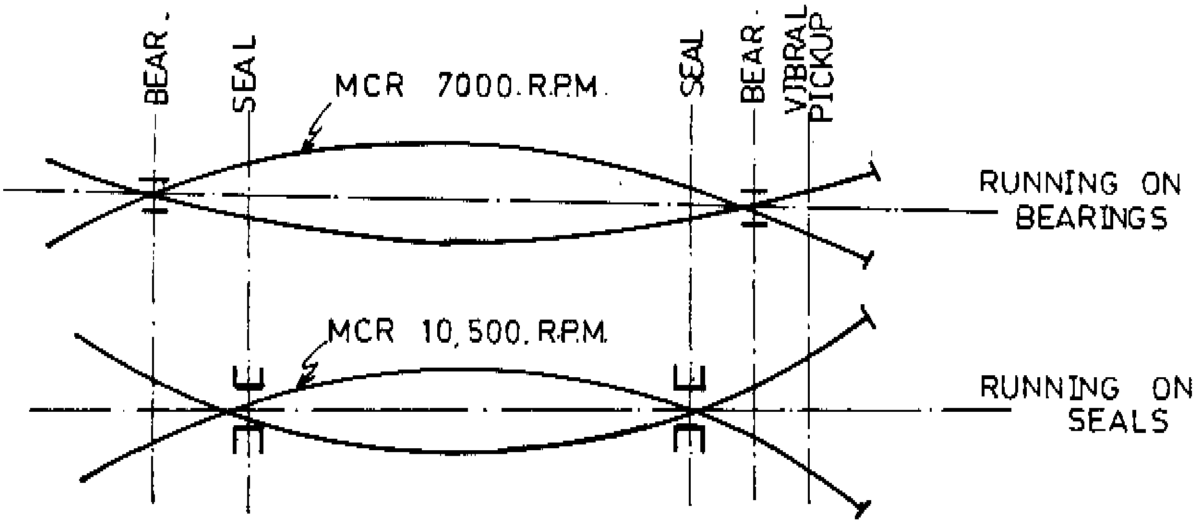
We have a pressurized type ammonia storage facility comprised of one 3000 MT capacity hortonsphere. We are in the process of erecting a second hortonsphere of similar capacity so that the existing one can be inspected periodically. The recent advances in ammonia storage techniques are primarily focused on increasing safety and reliability. However, the choise between atmospheric and pressurized storage will continue to be guided by a storage capacity since, normally, above 5000 MT atmospheric storage is preferred because of its lower operating cost and reduced risks of stress corrosion failure.

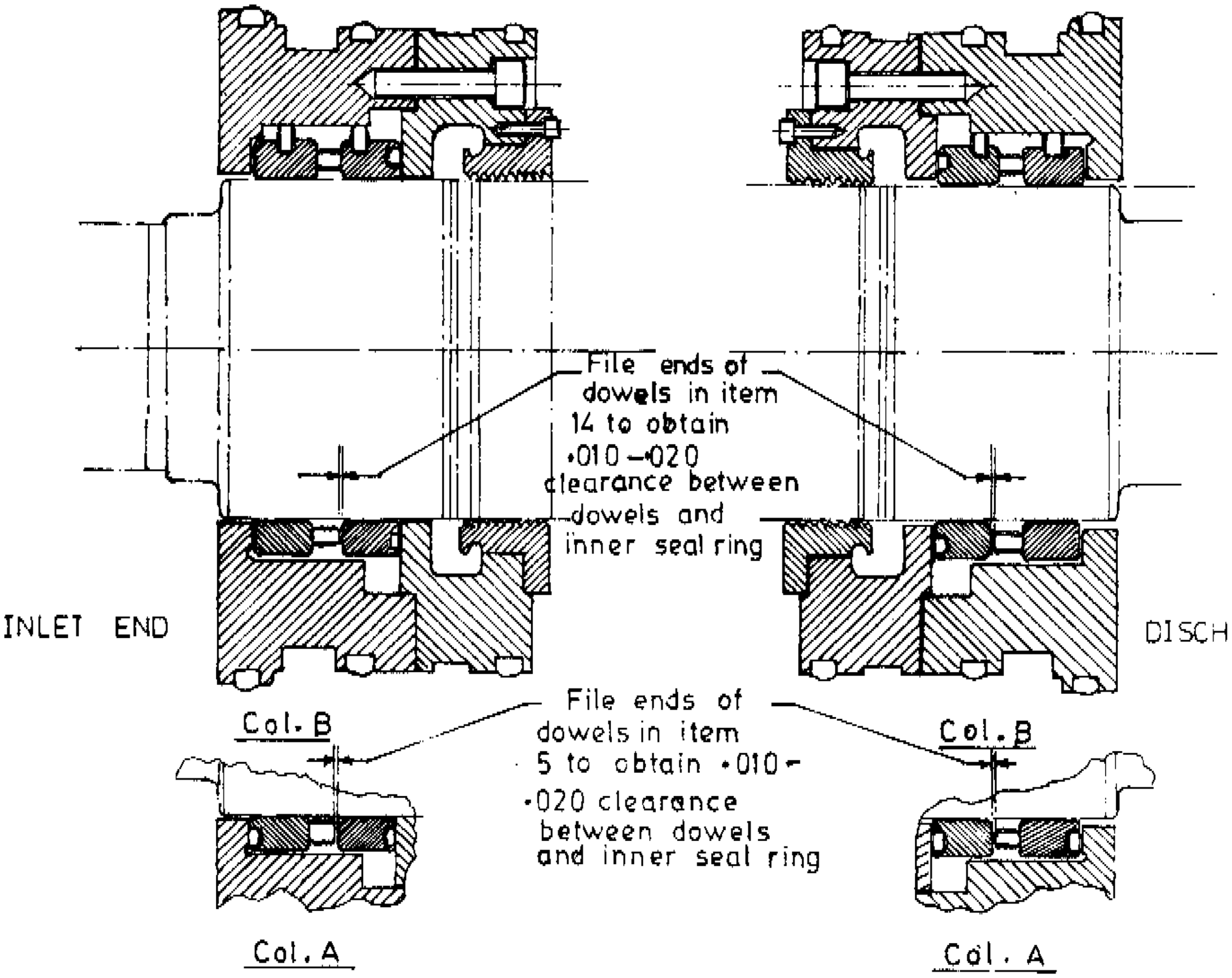
TABLE 1

Ammonia converter temperature

CONVERTER 'A'	Temp. Indicator		Temp. Recorder	
	Inlet	Outlet	Inlet	Outlet
1st bed	421	503	271	420
2nd bed	422	433	416	433
3rd bed	422	469	429	449
4th bed	452	460	441	462

TITLE:- OIL BUSHING SEAL CRITICAL 8 - 8	DATE	SHEET



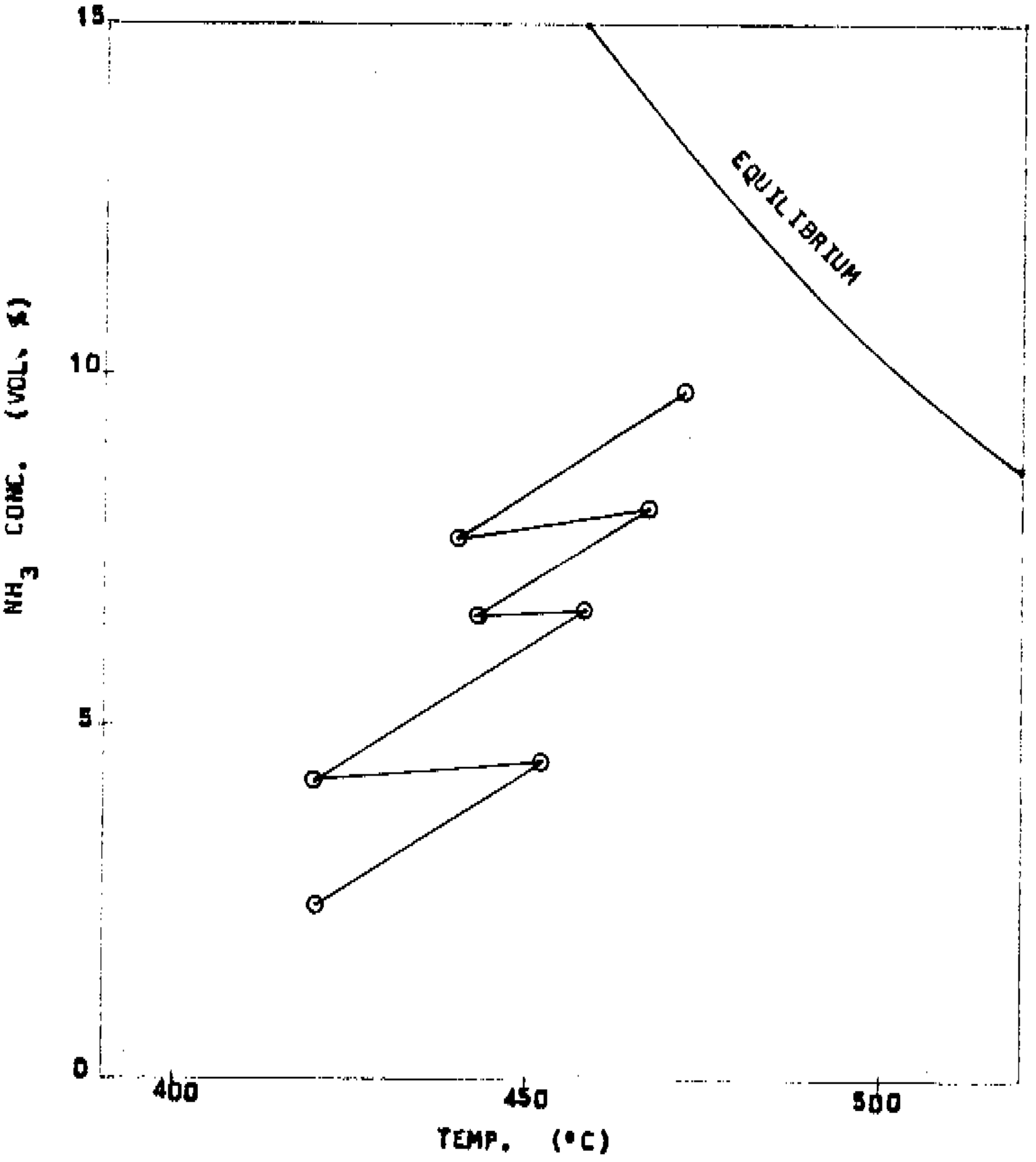


File ends of dowels in item 14 to obtain ·010 –·020 clearance between dowels and inner seal ring

File ends of dowels in item 5 to obtain ·010 – ·020 clearance between dowels and inner seal ring

ZUARI AGRO CHEMICALS LTD	SCALE		
	DRN		
	APPD		DRG NO.

AMMONIA CONVERTER 'B' (G.T.R.)



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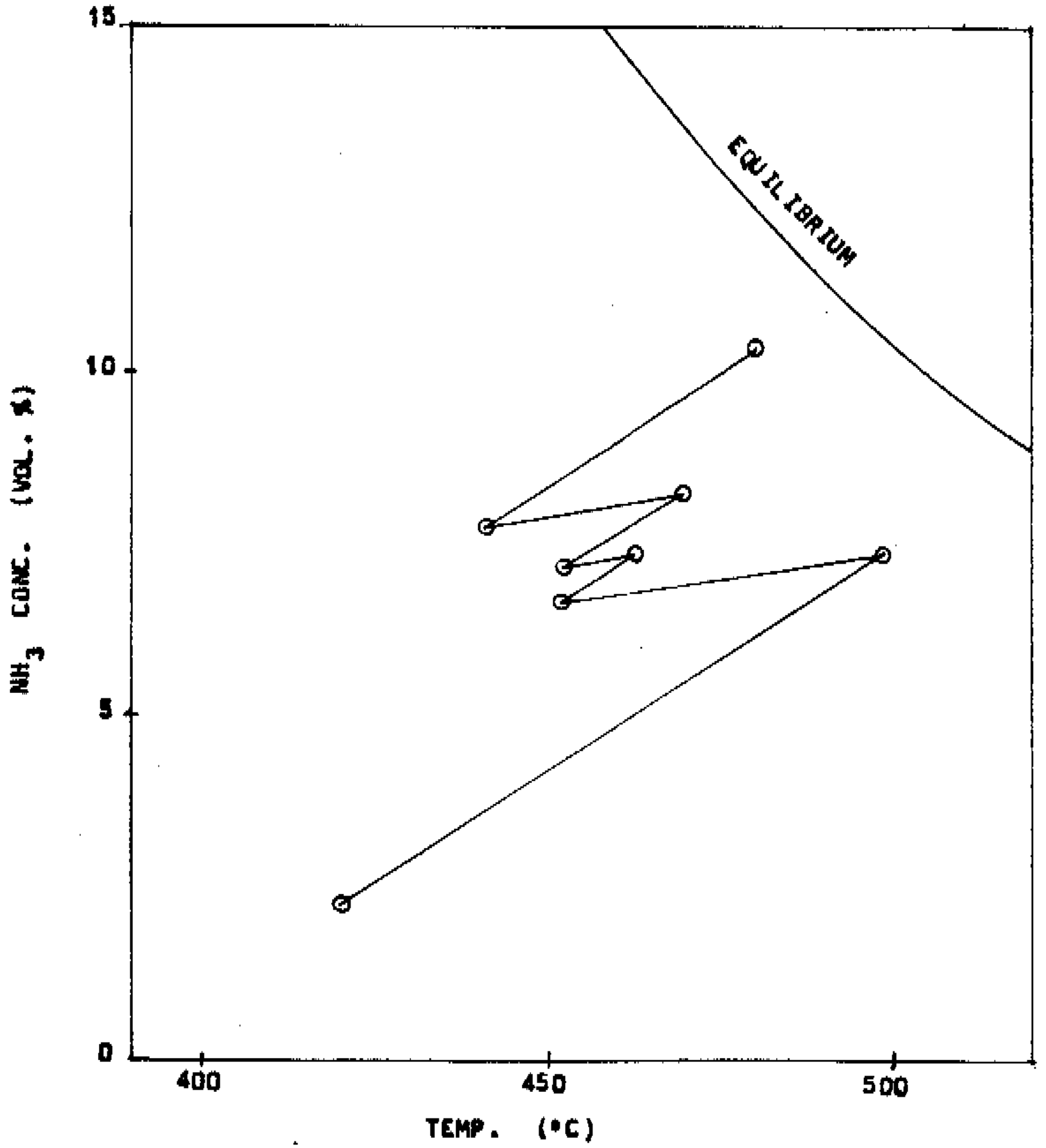
2.1 2.5 1.6 2.1

AMMONIA CONVERTER 'B' (18.12.85)



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5.1 0.7 1.1 2.6