NOISE LEVELS IN HIGH CAPACITY AMMONIA PLANTS

Proper installation of-siiencers makes a big difference; industry standards urged

R. Caputo
E. Denmark
1. Heitner
H. C. Mayo

M. W. Kellogg Co., Inc.
New York, N. Y.

Noise has been defined as unwanted sound. Its undesirable effects can be temporary or permanent hearing loss, inability of personnel to communicate effectively. and reduction in efficiency.

A brief discussion of acoustical terminology is presented below to aid in understanding the tabulated data. Sound power is defined as energy per unit time and is measured in watts. Sound intensity is 'measured in watts per square meter. Since sound power can vary from 10^{-9} watts for a very soft whisper to 10^{5} for a jet, a total variation of 10^{14} watts, it is normai practice to express sound power as a log function. An additional advantage of employing a log function is that the response of the human ear seems to be in direct proportion to the log of the sound intensity.

If W is the sound power of the noise source in watts and W is a reference sound power (frequently taken as 10^{-13} watts) then the sound power in decibels is defined as 10 log $\frac{W}{10^{-13}}$. Similarly, sound intensity level (I.L.) is defined in dicibels using a reference intensity of 10^{-12} watts per square meter. Thus:

I.L. = 10 $\log_{10} \frac{I}{10^{-12}}$ decibels.

It is difficult to measure sound power or intensity but comparatively easy to measure the variation in atmospheric pressure produced by noise, using microphones which convert the sound pressure into a voltage. It can be shown that $P^2 = \pi CI$ where:

P = root mean square sound pressure
π = the density of air
C = the velocity of sound in air, and,
I = the sound intensity (watts per square meter.).

Thus, in the definition of sound intensity instead of taking the ratio of I/I_o, we take the ratio of P^2/P_o^2 to obtain a definition of sound pressure level (SPD equal to 10 $\log_{10} \frac{P^2}{P_o^2}$ or SPL = 20 $\log_{10} P/P_o$. P_o, the reference pressure, is taken as 0.0002 dynes per cm^2 and thus the units of SPL are decibels referred to 0.0002 dynes per square centimeter.

Overall SPL values

To obtain a general idea of the magnitude of the readings presented in this article, general overall SPL values are presented in Table 1.

All of the noise levels presented in this article are sound pressure levels in decibels (referred to 0.0002 dynes per cm^2). correspondingly. noise levels presented in the various legal. insurance, and company specifications are usually in the same units. The instrument used for measurements in the 1.000 ton plants was a General Radio Co.—Model 1558A octave band noise analyzer. For 600 ton plant measurements, a Herman Hosmer Scott sound level meter Type 410B and sound analyzer type 420A were used.

The human ear is sensitive to frequencies between 20 and 10,000 cycles per second but the physical and psychological response to different frequencies vary, the higher audible frequencies being the more damaging. Thus a single overall SPL reading is not a complete description of the noise since what is needed is the noise intensity as a function of frequency. It is customary to divide the frequency spectrum into bands (one typical division being ,20 to 75, 75-150, 150-300. etc. up to 4800 to 10.000 cycles per second) and then to make measurements in each band. Where the upper frequency is twice the lower frequency the band is known as an octave. The data presented herein consists of frequency band readings and one overall reading.

Table 1. General overall SPL values.

Source	SPL (re 0.0002 dynes/cm^2)
Automobile horn at 3 ft.	115 (2)
Inside DC-6 Airliner	105 (2)
Air Compressor at Street construction site	102 (1)
N. Y. City Subway Train (Interior)	100 (1)
Inside auto at 50 mile/hr.	94 (1)
Inside bus at starting	92(1)
Normai N. Y. City traffic	88(1)

(1) M. W. Kellogg Company readings. (2): Published data

Table 2. Limiting noise levels established by California.

Frequency Band	Octave Band SPL (decibels re 0.0002 dynes /cm^2) Exposure Time (per normal work day)		
cycles / sec.	5 or more hrs.	2½ hrs.	1¼ hrs.
20-75	110	113	116
75-150	102	105	108
150-300	97	100	103
300-600	95	98	101
600-1200	95	98	101
1200-2400	95	98	101
2400-4800	95	98	101
4800-10,000	95	98	101

Specifications are required

In designing any plant for acceptable noise levels, specifications are required. Various government agencies, insurance companies. manufacturing companies and scholarly experts have prepared such specifications but no universally agreed upon standard exists jn the chemical industry.

In Table 2 *is* an extract from Group 6.1 Noise Control Safety Orders, State of California, Artical 55 Standards for Noise Control presenting limiting noise levels in various frequency bands for different exposure times.

If the limits are exceeded for the specified durations, the use of ear protectors is indicated.

It is possible to sum the SPL values in the frequency bands to give an overall SPL value. The curve in Figure l is useful in summing noise levels. Using the curve we note that the addition of two equal intensity sources increases the overall level by 3 decibels and the addition of two sources 10 decibels apart produces a negligible increase (0.44 db) in the overall level.

A typical example of this addition is the sum of the frequency bands of the California Noise Control Safety Levels presented in Figure 2.

The overall SPL is 111.3 or approximately 111 decibels.

In examining the California Noise Control Safety Leveïs three important features become apparent.

First: the greater permissible noise level in the lower frequencies.

Second: the introduction of an important variable from the safety point of view - the time of exposure.

Third: the purpose of the Orders. the prevention of hearing damage.

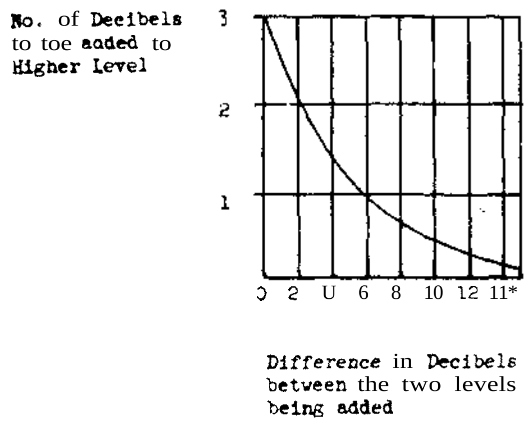

Figure 1. Curve above is useful in summing noise levels.

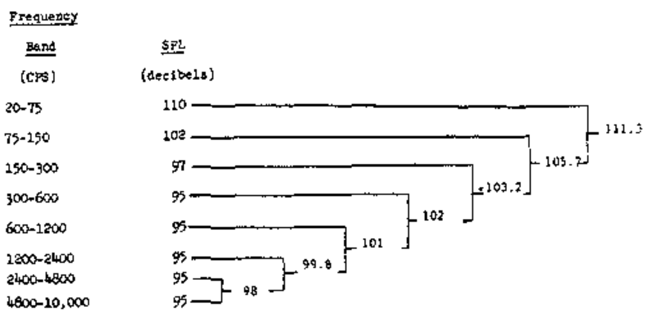

Figure 2. A typical example of addition of levels is the sum of the frequency bands noted above.

What the data shows

Data has been classified according to size of plant (600 or 1.000 con per day) and by type of operation (normal or start-up) Figures 3-8. Plot plans showing the points of measurement are included. In determining whether the noise levels are reasonable. comparison should be made with a Standard. We suggest that for the present. comparison be made with the Noise Control Safety Levels. State of California. It should be emphasized again that these levels are suggested limitations with avoidance of hearing damage as the criterion.

Comparison with the State of California levels shows the following:

600 Ton Plant-Normal Operation:
All points, except reformer furnace burner room meet the extended period safety leveSs. However, this room has low operator attendance requirements (less than 1¼ hours a day).

1.000 Ton Plant-Normal Operation:
Of the 36 readings taken, seven do not meet the State of California Safety Levels. Four of these points are in the burner area and the remaining three are in the compressor area. The burner area is an area of low operator attendance. It should be noted that the hogging jet was in operation in the compressor area during the period of data collection and therefore values obtained in the immediate vicinity of the jet may be higher than normal.

600 Ton Plant Start-Up (No Silencers):
An examination of the data indicates that three fourths of the ratings exceed the California Safety Levels.

These values will exist during every startup. The first startup with its many catalyst preparation steps has taken from one to three months: duration dependent on the extent of commissioning problems. However. subsequent startups are of short duration with atmospheric gas venting restricted to less than one day's duration.

1.000 Ton Plant - Startup (With Silencers):
Considering operator attendance requirements, all points except location 8, taken at grade below the air compressor vent. meet the California Safety Levels. Dependent on individual requirements, additional noise attenuation can be provided by means of a larger silencer and acoustical treatment. It was not possible to secure noise level readings while venting upstream of the high temperature shift converter. These values. however. should be somewhat higher than the reported values taken while venting upstream of the methanator.

Some observations have been made

An analysis of the data coupled with a knowledge of the installation and our operating experience. yields the following observations:

1. The most intense noise sources are the startup vents. Silencers do reduce these levels. This observation has been substantiated by resident personnel at 600 ton plants who were present both before and after installation of silencers on atmospheric vent piping. They reported a noticeable noise reduction but, unfortunately, numerical data to confirm this observation is unavailable.

2. Observations of the 1,000 ton plant at startup give indications that less than the expected noise attenuation was achieved while venting to atmosphere through the silencers. This is currently being investigated, and further data collection and evaluation is contemplated in the near future. One possible explanation is that other noise sources previously masked by the unsilenced vents are now the major noise producers. With this in mind. pressure reducing stations and pipe lines discharging to the atmospheric vent stacks are being reviewed. If pipe lines or pressure reducing stations are now dominant noise sources then acoustical treatment such as insulation and jacketing would be required to further attenuate noise levels.

3. If noise attenuation lower than the reported data is desired at specific equipment locations. then a variety of treatment techniques can be employed. These include not only silencers and acoustical insulation but also barriers. furnace air intake mufflers, energy absorption devices, and other plant design techniques. For confined areas of infrequent operator attendance, the use of ear protectors by operating personnel is an economical alternative.

4. It is possible for a plant to meet the requirements of the California Noise Control Safety Orders and still exceed the levels that are deemed acceptable by the plant or the local community. In the absence of plant or community specifications. actual noise

600 TPSD AMMONIA PLAKT NOISE LEVELS •
NORMAL OPERATION

RECORDED SOUND PRESSURE LEVELS (db re 0.0002 DYNES/CM²) FOR INDICATED FREQUENCY BANDS (CPS)

LOCATION OF NOISE MEASUREMENT	OVERALL	20-75	75-150	150-300	300-[illegible]	[illegible]-1200	1200-2400	2400-4800	4800-9600	9600-20KC
CALIFORNIA NOISE CONTROL SAFETY LEVELS		110	102	97	95	[illegible]5	95	95	95 (4800-10000)	
1- IN CONTROL ROOM	70	67	53	52	38	27	25	29	24	—
2- OUTSIDE CONTROL ROOM - SOUTH SIDE	95	84	81	87	77	77	68	67	63	57
3- ON AIR COMPRESSOR PLATFORM	94	80	82	82	80	82	84	85	77	73
4- OM REFRIGERANT COMPRESSOR PLATFORM	94	81	81	84	80	81	82	83	75	69
5- OM SYN «AS COMPRESSOR PLATFORM	99	81	85	ft*	63	88	86	92	84	81
fe- SOUTH-WEST CORNER OF BATTERY LIMITS	85	80	76	76	72	71	73	70	66	61
7- NORTH-WEST CORNER OF BATTERY LIMITS	83	75	74	75	69	72	71	63	42	36
8- NORTH-EAST CORNER of BATTERY LIMITS	90	83	74	77	76	74	72	69	60	49
9- SOUTH-EAST CORNER Of BATTERY LIMITS	80	74	73	72	68	66	fe4	62	52	43
10- BURNER END OF AUXILIARY BOILER - AT GRADE	101	93	92	94	89	84	82	83	79	71
11- NORTH SIDE OP METHANATOR AT GRADE	95	89	85	84	80	78	76	75	70	60
12- SOUTH SIDE OC METHANATOR AT GRADE	94	78	86	84	79	79	78	73	74	69
13- SOUTH SIDE Of CO_2 STRIPPER	99	82	86	SS	84	63	87	85	88	85
14- BETWEEN TWO SOLVENT CIRCULATION PUMPS	96	79	80	84	88	82	81	sa	76	72
15- WEST END OF PLANT; UNDER PIPE fiACK.	85	77	74	76	76	63	63	73	65	59
16- IN WATER TREATING BLDG.	84	76	75	75	74	73	73	76	66	6O
17- IN PRIMARY REFORMER BURNER SHACK	114	101	104	99	101	100	103	106	106	102
18- BETWEEN PRIMARY & SECONDARY REFORMERS	95	86	86	82	79	76	77	77	74	70
19- UNDER PIPE RACK - NEAR REFRIG FLASH DRUMS	94	80	85	83	79	79	77	86	77	72
20- UNDER ftft RACK - EASTERN PART OF PLOT	93	M	82	83	79	80	81	fcO	76	72

600 TPSD AMMONIA PLANT NOISE LEVELS - (VENT SILENCERS NOT PROVIDED)
START-UP OPERATION

THE FOLLOWING MEASUREMENTS WERE RECORDED WHILE VENTING UPSTREAM OF THE SHIFT CONVERTER AT THE TOP OF THE STEAM DRUM STRUCTURE (70% OF NORMAL FLOW)

	OVERALL	18.75-37.5	37.5-75	75-150	150-300	300-600	600-1200	1200-2400	2400-4800	4800-9600	9600-19.2KC
tl- IN WATER TREATING AREA	100	82	64	89	92	92	88	91	94	87	69
22- 35' FROM BURNERS ON AUXILIARY BOILER	98	90	93	90	91	88	83	86	87	82	67
23- ON BURNER PLATFORM OF AUXILIARY BOILER	116	99	109	103	112	108	104	101	98	97	85
24- 20' SOUTH OF DOOR TO LABORATORY	101	80	86	93	94	96	93	95	97	93	76
25- ON STEAM DRUM PLATFORM - 8' FROM VENT	120	HO	108	105	112	111	168	ut	117	113	97
26- IN PRIMARY REFORMER BURNER SHACK	108	95	98	97	100	96	98	104	102	90	90
11- ON PLATFORM OF SYN. GAS COMPRESSOR	107	90	95	86	91	33	96	101	103	100	86
28- ON PLATFORM OF REFRIGERANT COMPRESSOR	107	90	91	86	89	90	95	99	101	97	93

Figure 3. Noise levels in a 600 ton ammonia plant; normal operation.

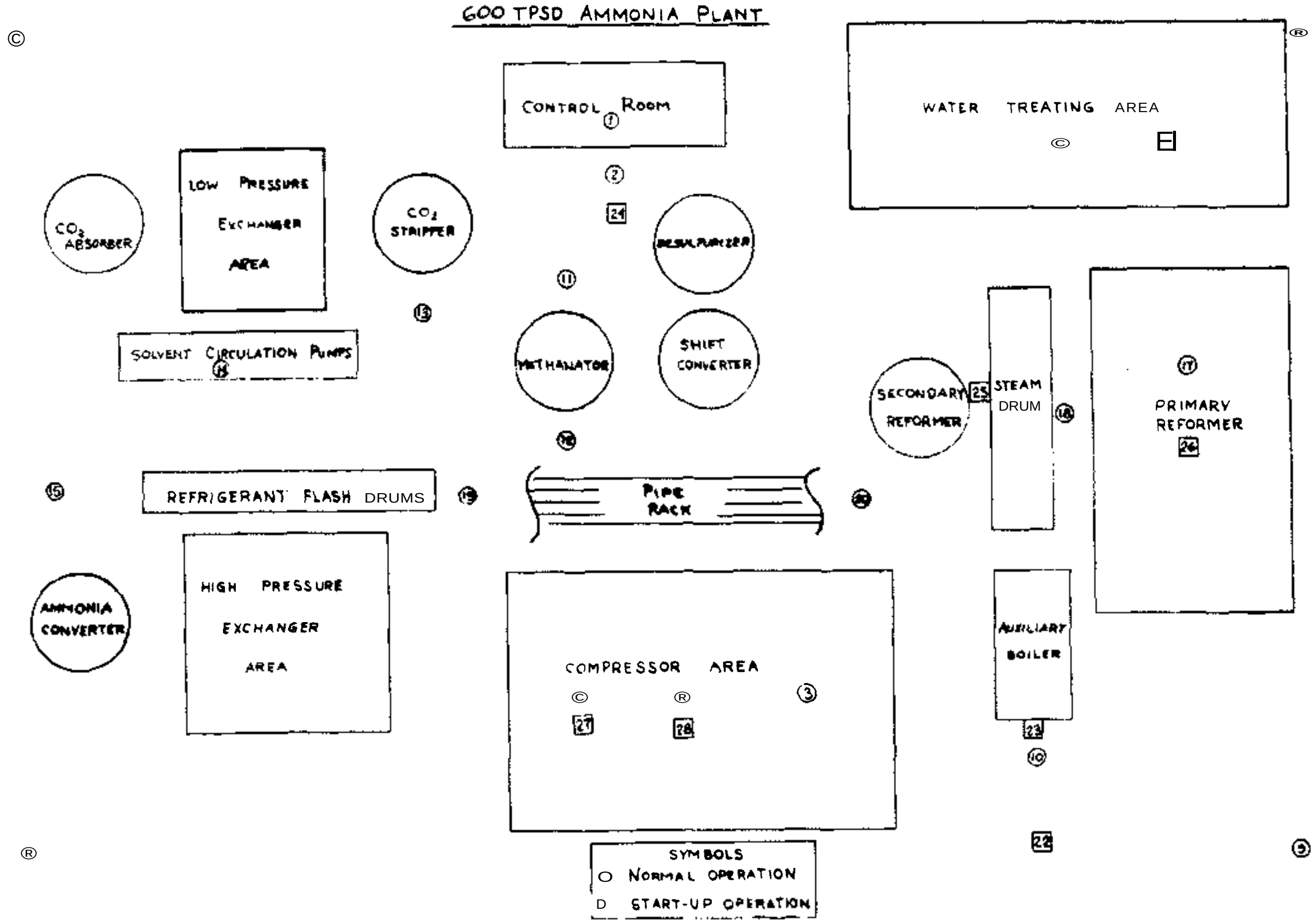

Figure 4. Plot plan of 600 ton plant showing measurement points.

1000 TPSD AMMONIA PLANT NOISE LEVELS – (VENT SILENCERS PROVIDED)
START-UP OPERATION

THE FOLLOWING READINGS WERE RECORDED DURING START-UP, WHILE VENTING UPSTREAM OF METHANATOR AND FROM AH COMPRESSOR EXHAUST. (FLOWS APPROXIMATELY 62% OF NORMAL)

RECORDED SOUND PRESSURE LEVELS (db n 0.0002 dynes/cm²) FOR INDICATED FREQUENCY BANDS (CPS)

LOCATION OF READING	OVERALL	18.75 - 37.5	37.5 - 75	75 - 150	150 - 300	300 - 600	600 - 1200	1200 - 2400	2400 - 4800	4800 - 9600	9600 - 19.2 k
CALIFORNIA NOISE CONTROL SAFETY LEVELS			110 (37.5-75)	102	97	95	95	95	95	95 (4800-9600)	
I- EAST BATTERY LIMIT	W	83	82	79	78	75	73	V	75	76	66
i- IN PRIMARY REFORMER BURNER SHACK	104	96	91	96	95	96	92	91	94	97	91
3- BETWEEN PRIMARY & SECONDARY REFORMER AT GRADE	101	86	88	91	90	86	88	93	93	95	88
4- NORTH END OF STEAM DRUM PLATFORM	100	86	87	ee	88	85	ee	91	94	90	8!
5- SOUTH END OF STEAM DRUM PLATFORM	104	86	ee	89	97	99	9+	94	96	90	«S
6- ON BURNER PLATFORM OF AUXILIARY BOILER	108	92	104	96	100	102	95	93	93	92	91
7— SOUTH OF AUXILIARY BOILER - ABOUT 20' AWAY	101	89	94	91	94	89	64	93	94	89	81
e- Ar GRADE; BELOW AIR COMPRESSOR VENT	107	86	88	93	94	93	97	103	103	99	90
9- NORTH OF SECONDARY REFORMER - ABOUT 20' AWAY	101	60	87	•6	et	84	85	91	94	97	92
10- EAST OF DESULFURIZER; ON ROAD	101	64	84	82	92	85	e*	92	W	96	90
11- NORTH BATTERY LIMIT	90	79	•1	74	79	76	77	81	6S	78	«7
12 IN CONTROL MOM	81	77	73	74	65	«J	58	62	64	59	49
13- NORTH OF METHANATOR	45	82	85	84	u	t/	83	87	85	88	<<l
(4- UNDER PIPE RACK - NORTH (f SYN-GAS COMPRESSOR	100	84	86	86	M	•7	88	94	94	93	90
15- SOUTH BATTERY LIMIT	99	84	88	87	91	86	67	92	93	90	81
16- NORTH SIDE w CO_2 STRIPPER - ABOUT 20' AWAY	92	81	84	•3	82	81	80	64	84	81	77
I? - IN LOW PRESSURE EXCHANGER AREA	91	80	83	82	82	79	80	88	81	76	69
18- NORTH OF CO_2 ABSORBER - ABOUT 5' AWAY	57	60	a0	80	80	76	74	76	75	72	<<t
19- WEST BATTERY LIMIT	87	82	83	80	7*	71	72	75	77	72	64

Figure 5. Noise levels in a 1,000 ton ammonia plant; at start-up.

levels can vary over a wide range from values that allow easy plant communication and community comfort to shattering values that are uncomfortable, fatiguing and potentially harmful.

The effect on Communications

With regard to plant communication, the following observations are representative of opinions by resident personnel on the earlier units.

a). On the first 600 ton plant, communication at startup was extremely difficult.

b). After the addition of silencers to this plant, communication at startup as well as normal operation did not present any problems except for some difficulty in the compressor and furnace areas.

c). On the silenced 1,000 ton plant, communication during startup and normal operation is acceptable except for some difficulty in the compressor and furnace areas, and adjacent pipe rack.

1000 TPSD AMMONIA PLANT NOISE LEVELS

NORMAL OPERATION

LOCATION OF NOISE MEASUREMENT	RECORDED SOUND PRESSURE LEVELS (db re 0.0002 DYNES/cm^2) FOR INDICATED FREQUENCY BANDS (CPS)										
	OVERALL	18.75-37.5	37.5-75	75-150	150-300	300-600	600-1200	1200-2400	2400-4800	4800-9600	9600-19.2K
CALIFORNIA NOISE CONTROL SAFETY LEVELS			110(20-75)	102	[illegible]	95	95	95	95	95 (4800-10000)	
1- IN PRIMARY REFORMER BURNER SHACK	113	88	92	97	100	100	100	100	[illegible]	101	86
2- SOUTH-WEST CORNER OF STEAM DRUM PLATFORM	95	78	82	84	87	84	[illegible]	89	92	80	69
3- NORTH-WEST CORNER OF STEAM DRUM PLATFORM	92	76	83	83	85	80	80	85	[illegible]	75	66
4- TOP EXTERNAL PLATFORM OF PRIMARY REFORMER - NW CORNER	98	79	[illegible]	91	90	90	84	89	91	86	71
5- SAME PLATFORM AS (4) - EAST SIDE OF [illegible]	94	79	85	84	67	86	77	74	[illegible]	80	68
6- BOTTOM EXTERNAL PLATFORM OF PRIMARY REFORMER - 3' FROM [illegible] BURNER - (NW SIDE)	112	81	92	97	93	93	97	99	103	104	93
7- SOUTH SIDE OF WATER TREATING AREA.	99	81	[illegible]	89	[illegible]	89	87	92	94	91	78
8- NORTH BATTERY LIMIT	92	82	86	86	[illegible]	[illegible]	80	82	83	75	67
9- 10' SOUTH OF CONTROL HOUSE MAIN DOOR	96	82	61	88	89	87	[illegible]	87	87	74	70
10- IN CONTROL ROOM	81	74	74	76	74	71	73	72	41	67	67
11- 15' NORTH OF SECONDARY REFORMER	99	85	[illegible]	89	90	88	86	81	94	87	77
12- ON ROAD EAST OF DESULFURIZERS	96	83	88	89	89	87	67	88	[illegible]	84	71
13- AT [illegible]; SOUTH-EAST SIDE OF SHIFT CONVERTER	95	86	91	[illegible]	89	[illegible]	86	89	96	82	70
14- UNDER RACK, 10' WEST OF PRIMARY REFORMER FURNACE	106	14	92	91	91	10	[illegible]	99	93	86	79
15- ON LOWER BURNER PLATFORM OF AUXILIARY BOILER	110	92	106	99	100	101	102	97	97	89	85
16- 15' SOUTH OF (15) AT GRADE	101	[illegible]	99	91	92	97	93	92	91	89	91
17- WEST OF AUXILIARY BOILER	94	88	90	86	87	94	83	[illegible]	88	[illegible]	72
18- NORTH OF AIR COMPRESSOR UNDER RACK	99	80	67	89	91	[illegible]	98	96	14	86	77
19- 5' SOUTH OF METHANATOR	94	81	87	87	91	87	66	89	87	[illegible]	71
20- 13' NORTH OF METHANATOR	[illegible]	80	85	86	91	89	86	91	86	78	77
21- UNDER RACK, NORTH OF SYN. GAS COMPRESSOR	100	83	85	86	90	86	89	97	96	90	79
22- 5' SOUTH OF CO_2 STRIPPER	95	[illegible]	[illegible]	88	88	85	86	90	91	[illegible]	74
23- 15' NORTH OF CO_2 STRIPPER	93	78	83	83	84	78	80	[illegible]	84	76	[illegible]
24- 5' FROM LEAN SOLVENT CIRCULATION PUMP	95	[illegible]	61	85	88	84	86	89	91	83	88
25- CENTER OF LOW PRESSURE EXCHANGER AREA	92	71	77	81	86	82	[illegible]	80	92	71	89
26- 5' NORTH OF CO_2 ABSORBER	89	77	71	63	[illegible]	76	79	76	76	75	69
27- 10' SOUTH OF CO_2 ABSORBER	93	77	79	81	67	80	[illegible]	84	84	80	69
28- WEST END OF REFRIGERANT FLASH DRUMS - ON PLATFORM	90	74	76	81	63	84	76	63	[illegible]	78	79
29- 10' SOUTH-WEST OF AMMONIA CONVERTER	87	74	77	76	75	71	71	72	74	[illegible]	[illegible]
30- SOUTH BATTERY LIMIT	95	87	88	86	67	87	67	88	89	82	73
31- CENTER HIGH PRESSURE EXCHANGER AREA	91	82	81	81	84	77	71	84	83	76	66
32- 4' EAST OF AMMONIA CONVERTER	89	78	77	71	82	17	77	80	60	71	47
33- UNDER RACK, CENTER OF PLOT	99	79	60	85	81	87	89	11	95	89	77
34- ON SYN. GAS COMPRESSOR PLATFORM	96	71	78	63	87	[illegible]	87	90	92	84	72
35- ON REFRIGERANT COMPRESSOR PLATFORM	104	70	71	85	10	89	92	98	97	[illegible]	78
36- ON AIR COMPRESSOR PLATFORM	104	70	71	92	91	89	92	97	98	88	74

Figure 7. Noise levels in a 1,000 ton ammonia plant; normal operation.

It is of interest to note that comparison of the data presented herein to speech interference levels presented in the literature would probably not be consistent with the above observations. In a recent article titled "Relieving Acoustic Fatigue" by G. C. Tolhurst (Machine Design - August, 1966), however, the following is noted - "A signal to noise ratio should be at least plus 12 db although it is possible to maintain good intelligibility of simple. connected discourse at a minus 8 db if the channel is wide enough". This point certainly confirms our observations.

Client noise requirements vary and in some cases are non-existant or unspecified. Similarly. communities bordering on industrial plants have varying noise ordinances or none at all. Therefore, with so subjective a topic, unilateral establishment of "proper" noise levels by competitive contractors is extremely difficult. Thus, in the present age of high-capacity plants, with 1.500 ton per day plants in the offing, we suggest that definite noise standards be established for the chemical industry. Such standards could be graded to reflect the varying requirements that industrial plants and local communities may impose. However, a more suitable approach' would be to adopt a minimum Standard, thereby allowing plants and communities with more stringent requirements to impose individual solutions tailored to satisfy the local environment.

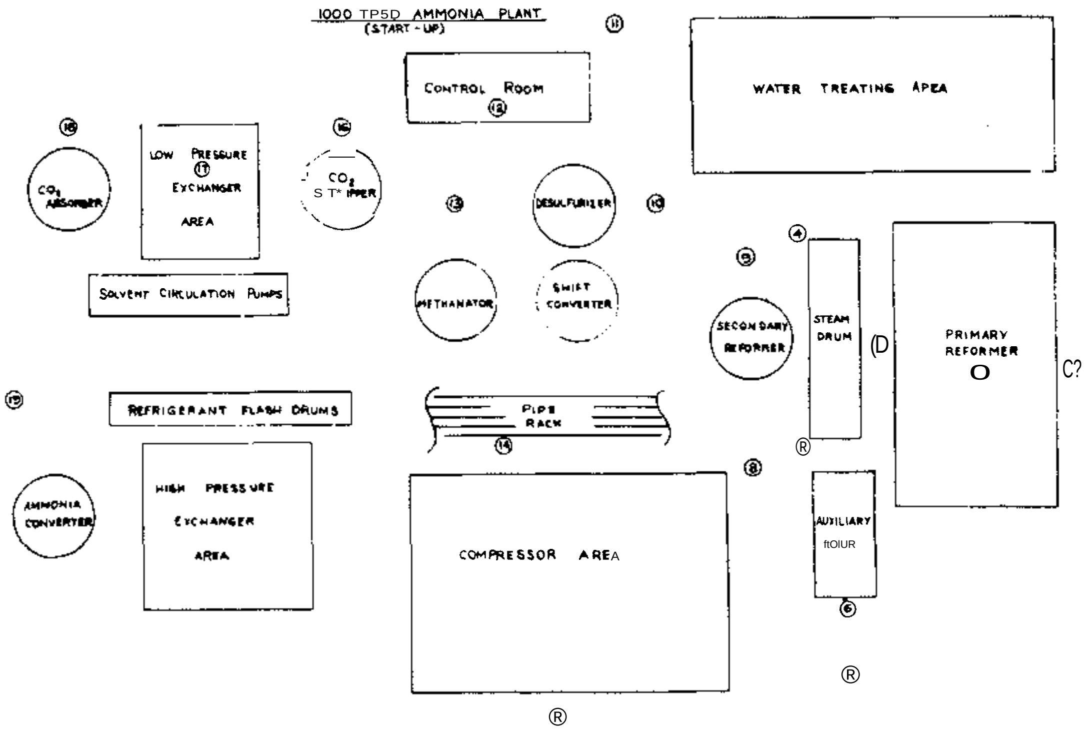

Figure 6. Plot plan of 1.000 ton plant showing measurement points (Start-up).

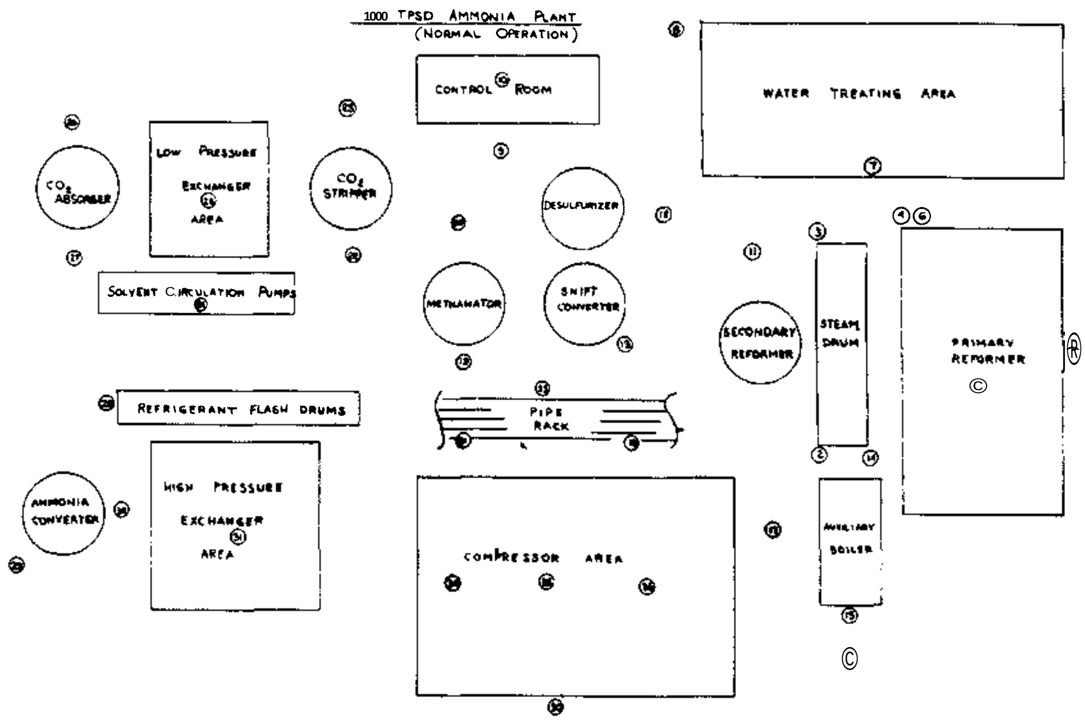

Figure 8. Plot plan of 1.000 ton ammonia plant showing measurement points (normal).