Causes of Shutdowns in Ammonia Plants

In addition to classifying the major causes of shutdowns, this survey helped identify the most hazardous areas of operation in large tonnage ammonia plants.

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This article reports on a survey undertaken to identify the causes of shutdowns in large tonnage ammonia plants. Seven 600-, two 750-, twelve 1,000, and one 1,500 ton/day ammonia plants participated in the survey, representing about two-thirds of the large tonnage, high pressure, centrifugal-type plants in North America. Eighteen of these plants were designed by M. W. Kellogg, one by Bechtel, two by C. F. Braun, and one by Chemico. The survey period covered operations from January, 1969 to May, 1971.

The primary causes of shutdowns were divided into five categories, i.e., instrument failures, electrical failures, major equipment failures, maintenance turnarounds, and "other". In addition, predominant major equipment problems were identified and areas where plant safety could be improved were noted.

Table 1
Annual downtime for large tonnage ammonia plants(1)

Pre-1968 Ammonia Plants		1968-1969 Ammonia Plants	
No. of Plants	Downtime Days	No. of Plants	Downtime Days
1	25	1	20
1	35	2	25
4	45	1	35
3	50	1	40
6	60	1	100
1	100		
Average = 52 days		Average = 41 days	

(1)Based on operation for a 28 month period from January, 1969 to May, 1971.

Downtime & equipment failures

One interesting piece of information obtained was the high average number of days downtime/yr:

Total survey average
49 days/yr.
9 shutdowns/yr.

This is broken down into the following categories:

1. Pre-1968 ammonia plants (16 facilities)
   52 days/yr.
   10 shutdowns/yr.
2. 1968-69 ammonia plants (6 facilities)
   41 days/yr.
   7 shutdowns/yr.

It can be readily seen that most of these plants have to operate at 107% of daily design capacity to meet their annual design production.

Downtime varied greatly between plants in each category. Table 1, which illustrates the fluctuations, shows there is a significant difference between the "newer" and the "older" ammonia plants. The six plants surveyed in the younger age group had about 75% of the average downtime of the older plants; however, if the two 100 day/yr. plants are omitted the difference is even greater, i.e., about one-half. This marked reduction in downtime is mainly due to improved equipment performance in the reforming section. Primary and secondary reforming area related equipment failures resulted in an average downtime of 19 days/yr. in the pre-1968 plants, and only 7.5 days/yr. in the 1968-69 plants.

One difference is undoubtedly age itself, an especially important factor for reformer tubes, convection section coils, and waste heat boiler tubes and insulation. Some design and specification changes have been made to up-grade the equipment in the newer plants, hence improving reliability. A few of these changes are increased tube wall thickness, improved outlet manifold design, better insulation in transfer header/secondary reformer/WHB system, increased capacity of auxiliary or

Table 2
General classification of major equipment failures

	Pre– '68 Plants (16 Plants) Days(1)	%	'68–'69 Plants (6 Plants) Days(1)	%	Total (22 Plants) Days(1)	%
Primary Reforming	13	(41)	½	(3)	9½	(34)
Secondary Reforming	6	(21)	7	(36)	6½	(24)
Purification	2	(7)	5	(27)	3	(10)
Synthesis Loop and Refrigeration	2	(5)	½	(2)	1	(5)
Major Compressors and their Turbines	7	(23)	6	(31)	7	(24)
Steam and Water Systems, Pumps, Misc.	1	(3)	–	(1)	1	(3)
Total	31	(100)	19	(100)	28	(100)

(1) Average number of downtime days/yr./plant.

Table 3
Top 10 major equipment failures causing the most downtime

Pre-1968 Ammonia Plants	'68–'69 Ammonia Plants	All Plants in Survey
Tubes & Risers	Waste Heat Boilers	Waste Heat Boilers
Waste Heat Boilers	Co_2 Purification Exchangers	Tubes & Risers
Syn Gas Compressor	Syn Gas Compressor	Syn Gas Compressor
Transfer Header	Air Compressor	CO_2 Purification Exchanger
Convection Section & Piping	Refrigeration Compressor	Transfer Header
Refrigeration Compressor	Syn Gas Catalysts	Convection Section & Piping
I D Fan	Convection Section & Piping	Refrigeration Compressor
Air Compressor	Syn Loop Exchangers	Air Compressor
Converter	Syn Gas Exchangers	I D Fan
Sec. Reformer Piping & Flanges	Relief Valves	Sec. Reformer Piping & Flanges

offsite boilers, and improved 1,500 lb./sq. in. gauge steam pressure control system. It is also very probable that the newer plants improved operation at the early stages because of experience gained from the older plants.

The biggest problem with many of the newer plants has been the CO_2 purification exchangers, most of which are in MEA service. They have also had somewhat more problems with the air and syn gas compressors than the older plants. To date, the newer, larger tonnage ammonia plants have had the majority of their problems in the purification and compression areas, as shown in Table 2.

Table 3 lists the "top 10" major equipment problems areas for pre-1968 ammonia plants, the 1968-69 plants, and the total of all surveyed ammonia plants. See Table 5 for a complete, detailed listing of equipment failures.

It is interesting to note that the first three problem areas in each list of Table 3 account for over 50% of all major equipment failures. There is a significant break between items 3 and 4, but only small differences, in days downtime, between the balance of items on the lists.

Many of the "older" plants have a definite problem in the "tube and riser" area. (Included in this category are collecting manifold cracks and thermowell failures). Of the 16 pre-1968 plants surveyed, only four did not show a shutdown due to "tubes and risers". The average was one shutdown/yr. which lasted 7½ days. Several plants have had 2- and 3 failures/yr. One plant is planning a 100% replacement of reformer tubes in 1972, and some of the other plants are making partial replacements annually.

Waste heat boiler failures appear to be the current number one industry problem on basis of total downtime. The failures have been split between tube and pressure shell failures. The number of failures is not so great, but the repair time required to pull the bundles, repair tubes, and/or repair or reinsulate the shell has been very high; averaging about 23 days/failure. Two plants have had multiple failures and waiting time for parts has been up to 40-50 days. Six of the plants surveyed have reinsulated their waste heat boiler shells. The transfer header failures have been similar to the waste heat boiler pressure shell failures in that a loss of shroud protection and insulation have resulted in ruptured pressure walls. (In one case a loss

Table 4
Classification of downtime and shutdowns of all 22 plants surveyed.

	% of Total Downtime Days	% of Total Number of S/D's
Turnaround	32%	10%
Equipment Failures	59	59
Instrument Failures	2	11
Electrical Failures	2	10
Other	5	10
	100%	100%

Total downtime days from January, 1969 to May, 1971 = 2,571 days.
Total number of shutdowns from January, 1969 to May, 1971 = 466.

of water level resulted in a rupture.) Four of the plants surveyed have relined the transfer header in full or in part.

The greatest number of shutdowns has been caused by failure of the syn gas compressor or its driver. These outages are usually of short duration, averaging about four days each. Bearings and, to a lesser extent, governor problems are most common. The overall average downtime of four days is somewhat higher than would be anticipated, but it is influenced by a few major failures of balance pistons, thrust bearings, turbine seal rings, etc., which sometime necessitate rotor and/or diaphragm replacement. Most plants are now scheduling major inspections every 2- to 3 yr. for all compressor trains.

Another item of concern is the number of exchanger failures throughout the industry. The total number (excluding WHB's) ranks third behind the "syn gas compressor" and "tubes and riser" failures. Most of the failures have been in the CO_2 purification exchanger, BFW preheat exchangers, and syn loop exchangers. Usually downtime from these failures is of short duration, averaging about 2 days/shutdown, and the repairs are of a tube plugging nature. Some design changes have resulted when buying new tube bundles, and most of the exchangers in MEA service now have stainless steel tubes in place of the original carbon steel. There has also been a bolt problem with the internal heads in some lean-rich MEA exchangers.

Seventy-five percent of the plants surveyed used MEA as the scrubbing media, so it was difficult to effectively evaluate other systems. However, there are generally more corrosion problems with MEA than Sulfinol or Hot Carbonate systems. It should also be pointed out that while only one shutdown was attributed to a CO_2 stripper leak, almost all plants are cladding the shells with stainless steel, or at least coating the internal shell. Many plants experiencing stripper leaks have repaired them in run. Some plants are also using a corrosion inhibitor to further protect the MEA system.

It was surprising to note that catalysts are not usually a primary cause of sudden shutdowns. They sometimes add impetus towards calling a turnaround, but frequently a plant will limp along until a major outage occurs which will allow changeout.

Shutdown classifications

One of the primary purposes of the survey was to classify various major causes of shutdowns. Table 4 summarizes the categories, and Table 6 provides a more complete breakdown.

Since 91% of the total downtime is related to turnarounds and equipment, major efforts are, and should be, placed on them. Instrument and electrical problems play a larger part when number of shutdowns are the criteria, but as a rule they result in short shutdowns, usually

Table 6
Number of shutdowns and downtime of large tonnage ammonia plants(1)

	Instrument Failures		Electrical Failures		Turnarounds		Equipment Failures		"Other" Shutdowns		Total		Longest Run
	No.	Days(4)	No.	Days(4)	No.	Days(4)	No.	Days(4)	No.	Days(4)	No.	Days(4)	Time, Days(3)
'63-'64 Ammonia Plants													
Totals (16 plants)	35	39	36	43	37	611	219	1,195	40	119	367	2,007	
Avg./yr./plant	1	1	1	1	1	16	6	31	1	3	10	52	161
'68-'69 Ammonia Plants													
Totals (6 plants)	15	16	9	15	12	200	54	310	9	23(2)	99	564	
Avg./yr./plant	1	1	½	1	1	14½	4	22½	½	1½	7	41	199
Total (22 plants)	50	55	45	58	49	811	273	1,505	49	142	466	2,571	3,762
% of Total	11%	2%	10%	2%	10%	32%	59%	58½%	10%	5½%			
Overall average/yr./plant	1	1	1	1	1	15½	5	29	1	3	9	49	171

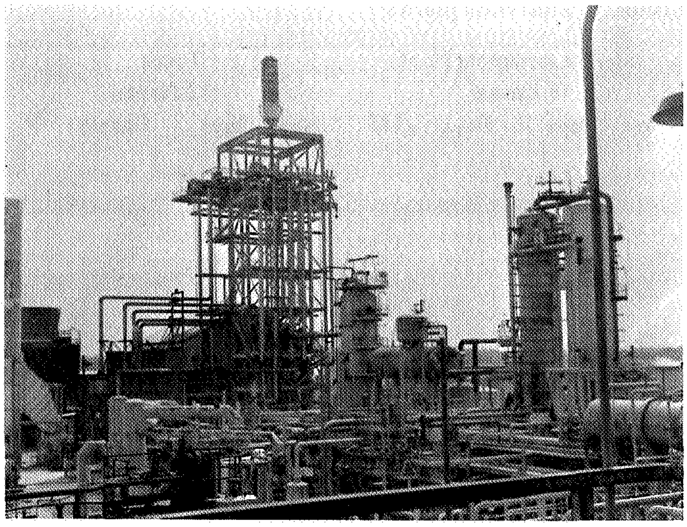
(1) Survey covers operations from January, 1969 to May, 1971 (28 months).
(2) Corrected to delete downtime resulting from high ammonia inventory.
(3) Longest run time is number of consecutive "production days" in which ammonia was produced.
(4) Number of days downtime attributed to respective failure.

Table 5
Equipment failures in large tonnage ammonia plants[1]

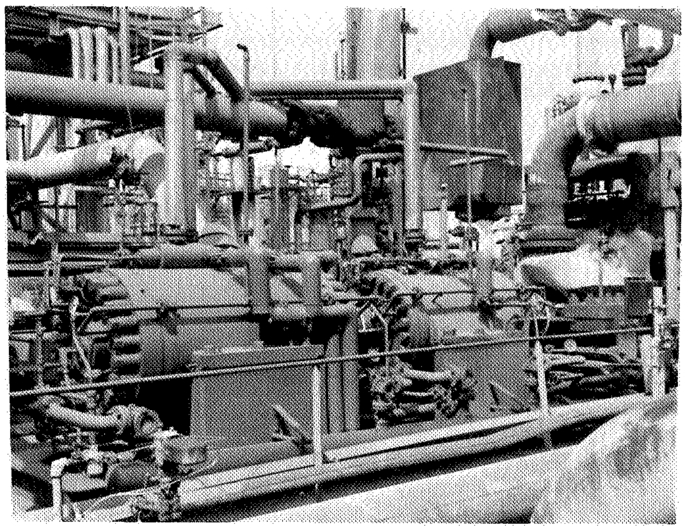
CLASSIFICATION OF FAILURE	'63–'67 Ammonia Plants (16 Plants)			'68–'69 Ammonia Plants (6 Plants)			Totals (22 Plants)		
	No.	Days	Days/Yr.[2]	No.	Days	Days/Yr.[2]	No.	Days	Days/Yr.[2]
Primary Reforming area									
Tubes & Risers	37	273		–	–		37	273	
I.D. Fan	10	47		–	–		10	47	
Transfer Header	7	91		–	–		7	91	
Catalyst	3	31		–	–		3	31	
Convection Section & Piping	6	66		1	7		7	73	
Sub total	63	508	13	1	7	½	64	515	10
Secondary Reformer & WHB's									
Waste Heat Boilers	10	207		3	96		13	303	
Piping & Flanges	9	41		–	–		9	41	
Sub total	19	248	6	3	96	7	22	344	6½
Purification									
Catalyst	2	7		2	9		4	16	
Exchangers	10	19		2	4		12	23	
CO_2 Purification - Strippers	1	1		–	–		1	1	
- Exchangers	16	36		13	58		29	94	
- Pumps & Piping	5	8		–	–		5	8	
Piping & Flanges	5	9		1	1		6	10	
Sub total	39	80	2	18	72	5	57	152	3
Syn Loop & Refrigeration									
Exchangers	5	17		4	6		9	23	
Converter	2	42		–	–		2	42	
Piping & Flanges	4	4		–	–		4	4	
Sub total	11	63	2	4	6	½	15	69	1
Compressors & Turbines									
Feed Gas Comp. & Turb.	4	6		–	–		4	6	
Air Comp. Turb.	8	46		6	18		14	64	
Syn Gas Comp. & Turb.	42	149		6	48		48	197	
Refrigeration Comp. & Turb.	13	52		4	15		17	67	
L.O. & S.D. Systems	9	18		3	1		12	19	
Sub total	76	271	7	19	82	6	95	353	7
Steam, Water, Pumps, Misc.									
Pumps	6	23		–	–		6	23	
Piping & Flanges	2	2		–	–		2	2	
Relief Valves	4	3		2	33		6	6	
Misc.	4	8		1	1		5	9	
Sub total	16	36	1	3	4	–	19	40	
Total	224	1,206	31	48	267	19	272	1,473	28

(1) Average number of downtime days/year/plant.

(2) Survey covers operations from Jan. 1969 to May, 1971 (28 months).



The M.W. Kellogg ammonia plant in Hopewell, Va.



A Clark centrifugal syn gas compressor.

lasting less than a day. In some instances they have resulted in major equipment damage, which is the greatest hazard in large plants. About 40% of the plants surveyed have some sort of "uninterruptible power supply" (or auxiliary battery) system. The main support for this type of system is that continuous power to instruments and critical small electrical motors allows a controlled shutdown during a power failure and, in some plants, permits continued operation of the "front-end" of the plant during a short power outage.

An average of all 22 plants showed one 15 day maintenance turnaround/yr. However, about one-third of the plants reported one turnaround for the 28 month survey period, another third reported two, and the last third reported 3 to 5. For many of these plants, especially those reporting low turnaround rates, outages resulting from major equipment failures have been either long enough and/or frequent enough that the annual turnaround was taken during these outages. It is interesting to note that the number of shutdowns from major equipment failures are six times greater than those for turnarounds, and that downtime is about double.

Safety

One of the main objectives of the survey was to identify areas in plant operations which have been the most hazardous. Following are some of the areas:

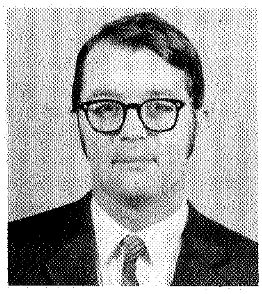
1. Reformer penthouse fires: Three have been reported.
2. Secondary reformer/waste heat boiler area piping and flange fires: Seven major flange fires were reported, and pressure shell ruptures on WHB's have resulted in fires.
3. Oil fires around steam turbines have resulted in a few major and numerous minor fires.
4. Ruptured piping and flange leaks in natural gas and hot syn gas lines and exchangers have resulted in several fires.
5. Leaking seals and flanges in the ammonia refrigeration system have caused several "near miss" accidents.

Most fires occurred at the "weak link" in the system – the flanged joint. Flanged joint rain shields are used by several plants to direct leaking gas in the least hazardous direction or to pipe it to a less hazardous location. Periodic checks for gas leaks throughout the plant can be made as an extra safety precaution.

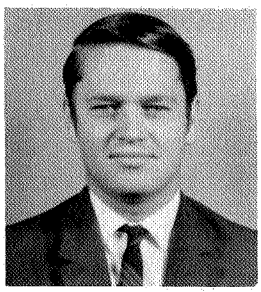
Allied has experienced many of the above mentioned fires and incidents, and to date have been extremly fortunate that no one has been seriously injured. We can only emphasize that care and thoroughness must be exercised when engineering, constructing, and maintaining hot gas flanges and pressure systems.

Acknowledgment

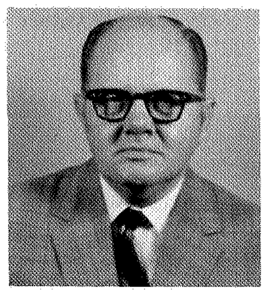
We would like to extend our appreciation to those companies and individuals who participated in the survey and answered the rather lengthy questionnaire. #



WILLIAMS, Gerald P.



SAWYER, J. G.



CLEGG, J. W.

DISCUSSION

Q. I see here where exchangers were the third largest cause of shutdowns. This may be getting back to a previous problem. On the syn gas compressor discharge, our cooler I think uses a carbon steel tubes, SA 106. Could anyone tell me what material are using in this service? Is anyone using any other kind of material for this service?

JIM ROBINETT, Du Pont - Beaumont. To answer that last question, we went to some kind of stainless - I don't remember just what it was in that heat exchanger, mainly because of water side corrosion. In fact, we've gone completely stainless in all of our heat exchangers to stay away from water side corrosion.

Q. One of the large contributors to downtime was the MEA system. Has anyone any leads on some way to prevent this corrosion, any steps at all? Is that considered in the survey?

SAWYER: It has been considered and there are several inhibitors on the market. I'd better not mention any names of companies. This is the main item now under consideration for reducing MEA corrosion problems. And apparently one or two are inhibitor systems relatively effective.

Q. The paper mentioned that the newer plants are having more trouble with the MEA system. Was that more trouble or a greater percentage of the trouble?

SAWYER: It was actually more days downtime, Gene. It was a higher percentage but it was also more days downtime.

Q. Is there any change in the design that's caused that you know of?

SAWYER: Not that I now of. I felt that actually the newer plants have more stainless in them than the older ones.

Q. Is this really because they design the systems tighter so that you're loading up the rich and lean solutions with CO_2 more to cause corrosion? Because I know some gas plants before we started tightening up on the design, did not have this problem under really the same conditions.

SAWYER: I agree. I don't know of any increase in the loadings in the plants that I'm familiar with. The systems are designed about the same, except for possibly materials of construction. So I really can't answer why there have been more problems in the newer plants.

T.C. CARROLL, American Oil: I think one of the main reasons is that with the higher reforming pressures the reboilers are seeing much higher temperatures, and it doesn't take but a few additional degrees in the 250^o range to increase tube-skin temperatures to a point where severe corrosion occurs. I think this is one of the main reasons for increased corrosion.

SAWYER: That's correct. However, in the survey as I recall the reboilers were not the major contributor towards downtime but it was in the lean-rich exchangers and the coolers themselves, not the reboilers. There were a few reboiler failures but not too many.

Q. Fifteen years ago they used to design for about 0.37-0.38 CO_2 loading, and now it's up around 0.5. That's a mol: mol ratio, and I believe this is too high.

SAWYER: Well, I believe, that most of the plants were designed for 0.4 or 0.45, that I'm familiar with at any rate.

HAYS MAYO, Cooperative Farm Chemicals Assn.: At the time I was associated with Hill Chemicals, the Borger plant used a commercially available inhibitor in the MEA system. At one of their 600 ton ammonia plants, Farmland Industries uses a different commercially available inhibitor. In both cases, corrosion has been reduced from about 10- to 20 mils per year to about one to two mils per year. In both cases the MEA concentration has been increased from approximately 20% to more than 25%. Both inhibitors effectively control corrosion.

I believe that Jim Finneran of Kellogg can answer the questions on loading.

JIM FINNERAN, M.W. Kellogg Co.: I assume your pre-1968 plants are all post-about 1965 plants.

SAWYER: You mean actual contract time?

FINNERAN: Startup time.

SAWYER: Right, they are in that neighborhood, '65, '66.

FINNERAN: So we're talking in general of the large and modern plants. I can say that from our point of view the design basis for the MEA systems has not changed from the 1965 plant to the latest ones; that is, in terms of liquid loading or temperatures or pressures within the system. There has in fact been an upgrading in material of construction and I think someone has mentioned here where there has been a tendency to replace carbon steel with alloyed steel. So that the statistical differences that you see are still sort of unexplained.

The materials are better and the process conditions are no worse. It may just be a statistical quirk. I can't explain it.

MAYO: Isn't it possible that this is one of those problems that we all run into when we attempt to sort out the causes of downtime that the more obscure causes tend to be buried in the bigger jobs, and the older plants that were having reformer fires and problems with compressors and reformers were repairing their exchangers during those outages and didn't make note of that fact?

FINNERAN: It's quite possible.

Q. Perhaps mainly operators filled out the questionnaires, but is any operators error type downtimes included in other categories?

SAWYER: We didn't ask for explanations of the "other" category, so I don't know.

ANON: A company at Pocatello told us about their activated carbon filters and sand filters, sidestream filters that they used on their MEA streams, and we continued to use inhibitors but we went home and put some of these sand filters and carbon filters on our two percent sidestream of our MEA. Our MEA went from corrosive yellow to clear white and it stayed this way and our corrosion's been greatly reduced. So I feel good about this.

FINNERAN: The usual design for most of the MEA plants includes an activated carson sidestream filter, but most of them do not use a sand filter. They have the sidestream bag filters, the sidestream carbon drum, and the reclaimer.

TONY TUCKER: African Explosives and Chemical Industries: I notice the transfer line failures are fairly high on your list. And we had trouble with that, the transfer line, it never caused a shutdown but we redesigned it about 18 months ago, a new shroud. We decided to use bubbled alumina. We installed this in March last year. We looked at it in March this year, and it might never have been in service. It was just in excellent condition.

And if anybody is interested in the design, I have it with me here.

SAWYER: I'd like, if I could to get Mr. Clark to comment upon their new transfer header? I guess it's about a year now since they installed their firebrick type with no shroud.

W.D. CLARK, ICI Billingham. We had the original design of transfer line on three units and had much trouble with buckling of the 304 liner, loss of the Insulag and overheating of the pressure shell. On one occasion the liners were so badly buckled that a small dog could not have got along the line. We finally designed and installed a special brick lining, with no inner metal liner and have installed two, and they look good. The third unit has a considerably modified version of the original type and looks like lasting two or three years: when it shows signs of trouble we will fit bricks.