PLANT EXPANSION AND MODIFICATION

GARDINIER NO. 7 PLANT

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In October 1981, Gardinier in East Tampa restarted their No. 7 Contact Acid Plant. This plant was originally a single absorption 800 TPD plant expanded to 1200-1400 TPD in the early seventies, modified in the mid-seventies to double absorption, and has now been expanded by Chemetics International to a capacity of 1850 tons/day of sulphuric acid. This paper will describe the original plant, the modifications to double absorption, and the subsequent expansion, as well as problems associated with the latest startup.

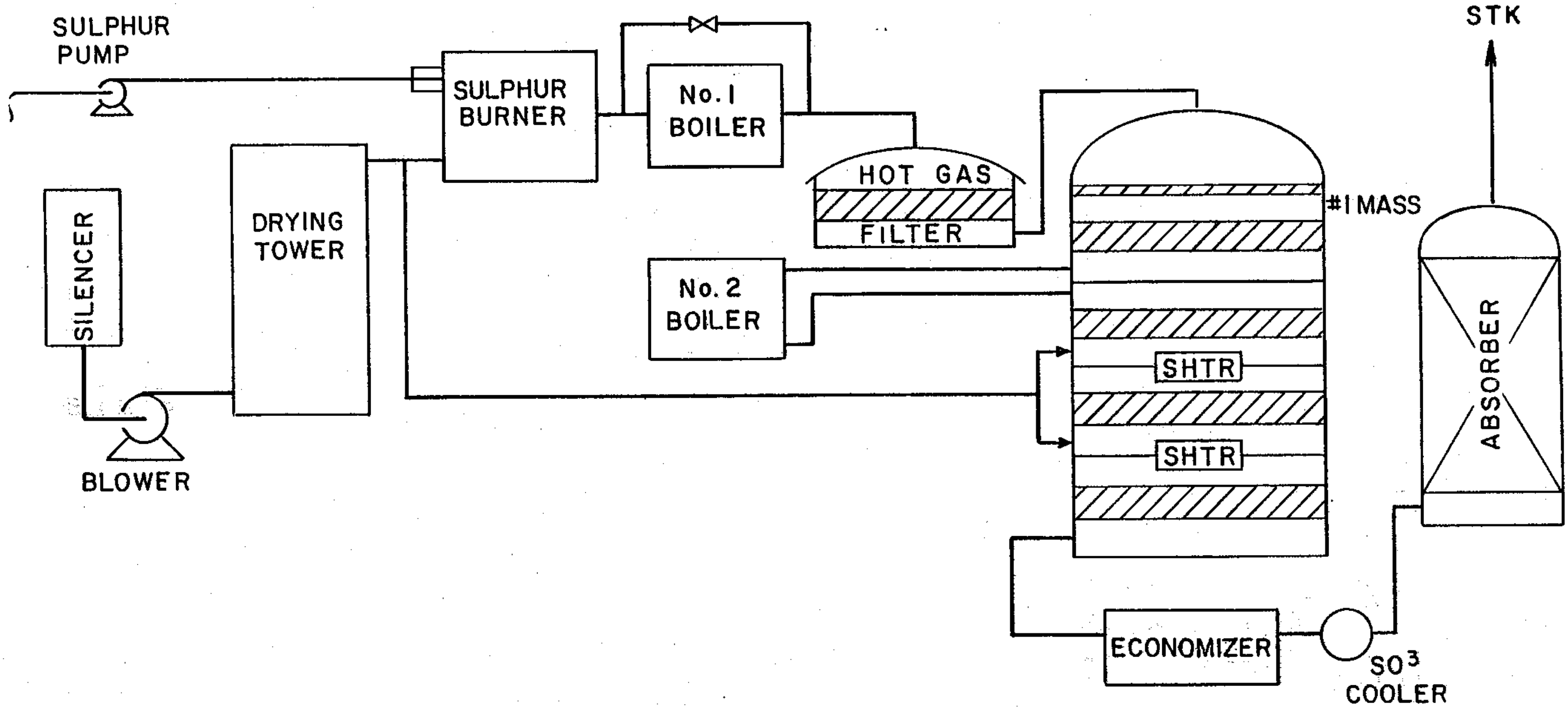
The Original Plant

The single absorption sulphuric acid plant known as Gardinier's No. 7 CAP was originally started in 1961 with a capacity of 800 TPD at 98% conversion efficiency or 1000 TPD at 95% efficiency. The plant was designed by Monsanto Envirochem and erected by Leonard Construction. The plant included a hot gas filter, a first mass split in two layers in a four pass converter, water tube boilers, and both air dilution and steam superheaters after the second and third catalyst masses. The steam system used softened and treated water to produce 300 psi, 650°F steam, used an Elliott condensing turbine drive on the blower, and cooled acid with brackish water in a cast iron pipe cooler. An SO_3 cooler was also used between the economizer and the absorber, rejecting excess heat to atmospheric air. A flow diagram of this plant is shown in Figure 1.

The turbine driving the main blower was then reworked to provide higher capacity on this plant, giving production rates in the early seventies of 1300-1400 TPD at 98% conversion efficiency.

With the flow arrangements shown in Figure 1 and the relatively relaxed emission constraints of the late 60's and early seventies, this plant produced reliably at rates up to 1400 TPD with blower discharge pressures of 150" and steam production rates

FIGURE I


SULPHUR PUMP
SULPHUR BURNER
No. 1 BOILER
HOT GAS FILTER
No. 2 BOILER
SILENCER
DRYING TOWER
BLOWER
#1 MASS
SHTR
SHTR
ECONOMIZER
SO3 COOLER
ABSORBER
STK

of about 1.30T/T acid. The steam produced was exported to the site primarily at 300 psi with some exported at low pressure. The key equipment in the plant as originally erected is shown in Table 1.

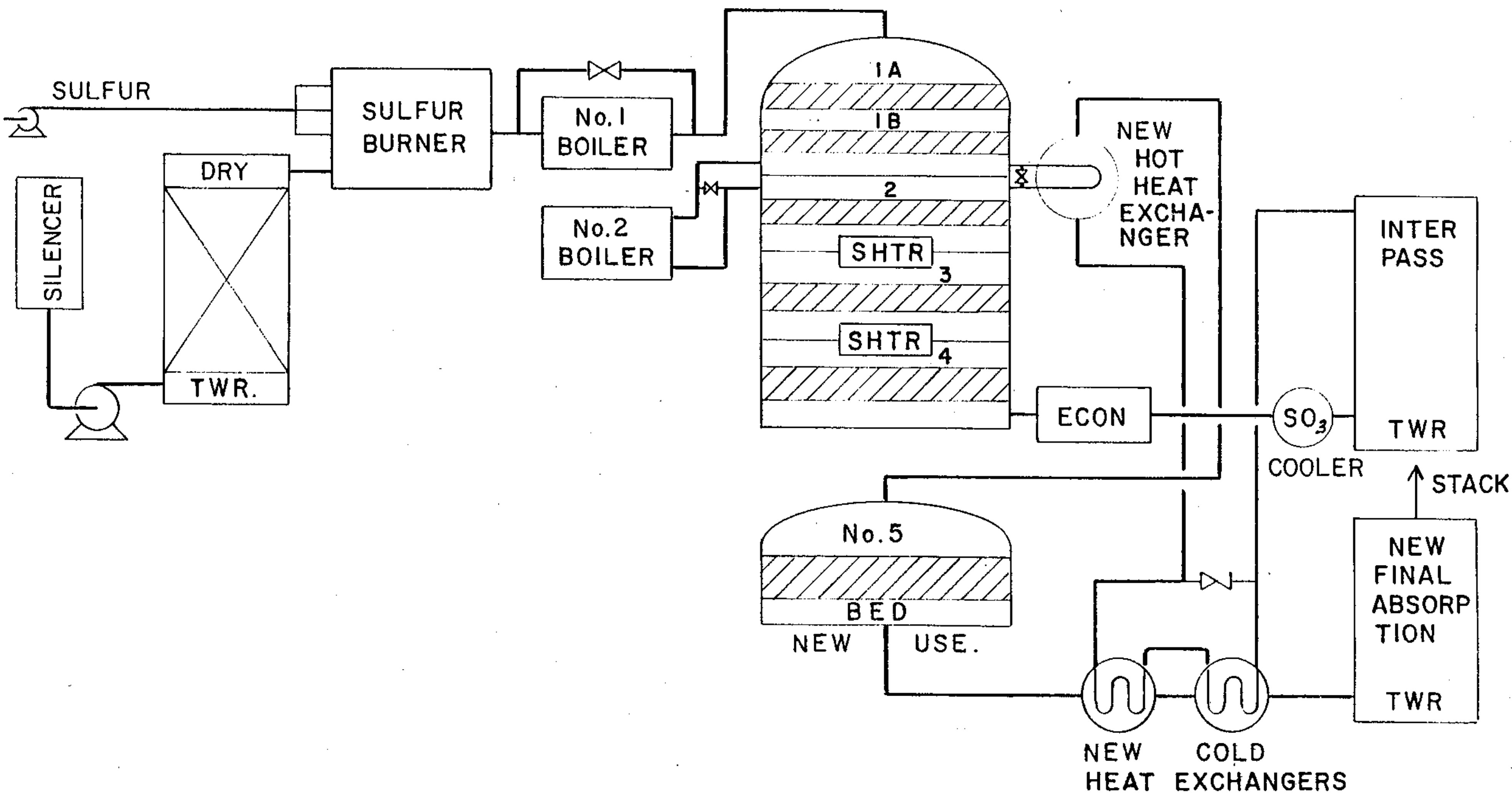
One other change of note during the early seventies in the hot gas filter in the expanded single absorption may also be of interest. Studies on this unit by Gardinier indicated that while the unit was good at collecting ash and protecting the first mass, the pressure saving when the plant was dirty did not balance the flow restriction when the plant was clean, i.e. a separate filter was not cost or production effective. As a result, the internals of this filter were removed and for several years prior to the modification to double absorption, this hot gas filter was an empty shell.

The Double Absorption Addition

When it became evident in the early seventies that the new EPA 4 lb/ton SO_2 emission standard would be imposed on the sulphuric acid plants in the fertilizer industry, Gardinier initiated a revamp of the No. 7 and 8 plants to double absorption, the program resulting in double absorption plant startups in 1977. In the modification, a number of new items of equipment were added to the No. 7 plant including a final absorption system and a heat exchanger train to reheat the gas leaving the existing absorber. In addition. the hot gas filter was converted from an ash collector to a final 5th catalyst bed. This additional equipment was designed for 1600 TPD production capacity. Gas strength in the plant was expected to rise to allow the 1400 TPD production levels.

The revised flow arrangement is shown in Figure 2. The drawing shows little change prior to the conversion system. Here, a gas-gas exchanger located parallel to the No. 2 waste heat boiler reduces steam formation at this point in favour of reheating gas prior to final conversion. The hot gas filter in the role of a final bed, two exchangers used to reheat the gas returning from the interpass or intermediate absorbers and a final absorption system complete the change. This additional equipment is listed in Table 2. The gas flow is little changed from the single

FIGURE 2
No.7 PLANT WITH DOUBLE ABSORPTION



absorption case. Air flows through the silencer, main blower, drying tower, and furnace as originally arranged. From the boiler the gas flows directly to the first pass, in place of going through the hot gas filter as originally designed. From the first pass which still contains two layers as before, the SO_3 gas is now split between SO_2 gas reheating and the No. 2 boiler before mixing and proceeding to the second pass. From the outlet of the second mass, the gas passes through an internal steam superheater to the third mass and through a second internal steam superheater to the fourth mass. From the fourth mass in the bottom of the existing converter, the SO_3 gas then flows through the economizer and SO_3 cooler to the absorber where the SO_3 present is absorbed in a circulating stream of absorbing acid which in turn was cooled in the cast iron pipe cooling rack previously described.

Conversion of SO_2 to SO_3 at this point was in the range 93-96% and the absorber off-gas contained about ½% SO_2. This gas is then reheated and the SO_2 converted to SO_3 in a final bed of catalyst located in the former hot gas filter. Heat up is accomplished initially using heat from the converted gases leaving the final bed (the former hot gas filter) and then using heat from a portion of the gas leaving the first catalyst mass. The fully converted gas from the final bed cooled in passing through the two cold reheat exchangers and passes to a new final absorption system where the SO_3 is absorbed, producing a tail gas with an SO_2 strength well below the limit set by EPA.

Initially it had been expected that this modification to the plant would not restrict production with the increased gas strength compensating for the increased flow resistance. The assumption was invalid due to the No. 1 Boiler where the recirculation rate through the boiler was too low for the tonnage of acid being produced resulting in boiler tube failures. In addition, the cast iron fins on the tubes in the water tube boiler expanded away from the carbon steel, reducing heat transfer significantly. With catalyst bed fouling and the boiler problems, steady operation was rapidly limited to 1100-1200 TPD.

Comparisons with other on-site plants indicated to plant engineers that the plant ought to be capable of 1800 TPD output. When the need for additional acid arose in 1979, a re-examination of the capacity of the No. 7 plant was raised early and together with the repair and replacement needs of the No. 1 Boiler led to the expansion we will now describe.

Plant Expansion

No sulphuric acid plant that Gardinier or we know of is immune to gradual deterioration and the No. 7 plant was no exception. A number of problem areas in this plant had been identified by 1979 including the No. 1 Boiler (of water-tube design), grids and gas distribution in the first as well as in the second mass, converter bulging, acid cooling and catalyst fouling and inactivity in several beds. The deteriorating plant capacity was of course an even more serious bottleneck. Following discussions between Chemetics and Gardinier, proposals for the plant repair and upgrading were developed by Chemetics and after appropriate review and negotiation, a contract was signed between Chemetics and Gardinier to upgrade the No. 7 Plant to 1850 TPD in March of 1980.

Obviously, a simple speed-up of the blower was out of the question for this expansion as this would have required over 300"WC and 10,000 HP in place of the 180" and 3400 HP then in service. A number of possibilities existed for the gas flow increase, including the following:

(1) Use of a larger or additional blower.
(2) Use of proven low pressure drop catalyst.
(3) Use of fewer catalyst passes (4 instead of 5).
(4) Use of higher strength gas.
(5) Use of additional equipment parallel to existing.
(6) Simplifications in ducting.
(7) Paralleling.

The first option is of course dependent on the subsequent steps so one must consider steps (2) to (6) prior to step 1. The specific proposals included to allow 1850 TPD gas flow at 180" blower discharge pressure were:

(1) All catalyst replaced with Topsoe ring catalyst to reduce flow resistance.

(2) A reduction in the number of passes from 5 to 4 by switching the existing 3rd and 4th beds to parallel from series with additional equipment added to allow the gas flow two parallel paths from the exit of the second bed all the way to the inlet of the first absorber. The additional equipment in this case includes a second external superheater and a new superheater/economizer as well as the necessary gas ducting.

(3) Additional surface in the tower mist eliminators .

The above changes gave adequate change in flow resistance for the expansion. No increase in gas strength was proposed as there was a doubt about the bricking in the furnace nor was tower repacking included. With the changes, a new blower and backpressure turbine were then specified, including, as well, a new silencer.

Maintenance problems in the plant prior to the expansion were also included in the project as follows:

(1) <u>No. 1 Boiler</u>

The water-tube unit and original steam drum were replaced with a fire-tube unit and much larger steam drum sized for efficient steam recovery at the full 1850 TPD rate. The steam drum was located to serve both the new boiler at grade and the existing elevated No. 2 boiler.

(2) No. 1 Bed

In the exit of No. 1 Bed the converter had bulged and the grids were also seriously bowed, making replacement necessary within the next two to three years. Plant experience had suggested 5-7 years normal lifetime. HS Meehanite grids and posts of Chemetics design were supplied and installed rated for 100,000 hours (12 years) life at 1200°F (650°C) with a 50" WC pressure drop across the bed. The two layers were also replaced by a single layer leaving more space for gas distribution above the catalyst. The opportunity was also taken to replace the the original slightly sagging grids in bed 2 with spare HR grids.

(3) Catalyst

A complete charge of Topsoe ring-type catalyst was installed, replacing the existing catalyst, part of which was original with the plant. The very low pressure drop of the rings saved 30" pressure on the blower.

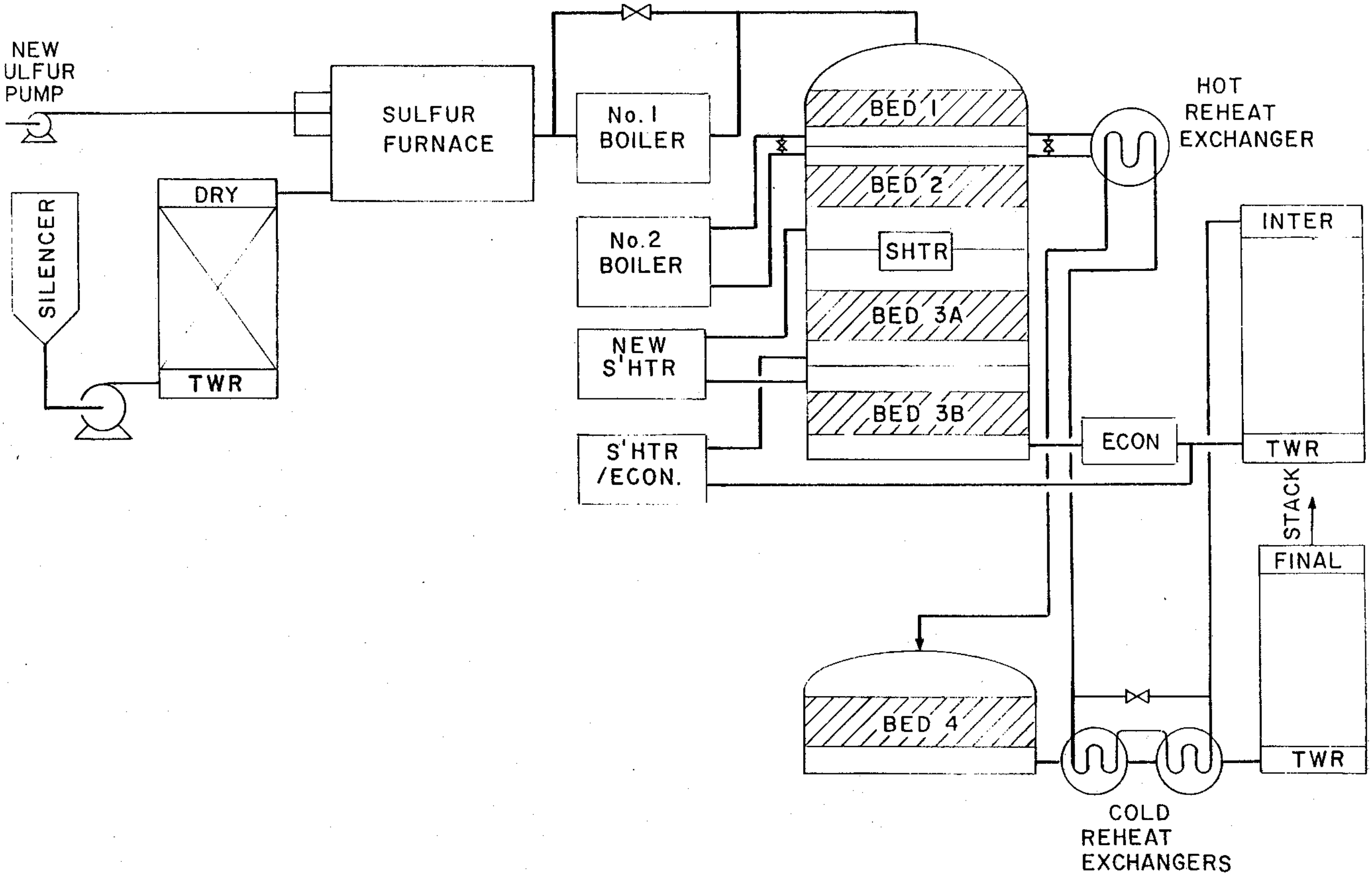
(4) Acid Coolers

CIL coolers were installed in place of the cast iron pipe coils in both drying and inter absorbing acid duties with a new fresh water cooling tower. The conversion was justified based on a demonstrated 12 day per year loss in production due solely to acid leaks in the coil system. The inter absorbing acid cooler came from the No. 9 Plant (2400 TPD) where it was replaced by an even larger unit.

The revised gas flow diagram is shown as Figure 3. The silencer here is new as is the blower. The furnace is unchanged while the higher flow of sulfur required has been accommodated by new sulphur pumps with much higher delivery pressure (300 ft.) and higher capacity than

FIGUI 3

THE EXPANDED PLANT



originally installed. The No. 1 boiler is new and of firetube design. The gas from the boiler feeds bed 1 which has new grids as does bed 2. A new superheater cools half of the gas flow from bed #2 in parallel with the existing bed 2/3 superheater which cools the other half. The gases then flow to beds 3A and 3B. A sealed divider between beds 3A and 3B prevents plate lifting and bypassing of beds 3A and 3B. A new superheater/economizer cools the gas leaving bed 3A while the existing economizer cools the gas from bed 3B. The relatively cool gas then flows to the intermediate absorber and signficantly improves the steam recovery. From the interpass tower onwards, the gas flow continues unchanged.

In other parts of the plant, boiler blowdown has been used via a flash tank and exchanger to preheat and deaerate incoming boiler feed water saving LP steam, a new larger deaerator and steam drum replace the older undersized units (for 1850 TPD) and, of course, new larger capacity BFW pumps replace the older pumps sized for much smaller capacity. The acid system was also upgraded by the replacement of the old C.I. trombone coolers with anodically protected CIL coolers and an additional pump including larger size acid piping were installed in the primary absorber circuit to cope with the higher heat load and acid flows needed. The additional equipment shown is listed in Table 3. While the list of changes in the plant is long, the changes resulted in the elimination of a number of problem items of equipment such as the boiler and acid coolers as well as the replacement of a number of other items with far more efficient new units. Most of the changes involved smaller items but when combined with the changes in the converter system, resulted in an expansion in the plant capacity from under 1200 TPD to over 1800 TPD while maintaining the same blower discharge pressure. <u>All</u> items of equipment in the plant were checked for the higher capacity and critically examined in terms of reliable performance at 1850 TPD.

The revised flowsheet and equipment have now been described and it remains to say that the changes were carried out betwen April 1980 and September 1981 with the plant startup in the September/October time period. The plant ran at 1850 TPD rates to check out performance predictions and I can report that the 180" clean performance at 1800 TPD was met within a couple of inches. Steam production over the seven day testrun corresponded to 1.2 tons/ton sulphuric, very close to the 1.30 tons/ton of the original single absorption plant and significantly in excess of the 1 ton/ton of the previous arrangement. A later problem occurred with the No. 1 Boiler and will be discussed later.

The blower and turbine have since been speeded up to well over 2000 TPD and at the present time, the ultimate capacity of the plant is still uncertain while still maintaining under 4 lbs SO_2/ton emission levels. .

Comparisons of Performance

Table 4 is attached to give some basis for comparison of the three versions of the No. 7 Contact Acid Plant. The tables are based on plant P-T surveys carried out in 1973, 1976 and 1981 respectively. Reviewing the data, the acid production and steam rates are shown first to indicate plant performance. While the data shows some inconsistencies which are attributable to plugged lines, etc., a number of points can be made about the effect of the changes:

(1) Steam Production - Tons/Ton

The three rates shown correspond to 1.23, 1.03, and 1.18 tons/ton respectively, suggesting that without a sucker blower, optimum economizing, etc. that reasonable steam production can be obtained from existing plant.

(2) Compression Requirements

In the three cases using most of the same equipment, the two high efficiency routes have essentially the same flow resistance (173" vs 184") despite a 62% increase in production rate. Compression work per unit of production has been held essentially constant. The essentially identical pressure also indicates that the severity of the containment problems in the converter and vessels, i.e. hot gas under pressure at pressure and elevated temperature is no worse than before, an important fact if reliability is to be maintained.

(3) Catalysis

Average bed inlet temperatures for the three plant arrangements were 856°F, 818°F, and 789°F. The 789°F average is for the new charge of Topsoe ring catalyst and includes a first mass inlet temperature of 753°F (400°C). A similar mass in No. 8 plant has now been in service for over 15 months and is operating at 788°F, compared to 758-760°F initially, suggesting some tail off in activity. The catalyst temperature profile has not been optimized to date.

(4) Acid Cooling

In the original arrangement as well as in the double absorption modification, acid temperatures were relatively high with acid leaving the absorber at 252°F in the single absorption case and entering the drying tower in the double absorption case at 165°F even at a lower level of production. In the expanded plant, the dry tower acid was entering at 103°F while the absorbing system was running between 174° and 228°F. The much lower temperatures should reduce pump and acid piping corrosion significantly in addition to improving reliability.

(5) Problems

It is almost a certainty that Murphy's law will strike somewhere in any complex project such as this expansion and several problems occurred during this project as well aside from the miscellaneous items promised such as the blower turbine which was slightly late. Both of the problems involved the steam system. First of the problems was in the deaerator where a guaranteed dissolved oxygen level of 7 ppb was not met and 35-50 ppb was actually obtained. This issue is still being dealt with by the supplier.

A second problem area which is technically more interesting was in the area of interaction of the steam drum and boiler. In the original plant design, water tube boilers were used for the No. 1 and 2 boiler positions resulting in an elevated steam drum to serve the two boilers. The plant changes eliminated the No. 1 water tube boiler but not the No. 2 leaving the need for an elevated steam drum serving both the new ground level fire-tube boiler and the elevated water tube No. 2 boiler. Downcomers and risers for the new boiler which were supplied as part of the boiler-steam drum system were therefore much more complex than usual as the lines had significant vertical and horizontal runs. The boiler supplied contains 1554 tubes 2" diameter x 16' long, has three downcomers of 14" diameter, and two risers of 18" diameter and the steam drum associated is 6½ ft diameter by 20 ft long (tan/tan).

After startup, noises in the boiler were noted as the rate of production in the boiler increased. The noises sounded metallic in nature as though tubes were colliding and peaked in volume every 5-10 seconds. Attempts were made to check out the noise by use of ultrasonic flowmeters on the water lines but gave only a zero reading leaving the owner, contractor, and boiler supplier with little more data than the plant and equipment drawings to consult. A subsequent tube failure by cracking near the tube-tubesheet weld led to shutdown, pulling of selected tubes, and an identification of the noises as in fact having been caused by tubes hitting each other in the region of the downcomer connections.

Initial corrective action included replacement of 4 tubes with cracks and 13 other suspected tubes, the diagnosis having been made using an ultrasonic inspection service which can detect incipient cracks. Baffles were also installed to reduce the high velocity water jet impact on the tube bundle, an Annubar was put into one of the downcomers, and the unit was restarted at reduced rate and tests carried out both on the noise and on the velocity in the circulating system. Noise was still present during these operations, although the intensity was approximately 1/3rd the intensity measured during the prior running and interestingly enough, decreased significantly on increase in steam generation rate. A number of proposals have since been put forward to account for the very low frequency tube collisions but at the time of writing, flow instability at the entrance to the downcomers at the steam drum and vapour accumulation and discharge in the essentially horizontal sections of the risers are the most likely causes. It is expected that the issue will be resolved by the time of this meeting, at which time the subject will be further discussed.

Summary

Many older sulphuric acid plants now in service are now becoming less and less economically attractive due to increasing maintenance costs and decreasing outputs. The actions taken on the Gardinier #7 which is now over 20 years old have resulted in a plant with much higher capacity (1850 vs 1200 TPD), elimination of most of the plant bottlenecks with an improved steam yield as well and a plant that should produce efficiently over the next decade. The cost was a small fraction of the cost of equivalent new plant.

TABLE 1

KEY EQUIPMENT

1. <u>Blower</u>
   - Elliott 90-H

1A <u>Blower Drive</u>
   - Elliott condensing turbine

2. <u>Drying Tower - Conventional</u>

3. <u>Sulphur Furnace</u>
   - Standard Brick lined unit
   - 3 guns on face of furnace

4. <u>No. 1 Boiler</u>
   - Water tube -Foster Wheeler - C.I. Gill Rings

5. <u>Hot Gas Filter - Standard</u>

6. <u>Converter</u>
   - C.S. shell and Meehanite and cast iron grids.

7. <u>Economizer</u>
   - C.I. Gill Rings

8. <u>Absorber - Conventional</u>
   - 25'4½" I.D. Brick - 30"11" wall - 14'-3" saddles (Originally rings)
   - 3000 GPM acid flow.

TABLE 3

EXPANSION - ADDITIONAL EQUIPMENT

1. Silencer

2. Blower - Allis-Chalmers Blower - 183 " P 3163 rpm
   107000 cfm 3685 HP

3. Blower Turbine - Terry 96500 lbs/hr. steam 3163 rpm

4. Sulphur pumps - 240 psi - 60 gpm - Lewis

5. No. 1 Boiler - new firetube unit - Bigelow - 16 ft. tubes x 2" x 1554 tubes

6. No. 1 Bed Converter grids - "HS" Meehanite - Chemetics design - rated for 100,000 hours at 1200°F and 50" W.C.

7. No. 2 Bed - New Inlet Duct.

8. New Superheater - Externally mounted unit to cool half the gas leaving bed 2 and entering bed 3B.

9. Superheater/Economizer - cools gas leaving bed 3A.

10. Interstage Absorber - 1 additional size 8 Lewis pump
    - additional HV panels.

11. Catalyst - complete replacement.

12. Final Tower - additional HV panels.

13. Dry and Interstage Acid Cooling - CIL coolers.

14. Deaerator - new - high capacity.

15. Steam Drum - new - high capacity.

16. BFW pumps - new - increased capacity (2 new units).

17. Blowdown Flash Tank and Heater - new.

18. Water Cooling Tower - additional cell.

TABLE 4
COMPARATIVE PROFILES – PRESSURE AND TEMPERATURE

Point	Single Absorption		Double Absorption		Expanded Plant	
Production (TPD)	1408		1120		1819	
Steam (lbs/hr.)	144,000		96,000		178,500	
% SO_2	9.2		9.3		10.6	
	T°F	P"WC	T	P	T	P
1. Air to Blower		-9"		-2.2"		-1.5"
2. Air from Blower		155.5"		173"		183.8"
3. Air from Dry Twr.		146.5	165	165	102	168.5
4. Furnace Exit	1673		1691		1836	
5. Boiler Exit		125.3		149		144.7
6. Hot Gas Filter Exit		120.5		N.A.		N.A.
7. To Bed 1	887	120.5	807	?	753	?
8. From Bed 1	1131		1131	130.3	1136	122.5
9. To Bed 2	867	87.3	836	123.5	828	113.3
10. From Bed 2	986	72	992	113.5	975	99.8
11. To Bed 3	845	70.3	834	112	796	98.5
12. From Bed 3	880	56	874	100.5	828	96.3
13. To Prim. Abs.	409		460			
14. From Prim. Abs.	172	1.5	187	58.5		69.8
15. From Cold Exchgrs.	-	N.A.	674	48	690	58.8
16. To Bed 4	824	54.3	813	99.5	779	48
17. From Bed 4	837	38.5	828	89.5	825	40.5
18. To Final Abs.	-		303	12.5	353	17
19. To Stack	172	0.5	165	0.5	167	0.5
20. To Bed 5	-	N.A.	798	41	-	N.A.
21. From Bed 5	-	N.A.	816	25	-	N.A.