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UNIDO/FAI Interregional Meeting on Safety in
the Design and Operation of Ammonia Plants

New Delhi, India,
20 - 24 January 1976

SAFETY IN THE DESIGN CONSIDERATIONS OF AMMONIA PLANTS FACT EXPERIENCES AT COCHIN AND UDYOGAMANDAL PLANTS 1/

by

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Via. Cochin, India

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SUMMARY

by

S. Chidambaram*

Some of FACT experiences in Cochin and Udyogamandal Naphtha reforming ammonia plants are listed as checklists of safety for future modern plants in India.

Due to improved high heat flux designs in superheater and boiler, Indian Boiler Regulations arbitrary design temperature basis of steam temperature + fixed constant was discussed as inadequate. The effect of wide turn down demanded from waste heat boilers, and silica migration with water carry over are mentioned for necessity of silica wash with feed water.

Reformer manifold material with cast instead of wrought high temperature steel is brought in the topic for safe substitution. The importance of using two layer refractory lining for hydrogen service is reproduced from API reports as many plants have experienced hot spots. Cochin experiences of burner performance in a high turbulent furnace, low steam production in synthesis loop due to insufficient insulation, NH_3 contamination in hydrofining recycle hydrogen by the centrifugal compressor antisurge system and cavitation in CO_2 solution pumps by dissolved gas NPSH requirement are mentioned as consultation topics. A small suggestion to design reformer with steam/carbon ratio of 3.5 instead of 3 is made considering naphtha specification, LT activity and Benfield steam requirement.

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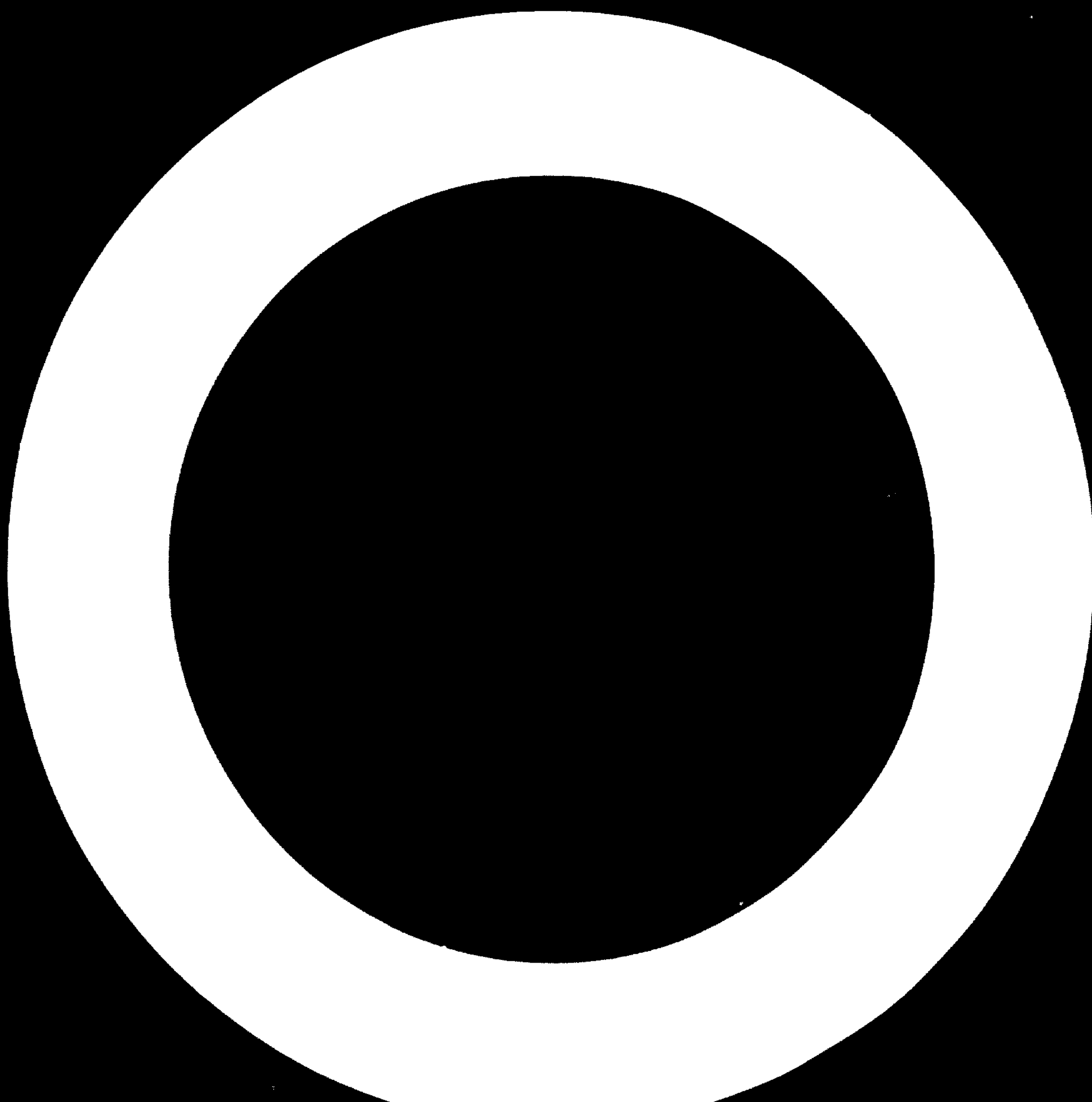


1.0 INTRODUCTION.

[illegible] route. [illegible] has two operating Ammonia plants with 600 T.P.D and [illegible] T.P.D capacities. The [illegible] plant was designed [illegible] and [illegible] with some [illegible] equipment. The 120[illegible] T[illegible] plant was engineered by [illegible] with [illegible] - ICI. The experience gained in these plants [illegible] may be considered for safety in the process design of Ammonia plants in our country.

2.0 HIGH [illegible]

The total energy concept with power recovery (1) has been found to reduce operating cost by inplant steam generated at pressures between 100-135 kg/cm2. This type of high pressure steam net work is of very specialised nature and are ordered with reputed boiler manufacturers. The only consideration, owner bothers is its statutory acceptance by Indian Boiler Regulations. Unfortunately I.B.R. rules for waste heat boilers are inadequate in many respects and failures are not uncommon in the system if the owner does not pay attention to various emergency conditions and cross-check with other codes.

A typical example is the present free supply natural draft direct fired steam superheater for Cochin plant improvement. Figure 1 and Table 1 explain clearly that the design temperature as stipulated by I.B.R. in relation with steam temperature does not necessarily mean to be a safe condition for the equipment. It can be argued that API RP530 - a design code for direct fired heaters - gives correspondingly a lower thickness when $P = \frac{2.4St}{D}$, is compared with IBR formula of $P = \frac{2S(t - 0.6)}{D - t + 0.6}$ when S the allowable stress value is same. However, API RP530 limits the application to only above 50 mm ID and below this ASME or TRD 301 gives much safer thicknesses when calculated with metal temperature as the basis of design conditions.

For convective type superheaters mounted in primary reformer flue gas duct, different type of problem arises. Normal NH_3 plants have the following heat recovery sources either as boilers or economisers:

a) [illegible] gas

b) [illegible] converted gas

c) [illegible] synthesis gas

d) [illegible] gas

Whenever [illegible] occurs due to any emergency, [illegible] steam generation [illegible] considerably. [illegible] are to be back on stream quickly, primary reformer operation [illegible] level, as that of full steaming conditions. The [illegible] temperature is to be calculated for zero steam flow and material [illegible] safety must be assured for this type of emergency. Simply designing for normal steam temperature [illegible] some experience in [illegible], would be able to [illegible] with a reasonable proximity and base his design on this(18).

In economisers, boiling out condition must be checked and avoided by suitably sizing the gas side [illegible] production condition arises with process side condition more or less maintained.

[illegible] 600 average stress to rupture at 10 000 hours as allowable stress at the design temperature. Babcock [illegible] Wilcox article (2) disagrees about this [illegible] and considers from metallurgical point of view, a conservative design criteria must be [illegible].

3.0 BOIL[illegible] [illegible] DEPOSIT[illegible] IN TURBINE[illegible]

Cochin synthesis turbine performance visibly deteriorated due to silica deposits and washing with LP steam and condensate was necessary to restore its original performance. Figures 2 & 3 (3) and table 2 give data on silica solubility in steam and VDI specification on boiler water. For the operating pressure of 134 kg/cm2 Cochin has boiler water quality in silica as 0.4 ppm and for this, silica volatility in steam should be limited to 0.01 ppm only. The high silica deposit was attributed to water carry over from different drums. The wide turn down demand and various operating conditions may probably be one reason for ineffective separation and water carry over. As such regular operation at low level was found necessary in the drums.

Another condition that may contribute to higher silica in steam may be pH lower range operation in the stipulated 9-10. Without caustic injection, it was found not possible to operate at high pH. Its use is still disputed even-though the supplier has recommended it for pH adjustment. Synthesis gas drum supplier recommend NH_3 injection, but its quantity and proportional loss with steam will affect turbine condensing parts and hence could not be tried.

We can only conclude that in selecting the high pressure waste heat boiler between 100-134 kg/cm2, silica problem [illegible] must be given due importance unless feedwater silica wash is incorporated in the drums as a mandatory item.

4.0 [illegible]

[illegible] other items are more and more [illegible] reports [illegible] corrosion data.

<u>Reformer manifold:</u> [illegible] alloys are offered as cheaper alternatives to [illegible] (2, 5) for [illegible] material. [illegible] in literature [illegible] formation of [illegible] embrittle [illegible] Ray [illegible] fraction [illegible] of the method of [illegible] allowable stress should not be [illegible] Miller [illegible] thickness (10) with allowances [illegible] taking only 75% of the [illegible]

[illegible] has used [illegible] or [illegible] for [illegible] hydrogen plant and this has [illegible] many shutdowns.

<u>Refractory lining:</u> [illegible] reformer [illegible], spool piece and transfer lines are the weak points [illegible] caused many shut downs due to frequent hot spots. There are many [illegible] and methods of lining with each one [illegible] of the consulting firms. It is worthwhile [illegible] two layer lining as minimum requirement. [illegible] selection must give suitable attention to [illegible] recommendation [illegible]

A typical spool piece [illegible] is reproduced as figure 4 [illegible] in Cochin, modification in these lines are being carried out.

5.0 <u>FURNACES</u>

Cochin has an auxiliary combustion chamber after primary reformer coffins to satisfy the steam network heat balance. This type of furnaces are to be compact to ensure thorough mixing for completing the combustion, are to have high turn-down firing flexibility and are to withstand the high hurricane wind issuing from primary coffins.

For most of the services with 0% mechanical/air atomised combustion, normal text book firing volume of 7.5 $\times 10^5$ KCals/h.m^3 are found quite adequate, but in this service, furnace effective volume is determined by the type of burner and other aerodynamic considerations (13).

Cochin has [illegible] fitted with [illegible] swirlers for spread out flame to confine in effective volume. But due to the heavy eddies, the whole combustion chamber is turned to be a flame box with severe damage to burner tips, swirlers, quarl blocks, refractory and mortar. Presently it is planned to be replaced with jet flame characteristic burner with increased length of flame for its resistance against high inside turbulence [illegible] 600 mm for after combustion [illegible] other suppliers.

Correct specification of furnace condition must be prepared for this type of combustion chamber for finding the suitable burners.

6.0 [illegible]

[illegible] sulphur, chlorine and [illegible] at [illegible] of LTS is noted due to these poisons and [illegible] frequent shut downs. The effect of activity deterioration as reported by [illegible] (14) is given below:

	[illegible]	[illegible]	
		Ar.	CH_4
Design case	40	0,29	,68
LTS 75% active	70	0,29	1,12
LTS 50% active	100	0,29	1,47

In a typical kinetic study for deciding allowance of LT volume, it was found that it is worth to base primary steam/carbon ratio of 3,5 instead of 3,0 for the following reasons:

1. Naphtha feedstock specification given by [illegible] always for worst crude derivative like [illegible] oil. These 2.0 [illegible] naphthas have increased specific gravity and aromatics before and after hydrofining and stripping by dehydrogenation of naphthanes. Thus PONA analysis on aromatics will be minimum 26,5% Vol. for which reformer catalyst loading need be reduced from 1 to 0,7 Te naphtha/hr.m3 catalyst (15). Thus the number of reformer tubes are controlled by catalysts volume and not for heat flux consideration. The investment difference between S/C of 3 & 3,5 will not be appreciable.

2. Incorporation of quench vessels for increasing steam/gas ratio at downstream has given many mechanical problems and failures due to 'wind and water' interface (15).

3. LTS catalyst cost constitutes approximately 35% of total catalysts in NH3 plant. For a typical 2,8% to 0,3% CO conversion, operation at S/C 3,5 requires 7,27 m3/100 TPD NH3 and S/C 3,0 require 8,1 m3/100 TPD NH3 (15). LT Catalysts.

4. For a typical split flow single stage regeneration (with no flash cooling) Benfield system, operation with S/C of 3,5 alone will satisfy the regeneration efficiency of 0,45 Nm3 CO2/Kg steam.

[illegible] modern plants on a similar basis, with [illegible] activity allowed [illegible] the plant performance [illegible] basis.

7.0 [illegible]

[illegible] higher [illegible] gases. [illegible] is [illegible] the [illegible] lean solution pump [illegible] of impeller [illegible] noticed.

8.0 [illegible]

[illegible] has single antisurge system for combined synthesis and recycle compressor similar to ref.(16), with a small omission of manual loading station between the synthesis and recycle discharge lines. As these gases are to go to chillers combined for stripping carbon oxides, it was considered that they can be connected at compressor discharge itself, after antisurge tapping. However, such an arrangement caused [illegible] to seep into the low pressure stages and to recycle hydrogen through antisurge line during compressor unloading operations. A double antisurge system is ideal or an isolation loading valve may be an alternative to avoid this problem.

9.0 NH3 [illegible]

A brief sketch of Cochin NH3 converter is shown in Fig. 5. The internal boilers are designed to recover 1.58 [illegible] steam [illegible] NH3 with feed water at [illegible]. But in actual operation, 1.1 is the maximum attained figure and any attempt to reduce the converter exit temperature by boiler valves resulted only in thermic level adjustment in catalyst beds with no effect in steam production increase.

It is attributed that insufficient insulation over the Recuperator exchanger as shown in Fig. 6 [illegible] causing this problem. As a part of plant operation improvement for Cochin, another gas to gas exchanger in series outside mounted is planned, so that the design steam production rate can be achieved.

Another interesting [illegible] noted is the equilibrium NH3 vapour content and dew point. [illegible] gives a higher figure than used by the process designers. Cochin operation and load on refrigeration loop suggest that literature data is more reliable. It is good to note such factor in sizing the refrigeration loop to avoid ending with a very tightly designed loop.

10.0 CONCLUSION

A brief [illegible] of study in design, in the points listed by UNIDO/IAI expert., with [illegible] experience is attempted in this article.

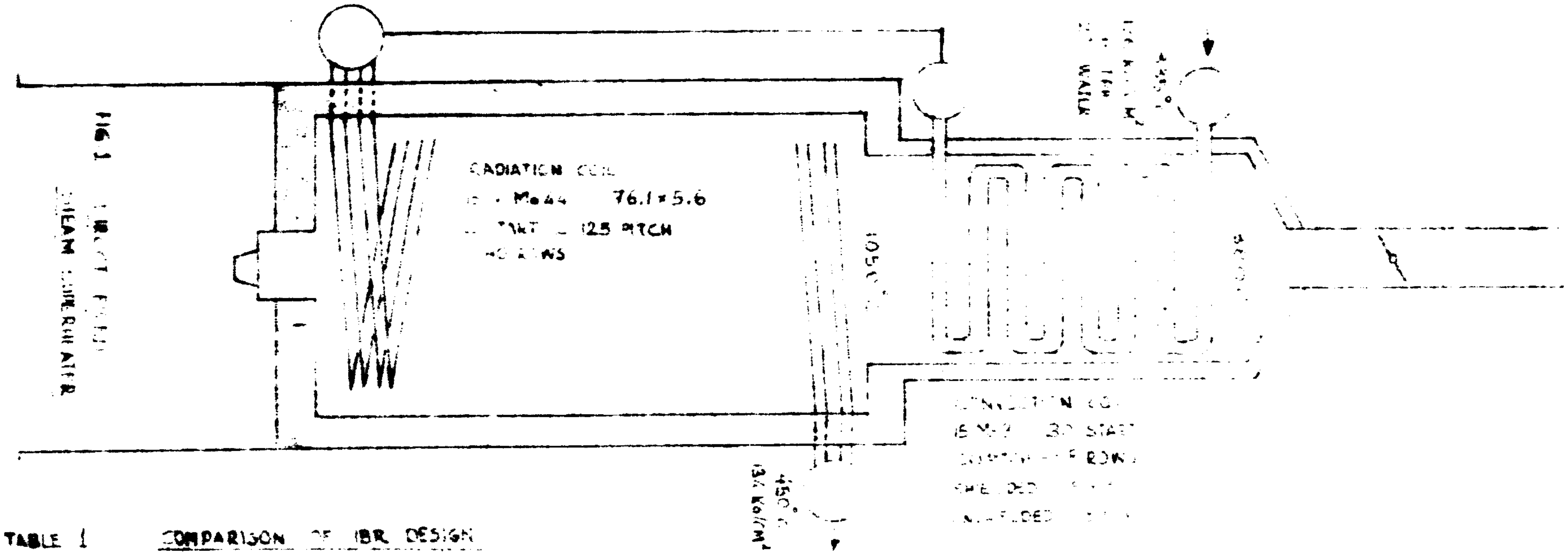
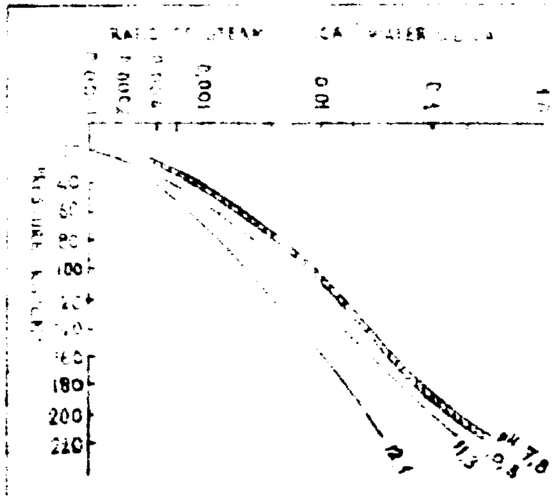


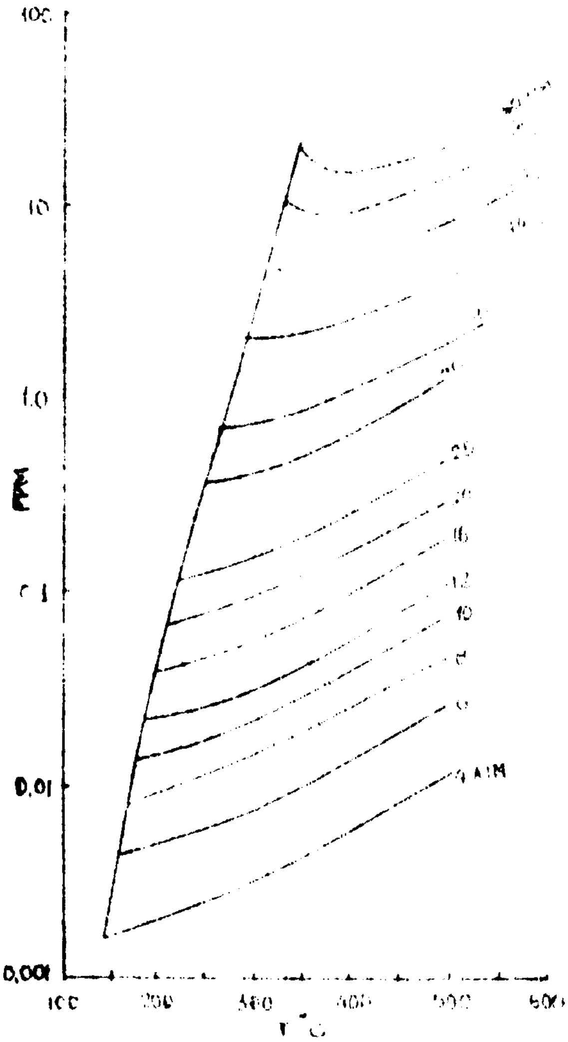
FIG 1 DIRECT FIRED STEAM SUPERHEATER

TABLE 1 COMPARISON OF IBR DESIGN WITH ACTUAL PERFORMANCE

POSITION	STEAM TEMP °C	IBR BASE DESIGN TEMP °C	CALCULATED METAL TEMP INCL ALLOWANCE	APPROXIMATE % REDUCTION IN ALLOWABLE STRESS VALUE
SHIELDED COILS	335	335+39 = 374	350+55 = [illegible]	4
UNSHIELDED COILS	355	355+50 = 405	454+55 = 509	2.6
RADIATION COILS	450	450+50 = 500	476+55 = 531	2.2



RATIO OF SILICA IN STEAM TO SILICA IN BOILER AS A FUNCTION OF PRESSURE AND pH



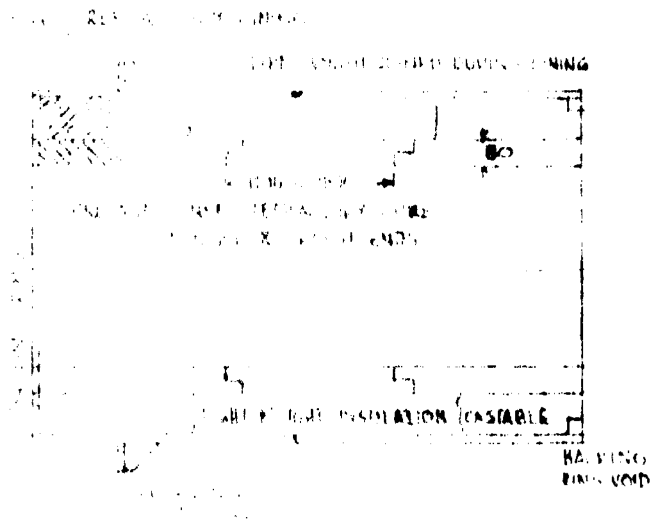


TABLE 2 : GERMAN BOILER WATER SPECIFICATION

PRESSURE BAR	64	80	110	125	>160
CONDUCTIVITY AT 25°	<2500	<300		<50	
P VALUE mval/kg	0.1 to 1.0	[illegible]		<0.1	
PH VALUE AT 25°C	10-11	9-10.5		[illegible]	
SiO_2 mg/kg	<8	[illegible]	[illegible]	<1,2	[illegible]
PO_4 mg/kg	<15	2 To [illegible]			

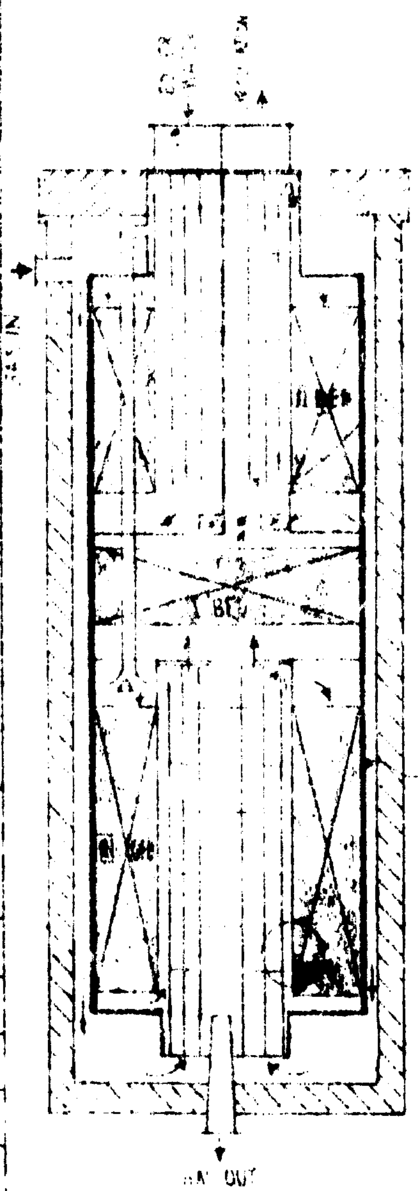


FIG. 5 NH3 CONVERTER SKETCH

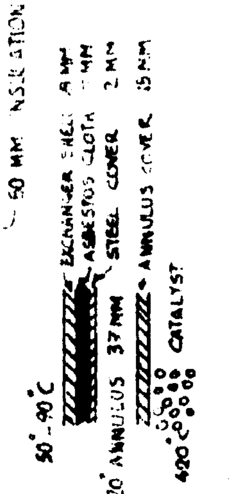


FIG. 6

SECTION AA

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